RECOVERY PLAN

FOR THE EVOLUTIONARILY SIGNIFICANT UNITS OF

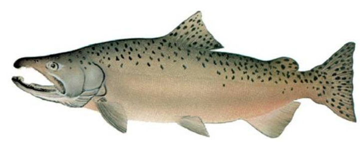
SACRAMENTO RIVER WINTER-RUN CHINOOK SALMON
AND
CENTRAL VALLEY SPRING-RUN CHINOOK SALMON

AND

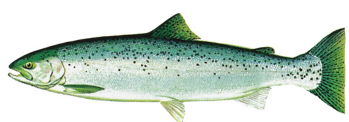
THE DISTINCT POPULATION SEGMENT OF

CALIFORNIA CENTRAL VALLEY STEELHEAD

Winter-run



Spring-run



Steelhead

National Marine Fisheries Service

West Coast Region

Sacramento, California

July 2014

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COVER PAGE FISH IMAGE SOURCES:

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Spring-run image: http://www.fws.gov/yreka/HydroTF-LRP.html

Steelhead image: http://commons.wikimedia.org/wiki/File:Lake_Washington_Ship_Canal_Fish_Ladder_pamphlet_-_ocean_phase_Steelhead.jpg

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List of Acronyms

AFRP	Anadromous Fish Restoration Program
Bay/Delta	San Francisco Bay/Sacramento-San Joaquin Delta
BRT	Biological Review Team
CALFED	CALFED Bay-Delta Program
CAMP	Comprehensive Assessment and Monitoring Program
CBDA	California Bay/Delta Authority
CCWD	Contra Costa Water District
CCWMG	Cow Creek Watershed Management Group
CDFW	California Department of Fish and Wildlife
CESA	California Endangered Species Act
CMARP	Comprehensive Monitoring Assessment and Research Program
cm	centimeters
cm/sec	centimeters per second
CNFH	Coleman National Fish Hatchery
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVSEPWT	Central Valley Salmonid Escapement Project Work Team
CWT	Coded Wire Tag
Delta	Sacramento-San Joaquin Delta
DPS	Distinct Population Segment
DWR	Department of Water Resources
ERP	Ecosystem Restoration Program
ESA	Federal Endangered Species Act
ESU	Evolutionarily Significant Unit
EWA	Environmental Water Account
FERC	Federal Energy Regulatory Commission
FL	fork length
FRFH	Feather River Fish Hatchery
ft/sec	feet per second
HGMPs	Hatchery and Genetic Management Plans
IEP	Interagency Ecological Program
LSNFH	Livingston Stone National Fish Hatchery
m	meters
mi^2	square miles
m/sec	millimeters per second
mm	millimeters
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PCSRF	Pacific Coastal Salmon Recovery Fund
PRD	Protected Resources Division
PVA	Population Viability Analyses
QC	Quality Control
RBDD	Red Bluff Diversion Dam
Reclamation	Bureau of Reclamation
RM	River Mile
RST	Rotary Screw Trap
SWP	State Water Project
TRT	Technical Recovery Team
USACOE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USFS	U.S. Forest Service
VSP	Viable Salmonid Population

EXECUTIVE SUMMARY

Introduction: Recovery is the process by which listed species and their ecosystems are restored and their future is safeguarded to the point that protections under the Endangered Species Act (ESA) are no longer needed. The goal of this Recovery Plan is to recover the endangered Sacramento River winter-run Chinook salmon Evolutionarily Significant Unit (ESU), the threatened Central Valley spring-run Chinook salmon ESU, and the threatened California Central Valley steelhead Distinct Population Segment (DPS). Recovering these species and the Central Valley, San Francisco Bay-Delta Estuary, and Pacific Ocean ecosystems that support them will be challenging and will require shifts in societal values. Californians must work together towards a conservation ethic and practice that ensures wild salmon and steelhead are an important part of coastal California and Central Valley culture for many generations to come.

Background: The rivers draining the Great Central Valley of California ("Central Valley") and adjacent Sierra Nevada and Cascade Range once were renowned for their production of large numbers of Pacific salmon (Clark 1929; Skinner 1962 *in* Yoshiyama *et al.* 1998). The Central Valley rivers and creeks historically have been the source of most of the Pacific salmon produced in California waters (CDFW 1950, 1955; Fry and Hughes 1951; Skinner 1962; CDWR 1984 *in* Yoshiyama *et al.* 1998). Chinook salmon *(Oncorhynchus tshawytscha)* historically were, and remain today, the only abundant salmon species in the Central Valley (Eigenmann 1890; Rutter 1908 *in* Yoshiyama *et al.* 1998), although small numbers of other salmon species also have occurred occasionally in its rivers (Collins 1892; Rutter 1904a, 1908; Hallock and Fry 1967; Moyle *et al.* 1995 *in* Yoshiyama *et al.* 1998). Steelhead (anadromous *O. mykiss)* were common in Central Valley tributaries (USFC 1876; Clark 1973; Latta 1977; Reynolds *et al.* 1993 *in* Yoshiyama *et al.* 1998), but records for them are few and fragmented, partly because they did not support commercial fisheries (Yoshiyama *et al.* 1998).

Populations of native Chinook salmon and steelhead have declined dramatically since European settlement of the Central Valley in the mid-1800s. California's salmon resources began to decline in the late 1800s, and continued to decline in the early 1900s, as reflected in the decline of Chinook salmon commercial harvest. The total commercial catch of Chinook salmon in 1880 was 11 million pounds; by 1922 it had dropped to seven million pounds, and it reached a low of less than three million pounds in 1939 (Lufkin 1996).

Another major factor affecting anadromous salmonids during this period was hydraulic gold mining, which began in the 1850s. By 1859, an estimated 5,000 miles of mining flumes and canals diverted streams used by salmonids for spawning and nursery habitat. Habitat alteration and destruction also resulted from the use of hydraulic cannons, and from hydraulic and gravel mining, which leveled hillsides and sluiced an estimated 1.5 billion cubic yards of debris into the streams and rivers of the Central Valley (Lufkin 1996).

Despite the prohibition of hydraulic mining in 1894, habitat degradation continued. Habitat quantity and quality have declined due to: construction of levees and barriers to migration, modification of natural hydrologic regimes by dams and water diversions, elevated water temperatures, and water pollution from agriculture and industry (Lufkin 1996).

Although the effects of habitat degradation on fish populations were evident by the 1930s, rates of decline for most anadromous fish species increased following construction of major water project facilities (USFWS 2001), which primarily occurred around the mid- 1900s. Many of these water development projects completely blocked the upstream migration of Chinook salmon and steelhead to spawning and rearing habitats, and altered flow and water temperature regimes downstream from terminal dams. As urban and agricultural development of the Central Valley continued, numerous other stressors to anadromous salmonids emerged and continue to affect the viability of these fish today. Some of the more important stressors include: the high demand for limited water supply resulting in reduced instream flows, increased water temperatures, and highly altered hydrology in the Sacramento-San Joaquin Delta, barriers to historic habitat, widespread loss of tidal marsh, riparian and floodplain habitat, poor water quality, commercial and/or recreational harvest, and predation from introduced species such as striped bass.

Recovery Strategy: Recovery of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead across such a vast and altered ecosystem as the Central Valley will require a broadly focused, science-based strategy. The scientific rationale for the strategy in this plan focuses on two key salmonid conservation principles. The first is that functioning, diverse, and interconnected habitats are necessary for a species to be viable. That is, salmon and steelhead recovery cannot be achieved without providing sufficient habitat. Anadromous salmonids persisted in the Central Valley for thousands of years because the available habitat capacity and diversity allowed species to withstand and adapt to environmental changes including catastrophes such as prolonged droughts, large wildfires, and volcanic eruptions.

To help return the habitat capacity and diversity in the Central Valley to a level that will support viable salmon and steelhead, we have identified and prioritized recovery actions based on a comprehensive life stage-specific threats assessment. Minimizing or eliminating stressors to the fish and their habitat in an efficient and structured way is a key aspect of the recovery strategy.

The second salmonid conservation principle guiding the recovery strategy is that a species' viability is determined by its spatial structure, diversity, productivity, and abundance (McElhany *et al*. 2000). Abundance and population growth rate are self-explanatory parameters that are clearly important to species and population viability, while spatial structure and diversity are just as important, but less intuitive. Spatial structure refers to the arrangement of populations across the landscape, the distribution of spawners within a population, and the processes that produce these patterns. Species with a restricted spatial distribution and few spawning areas are at a higher risk of extinction from catastrophic environmental events (e.g., a single landslide) than are species with more widespread and complex spatial structure. Species or population diversity concerns the phenotypic (morphology, behavior, and life-history traits) and genetic characteristics of populations. Phenotypic diversity allows more populations to use a wider array of environments and protects populations against short-term temporal and spatial environmental changes. Genetic diversity, on the other hand, provides populations with the ability to survive long-term changes in the environment. It is the combination of phenotypic and genetic diversity expressed in a natural setting that provides populations with the ability to adapt to long-term changes (McElhany *et al.* 2000).

Bridging the gap between the species and population levels are population groups or salmonid ecoregions, which are delineated based on climatological, hydrological, and geological characteristics. The Central Valley Technical Recovery Team (TRT) identified four population groups (hereafter referred to as diversity groups) that Chinook salmon historically inhabited in the Central Valley:

- The basalt and porous lava diversity group composed of the upper Sacramento River, McCloud River, Pit River and Battle Creek watersheds;
- The northwestern California diversity group composed of streams that enter the mainstem Sacramento River from the northwest;
- The northern Sierra Nevada diversity group composed of streams tributary to the Sacramento River from the east, and including the Mokelumne River; and
- The southern Sierra Nevada diversity group composed of streams tributary to the San Joaquin River from the east.

Based on the two scientific principles described above and on a comparison of current species viability, relative to historic viability, the basic strategy put forth in this recovery plan is to secure all extant populations and to reintroduce populations to historic habitat such that each salmonid diversity group in the Central Valley supports viable populations. The TRT concluded that recovery of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead would require that no more populations are allowed to become extirpated and that habitat must be expanded to allow for the establishment of additional populations (Lindley *et al.* 2007).

The primary means of securing existing populations is to reduce or eliminate threats to those populations and their habitats. To help guide threat abatement efforts, watersheds and recovery actions have been prioritized. Watersheds that are currently occupied by at least one of the listed Chinook salmon and steelhead species have been prioritized among three levels. Of highest priority are core 1 populations, which have been identified, based on their known ability or potential to support independent viable populations. Core 1 populations form the foundation of the recovery strategy and must meet the population-level biological recovery criteria for low risk of extinction set out in Table 5-1. NMFS believes that core 1 populations should be the first focus of an overall recovery effort. Core 2 populations are assumed to have the potential to meet the moderate risk of extinction criteria set out in Table 5-1. These dependent populations are of secondary importance for recovery efforts. Core 3 populations are present on an intermittent basis and are characterized as being dependent on other nearby populations for their existence. The presence of these populations provides increased life history diversity to the ESU/DPS and is likely to buffer against local catastrophic occurrences that could affect other nearby populations. Connectivity between populations and genetic diversity may be enhanced by working to recover smaller core 3 populations that serve as stepping stones for dispersal. General guidance for how this watershed prioritization should be applied is that if a core 1 watershed and a core 2 (or 3) watershed had a similar problem affecting salmon and/or steelhead, then efforts should be directed at fixing the problem in the core 1 watershed first.

Unoccupied habitats that historically supported winter-run Chinook salmon, spring-run Chinook salmon, or steelhead have been prioritized regarding fish reintroductions. These unoccupied habitats have been prioritized as primary areas, candidates, or have been ruled out as places to reintroduce one or more of the species. Primary areas for reintroductions are areas where there is a known high likelihood of success based on species-specific life history needs, and available habitat quality and quantity. Specific primary reintroduction areas include the McCloud River, Battle Creek, the Yuba River, and the San Joaquin River. Candidate areas for reintroduction are unoccupied habitats that require further study of their potential for successful reintroductions. Some areas that were historically accessible to anadromous salmonids, but are no longer because of dams, have been excluded from consideration for reintroductions because they are so critically impaired by hydroelectric development and channel inundation that we felt efforts should be focused on areas with a higher potential for success.

Because recovery of winter- and spring-run Chinook salmon and steelhead will require implementation over a large landscape and over an extended period of time, a stepwise strategy has been adopted, based on the prioritization of watersheds and recovery actions. As this Recovery Plan is implemented over time, additional information will become available to help determine the degree to which the threats have been abated, to further develop understanding of the linkages between threats and population responses, to identify any additional threats, and to evaluate the viability of Chinook salmon and steelhead in the Central Valley.

Recovery Goals, Objectives, and Criteria: The overarching goal of this Recovery Plan is the removal of the Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, and California Central Valley steelhead DPS from the Federal List of Endangered and Threatened Wildlife (50 C.F.R. 17.11). The objectives and criteria to accomplish this goal builds upon the technical input and guidance provided by the TRT, and much of the following discussion is taken directly from information developed by the TRT (Lindley *et al.* 2004; 2006; 2007).

In order for the Chinook salmon ESUs and the steelhead DPS to achieve recovery, each diversity group must be represented, and population redundancy within the groups must be met to achieve diversity group recovery. Therefore, ESU-level recovery criteria include the following:

Winter-run Chinook salmon ESU:

- Three populations in the Basalt and Porous Lava Diversity Group at low risk of extinction

Spring-run Chinook salmon ESU and **Central Valley steelhead DPS**:

- One population in the Northwestern California Diversity Group at low risk of extinction

- Two populations in the Basalt and Porous Lava Diversity Group at low risk of extinction
- Four populations in the Northern Sierra Nevada Diversity Group at low risk of extinction
- Two populations in the Southern Sierra Nevada Diversity Group at low risk of extinction
- Maintain all Core 2 populations at moderate risk of extinction.

Recovery criteria at the population level were established by the Central Valley TRT and are included in this recovery plan (and apply to all three species), as described in Lindley *et al*. (2007). The TRT incorporated the four viable salmonid population parameters (McElhany *et al*. 2000) into assessments of population viability, and two sets of population viability criteria were developed, expressed in terms of extinction risk. The first set of criteria deal with direct estimates of extinction risk from population viability models. If data are available and such analyses exist and are deemed reasonable for individual populations, such assessments may be efficient for assessing extinction risk. In addition, the TRT also provided simpler criteria. The simpler criteria include population size (and effective population size), population decline, catastrophic rate and effect, and hatchery influence. For a population to be considered at low risk of extinction (i.e., < 5 percent chance of extinction within 100 years), the population viability assessment must demonstrate that risk level or all of the following criteria must be met:

- Census population size is >2,500 adults -or- Effective population size is >500
- No productivity decline is apparent
- No catastrophic events occurring or apparent within the past 10 years
- Hatchery influence is low (see Figure 4-1).

Additionally, threat abatement criteria must be met demonstrating that specific threats have been alleviated. The following threat abatement criteria have been established to ensure that each of the five ESA listing factors are addressed before a species can be delisted:

- Populations have unobstructed access to Core 1, 2, and 3 watersheds and assisted access to primary watersheds for reintroduction that are obstructed. Man-made structures (e.g., bridges and water diversions) affecting these watersheds and in migratory habitat must meet NMFS salmonid passage guidelines for stream crossings and screening criteria for anadromous salmonids (Listing Factors 1, 4, and 5)
- Utilization for commercial, recreational, scientific, and educational purposes is managed, such that all Core 1 populations meet the low extinction risk category for abundance (see Table 5-1) (Listing Factor 2)
- Hatchery programs are operated so that all Core 1 populations meet the low extinction risk criteria for hatchery influence (see Table 5-1) (Listing Factors 3 and 5)
- Migration and rearing corridors meet the life-history, water quality and habitat requirements of the listed species, such that the corridor

supports multiple viable populations (Listing Factors 1, 3, 4, and 5)

Recovery Actions: This Recovery Plan establishes a strategic approach to recovery, which identifies and prioritizes recovery actions at the Statewide, Central Valley wide, and site-specific levels. Three steps were taken to prioritize recovery actions as they are presented in this plan. First, results from the threats assessment and prioritization process (described in Appendix B) were used to guide the identification of watershed- and site-specific recovery actions for each diversity group and population. This step prioritized recovery actions separately for each species. The second step to prioritize recovery actions was undertaken through consideration of specific actions that benefit multiple species and populations. Results from the second step included tables of recovery actions listed in descending order of priority by geographic region (e.g., Delta, mainstem Sacramento River, Diversity Group) based on multiple species benefits. These first two steps were the only steps taken to prioritize recovery actions that were presented in the Co-Manager Review Draft Recovery Plan. Based on feedback from co-managers, it was apparent that the priority with which recovery actions should be undertaken was not clear. To address this, we implemented a third step and prioritized each of the region-specific recovery actions according to three categories. Priority 1 actions are those critical actions that address threats that generally ranked among the most important threats to one or more of the species; priority 2 actions address threats of moderate importance, and priority 3 actions are among the least important to implement. Actions were identified as priority 1, 2, or 3 based on the first two prioritization steps and on the best professional judgment of agency co-managers, including biologists from CDFW, USFWS, USFS, and NMFS.

Prioritized recovery actions for each of the following scales or regions are described in chapter 6 in the form of implementation tables: California-wide, Central Valley-wide, Pacific Ocean, San Francisco Bay, Delta, mainstem Sacramento River, mainstem San Joaquin River, and each of the four diversity groups. These implementation tables describe each action, the time frames and, if possible, the costs associated with it. Cost estimates have been provided wherever practicable, but in some cases where the uncertainties regarding the exact nature or extent of the recovery actions is unknown, these costs estimates can only be provided after site-specific investigations are completed.

Investment in recovery of salmon and steelhead will result in economic, societal and ecosystem benefits. Monetary investments in watershed restoration projects can promote the economy in a myriad of ways. These include stimulating the economy directly through the employment of workers, contractors and consultants, and the expenditure of wages and restoration dollars for the purchase of goods and services. Habitat restoration projects have been found to stimulate job creation at a level comparable to traditional infrastructure investments such as mass transit, roads, or water projects (Oregon Watershed Enhancement Board 2010). In addition, viable salmonid populations provide ongoing direct and indirect economic benefits as a resource for fish, recreation, and tourist related activities. Dollars spent on salmon and steelhead recovery will promote local, state, Federal and tribal economies, and should be viewed as an investment with both societal (clean rivers, healthy ecosystems) and economic returns.

The largest direct economic returns resulting from recovered salmon and steelhead are associated with sport and commercial fishing. On average 1.6 million anglers fish the Pacific region annually (Oregon, Washington and California) and 6 million fishing trips were taken annually between 2004 and 2006 (NMFS 2010a). Most of these trips were taken in California and most of the anglers lived in California. The California salmon fishery is estimated to generate $118 to $279 million in income annually, and provide roughly two to three thousand jobs (Michael 2010). With a revived sport and commercial fishery, these substantial economic gains and the creation of jobs would be realized across California, but most notably for river communities and rural coastal counties.

Many of the actions identified in this Recovery Plan are designed to improve watershed-wide processes which will benefit many native species of plants and animals (including other state and federally listed species) by restoring natural ecosystem functions. In addition, restoration of habitat in watersheds will provide substantial benefits for human communities. Some of these benefits are: improving and protecting the quality of important surface and ground water supplies; reducing damage from flooding resulting from floodplain development; and controlling invasive exotic animal and plant species which can threaten water supplies and increase flooding risk. Restoring and maintaining healthy watersheds also enhances important human uses of aquatic habitats, including outdoor recreation, ecological education, field based research, aesthetic benefits, and the preservation of tribal and cultural heritage.

The final category of benefits accruing to recovered salmon and steelhead populations are even more difficult to quantify and are related to the ongoing costs associated with maintaining populations that are at risk of extinction. Significant funding is spent annually by entities (Federal, State, local, private) in order to comply with the regulatory obligations that accompany populations that are listed under the ESA.

Important activities, such as water management for agriculture and urban use, are now constrained to protect ESA listed populations of salmon and steelhead. Examples of these types of obligations include such requirements as: ESA section 7 consultations, development and implementation of Habitat Conservation Plans, the provision of fish passage at impassible barriers, and a high degree of uncertainty for the regulated entities. Recovering the salmonid populations so the protections of the ESA are no longer necessary will also result in elimination of the regulatory requirements imposed by the ESA, and allow greater flexibility for land and water managers to optimize their activities and reduce costs related to ESA protections. Salmon recovery is best viewed as an opportunity to diversify and strengthen the economy while enhancing the quality of life for present and future generations.

Implementation: It is a challenging undertaking to facilitate a change in practice and policy that reverses the path towards extinction of a species to one of recovery. This change can only be accomplished with effective outreach and education, strong partnerships, focused recovery strategies and solution-oriented thinking that can shift agency and societal attitudes, practices and understanding. Implementation of the recovery plan by NMFS will take many forms and is described in the NMFS

Protected Resources Division (PRD) Strategic Plan 2006 (NMFS 2006). The Recovery Planning Guidance (NMFS 2010b) also outlines how NMFS shall cooperate with other agencies regarding plan implementation. These documents, in addition to the ESA, shall be used by NMFS to set the framework and environment for plan implementation. The PRD Strategic Plan asserts that species conservation (in implementing recovery plans) by NMFS will be more strategic and proactive, rather than reactive. To maximize existing resources with workload issues and limited budgets, the PRD Strategic Plan champions organizational changes and shifts in workload priorities to focus efforts towards "*…those activities or areas that have biologically significant beneficial or adverse impacts on species and ecosystem recovery* (NMFS 2006)." The resultant shift will reduce NMFS engagement on those activities or projects not significant to species and ecosystem recovery.

NMFS actions to promote and implement recovery planning shall include:

- Coordinating priorities and actions with the Anadromous Fish Restoration Program, the Ecosystem Restoration Program, and other key funding sources.
- Creating and maintaining partnerships with fish and water stakeholder groups, including Federal, State, and local governments, water agencies, fishing groups, and watershed conservation groups.
- Formalizing recovery planning goals on a program-wide basis to prioritize work load allocation and decision-making (to include developing the mechanisms to make implementation (e.g., restoration) possible).
- Supporting outreach and education programs.
- Facilitating a consistent framework for research, monitoring, and adaptive management that can directly inform recovery objectives and goals.
- Establishing an implementation tracking system that is adaptive, web-based, and pertinent to support the annual reporting for the Government Performance and Results Act, Biennial Recovery Reports to Congress and the 5-Year Status Reviews.

NMFS' efforts must be as far-reaching (beyond those under the direct regulatory jurisdiction of NMFS) as the issues adversely affecting the species. Thus, to achieve recovery, NMFS will need to promote the recovery plan and provide needed technical information and assistance to other entities that implement actions that may impact the species' recovery. For example, NMFS will work with key partners on high priorities such as facilitating passage assessment and working with Counties to ensure protective measures consistent with recovery objectives are included in their General Plans.

Many complex and inter-related biological, economic, social, and technological issues must be addressed in order to recover anadromous salmonids in the Central Valley. Policy changes at the Federal, State and local levels will be necessary to implement many of the recovery actions identified in this Recovery Plan. For example, without substantial strides in habitat restoration, fish passage, and changes in water use, recovery will be difficult if not impossible. In some cases, conflicting regulatory mandates that influence water and aquatic resources management will need to be resolved. Most importantly, recovering winter-run Chinook salmon, spring-run Chinook salmon, and steelhead will require a focused effort that secures existing populations, re-establishes populations in watersheds that historically supported them, and restores the ecological function of the habitats upon which the species depend for their long-term survival.

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1.0 Introduction

"Salmon was now abundant in the Sacramento. Those which we obtained were generally between three and four feet in length, and appeared to be of two distinct kinds. It is said that as many as four different kinds ascend the river at different periods. The great abundance in which this fish is found gives it an important place among the resources of the country."

- Captain John C. Frémont, memoirs for 30 March-5 April 1846 *in* Yoshiyama et al. 1998

The rivers draining the Great Central Valley of California ("Central Valley") and adjacent Sierra Nevada and Cascade Range once were renowned for their production of large numbers of Pacific salmon (Clark 1929; Skinner 1962 *in* Yoshiyama *et al.* 1998). The Central Valley system historically has been the source of most of the Pacific salmon produced in California waters (CDFW 1950, 1955; Fry and Hughes 1951; Skinner 1962; CDWR 1984 *in* Yoshiyama *et al.* 1998).

Chinook salmon *(Oncorhynchus tshawytscha)* historically were, and remain today, the only abundant salmon species in the Central Valley system (Eigenmann 1890; Rutter 1908 *in* Yoshiyama *et al.* 1998), although small numbers of other salmon species also have occurred occasionally in its rivers (Collins 1892; Rutter 1904a, 1908; Hallock and Fry 1967; Moyle *et al.* 1995 *in* Yoshiyama *et al.* 1998). Steelhead (anadromous *O. mykiss)* apparently were common in Central Valley tributaries (USFC 1876; Clark 1973; Latta 1977; Reynolds *et al.* 1993 *in* Yoshiyama *et al.* 1998), but records for them are few and fragmented, partly because they did not support commercial fisheries (Yoshiyama *et al.* 1998).

Anadromous salmonids, in particular Chinook salmon, have and continue to be an important resource, both revered and harvested by humans. The Native American people depended upon these fishes for subsistence, ceremonial, and trade purposes. Prior to Euro-American settlement, Native Americans within the Central Valley drainage harvested Chinook salmon at estimated levels that reached 8.5 million pounds or more annually (Yoshiyama *et al.* 1998). With the advent of the California gold rush in the mid-1800s, a commercial Chinook salmon fishery developed in the San Francisco Bay and Sacramento-San Joaquin Delta ("Delta") region. Annual catches by the early in-river fisheries commonly reached 4-10 million pounds. The first west coast salmon cannery opened on a scow moored near Sacramento in 1864. Within 20 years, 19 canneries were operating in the Delta region, and processed a peak of 200,000 cases (each case comprised of 48, 1-pound cans) in 1882 (Lufkin 1996). The salmon fishery remained centered in the Delta region until the early 1900s, when ocean salmon fishing began to expand and eventually came to dominate the fishery.

1.1 The Great Central Valley of California

The northern half of the Central Valley is comprised of the Sacramento River Basin (covering approximately 24,000 square miles [mi^2]), with the southern half (covering approximately 13,540 mi^2) primarily composed of the San Joaquin River Basin (**Figure 1-1**). The broad expanse of the Central Valley region of California once encompassed numerous salmon-producing streams that drained the Sierra Nevada and Cascade mountains on the east and north and, to a lesser degree, the lower-elevation Coast Range on the west. The large areal extent of the Sierra Nevada and Cascades watersheds, coupled with regular, heavy snowfalls in those regions, provided year-round streamflows for a number of large rivers which supported substantial runs of Chinook salmon (Yoshiyama *et al.* 1998).

Figure 1-1. Central Valley Region of California

In the Sacramento River Basin, most Coast Range streams historically supported regular salmon runs, although their runs were limited by the volume and seasonal availability of streamflows due to the lesser amount of snowfall west of the valley (Yoshiyama *et al.* 1998). In the San Joaquin River Basin, a number of major streams (e.g., the Merced, Tuolumne, and upper San Joaquin rivers) sustained very large salmon populations, while other streams with less regular streamflows had intermittent salmon runs in years when rainfall provided sufficient flows. All of the west side San Joaquin River Basin streams flowing from the Coast Range were highly intermittent (Elliott 1882) and none are known to have supported anadromous salmonids (Yoshiyama *et al.* 1998).

1.2 Salmon & Steelhead at Risk

Since settlement of the Central Valley in the mid-1800s, populations of native Chinook salmon and steelhead have declined dramatically. California's salmon resources began to decline in the late 1800s, and continued to decline in the early 1900s, as reflected in the decline of commercial harvest. The total commercial catch of Chinook salmon in 1880 was 11 million pounds, by 1922 it had dropped to 7 million pounds, and reached a low of less than 3 million pounds in 1939 (Lufkin 1996).

History and Current Status of Commercial Harvest

Although Chinook salmon remain an important resource, fishing for salmon has changed, most notably, in the last 20 years. 28 evolutionarily significant units (ESU'S) and distinct population segments (DPS's) of salmonids have been listed under the List of Endangered and Threatened Wildlife by the National Marine Fisheries Service (NMFS) on the West Coast of the United States since 1989. This is significant because commercial ocean harvest and sport fishing for salmon has undergone dramatic management and regulatory implementations in order to continue with the commercial fishery while at the same time finding and implementing an exploitation rate that enables sustained Chinook populations into the future. It is also now possible for the ocean fishery to be managed for specific river fisheries through genetic sampling of the ocean harvest along the Pacific Coast. This change has altered the way ocean harvest is regulated, and further protects critical species in that life stage.

New matrixes developed by the National Oceanic and Atmospheric Administration (NOAA) Pacific Northwest Region emphasize that commercial fishing or ocean harvest is a critical parameter in the decisions used to manage sustainable fisheries or to reestablish adequate escapement levels.

Commercial and recreational ocean salmon fisheries in the U.S. Exclusive Economic Zone off the coasts of Washington, Oregon, and California are authorized by NMFS under the Magnuson-Stevens Fishery Conservation and Management Act (MSA). Specifically, these fisheries are managed under the Federal Pacific Coast Salmon Fishery Management Plan (FMP) (PFMC 2003). Consistent with the FMP, detailed management regulations are developed annually, designed to respond to new information and the current status of each salmon stock. Pursuant to the MSA, the Pacific Fishery Management Council (PFMC) develops recommendations for the development of the FMP, FMP amendments, and annual management measures and provides those recommendations to the Secretary of Commerce, through NMFS, for review and approval. The Secretary may approve the PFMC's recommendations for implementation as federal regulation if found to be consistent with the MSA and other applicable law, including the ESA.

The number of Chinook salmon harvested in the California commercial salmon fishery dramatically declined starting in 2006. From 1978 to 2005, the annual salmon harvest for the California commercial fishery exceeded 300,000 in all but one year (2001). In 2006 the fishery collapsed resulting in complete fishery closures in 2008 and 2009, and a heavily restricted fishery in 2010. The average Chinook salmon harvest in the fishery in 2006, 2007, and 2011 was approximately 85,000 (PFMC 2012).

Sources of Habitat Decline

A major factor affecting Chinook salmon and steelhead was hydraulic gold mining, which began in the 1850s. By 1859, an estimated 5,000 miles of mining flumes and canals diverted streams used by salmonids for spawning and nursery habitat. Habitat alteration and destruction also resulted from the use of hydraulic cannons, which leveled hillsides and sluiced an estimated 1.5 billion cubic yards of debris into the streams and rivers of the Central Valley (Lufkin 1996).

Evan though hydraulic mining was prohibited in 1894, other habitat degradation continued. Habitat quantity and quality have declined due to construction of levees and barriers to migration, modification of natural hydrologic regimes by dams and water diversions, elevated water temperatures, and water pollution (Lufkin 1996). Although the effects of habitat degradation on fish populations were evident by the 1930s, rates of decline for most anadromous fish species increased following completion of major water project facilities (USFWS 2001) which primarily occurred around the mid- 1900s.

Numerous water development projects blocked the upstream migration of Chinook salmon and steelhead, and altered flow and water temperature regimes downstream from terminal dams. An extensive network of reservoirs and aqueducts has been developed throughout much of California to provide water to major urban and agricultural areas. The two largest water projects in California are the State Water Project (SWP) and the Federal Central Valley Project (CVP). The CVP delivers on average over 7 million acre-feet per year. CVP water is used to irrigate 3 million acres of farmland in the San Joaquin Valley, as well as provide water for urban use in Contra Costa, Santa Clara, and Sacramento counties. The largest state-built water and power project in the United States, the SWP spans 600 miles from Northern California to Southern California, providing drinking water for 23 million people and irrigation water for 750,000 acres of farmland (see www.aquafornia.com for more information about California water management).

An estimated 1,126 miles of stream remain of the more than 2,183 miles of Central Valley streams that were historically accessible by Chinook salmon – indicating an overall loss of at least 1,057 miles (48 percent) of the original total (Yoshiyama *et al.* 2001). The estimated habitat loss includes the lengths of stream used by salmon mainly as migration corridors, in addition to holding and spawning habitat. This estimated loss of habitat does not include the Delta, comprising about 700 miles of river channels and sloughs (USFWS 1995), available to various degrees as migration corridors or rearing areas for Chinook salmon and steelhead.

It is likely that the lower reaches of the Sacramento and San Joaquin rivers historically were used as rearing areas (at least during some flow regimes) as the juveniles moved downstream, but recently they have been less suitable for rearing due to alterations in channel morphology and other degraded environmental conditions. In terms of only spawning and holding habitat, the proportionate loss of historically available habitat far exceeds 48 percent, much of which was located in upper stream reaches that have been rendered inaccessible by terminal dams (Yoshiyama *et al.* 2001). Excluding the lower stream reaches that were used as adult migration corridors (and, to a lesser degree, for juvenile rearing), it has been estimated that at least 72 percent of the original Chinook salmon spawning and holding habitat in the Central Valley drainage is no longer available (Yoshiyama *et al.* 2001).

The amount of steelhead habitat lost most likely is much higher than that for Chinook salmon, because steelhead were undoubtedly more extensively distributed. Due to their superior leaping and swimming ability and the timing of their upstream migration, which coincided with the winter rainy season, steelhead likely used at least hundreds of miles of smaller tributaries not accessible to even the highest migrating winter-run and spring-run Chinook salmon (Yoshiyama *et al.* 2001).

In addition to commercial exploitation, large-scale habitat degradation, blockage of historically available habitat and altered flow and water temperature regimes, other factors that may have adversely affected natural stocks of Chinook salmon and steelhead include overharvest, illegal harvest, hatchery production, entrainment, and introduction of competitors, predators and diseases. Fish populations also vary due to natural events, such as droughts and poor ocean conditions (e.g., El Niño). However, populations in healthy habitats typically recover within a few years after natural events. In the Central Valley, the decline of fish populations has continued through cycles of beneficial and adverse natural conditions, indicating the need to improve habitat (USFWS 2001).

1.3 The Recovery Planning Process

The Federal Endangered Species Act of 1973 (ESA), as amended (16 U.S.C. 1531 *et seq.*) mandates the National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS) to develop and implement plans (i.e., recovery plans) for the conservation and survival of NMFS listed species. Winter-run Chinook salmon are listed as endangered under the Federal ESA, and spring-run Chinook salmon and steelhead are listed as threatened. Implementation of the Recovery Plan for the Sacramento River winter-run Chinook salmon Evolutionarily Significant Unit (ESU), Central Valley spring-run Chinook salmon ESU, and California Central Valley steelhead Distinct Population Segment[1] (DPS) is vital to the continued persistence and recovery of these populations.

The recovery plan is a comprehensive plan that serves as a road map for species recovery – it lays out where we need to go and how best to get there. A recovery plan is one of the most important tools to ensure sound scientific and logistical decision-making throughout the recovery process. Primarily, a recovery plan should do the following:

- Delineate those aspects of the species' biology, life history, and threats that are pertinent to its endangerment and recovery;

- Outline and justify a strategy to achieve recovery;

- Identify the actions necessary to achieve recovery of the species; and

- Identify goals and criteria by which to measure the species' achievement of recovery (NMFS 2010b).

Although recovery plans provide guidance, they do not have the force of law. The success of this Recovery Plan depends upon the cooperation of all stakeholders and regulatory entities to ensure appropriate implementation.

Pursuant to Section 4(f) of the ESA, a recovery plan must be developed and implemented for the conservation and survival of species listed as threatened or endangered unless it finds that a recovery plan will not promote the conservation of the species. A recovery plan must, to the maximum extent practicable, include the following:

- A description of site-specific management actions necessary for recovery;
- Objective, measurable criteria, which when met, will allow delisting of the species; and
- Estimates of the time and cost to carry out the recovery measures.

The purpose of this Recovery Plan is to guide implementation of recovery of the species by resolving the threats to the species and thereby ensuring viable Chinook salmon ESUs and the steelhead DPS. This Recovery Plan may be used to inform all stakeholders including Federal, State, Tribal, and local agencies and land use actions, but it does not place regulatory requirements on such entities.

Past recovery plans generally have focused on the abundance, productivity, habitat and other life history characteristics of a species. While knowledge of these characteristics is certainly important for making sound conservation management decisions, the long-term

[1] On January 5, 2006, NMFS departed from their previous practice of applying the ESU policy to steelhead. NMFS concluded that within a discrete group of steelhead populations, the resident and anadromous life forms of steelhead remain "markedly separated" as a consequence of physical, ecological and behavioral factors, and may therefore warrant delineation as a separate DPS (71 FR 834).

sustainability of a species in need of recovery can only be ensured by alleviating the threats that are contributing to the status of the species as threatened or endangered. Therefore, the identification of the threats to the species is a key component of this Recovery Plan.

To be most useful for recovery planning, a threats assessment should be used to determine the relative importance of various threats to a species. A threats assessment includes: (1) identifying threats and their sources; (2) evaluating the effects of threats; and (3) ranking each threat based on relative effects. The Interim Endangered and Threatened Species Recovery Planning Guidance (NMFS 2010b) recommends "*…using a threats assessment for species with multiple threats to help identify the relative importance of each threat to the species' status, and, therefore, to prioritize recovery actions in a manner most likely to be effective for the species' recovery*." This Recovery Plan uses this recommended approach to identify and prioritize threats to the Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon ESUs, and the California Central Valley steelhead DPS. The prioritized threats are then used to guide the identification of specific recovery actions.

The methodology used in the threats assessment for this Recovery Plan is generally described in the next chapter (Background) and is fully described in Appendix B.

1.3.1 A Collaborative Effort

Central Valley Technical Recovery Team

As part of its recovery planning efforts, the NMFS Southwest Region (now part of the West Coast Region) designated the Central Valley as a "Recovery Domain." The NMFS Southwest Region established the Central Valley Technical Recovery Team (TRT) to provide technical assistance to the recovery planning process for the Central Valley Domain. The NMFS' intent in establishing the Central Valley TRT was to seek unique geographic and species expertise, and to develop a solid scientific foundation for the Recovery Plan. The Central Valley TRT identified unique habitat and biological characteristics of the three species, made technical findings regarding limiting factors and stressors for each ESU and DPS and its component populations, recommended biological viability criteria at the ESU/DPS- and population-level, and provided scientific review of local and regional recovery planning efforts.

The Central Valley TRT, a collaborative body of biologists that were selected based on their expertise and local knowledge, produced three documents heavily relied upon in preparation of the Recovery Plan: (1) *Population Structure of Threatened and Endangered Chinook Salmon ESUs in California's Central Valley Basin* (Lindley *et al.* 2004); (2) *Historical Population Structure of Central Valley Steelhead and its Alteration by Dams* (Lindley *et al.* 2006); and (3) *Framework for Assessing Viability of Threatened and Endangered Chinook Salmon and Steelhead in the Sacramento-San Joaquin Basin* (Lindley *et al.* 2007).

Public Participation

NMFS conducted a series of Recovery Planning Workshops, designed as round-table discussions, to solicit information and promote dialogue as part of the development of the Federal Recovery Plan for winter-run Chinook salmon, spring-run Chinook salmon and steelhead in the Central Valley Domain. Public workshops were held in Sacramento, California on July 20, 2006, in Redding, California on August 15, 2006, and in

Stockton, California on August 17, 2006. At these workshops, NMFS provided a general overview of: (1) the Federal recovery planning process; (2) the timeline for NMFS recovery plan development; (3) the current understanding of Chinook salmon and steelhead populations and their habitats; and (4) threats identified in original ESA listing documents.

Following the overviews, workshop participants were separated into smaller facilitated discussion groups to generate more in-depth dialogue and identify threats to specific Chinook salmon and steelhead populations and their habitats.

Information obtained at the initial series of workshops also was used in additional workshops to develop recovery actions that reduce or eliminate identified threats. These additional workshops were held in Sacramento, California on May 22, 2007 and in Redding, California on May 24, 2007.

In October of 2009, NMFS released a Public Draft Recovery Plan for Central Valley salmon and steelhead, commencing a 60-day public review and comment period (74 FR 51553; October 7, 2009). Based on requests from the public for additional review time, this comment period was extended an additional 60 days (74 FR 61329; November 24, 2009). NMFS received 78 written comment submissions from the public as well as several verbal comments. Many of the public comments and suggested edits have strengthened this Recovery Plan. Following release of the Public Draft Recovery Plan, a total of eight public workshops were held in Sacramento (three workshops), Chico (three workshops), Salida, and Mt. Shasta to help establish working relationships with local communities and to obtain stakeholder input.

Existing Efforts

Local water agencies and irrigation districts, municipal and county governmental agencies, watershed groups, and State and Federal agencies have undertaken major habitat restoration efforts in many parts of the Central Valley and Delta. These actions include the addition of gravel below dams, removal of small dams, screening water diversions, fish passage improvements, riparian revegetation, bank protection, structural habitat enhancement, restoration of floodplain and tidal wetlands, development and implementation of new flow and water temperature requirements below dams, and operational constraints in the Delta. Major restoration efforts that impact salmon and steelhead recovery throughout the Central Valley include the programs established under the Anadromous Fish Restoration Program (AFRP) of the Central Valley Project Improvement Act (CVPIA) and the Ecosystem Restoration Program (ERP). Shared purposes of the AFRP and the ERP are to protect and restore diversity within and among the various naturally-producing populations of Chinook salmon and steelhead in the Central Valley, and to restore the habitats upon which the populations depend.

The AFRP promotes collaboration between the Department of Interior (USFWS and the Bureau of Reclamation [Reclamation]) with other agencies, organizations and the public to increase natural production of anadromous fish in the Central Valley by augmenting and assisting restoration efforts presently conducted by local watershed workgroups, the California Department of Fish and Wildlife (CDFW), and others. Purposes of the CVPIA (Section 3402) relevant to the AFRP are: (1) to protect, restore, and enhance fish, wildlife, and associated habitats in the Central Valley; (2) to address impacts of the CVP on fish, wildlife, and associated habitats; (3) to improve the operational flexibility of the

CVP; (4) to contribute to the State of California's interim and long-term efforts to protect the San Francisco Bay and Sacramento-San Joaquin Delta Estuary; and (5) to achieve a reasonable balance among competing demands for the use of CVP water, including the requirements of fish and wildlife, agricultural, municipal and industrial, and power contractors (USFWS 2001).

The ERP is CDFW's principal program designed to restore the ecological health of the Bay/Delta ecosystem. The ERP includes actions throughout the Bay/Delta watershed and focuses on the restoration of ecological processes and important habitats. In addition, the ERP aims to reduce the effects of stressors that inhibit ecological processes, habitats and species (CALFED 1999b).

Another major effort that could impact Central Valley salmon and steelhead recovery, if implemented, is the Bay Delta Conservation Plan (BDCP). The dual goals of the BDCP are to provide a comprehensive ecosystem restoration program for the delta and a reliable water supply. Further information is available at the BDCP website: http://baydeltaconservationplan.com/.

1.4 Recovery Plan Content

This introductory chapter provides an overview of many important facets of this Recovery Plan, and in particular describes the collaborative processes of the plan. The remainder of this Recovery Plan for the Sacramento River winter-run Chinook salmon ESU, the Central Valley spring-run Chinook salmon ESU and the California Central Valley steelhead DPS is presented in several chapters.

The second chapter provides background including the current regulatory status, a description of the population trends and distribution of each species, and a description of the life history and habitat requirements for each species. A brief description of the reasons for listing and a current threats assessment is then presented (a detailed threats assessment is presented in Appendix B). Finally, current conservation efforts and biological constraints are discussed, including limiting factors that should be considered for the species recovery.

Next, the Recovery Strategy Chapter presents and justifies the recommended recovery program for each species. This chapter also describes the key facts, concepts and assumptions upon which the recovery program is based.

The following chapter describes the recovery goals, objectives, and criteria. The ultimate goal of the Recovery Plan is delisting of the Chinook salmon ESUs and the steelhead DPS. The recovery objectives basically subdivide the goal into discrete components which collectively describe the conditions necessary for delisting. Recovery criteria are the objective and measurable standards upon which decisions to delist the ESUs and DPS are based.

Next, the specific actions that should be implemented to achieve recovery are presented in the Recovery Actions Chapter. That chapter is intended to satisfy the requirement under the ESA (Section 4 (f)(1)(B)(iii)) that Recovery Plans must contain to the maximum extent practicable "*…estimates of the time required and the cost to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal*." Recovery actions are linked to the identified threats (or stressors) individually for specific populations of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead within the Central Valley Domain, and are prioritized according to the priority of threats addressed.

This Recovery Plan includes a chapter discussing the impacts of climate change on Central Valley salmonids, including how those impacts are expected to affect recovery efforts in the coming decades.

Lastly, a chapter on how this plan will be implemented is provided. The chapter discusses the time and cost to recovery, the benefits of recovery, and the various tools under the ESA that can be used to implement anadromous salmonid recovery in the Central Valley.

2.0 Background

"The requirement for determining that a species no longer requires the protection of the ESA is that the species no longer be in danger of extinction or likely to become endangered in the foreseeable future based on evaluation of the listing factors specified in ESA Section 4(a)(1). Any new factors identified since listing must also be addressed in this analysis to ensure that the species no longer requires protection."

- NMFS Supplement to the Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan 2005

The Central Valley Domain encompasses the Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, and California Central Valley steelhead DPS. Following are descriptions of the current regulatory status, life histories, population trends and distribution, and the habitat requirements for winter- and spring-run Chinook salmon, and steelhead in the Central Valley. A brief description of the reasons for listing and a current threats assessment is then presented (a detailed threats assessment is presented in Appendix B). Finally, current conservation efforts and biological constraints are discussed, including limiting factors that should be considered for recovery of winter-run and spring-run Chinook salmon, and steelhead within the Central Valley Domain.

2.1 Winter-run Chinook Salmon

2.1.1 ESA Listing Status

The Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*) ESU, currently listed as endangered, was listed as a threatened species under emergency provisions of the ESA in August 1989 (54 FR 32085: August 4, 1989) and listed as a threatened species in a final rule in November 1990 (55 FR 46515; November 5, 1990). In June 1992, NMFS proposed that winter-run Chinook salmon be reclassified as an "endangered"[2] species (57 FR 27416; June 19, 1992). NMFS finalized its proposed rule and re-classified winter-run Chinook salmon as an endangered species on January 4, 1994 (59 FR 440). NMFS concluded that winter-run Chinook salmon in the Sacramento River warranted listing as an endangered species due to several factors, including: (1) the continued decline and increased variability of run sizes since its first listing as a threatened species in 1989; (2) the expectation of weak returns in future years as the result of two small year classes (1991 and 1993); and (3) continued threats to the winter-run Chinook salmon.

[2] Under the ESA, an "endangered species" is, with the exception of insects determined to be pests, "…any species which is in danger of extinction throughout all or a significant portion of its range…" (16 USC § 1532(6)).

On June 14, 2004, NMFS issued a proposed rule to reclassify the listing status of winter-run Chinook salmon from endangered to threatened (69 FR 33102). To prevent further decline of the ESU by preventing take of this species from activities that harm fish and fish habitat, NMFS proposed to apply the ESA Section 9(a) take prohibitions with specific limitations to winter-run Chinook salmon under ESA Section 4(d) (69 FR 33102).

Following a series of extensions to the public comment period on the proposed listing determinations, the public comment period closed during November 2004 (69 FR 61348; October 18, 2004). On June 28, 2005, NMFS issued a final listing determination for the Sacramento River winter-run Chinook salmon ESU, which concluded that the Sacramento River winter-run Chinook salmon ESU is "in danger of extinction" due to risks to the ESU's diversity and spatial structure and, therefore, continues to warrant listing as an endangered species under the ESA (70 FR 37160). Additionally, the Sacramento River Winter-run Chinook salmon was listed as endangered under the California ESA in 1989.

The Sacramento River winter-run Chinook salmon ESU includes winter-run Chinook salmon spawning naturally in the Sacramento River and its tributaries, as well as winter-run Chinook salmon that are part of the conservation hatchery program at the Livingston Stone National Fish Hatchery (LSNFH) (70 FR 37160). The Sacramento River winter-run Chinook salmon ESU is depicted in **Figure 2-1**.

2.1.2 Species Description and Taxonomy

Chinook salmon, also referred to as king salmon in California, are the largest of the Pacific salmon. The following physical description of the species is provided by Moyle (2002). Spawning adults are olive to dark maroon in color, without conspicuous streaking or blotches on the sides. Spawning males are darker than females, and have a hooked jaw and slightly humped back. There are numerous small black spots in both sexes on the back, dorsal fins, and both lobes of the tail. They can be distinguished from other spawning salmon by the color pattern, particularly the spotting on the back and tail, and by the dark, solid black gums of the lower jaw. Parr have 6 to 12 parr marks, each equal to or wider than the spaces between them and most centered on the lateral line. The adipose fin of parr is pigmented on the upper edge, but clear at its base. The dorsal fin occasionally has one or more spots on it but the other fins are clear.

2.1.3 Life History/Habitat Requirements

Chinook salmon is the most important commercial species of anadromous fish in California. Chinook salmon have evolved a broad array of life history patterns that allow them to take advantage of diverse riverine conditions throughout the year. Four principal life history variants are recognized and are named for the timing of their upstream migration: fall-run, late fall-run, winter-run, and spring-run. The Sacramento River supports all four runs of Chinook salmon. The larger tributaries to the Sacramento River (American, Yuba, and Feather rivers) and rivers in the San Joaquin Basin also provide habitat for one or more of these runs.

Winter-run Chinook salmon are unique because they spawn during summer months when air temperatures usually approach their yearly maximum. As a result, winter-run Chinook salmon require stream reaches with cold water sources that will protect embryos and juveniles from the warm ambient conditions in summer.

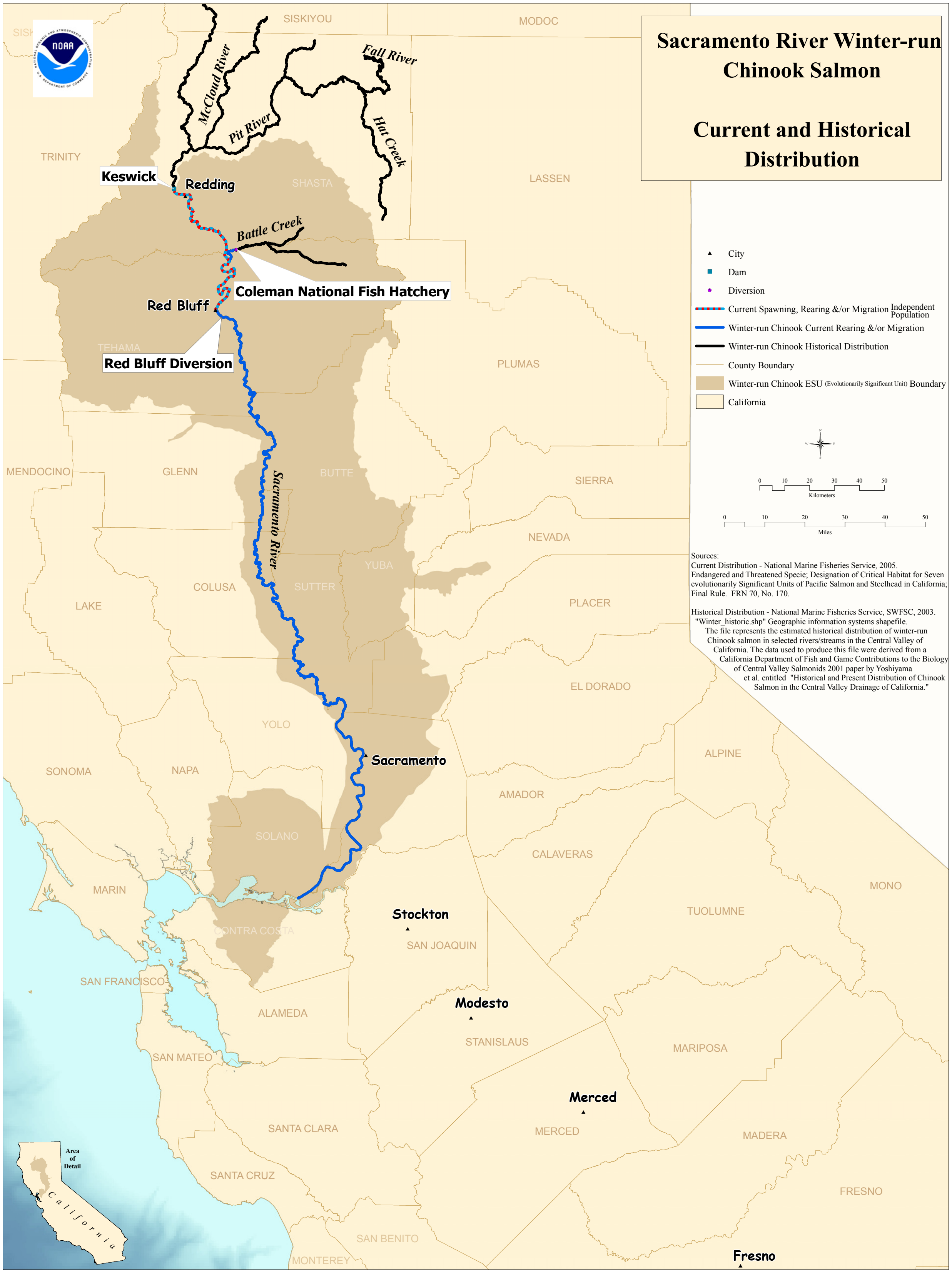

Figure 2-1. Current and Historical Sacramento River Winter-run Chinook Salmon Distribution.

Table 2-1 depicts the temporal occurrence of winter-run Chinook salmon life stages in the Sacramento River. Adult winter-run Chinook salmon immigration and holding (upstream spawning migration) through the Delta and into the lower Sacramento River occurs from December through July, with a peak during the period extending from January through April (USFWS 1995). Winter-run Chinook salmon are sexually immature when upstream migration begins, and they must hold for several months in suitable habitat prior to spawning. Winter-run Chinook salmon primarily spawn in the mainstem Sacramento River between Keswick Dam (River Mile [RM] 302) and the Red Bluff Diversion Dam (RBDD) (RM 243). Spawning occurs between late-April and mid-August, with a peak in June and July as reported by CDFW annual escapement surveys (2000-2006). Winter-run Chinook salmon embryo incubation in the Sacramento River can extend into October (Vogel and Marine 1991).

Winter-run Chinook salmon fry rearing in the upper Sacramento River exhibit peak abundance during September, with fry and juvenile emigration past RBDD primarily occurring from July through November (Poytress and Carillo 2010, 2011, 2012). Emigration of winter-run Chinook salmon juveniles past Knights Landing, located approximately 155.5 river miles downstream of the RBDD, reportedly occurs between November and March, peaking in December, with some emigration continuing through May in some years (Snider and Titus 2000a; Snider and Titus 2000c).

A description of freshwater habitat requirements for winter-run Chinook salmon is presented in the following sections. Habitat requirements are organized by life stage.

Adult Immigration and Holding

Suitable water temperatures for adult winter-run Chinook salmon migrating upstream to spawning grounds range from 57°F to 67°F (NMFS 1997). However, winter-run Chinook salmon are immature when upstream migration begins, and need to hold in suitable habitat for several months prior to spawning. The maximum suitable water temperature reported for holding is 59°F to 60°F (NMFS 1997). Because water temperatures in the lower Sacramento River below the RBDD generally begin exceeding 60 degrees Fahrenheit (°F) in April, it is likely that little, if any, suitable holding habitat exists in the lower Sacramento River. It most likely is only used by adults as a migration corridor. Following installation of the water temperature control device on Shasta Dam in 1997, it is possible that some deep water pool habitat may exist for a short distance downstream of the RBDD with suitable cold water temperatures for adult holding.

Adult Chinook salmon reportedly require water deeper than 0.8 feet and water velocities less than 8 feet per second (ft/sec) for successful upstream migration (Thompson 1972). Adult Chinook salmon are less capable of negotiating fish ladders, culverts, and waterfalls during upstream migration than steelhead, due in part to slower swimming speeds and inferior jumping ability (Bell 1986; Reiser *et al.* 2006).

Chinook salmon generally hold in pools with deep, cool, well-oxygenated water. Holding pools for adult Chinook salmon have reportedly been characterized as having moderate water velocities ranging from 0.5 to 1.3 ft/sec (DWR 2000).

Table 2-1. The Temporal Occurrence of Adult and Juvenile Sacramento River Winter-run Chinook Salmon in the Sacramento River

Winter run relative abundance	High				Medium				Low			
a) Adult freshwater												
Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sacramento River basin[a,b]												
Sacramento River spawning[c]												
b) Juvenile migration												
Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sacramento River@ Red Bluff[d]												
Sacramento River @ Knights Landing[e]												
Sacramento trawl @ Sherwood Harbor[f]												
Midwater trawl @Chipps Island[g]												

Sources: [a] (Yoshiyama *et al.* 1998); (Moyle 2002); [b](Myers *et al.* 1998) ; [c] (Williams 2006) ; [d] (Martin *et al.* 2001); [e] Knights Landing Rotary Screw Trap Data, CDFW (1999-2011)); [f,g] Delta Juvenile Fish Monitoring Program(DJFMP), USFWS (1995-2012)

Spawning

Spawning occurs from mid-April to mid-August, peaking in June and July, in the Sacramento River reach between Keswick Dam and RBDD (Vogel and Marine 1991; CDFW Annual escapement survey reports, 2000-2006). Chinook salmon spawn in clean, loose gravel, in swift, relatively shallow riffles, or along the margins of deeper river reaches where suitable water temperatures, depths, and velocities favor redd construction and oxygenation of incubating eggs. Winter-run Chinook salmon were adapted for spawning and rearing in the clear, spring-fed rivers of the upper Sacramento River Basin, where summer water temperatures were typically 50°F to 59°F. Water temperature conditions were created by glacial and snowmelt water percolating through porous volcanic formations that surround Mt. Shasta and Lassen Peak, which cover much of northeastern California. Chinook salmon require clean loose gravel from 0.75 to 4.0 inches in diameter for successful spawning (NMFS 1997). The construction of dams in the upper Sacramento River has eliminated the major source of suitable gravel recruitment to reaches of the river below Keswick Dam. Gravel sources from the banks of the river and floodplain have also been substantially reduced by levee and bank protection measures. Levee and bank protection measures restrict the meandering of the river, which would normally release gravel into the river through natural erosion and deposition processes. Moyle (2002) reported that water velocity preferences (i.e., suitability greater than 0.5) for Chinook salmon spawning range from 0.98 ft/sec to 2.6 ft/sec (0.3 to 0.8 meters per second (m/sec)) at a depth of a few centimeters (cm) to several meters (m), whereas USFWS (2003) reported that winter-run Chinook salmon prefer water velocities range from 1.54 ft/sec to 4.10 ft/sec (0.47 to 1.25 meters per second) at a depth of 1.4 to 10.1 feet (0.4 to 3.1 m).

Today, Shasta Dam denies access to historical winter-run Chinook salmon spawning habitats and they persist mainly because water released from Shasta Reservoir during the summer has been, for the most part, sufficiently cold. Spawning habitat for Sacramento River winter-run Chinook salmon is restricted to the Sacramento River primarily between RBDD and Keswick Dam.

Embryo Incubation

In the Sacramento River, winter-run Chinook salmon spawning occurs from late April through mid-August. Because the embryo incubation life stage begins with fertilized egg deposition and ends with fry emergence from the gravel, embryo incubation occurs from late April through mid-October. Fry emergence occurs from mid-June through mid-October (NMFS 1997). Within the appropriate water temperature range, eggs normally hatch in 40 to 60 days. Newly hatched fish (alevins) normally remain in the gravel for an additional four to six weeks until the yolk sac has been absorbed (NMFS 1997).

Physical habitat requirements for embryo incubation are the same as the requirements discussed above for spawning. However, it is also important that flow regimes remain relatively constant or at least not decrease significantly during the embryo incubation life stage.

Juvenile Rearing and Outmigration

Upon emergence from the gravel, fry swim or are displaced downstream (Healey 1991). Fry seek streamside habitats containing beneficial aspects such as riparian vegetation and associated substrates that provide aquatic and terrestrial invertebrates for food, predator avoidance cover, and slower water velocities for resting (NMFS 1996a). These shallow water habitats have been described as more productive juvenile salmon rearing habitat than the deeper main river channels. Higher juvenile salmon growth rates, partially due to greater prey consumption rates, as well as favorable environmental temperatures have been associated with shallow water habitats (Sommer *et al.* 2001b). Similar to adult salmon upstream movement, juvenile salmon downstream movement is primarily crepuscular. Once downstream movement has commenced, salmon fry continue this movement until reaching the estuary or they might reside in the stream for a time period that varies from weeks to a year (Healey 1991). Juvenile Chinook salmon migration rates vary considerably, presumably depending on the physiological stage of the juvenile and hydrologic conditions. Kjelson *et al.* (1981) found Chinook salmon fry traveled as fast as 30 kilometers (km) per day in the Sacramento River. Sommer *et al.* (2001b) found travel rates ranging from approximately 0.8 km (0.5 miles) per day, up to more than 9.7 km (6 miles) per day in the Yolo Bypass.

As juvenile Chinook salmon grow they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures (Healey 1991). Catches of juvenile salmon in the Sacramento River near West Sacramento by the USFWS (USFWS 1997) exhibited larger juvenile captures in the main channel and smaller-sized fry along the margins. Where the river channel is greater than nine to ten feet in depth, juvenile salmon tend to inhabit the surface waters (Healey 1979). Streamflow and/or turbidity increases in the upper Sacramento River basin are thought to stimulate emigration (Poytress 2007).

Emigration of juvenile Sacramento River winter-run Chinook salmon past RBDD may begin after almost one year in the river. They begin to move down river as early as mid-July, typically peaking numbers in September, and can continue through March in dry years (NMFS 1997; Vogel and Marine 1991). From 1995 to 1999, all Sacramento River winter-run Chinook salmon outmigrating as fry passed RBDD by October, and all outmigrating pre-smolts and smolts passed RBDD by March (Martin *et al.* 2001).

As Chinook salmon begin the smoltification stage, they are found rearing further downstream where ambient salinity reaches 1.5 to 2.5 parts per thousand (Healey 1979). Within the Delta, juvenile Chinook salmon forage in shallow areas with protective cover, such as tidally influenced sandy beaches and vegetated zones (Healey 1979). Cladocerans, copepods, amphipods, and larvae of diptera, as well as small arachnids and ants are common prey items (Kjelson *et al.* 1981; MacFarlane and Norton 2002; Sommer *et al.* 2001a).

Juvenile Chinook salmon movements within the estuarine habitat are dictated by the interaction between tidally-driven salt water intrusions through the San Francisco Bay and fresh water outflow from the Sacramento and San Joaquin rivers. Juvenile Chinook salmon follow rising tides into shallow water habitats from the deeper main channels and return to the main channels when the tides recede (Healey 1991). Kjelson *et al.* (1981) reported that juvenile Chinook salmon demonstrated a diel migration pattern, orienting themselves to nearshore cover and structure during the day, but moving into more open, offshore waters at night. The fish also distributed themselves vertically in relation to ambient light. During the night, juveniles were distributed randomly in the water column, but would school up during the day into the upper three meters of the water column. Juvenile Chinook salmon were found to spend about 40 days migrating through the Delta to the mouth of San Francisco Bay, and grew little in length or weight until they reached the Gulf of the Farallon Islands (MacFarlane and Norton 2002).

Juvenile Sacramento River winter-run Chinook salmon occur in the Delta primarily from November through early May, using size-at-date criteria from trawl data in the Sacramento River at West Sacramento (RM 57) (USFWS 2001). The timing of migration varies somewhat due to changes in river flows, dam operations, and water year type. Winter-run Chinook salmon juveniles remain in the Delta until they reach a fork length (FL) of approximately 118 millimeters (mm) and are from five to 10 months of age. Emigration to the ocean begins as early as November and continues through May (Fisher 1994; Myers *et al.* 1998). The importance of the Delta in the life history of Sacramento River winter-run Chinook salmon is not well understood.

Central Valley Chinook salmon begin their ocean life in the Gulf of the Farallones, then they distribute north and south along the continental shelf primarily between Point Conception and Point Arena, although some winter-run Chinook salmon migrate up and beyond Washington State. Upon reaching the ocean, juvenile Chinook salmon feed voraciously on larval and juvenile fishes, plankton, and terrestrial insects (Healey 1991; MacFarlane and Norton 2002). Chinook salmon grow rapidly in the ocean environment, with growth rates dependent on water temperatures and food availability (Healey 1991).

2.1.4 Abundance Trends and Distribution

One of the main threats to the Sacramento River winter-run Chinook salmon ESU is that it consists of only one population. Furthermore the one population is small (Good *et al.* 2005). The population declined from an escapement of near 100,000 in the late 1960s to fewer than 200 in the early 1990s (Good *et al.* 2005). More recent population estimates of 8,218 (2004), 15,730 (2005), and 17,153 (2006) show a three-year average of 13,700 returning winter-run Chinook salmon (CDFW Website 2007). However, the run size decreased to 2,542 in 2007 and 2,850 in 2008. **Figure 2-2** depicts the estimated run sizes of Sacramento River winter-run Chinook salmon from 1967 through 2012.

The LSNFH winter-run Chinook salmon conservation program on the upper Sacramento River is one of the most important reasons that Sacramento River winter-run Chinook salmon still persist. The LSNFH has been producing and releasing winter-run Chinook salmon since 1998. This conservation program has apparently resulted in a net increase in the numbers of returning adult winter-run Chinook salmon, although hatchery fish make up a significant portion of the population (Brown and Nichols 2003). Since 2003, LSNFH winter-run program has exceeded best management practices for conservation and recovery of natural salmonid populations.

Table 2-2 shows the annual number of winter-run Chinook salmon released from the facility from 1998 through 2012. The fish are marked with coded wire tags (CWT), adipose fin clipped and released as smolts each winter in late January or early February. The table also provides information based on data acquired during mark-recapture studies on the amount of time required by the smolts to migrate through the Delta.

Winter-run Chinook salmon originally spawned in the upper Sacramento River system (Little Sacramento, Pit, McCloud and Fall rivers) and in Battle Creek (Yoshiyama *et al*. 1996). There is no evidence that the winter-run existed in any of the other drainages prior to watershed development (Yoshiyama *et al.* 1996). The unique life history timing pattern of winter-run Chinook salmon, requiring cold summer flows, argues against this run occurring in drainages other than the upper Sacramento system and Battle Creek. Watershed development has eliminated all historical spawning habitats above Keswick Dam (approximately 200 river miles) and approximately 47 of the 53 miles of potential habitat in Battle Creek (Yoshiyama *et al.* 1996). Figure 2-1 depicts the current and historical distribution of Sacramento River winter-run Chinook salmon.

Currently, winter-run Chinook salmon spawning habitat is likely limited to the reach of the Sacramento River extending from Keswick Dam downstream to the RBDD. Prior to construction of Shasta and Keswick dams, the mainstem Sacramento River primarily functioned as a rearing and migration corridor because warm water temperatures likely precluded spawning. Winter-run Chinook salmon still have access to Battle Creek throughout the duration of their migration period by either passing through the Coleman National Fish Hatchery (CNFH) (December through February) or by ascending the fish ladder located at the CNFH weir (March through July).

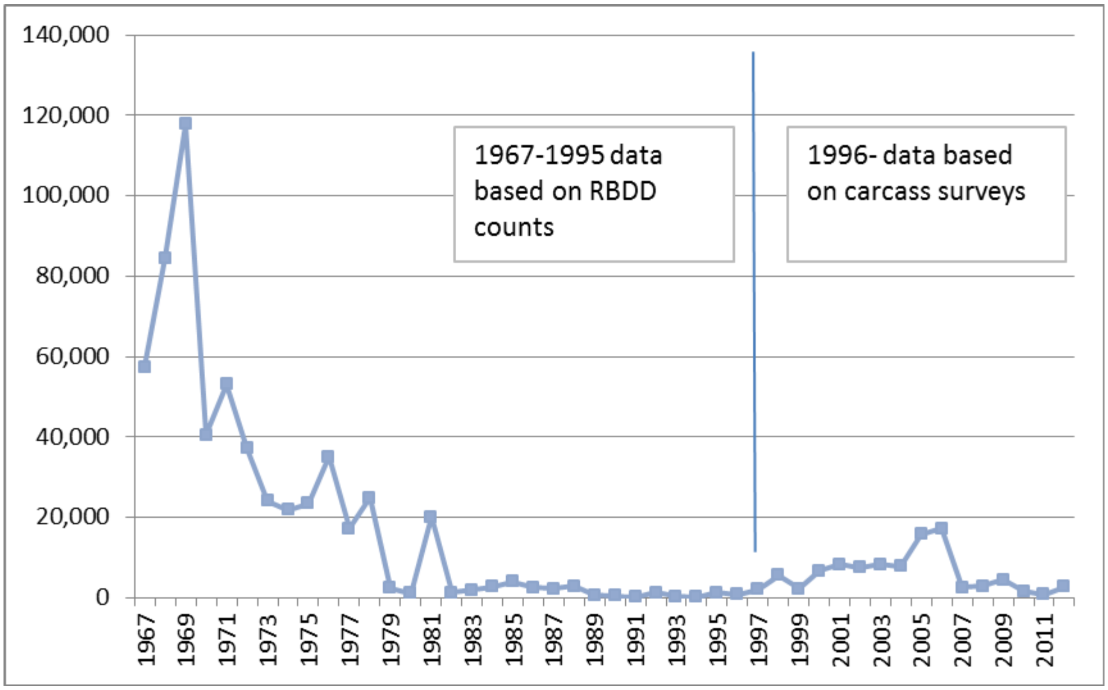

Figure 2-2. Estimated Sacramento River Winter-run Chinook Salmon Run Size (1967 – 2012).
***Source:* http://www.fws.gov/stockton/afrp/**

Table 2-2. Winter-run Chinook Salmon Juvenile Releases from LSNFH (Broodyears 1998-2012) and Date of Initial Recapture at Chipps Island.

Brood Year	Upper Sacramento River Release Date	Number of Pre-Smolts Released[1]	Initial Date[2] of Recapture at Chipps Island
1998	1/28/1999	153,908	3/15/1999
1999	1/27/2000	30,840	3/18/2000
2000	2/01/2001	166,206	3/09/2001
2001	1/30/2002	252,684	3/20/2002
2002	1/30/2003	233,613	2/14/2003
2003	2/05/2004	218,617	2/20/2004
2004	2/03/2005	168,261	2/22/2005
2005	2/02/2006	173,344	2/17/2006
2006	2/08/2007	196,288	2/17/2007
2007	1/31/2008	71,883	3/12/2008
2008	1/29/2009	146,211	2/20/2009
2009	2/10-11/2010	198,582	2/26/2010
2010	2/3/2011	123,859	3/21/2011
2011	2/9/2012	194,264	3/23/2012
2012	2/7/2013	181,857	
Source: ([1]USFWS Red Bluff; [2] Redler 2013)			

Winter-run Chinook salmon are believed to have historically occurred in Battle Creek as one of four independent Central Valley populations (Lindley *et al.* 2004). Hydroelectric facilities and operations likely caused the extirpation of winter-run Chinook salmon from the Battle Creek watershed in the early 1900s (Reynolds *et al.* 1993). Watershed restoration actions associated with the Battle Creek Salmon and Steelhead Restoration Project are expected to restore conditions that will allow for successful reintroduction of winter-run Chinook salmon to Battle Creek.

The USFWS initiated the winter-run Chinook salmon propagation program at the CNFH in 1989. Although the winter-run Chinook salmon propagation program was located on Battle Creek, the program had the goal of supplementing natural spawning in the mainstem of the upper Sacramento River. To encourage adults to return to the Sacramento River rather than the location of the hatchery on Battle Creek, hatchery-produced juvenile winter-run Chinook salmon were released into the mainstem Sacramento River at the pre-smolt life stage. Unfortunately, this strategy was not successful at achieving a successful imprint to the upper Sacramento River and adults instead returned to the location of the hatchery on Battle Creek. To improve imprinting to the upper Sacramento River, the winter-run Chinook salmon propagation program was moved in 1997 to a new facility, the LSNFH, located immediately downstream of Shasta Dam. Within a few years of relocating the winter-run Chinook salmon propagation program, returns of adult winter-run Chinook salmon to Battle Creek declined to zero. During recent years, a few winter-run Chinook salmon adults have been observed in Battle Creek; these fish are likely strays from the mainstem Sacramento River.

A winter-run Chinook salmon migration to the Calaveras River may have occurred between 1972 and 1984, but this population appears to have been extirpated by drought conditions, which were exacerbated by irrigation diversions (NMFS 1997; NMFS 1999; NMFS 2003). This Calaveras River population is also thought to have been late fall-run or fall-run Chinook salmon that were mistakenly identified as winter-run Chinook salmon (Yoshiyama *et al.* 2000). Winter-run Chinook salmon did not historically occur in the Calaveras River because the natural river conditions were not suitable to support the species life history requirements (e.g., cold water during the spring and summer for holding, spawning, and embryo incubation).

The Sacramento River winter-run Chinook salmon population is dependent upon the provision of suitably cool water temperatures during the spawning, embryo incubation, and juvenile rearing period. Water temperatures in the upper Sacramento River are the result of interaction among: (1) ambient air temperature; (2) volume of water; (3) water temperature at release from Shasta and Trinity dams; (4) total reservoir storage; (5) location of reservoir thermocline; (6) ratio of Spring Creek Power Plant release to Shasta Dam release; (7) operation of Temperature Control Device (TCD) on Shasta Dam; and (8) tributary inflows (NMFS 1997). Water temperature varies with location and distance downstream of Keswick Dam, and depends upon the annual hydrologic conditions and annual operation of the Shasta-Trinity Division of the CVP (NMFS 1997). In general, water released from Keswick Dam warms as it moves downstream during the summer and early fall months at a critical time for the successful development and survival of juvenile winter-run Chinook salmon (NMFS 1997).

2.1.5 Critical Habitat

Critical habitat for listed salmonids is comprised of physical and biological features essential to the conservation of the species including: space for the individual and population growth and for normal behavior; cover; sites for breeding, reproduction and rearing of offspring; and habitats protected from disturbance or are representative of the historical geographical and ecological distribution of the species. Physical and biological features that are essential for the conservation of winter-run Chinook salmon, based on the best available information, include (1) access from the Pacific Ocean to appropriate spawning areas in the upper Sacramento River; (2) the availability of clean gravel for spawning substrate; (3) adequate river flows for successful spawning, incubation of eggs, fry development and emergence, and downstream transport of juveniles; (4) water temperatures between 42.5 and 57.5 °F (5.8 and 14.1 degrees Celsius (°C)) for successful spawning, egg incubation, and fry development; (5) habitat and adequate prey free of contaminants; (6) riparian habitat that provides for successful juvenile development and survival; and (7) access of juveniles downstream from the spawning grounds to San Francisco Bay and the Pacific Ocean (58 FR 33212, 33216-17; June 16, 1993).

On August 14, 1992, NMFS published a proposed critical habitat designation for winter-run Chinook salmon (57 FR 36626). The habitat proposed for designation included: (1) the Sacramento River from Keswick Dam, Shasta County (RM 302) to Chipps Island (RM 0) at the westward margin of the Delta; (2) all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait; (3) all waters of San Pablo Bay westward of the Carquinez Bridge; and (4) all waters of San Francisco Bay to the Golden Gate Bridge (NMFS 1997).

On June 16, 1993, NMFS issued the final rule designating critical habitat for winter-run Chinook salmon (58 FR 33212). The habitat identified in the final designation is identical to that in the proposed ruling except that critical habitat in San Francisco Bay is limited to those waters north of the San Francisco-Oakland Bay Bridge. **Figure 2-3** depicts the designated critical habitat and distribution for Sacramento River winter-run Chinook salmon.

2.1.6 Reasons for Listing

Section 4 of the ESA requires the Secretary of the Interior or Commerce, depending upon the species involved, to determine if any species is an endangered or threatened species for any of the following factors: (1) present or threatened destruction, modification or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific or educational purposes; (3) disease or predation; (4) inadequacy of existing regulatory mechanisms; or (5) other natural or manmade factors affecting its continued existence. Each of these factors with respect to winter-run Chinook salmon are discussed in detail in past status reviews (52 FR 6041, February 27, 1987; Good *et al.* 2005; NMFS 2011) and are summarized below.

The Present or Threatened Destruction, Modification, or Curtailment of Winter-run Chinook Salmon's Habitat or Range.

<u>Habitat Loss and Degradation</u>

Key reasons why winter-run Chinook salmon were listed under the ESA in 1989 include blockage of historical habitat by Shasta and Keswick dams, warm water releases from

Shasta Dam, juvenile and adult passage constraints at RBDD and Anderson-Cottonwood Irrigation District's (ACID) diversion dam, water exports in the southern Delta, loss of rearing habitat, heavy metal contamination from Iron Mountain Mine, and entrainment in a large number of unscreened or poorly screened water diversions (NMFS 1997). Since winter-run Chinook salmon were listed, the passage problems at RBDD and ACID's dam have been addressed and contamination from Iron Mountain Mine has been contained. Additionally, water temperature management has improved since the time when the ESU was listed, although warm water temperatures in the Sacramento River downstream of Keswick Dam remain a concern, particularly in drier years.

A Single Population

The range of winter-run Chinook salmon has been greatly reduced by Keswick and Shasta dams on the Sacramento River and by hydroelectric development on Battle Creek. Currently, winter-run Chinook salmon spawning is limited to the mainstem Sacramento River downstream of Shasta and Keswick dams where the naturally-spawning population is artificially maintained by cool water releases from the dams. Within the Sacramento River, the spatial distribution of spawners is largely governed by water year type and the ability of the CVP to manage water temperatures.

The fact that this ESU is comprised of a single population with very limited spawning and rearing habitat increases its risk of extinction due to local catastrophe or poor environmental conditions. There are no other natural populations in the ESU to buffer it from natural fluctuations. A single catastrophe with effects persisting for four or more years could result in extinction of the Sacramento River winter-run Chinook salmon ESU (Lindley *et al.* 2007). Such potential catastrophes include volcanic eruption of Lassen Peak, prolonged drought which depletes the cold water pool in Shasta Reservoir or some related failure to manage cold water storage, a spill of toxic materials with effects that persist for four years, or a disease outbreak.

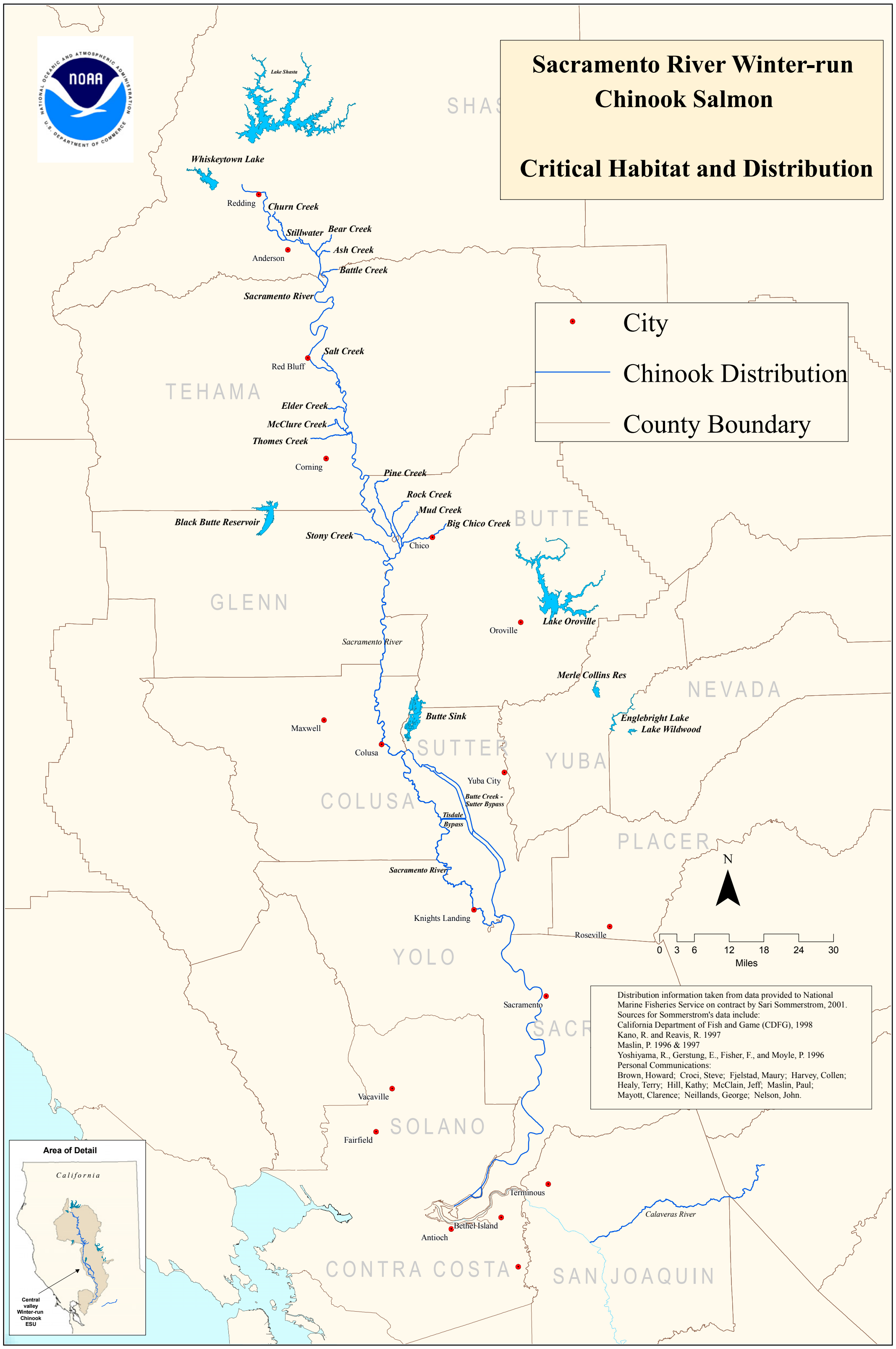

Figure 2-3. Sacramento River Winter-run Chinook Salmon Designated Critical Habitat and Distribution

After two years of drought, Shasta Reservoir storage would be insufficient to provide cold water throughout the winter-run Chinook salmon spawning and embryo incubation season, resulting in partial or complete year-class failure. A severe drought lasting more than 3 years would likely result in the extinction of winter-run Chinook salmon. The probability of extended droughts is increasing as the effects of climate change continue (see Chapter 6).

An ESU that is represented by a single population is less able to withstand environmental variation than an ESU with multiple populations because of reduced life history and genetic diversity. The genetic integrity of winter-run Chinook salmon has been compromised due to having passed through several "bottlenecks" in the 20th century. Construction of Shasta Dam merged at least three independent winter-run Chinook populations into a single population, representing a substantial loss of genetic diversity, life history variability, and local adaptation. Episodes of critically low abundance, particularly in the early 1990s, for the single remaining population imposed ''bottlenecks'' that further reduced genetic diversity (Good *et al.* 2005).

Small Population Size

Chief among the threats facing winter-run Chinook salmon is small population size—escapement fell below 200 fish in the 1990s. In 1989, the CDFW estimated that the winter-run Chinook salmon size was only 547 fish. This unexpectedly small return represented nearly a 75 percent decline from the consistent, but low, run size of 2,000 to 3,000 fish that had occurred since 1982. The run size estimate made by the CDFW for 1991 was 191 fish. Population size declined from highs of near 100,000 fish in the late 1960s, indicating a sustained period of poor survival (Good *et al.* 2005).

Overutilization of Winter-Run Chinook Salmon for Commercial, Recreational, Scientific, or Educational Purposes

Commercial and Recreational Fisheries

When the winter-run Chinook salmon ESU was being evaluated by NMFS for listing under the ESA in the late 1980s, overutilization was not considered to be an important factor in the species decline. A winter-run Chinook salmon status review published in 1987 stated: "NMFS believes that any stock (even marginally healthy one) should be able to maintain stable population levels at the moderate harvest levels to which winter-run chinook are subjected and that harvests have not been instrumental in the decline of winter-run chinook in the Sacramento River" (52 FR 6041, 6045; February 27, 1987). Two years later when the emergency rule to list winter-run Chinook salmon was published, overutilization was still considered unimportant; the primary reasons for the species decline were identified as the construction and operation of RBDD and other human activities that had degraded spawning and rearing habitat in the Sacramento River (54 FR 32085; August 4, 1989).

In the years following the ESA listing of winter-run Chinook salmon, more information on the impacts of the ocean fisheries on the ESU became available, and it was recognized that the fisheries may play a greater role in the viability of the ESU than previously thought. In 1996 and 1997 NMFS issued a biological opinion and amendment which considered the effects of ocean salmon fisheries on winter Chinook salmon. Those documents determined that the ocean fisheries jeopardize winter-run Chinook salmon and, as part of the reasonable and prudent alternative, fishery restrictions were adopted to protect the ESU.

There have been five biological opinions issued for the ocean salmon fishery's effects on winter-run (1991, 1996/1997, 2002, 2004, and 2010). Similar to the 1996/1997 biological opinion, the 2010 biological opinion determined that the fisheries jeopardized the species. To avoid jeopardy, the action agency (NMFS Sustainable Fisheries Division) continues to implement the reasonable and prudent alternative, which: (1) specifies that the previous consultation standards for winter-run Chinook salmon regarding minimum size limits and seasonal windows south of Point Arena for both the commercial and recreational fisheries will continue to remain in effect at all times regardless of abundance estimates or impact rate limit; and (2) establishes an abundance-based management framework where, during periods of relatively low abundance, the fisheries are restricted in order to lower the impact rate on winter-run Chinook salmon.

Based on data from 1968-73 and 1975, Hallock and Fisher (1985) reported that the freshwater sport fishery harvested an average of 8.5 percent of the in-river run. Freshwater harvest of winter-run Chinook salmon was largely eliminated in 2002 when the opening of the Sacramento River recreational fishing season was adjusted so that the fishery would have only limited overlap with the adult immigration and spawning life stages.

Disease or Predation

Disease

Disease was not an important factor in the listing of winter-run Chinook salmon (52 FR 6041, 6045; February 27, 1987) and the impact of disease has probably been negligible since then. There is no evidence that winter-run Chinook salmon experience unusual levels of disease. Winter-run Chinook salmon juveniles from LSNFH have been notably healthy and free of disease problems. There have been no outbreaks of Infectious Hematopoietic Necrosis Virus or Bacterial Kidney Disease at LSNFH (USFWS 2011).

Predation

Predation is an ongoing threat to this ESU, especially in the lower Sacramento River and Delta where there are high densities of non-native (i.e., striped bass, smallmouth bass, and largemouth bass) and native species (e.g., pikeminnow) that prey on outmigrating juvenile salmon. The presence of man-made structures in the freshwater habitat likely contributes to increased predation levels. Since the 1970s, RBDD has been an area of high salmon predation, primarily by pikeminnow (Vogel 2011). Numerous corrective measures at RBDD have been taken over the last few decades to reduce predation. Since 2012, the dam is no longer operated with the gates in. This operational change should greatly reduce predation on juvenile salmon at RBDD.

Degraded conditions in the lower Sacramento River and Delta are a significant source of mortality for Chinook salmon (Cummins *et al.* 2009; Vogel 2011). Predation is hypothesized to be an important source of this mortality (Cummins *et al.* 2009; Vogel 2011; Moyle 2002). Moyle (2002) states, "*What we do not know is whether these species [native species], now mostly depleted, can recover their populations in the presence of a large population of striped bass…A large population of striped bass, for example, could devastate a small population of salmon.*" Consistent with Moyle (2002), a predation model developed by Lindley and Mohr (2003) found that a large striped bass population may impede winter-run Chinook salmon recovery.

The Inadequacy of Existing Regulatory Mechanisms

Laws relevant to the protection and restoration of winter-run Chinook salmon are the ESA, the Magnuson-Stevens Fishery Conservation and Management Act, the CVPIA, the Federal Power Act, the Fish and Wildlife Coordination Act, the Clean Water Act, the National Environmental Policy Act, and numerous State laws administered by CDFW, DWR, or the SWRCB. These laws and associated regulations generally provide adequate mechanisms for recovering winter-run Chinook salmon (52 FR 6041, 6046; February 27, 1987); however some of the goals of these existing mechanisms have not yet been achieved.

Other Natural or Manmade Factors Affecting the Continued Existence of Winter-Run Chinook Salmon

Hatchery Production

Although the LSNFH winter-run Chinook salmon program is one of the most important reasons that the species still persists, the use of a hatchery program to supplement the population raises concerns about the genetic integrity and fitness of the population. There is a strong perception that hatchery fish may negatively affect the genetic constitution of wild fish (Allendorf *et al.* 1997; Hindar *et al.* 1991; Waples 1991). One of the main factors contributing to this perception is the observation of a reduction in wild fish populations following the initiation of a hatchery release program (Hilborn 1992; Washington and Koziol 1993). An explanation offered for this observation is that hatchery fish are adapted to the hatchery environment; therefore, natural spawning with wild fish reduces the fitness of the natural population (Taylor 1991). Researchers from the University of California at Davis have documented that hatchery Chinook salmon were more vulnerable to predation by Sacramento pikeminnow as they pass RBDD than were wild Chinook salmon (Lufkin 1996). To minimize hatchery effects in the population, LSNFH preferentially collects wild winter-run Chinook salmon adults for the program. A maximum of 15 percent of the estimated winter-run Chinook salmon run, but no more than 120 natural-origin winter-run Chinook salmon per broodyear may be collected for broodstock use. If necessary, up to 10 percent (a maximum of 12 fish) of the LSNFH broodstock may be composed of hatchery adult returns. To ensure that hatchery production does not overwhelm the recovering population, annual hatchery releases are kept within the 200,000 to 250,000 range and the effects of the program are well-monitored.

The rising proportion of hatchery fish among returning adults threatens to shift the population from a low to moderate risk of extinction. Lindley *et al.* (2007) recommend that in order to maintain a low risk of genetic introgression with hatchery fish, no more than five percent of the naturally-spawning population should be composed of hatchery fish. Since 2001, hatchery origin winter-run Chinook salmon have made up more than five percent of the run, and in 2005 the contribution of hatchery fish exceeded 18 percent (Lindley *et al.* 2007). Potential consequences to wild fish stocks from hatchery production include hybridization and genetic introgression, competition, predation, and increasing fishing pressure (Waples 1991).

Because LSNFH is a conservation hatchery using best management practices, a more appropriate tool to determine associated genetic risk may be the Proportionate Natural Influence (PNI). PNI is an index of gene flow rates between hatchery and natural populations that can be calculated by using the following formula:

PNI Approx = pNOB/(pNOB+pHOS)

Where pNOB is defined as the Proportion of Natural Origin Brood Stock, and pHOS as the Proportion of Hatchery Origin In-River Spawners.

The Hatchery Scientific Review Group (HSRG), an independent scientific review panel for the Pacific Northwest Hatchery Reform Project, developed guidelines as minimal requirements for minimizing genetic risks of hatchery programs to naturally spawning populations. One of those guidelines is that PNI must exceed 0.5 in order for the natural environment to have a greater influence than the hatchery environment on the genetic constitution of a naturally-spawning population. A second guideline is that PNI should be greater than 0.67 for natural populations considered essential for the recovery or viability of an ESU/DPS.

The average PNI for LSNFH winter-run Chinook salmon from 2003 through 2012 is 0.89 (Null 2013); a level which satisfies the HSRG guidelines for minimizing the genetic effects of hatchery programs on natural populations.

In summary, LSNFH is one of the most important reasons that Sacramento River winter-run Chinook salmon still persist and the hatchery is considered beneficial to the ESU over the short term. However, if the continued existence of the ESU depends on LSNFH, it by any reasonable definition cannot be characterized as having a low risk of extinction, and therefore the ESU should not be delisted on that basis. If the status of the ESU improves such that it has a high likelihood of persistence without LSNFH, then the LSNFH winter-run Chinook program should be phased out and eventually terminated. To obtain long-term sustainability, ESUs need to have some low-risk populations with essentially no hatchery influence in the long run; they could have additional populations with some small hatchery influence, but there needs to be a core of populations that are not dependent on hatchery production.

2.1.7. Threats Assessment

A detailed threats assessment was conducted for the Sacramento River winter-run Chinook salmon ESU (Appendix B). The threats/stressors affecting each winter-run Chinook salmon life stage are described in that appendix. A stressor matrix[3], in the form of a single Microsoft Excel worksheet, was developed to structure the winter-run Chinook salmon population, life stage, and stressor information into hierarchically-related tiers so that stressors to the ESU could be prioritized. The individual tiers within the matrix, from highest to lowest, are: (1) population; (2) life stage; (3) primary stressor category; and (4) specific stressor. These individual tiers were related hierarchically so that each variable within a tier had several associated variables at the next lower tier, except at the lowest (i.e., fourth) tier.

[3] For winter-run Chinook salmon, a single stressor matrix was developed corresponding to the mainstem upper Sacramento River population, whereas for spring-run Chinook salmon and steelhead, multiple individual stressor matrices were developed corresponding to each of the extant populations for these species.

The general steps required to develop and utilize the winter-run Chinook salmon stressor matrix are described as follows:

- Each life stage within the population was weighted so that all life stage weights in the population summed to one
- Each primary stressor category within a life stage was weighted so that all primary stressor category weights in a life stage summed to one
- Each specific stressor within a primary stressor category was weighted so that all specific stressor weights in a primary stressor category summed to one
- A composite weight for each specific stressor was obtained by multiplying the product of the population weight, the life stage weight, the primary stressor weight, and the specific stressor weight by 100
- A normalized weight for each specific stressor was obtained by multiplying the composite weight by the number of specific stressors within a particular primary stressor group
- The stressor matrix was sorted by the normalized weight of the specific stressors in descending order

Specific information explaining the individual steps taken to generate this prioritized list are provided in Appendix B.

The completed stressor matrix sorted by normalized weight is a prioritized list of the life stage-specific stressors affecting the ESU. Each life stage of winter-run Chinook salmon is affected by stressors of “Very High” importance. These stressors include:

- The barriers of Keswick and Shasta dams, which block access to historic staging and spawning habitat
- Flow fluctuations, water pollution, water temperature impacts in the upper Sacramento River during embryo incubation
- Loss of juvenile rearing habitat in the form of lost natural river morphology and function, and lost riparian habitat and instream cover
- Predation during juvenile rearing and outmigration
- Ocean harvest
- Entrainment of juveniles at the C.W. Jones and Harvey O. Banks pumping plants

The complete prioritized list of life stage-specific stressors to the Sacramento River winter-run Chinook salmon ESU is presented in Appendix B.

2.1.8 Conservation Measures

Artificial Propagation

Captive broodstock and conservation hatchery programs were established for the Sacramento River winter-run Chinook salmon ESU in the early 1990s. The captive broodstock program was originally located at the Bodega Marine Laboratory and the hatchery program was initially established at the CNFH and then later re-located to the LSNFH. These programs were established to augment the naturally spawning population in the Sacramento River as well as to provide a captive broodstock in case the natural population was unexpectedly decimated. The programs were successful in helping to stop winter-run Chinook salmon from going extinct. The captive broodstock program was discontinued in January 2005 and the final captive broodstock fish were utilized for a research study in 2006. The LSNFH winter-run Chinook salmon hatchery program continues to supplement the natural population while minimizing genetic risks.

LSNFH is expected to play a continuing role as a conservation hatchery for the protection and enhancement of the existing winter-run Chinook salmon population below Keswick and Shasta dams, and potentially will play a role in re-establishing winter-run salmon to habitats upstream of Shasta Dam and to Battle Creek.

Endangered Species Act

Actions taken by Reclamation and DWR to ensure that their operations of the CVP and SWP comply with Section 7 of the ESA likely contributed to habitat improvements benefiting the Sacramento River winter-run Chinook salmon ESU. Implementation of the reasonable and prudent alternative in biological opinions for the CVP and SWP has improved fish habitat and passage conditions in the Sacramento River and the Delta through maintenance of minimum water flows during fall and winter months, establishment of temperature criteria to support spawning and rearing upstream of RBDD (coupled with water releases from Shasta Dam), operation of the RBDD gates for improved adult and juvenile fish passage, and constraints on Delta water exports to reduce impacts on juvenile outmigrants.

Ecosystem Restoration Program

Two large, ongoing comprehensive conservation programs in the Central Valley provide a wide range of ecosystem and species-specific protective efforts potentially benefiting Chinook salmon – the State's ERP (formerly the CALFED Bay/Delta Program) and the CVPIA. CALFED was a cooperative effort of more than 20 State and Federal agencies working with local communities to improve water quality and reliability for California's water supplies, and has made efforts to restore the Bay/Delta. The ERP has funded projects involving habitat restoration, floodplain restoration and protection, instream and riparian habitat restoration and protection, fish screening and passage, research on non-native species and contaminants, research and monitoring of fishery resources, and watershed stewardship and outreach. A full description of ERP projects and achievements is available at http://www.dfg.ca.gov/ERP/. A few ERP accomplishments that improved salmon and steelhead habitat include:

- restoration and protection of 8,000 acres of wetlands in San Pablo Bay and Suisun Marsh;
- protection of more than 11,000 acres and 18 river miles for riparian and shaded-riverine-aquatic habitat;
- restoration of more than 3,900 acres and 59 miles of riparian and riverine aquatic habitat; and
- installation or improvement of 70 fish screens (11 that draw >250 cfs).

Overall, the ERP has been a beneficial program for winter-run Chinook salmon. Continued implementation of stage two of ERP, which runs through the year 2030, will be needed to advance winter-run Chinook salmon recovery.

CALFED also established the Environmental Water Account (EWA) to protect migratory fish from entrainment and to increase water supply reliability for the SWP and CVP. A review of the success of EWA revealed that the benefit to salmon is unclear (White and Brandes 2004).

Central Valley Project Improvement Act

The CVPIA balances the priorities of fish and wildlife protection, restoration, and mitigation with irrigation, domestic water use, fish and wildlife enhancement, and power augmentation. The CVPIA was enacted in 1992 with a mandated goal of doubling the natural production of anadromous fish, including winter-run Chinook salmon. Reclamation and USFWS have conducted studies and implemented hundreds of actions, including modifications of CVP operations, management and acquisition of water for fish and wildlife needs, flow management for fish migration and passage, increased water flows, replenishment of spawning gravels, restoration of riparian habitats, and screening of water diversions. Individual actions implemented under the CVPIA that have improved conditions for winter-run Chinook salmon include:

- Installing and operating the Shasta Temperature Control Device;
- Improved and continued efforts for passage at RBDD;
- Completion of state-of-the-art screen and passage improvements at the diversions for the Glen-Colusa Irrigation District and Anderson-Cottonwood Irrigation District; and
- Screening most of the larger diversions in the system (Cummins *et al.* 2009).

An independent review of the CVPIA Fisheries Program identified several successes of the program, but ultimately concluded that, "*After 16 years of implementation the CVPIA anadromous fish program is not close to its stated doubling goal, nor has it solved the problems that led to the listing of several species of salmon and steelhead under the ESA* (Cummins *et al*. 2009)."

Fisheries Management Measures

Seasonal time/area restrictions and minimum size limits for the sport and commercial ocean salmon fisheries are in place for the protection of winter-run Chinook salmon. Additionally, there is a regulatory management framework to further reduce ocean fishery impacts when the status of winter-run is declining or unfavorable (NMFS 2012a). The State has established specific in-river fishing regulations and no-retention prohibitions designed to protect winter-run Chinook salmon during their freshwater life stages.

2.2 Spring-run Chinook Salmon

2.2.1 ESA Listing Status

Central Valley spring-run Chinook salmon (*O. tshawytscha*), currently listed as threatened, were proposed as endangered by NMFS on March 9, 1998 (63 FR 11482). NMFS (1998) concluded that the Central Valley spring-run Chinook salmon ESU was in danger of extinction because native spring-run Chinook salmon have been extirpated from all tributaries in the San Joaquin River Basin, which represented a large portion of the historic range and abundance of the ESU as a whole. Moreover, the only streams considered to have wild spring-run Chinook salmon at that time were Mill and Deer creeks, and Butte Creek (tributaries to the Sacramento River). These populations were considered relatively small with sharply declining trends.

Hence, demographic and genetic risks due to small population sizes were considered to be high. NMFS (NMFS 1998) also determined that habitat problems were the most important source of ongoing risk to this ESU.

On September 16, 1999, NMFS listed the Central Valley ESU of spring-run Chinook salmon as a "threatened" species (64 FR 50394). Although in the original Chinook salmon status review and proposed listing it was concluded that the Central Valley spring-run Chinook salmon ESU was in danger of extinction (Myers *et al.* 1998), in the status review update, the Biological Review Team (BRT) majority shifted to the view that this ESU was not in danger of extinction, but was likely to become endangered in the foreseeable future. A major reason for this shift was data indicating that a large run of spring-run Chinook salmon on Butte Creek in 1998 was naturally produced, rather than strays from the Feather River Fish Hatchery (FRFH).

NMFS determined that the Central Valley spring-run Chinook salmon ESU is likely to become endangered in the foreseeable future throughout all or a significant portion of their range after reviewing the best available information, including public and peer review comments, biological data on the species' status, and an assessment of protective efforts (64 FR 50394). On March 11, 2002, pursuant to a January 9, 2002 rule issued by NMFS under Section 4(d) of the ESA (16 USC § 1533(d)), the take restrictions that apply statutorily to endangered species began to apply with specific limitations to the Central Valley ESU of spring-run Chinook salmon (67 FR 1116). On June 14, 2004, following a five-year species status review, NMFS proposed that the Central Valley spring-run Chinook salmon remain a threatened species based on the BRT strong majority opinion that the Central Valley spring-run Chinook ESU is ''likely to become endangered within the foreseeable future'' (69 FR 33102). The BRT based its conclusions on the greatly reduced distribution of the Central Valley spring-run Chinook ESU and hatchery influences on natural populations. In addition, the BRT noted moderately high risk for the abundance, spatial structure, and diversity Viable Salmonid Population (VSP) criteria, and a lower risk for the productivity criterion reflecting positive trends. On June 28, 2005, NMFS reaffirmed the threatened status of the Central Valley spring-run Chinook salmon ESU (70 FR 37160). **Figure 2-4** depicts the Central Valley spring-run Chinook salmon ESU.

2.2.2 Species Description and Taxonomy

The Chinook salmon, also largely referred to as king salmon in California, are the largest of the Pacific salmon. The following physical description of the species is provided by Moyle (2002). Spawning adults are olive to dark maroon in color, without conspicuous streaking or blotches on the sides. Spawning males are darker than females, and have a hooked jaw and slightly humped back. There are numerous small black spots in both sexes on the back, dorsal fins, and both lobes of the tail. They can be distinguished from other spawning salmon by the color pattern, particularly the spotting on the back and tail, and by the dark, solid black gums of the lower jaw. Parr have 6 to 12 parr marks, each equal to or wider than the spaces between them and most centered on the lateral line. The adipose fin of parr is pigmented on the upper edge, but clear at its base. The dorsal fin occasionally has one or more spots on it but the other fins are clear.

2.2.3 Life History/Habitat Requirements

The habitat requirements for spring-run Chinook salmon are the same as those described above for winter-run Chinook salmon. The primary differences in the habitat requirements between the two runs are the duration and the time of year that the different life stages of the species utilize the habitat.

Adult Central Valley spring-run Chinook salmon leave the ocean to begin their upstream migration in late January and early February (CDFW 1998), and enter the Sacramento River between March and September, primarily in May and June (Moyle 2002; Yoshiyama *et al.* 1998). Spring-run Chinook salmon generally enter rivers as sexually immature fish and must hold in freshwater for up to several months before spawning (Moyle 2002). While maturing, adults hold in deep pools with cold water. Spawning normally occurs between mid-August and early October, peaking in September (Moyle 2002).

The length of time required for embryo incubation and emergence from the gravel is dependent on water temperature. For maximum embryo survival, water temperatures reportedly must be between 41°F and 55.4°F and oxygen saturation levels must be close to maximum (Moyle 2002).

Under those conditions, embryos hatch in 40 to 60 days and remain in the gravel as alevins (the life stage between hatching and egg sack absorption) for another 4 to 6 weeks before emerging as fry (Moyle 2002).

Spring-run fry emerge from the gravel from November to March (Moyle 2002). Juveniles may reside in freshwater for 12 to 16 months, but some migrate to the ocean as young-of-the-year in the winter or spring months within eight months of hatching (CALFED 2000b). The average size of fry migrants (approximately 40 mm between December and April in Mill, Butte, and Deer creeks) reflects a prolonged emergence of fry from the gravel (Lindley *et al.* 2004). By contrast, studies in Butte Creek (Ward *et al.* 2003) found the majority of spring-run migrants to be fry moving downstream primarily during December, January, and February, and that these movements appeared to be influenced by flow. Small numbers of spring-run juveniles remained in Butte Creek to rear and migrate as yearlings later in the spring. Juvenile emigration patterns in Mill and Deer creeks are very similar to patterns observed in Butte Creek, with the exception that Mill and Deer creek juveniles typically exhibit a later young-of-the-year migration and an earlier yearling migration (Lindley *et al.* 2004). By contrast, data collected on the Feather River suggests that the bulk of juvenile emigration occurs during November and December (DWR and Reclamation 1999; Painter *et al.* 1977). Seesholtz *et al.* (2003) speculate that because juvenile rearing habitat in the Low Flow Channel of the Feather River is limited, juveniles may be forced to emigrate from the area early due to competition for resources. **Table 2-3** depicts the temporal occurrence of spring-run life stages in the Sacramento River.

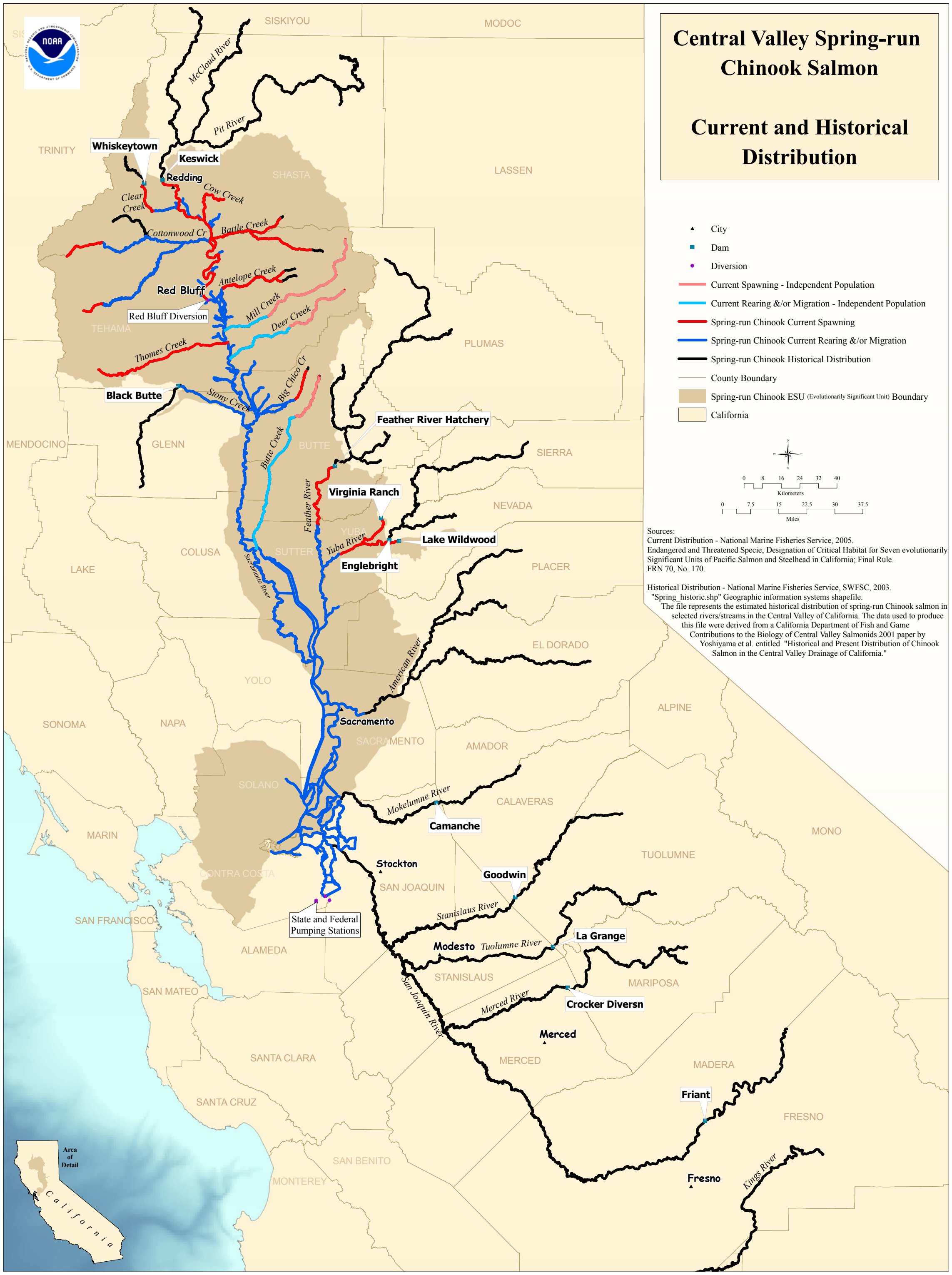

Figure 2-4. Central Valley Spring-run Chinook Salmon ESU, and Current and Historical Distribution.

2.2.4 Abundance Trends and Distribution

Historically, spring-run Chinook salmon occurred in the headwaters of all major river systems in the Central Valley where natural barriers to migration were absent.

The Central Valley as a whole is estimated to have supported spring-run Chinook salmon runs as large as 600,000 fish between the late 1880s and 1940s (CDFW 1998). More than 500,000 Central Valley spring-run Chinook salmon were caught in the Sacramento-San Joaquin commercial fishery in 1883 (Yoshiyama *et al.* 1998).

Although spring-run Chinook salmon were probably the most abundant salmonid in the Central Valley under historic conditions, large dams eliminated access to almost all historical habitat and the spring-run has suffered the most severe declines of any of the four Chinook salmon runs in the Sacramento River Basin (Fisher 1994).

Beginning in the 1880s, harvest, water development, construction of dams that prevented access to headwater areas and habitat degradation significantly reduced the number and range of spring-run Chinook salmon.

Before construction of Friant Dam, nearly 50,000 adults were counted in the San Joaquin River (Fry 1961). The San Joaquin populations essentially were extirpated by the 1940s, with only small remnants of the run persisting through the 1950s in the Merced River (Yoshiyama *et al.* 1998). From 1970 through 2012, Central Valley spring-run Chinook salmon run size estimates have fluctuated from highs near 30,000 to lows near 3,000 (**Figure 2-5**).

The only known streams that currently support self-sustaining populations of non-hybridized spring-run Chinook salmon in the Central Valley are Mill, Deer and Butte creeks (CDFW 1998). Each of these populations is small and isolated. **Figure 2-6** depicts the annual run size estimates for these populations. These populations are genetically distinct from other populations classified as spring-run in the Central Valley (e.g., Feather River) (DWR 2004a). Banks *et al.* (2000) suggest the spring-run phenotype in the Central Valley is shown by two genetically distinct subpopulations, 1) Butte Creek, and 2) Deer and Mill creeks. Although the spring-run Chinook salmon in Deer and Mill creeks represent a single genetically distinct subpopulation, they are considered in this Recovery Plan as two separate populations because Deer and Mill creeks provide two discrete spawning areas with independent population dynamics Lindley *et al*. (2004).

The FRFH was constructed in the mid-1960s by DWR to mitigate for the loss of Chinook salmon and steelhead spawning habitat by construction of Oroville Dam. The FRFH was opened in 1967 (DWR 2002) and is operated by CDFW. The FRFH is the only hatchery in the Central Valley producing spring-run Chinook salmon. The current production target for spring-run Chinook salmon at the FRFH is two million smolts.

Prior to 2004, FRFH hatchery staff differentiated spring-run from fall-run by opening the ladder to the hatchery on September 1. Those fish ascending the ladder from September 1 through September 15 were assumed to be spring-run Chinook salmon while those ascending the ladder after September 15 were assumed to be fall-run (Kastner 2003). This practice led to considerable hybridization between spring- and fall-run Chinook salmon (DWR 2004a). Since 2007, the fish ladder remains open for 9.5 months of the year (September 15 through June 30) and those fish ascending the ladder are marked with an external tag and returned to the river. This practice allows FRFH staff to identify those previously marked fish as phenotypic spring-run when they re-enter the ladder in September reducing the potential for hybridization between the spring and fall runs (DWR 2004a).

The FRFH also releases a significant portion of its spring-run production into San Pablo Bay (1,000,000 juvenile smolts). This practice increases the chances that these fish will stray into other Central Valley streams when they return as adults to spawn. This straying has the potential for genetic hybridization to occur between FRFH spring-run with local spring-run and fall-run populations, increasing the risk of genetic introgression and subsequent homogeneity among Central Valley Chinook salmon runs. In addition, this straying has the potential to transfer genetic material from hatchery fish to wild naturally-spawning fish and is generally viewed as an adverse hatchery impact. Of particular concern would be the straying of hatchery fish into Deer, Mill, or Butte creeks, affecting the genetic integrity of the only significantly distinct spring-run Chinook salmon in the Central Valley (DWR 2004a). **Figure 2-7** shows the total Central Valley spring-run Chinook salmon spawning run size estimates broken down by constituent component for the years 1970 through 2008. The figure indicates that since about 1982, the proportion of the spring-run in the Central Valley comprised of FRFH fish has substantially increased. The current and historical distribution of Central Valley spring-run Chinook salmon was presented in **Figure 2-4**.

Table 2-3. Temporal Occurrence of Adult and Juvenile Sacramento River Spring-run Chinook Salmon in the Sacramento River

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult												
Sacramento River Basin[1,2]			Medium	Medium	High	High	Medium	Medium	Medium			
Sacramento River[3]			Medium	Medium	Medium	Medium	Medium					
Mill Creek[4]			Low	Medium / High	High	High / Medium	Medium / Low	Low /				
Deer Creek[4]			Low	Medium / High	High	High / Medium	Medium /					
Butte Creek[4]		Medium	Medium	Medium	Medium	Medium	Medium					
Juvenile												
Sacramento River Tributaries[5]	Medium	Medium	Medium							Medium	High	High
Upper Butte Creek[6]	High	High	Medium	Medium	Medium	Low				Low	Low	High
Mill, Deer, Butte Creeks[4]	High	High	Medium	Medium	Medium	Low				Low	Low	Low
Sacramento River at RBDD[3]	High	Low	Low	Low							High	High
Sacramento River at KL[7]	Medium	High	High	High	High	Medium	Low	Low	Low	Low	Low	High
Chipps Island (Trawl)[8*]	Medium	High	High	High	High	Medium	Low	Low	Low	Low	Low	High

Sources: [1]Yoshiyama et al. 1998; [2]Moyle 2002; [3]Myers et al. 1998; [4]Lindley et al. 2006a; [5]CDFW 1998; [6]McReynolds et al. 2005; Ward et al. 2002, 2003; [7]Snider and Titus 2000, [8]USFWS 2001

Relative Abundance: = High = Medium = Low

* Note: By the time yearly spring-run Chinook salmon reach Chipps Island they cannot be distinguished from fall-run yearlings.

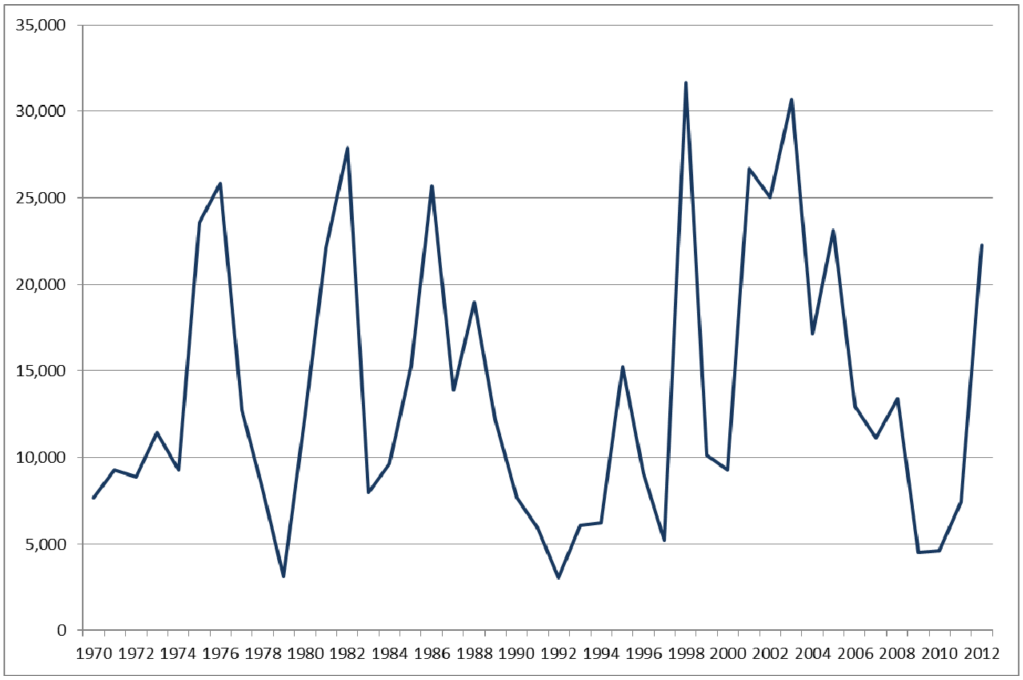

Figure 2-5. Central Valley Spring-run Chinook Salmon Run Size Estimates (1970–2012).

Source: (CDFW GRANDTAB http://www.fws.gov/stockton/*)*

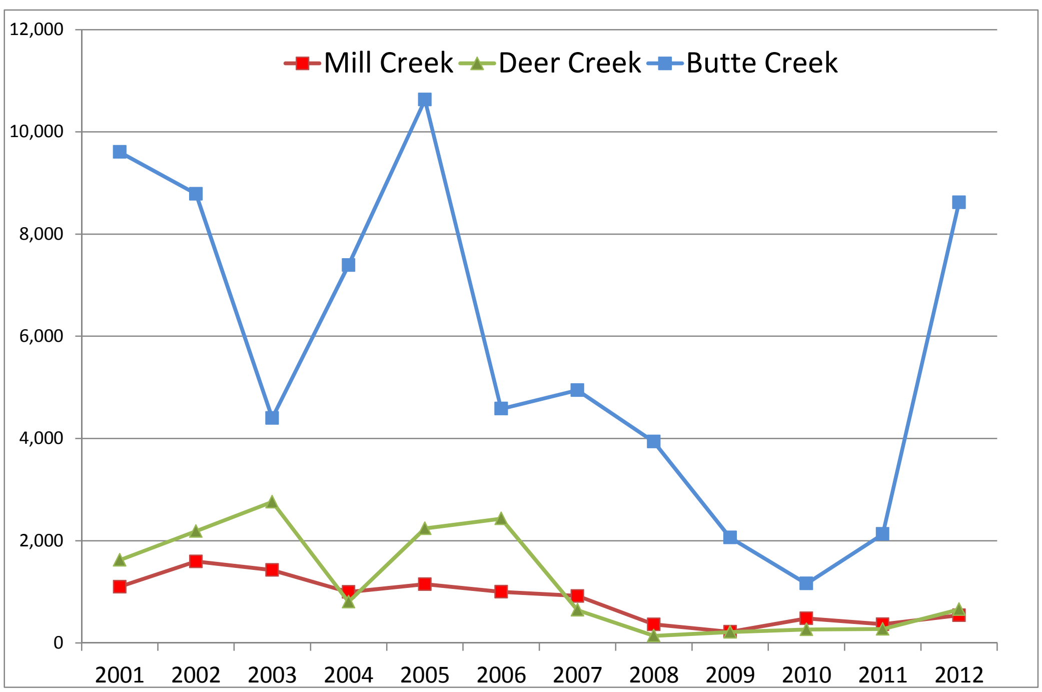

Figure 2-6. Mill, Deer, and Butte Creek Spawning Run Size Estimates for Central Valley Spring-run Chinook Salmon (2001–2012). All estimates were obtained by snorkel surveys. Source: (CDFW GRANDTAB and Annual Reports)

2.2.5 Critical Habitat

When designating critical habitat, NMFS focuses on "Primary Constituent Elements" (PCEs), which are the principal biological or physical constituent elements within the defined area that are essential to the conservation of the listed species (50 CFR 424.12(b)). PCEs considered essential for the conservation of the Central Valley spring-run Chinook salmon ESU are those sites and habitat components that support one or more life stages(50 CFR 226.211(c)), including:

- Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation and larval development.
- Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.
- Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival.
- Estuarine areas free of obstruction and excessive predation with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.

NMFS proposed[4] critical habitat for Central Valley spring-run Chinook salmon on December 10, 2004 (69 FR 71880), and published a final rule designating critical habitat for this species on September 2, 2005 (70 FR 52488). **Figure 2-8** depicts the designated critical habitat and distribution for Central Valley spring-run Chinook salmon.

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[4] NMFS proposed critical habitat for Central Valley spring-run Chinook salmon on February 5, 1999 (63 FR 11482) in compliance with Section 4(a)(3)(A) of the ESA, which requires that, to the maximum extent prudent and determinable, NMFS designates critical habitat concurrently with a determination that a species is endangered or threatened (NMFS 1999). On February 16, 2000 (65 FR 7764), NMFS published a final rule designating critical habitat for Central Valley spring-run Chinook salmon. Critical habitat was designated to include all river reaches accessible to listed Chinook salmon in the Sacramento River and its tributaries in California. Also included were river reaches and estuarine areas of the Delta, all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait, all waters of San Pablo Bay westward of the Carquinez Bridge, and all waters of San Francisco Bay (north of the San Francisco/Oakland Bay Bridge) from San Pablo Bay to the Golden Gate Bridge.

In response to litigation brought by the National Association of Homebuilders (NAHB) (NAHB v. Evans, 2002 WL 1205743 No. 00–CV–2799 (D.D.C.)), NMFS sought judicial approval of a consent decree withdrawing critical habitat designations for 19 Pacific salmon and *O. mykiss* ESUs. The District Court in Washington DC approved the consent decree and vacated the critical habitat designations by Court order on April 30, 2002 (NAHB v. Evans, 2002 WL 1205743 (D.D.C. 2002)).

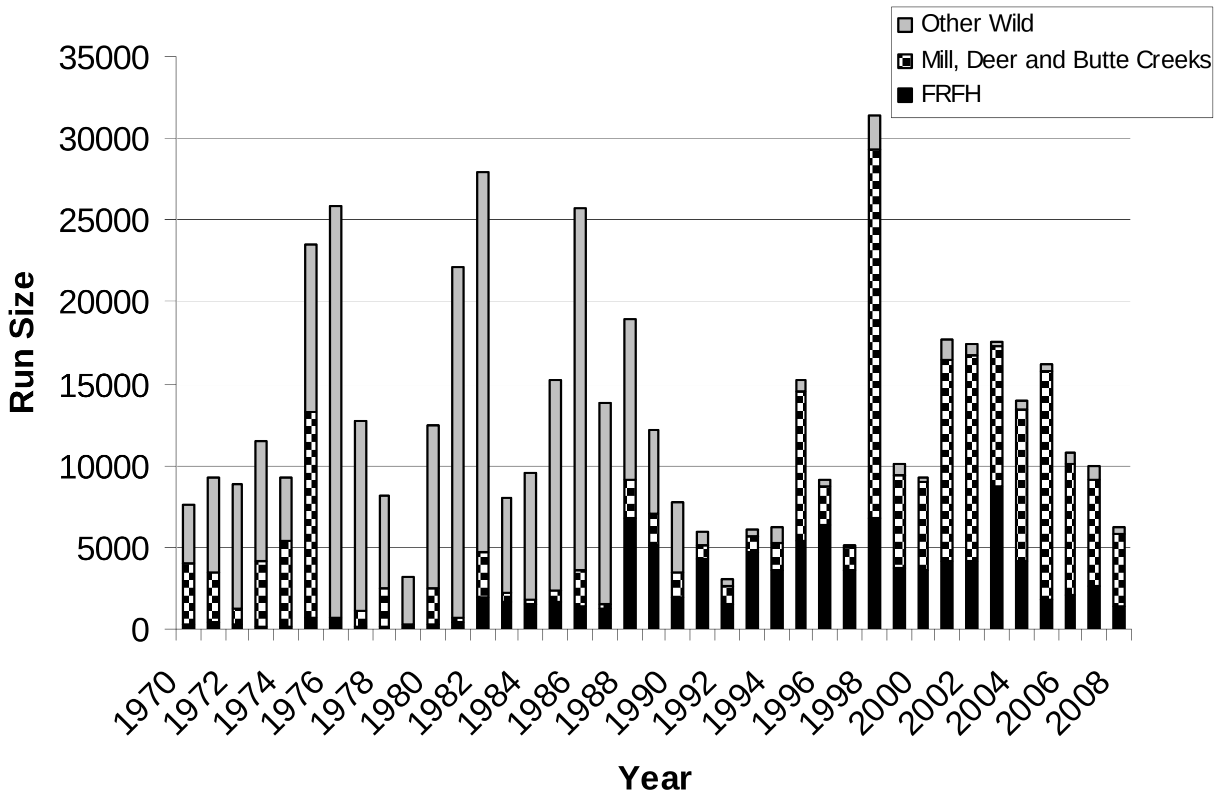


Figure 2-7. Central Valley Spring-run Chinook Salmon Spawning Run Size Composition (1970–2008)

Source: (CDFW GRANDTAB 2009)

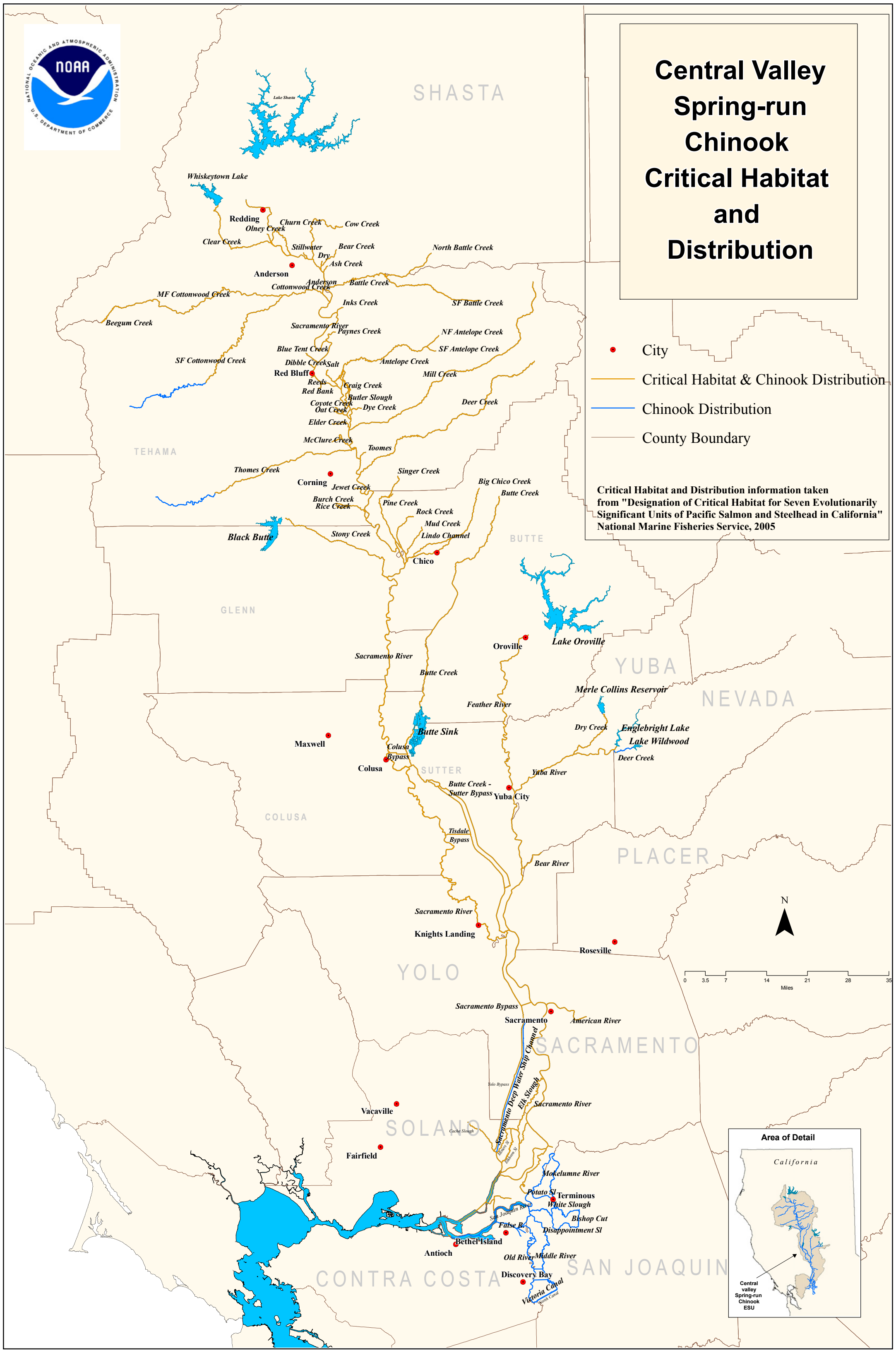


Figure 2-8. Central Valley Spring-run Chinook Salmon Designated Critical Habitat and Distribution

2.2.6 Reasons for Listing

The Central Valley spring-run Chinook salmon ESU is currently faced with three primary threats: (1) loss of most historic spawning habitat; (2) degradation of the remaining habitat; and (3) genetic introgression with the FRFH spring-run Chinook salmon strays. Spring-run Chinook salmon require cool freshwater in summer, most of which is upstream of impassable dams. The ESU is currently limited to independent populations in Mill, Deer, and Butte creeks, persistent and presumably dependent populations in the Feather and Yuba rivers and in Big Chico, Antelope, and Battle creeks, and a few ephemeral or dependent populations in the Northwestern California region (e.g., Beegum, Clear, and Thomes creeks). This ESU continues to be threatened by habitat loss, degradation and modification, small hydropower dams and water diversions that reduce or eliminate instream flows during migration, unscreened or inadequately screened water diversions, excessively high water temperatures, and predation by non-native species.

The potential effects of climate change are likely to adversely affect spring-run Chinook salmon and their recovery. These effects are more thoroughly discussed in Chapter 6.

Listing Factors for Spring-run Chinook Salmon

Section 4 of the ESA requires the Secretary of the Interior or Commerce, depending upon the species involved, to determine if any species is an endangered or threatened species for any of the following listing factors: (1) present or threatened destruction, modification or curtailment of its habitat or range; (2) overutilization for commercial, recreational. scientific or educational purposes; (3) disease or predation; (4) inadequacy of existing regulatory mechanisms; or (5) other natural or manmade factors affecting its continued existence. Each of these listing factors with respect to spring-run Chinook salmon are summarized below.

The Present or Threatened Destruction, Modification, or Curtailment of Spring-run Chinook Salmon's Habitat or Range.

<u>Habitat Loss</u>

Loss of historic spawning habitat was a major reason for listing spring-run Chinook salmon under the ESA and it remains an important threat, as most of that habitat continues to be blocked by the direct or indirect effects of dams. Perhaps 15 of the 19 historical populations of Central Valley spring-run Chinook salmon are extinct, with their entire historical spawning habitats behind various impassable dams (Lindley *et al*. 2007). The construction of dams in the Central Valley has eliminated virtually all historic spawning habitat of spring-run Chinook salmon in the basin. Native spring-run Chinook salmon have been extirpated from all tributaries in the San Joaquin River Basin, which represents a large portion of the historic range and abundance of the ESU.

Like most spring-run Chinook salmon, Central Valley spring-run Chinook salmon require cool freshwater while they mature over the summer. In the Central Valley, summer water temperatures are reportedly suitable for Chinook salmon only above 150 to 500-m elevations, and most of that high elevation habitat is now upstream of impassable dams (NMFS 2005). Current spawning is restricted to the mainstem and a few river tributaries in the Sacramento River

(NMFS 1998). Naturally-spawning populations of Central Valley spring-run Chinook salmon currently are restricted to accessible reaches of the upper Sacramento River, Antelope Creek, Battle Creek, Beegum Creek, Big Chico Creek, Butte Creek, Clear Creek, Deer Creek, Feather River, Mill Creek, and Yuba River (CDFW 1998).

The construction of Shasta and Keswick dams on the Sacramento River and Oroville Dam on the Feather River and subsequent blocking of upstream migration has eliminated the spatial separation between spawning fall-run and spring-run Chinook salmon. Reportedly, spring-run Chinook salmon migrated to the upper Feather River and its tributaries from mid-March through the end of July (CDFW 1998). Fall-run Chinook salmon reportedly migrated later and spawned in lower reaches of the Feather River than spring-run Chinook salmon (Yoshiyama *et al.* 2001). The same pattern likely also existed on the Sacramento River. Restricted access to historic spawning grounds currently causes spring-run Chinook salmon to spawn in the same lowland reaches that fall-run Chinook salmon use as spawning habitat. The overlap in spawning site locations, combined with an overlap in spawning timing (Moyle 2002) with temporally adjacent runs, is responsible for interbreeding between spring-run and fall-run Chinook salmon in the lower Feather River (Hedgecock *et al.* 2001) and in the Sacramento River below Keswick Dam.

In the upper Sacramento River, lower Feather River, and lower Yuba River, spring-run Chinook salmon spawning may occur a few weeks earlier than fall-run spawning, but currently there is no clear distinction between the two because of the disruption of spatial segregation by Shasta and Keswick dams on the Sacramento River, Oroville Dam on the Feather River, and Englebright Dam on the Yuba River. Thus, spring-run and fall-run Chinook salmon spawning overlap temporally and spatially. This presents difficulties from a management perspective in determining the proportional contribution of total spawning escapement by the spring- and fall-runs. Because of unnaturally high densities of spawning, particularly in the in the Low Flow Channel of the Feather River, spawning habitat is likely a limiting factor. Intuitively, it could be inferred that the slightly earlier spawning Chinook salmon displaying spring-run behavior would have better access to the limited spawning habitat, although early spawning likely leads to a higher rate of redd superimposition. Redd superimposition occurs when spawning Chinook salmon dig redds on top of existing redds dug by other Chinook salmon. The rate of superimposition is a function of spawning densities and typically occurs in systems where spawning habitat is limited (Fukushima *et al.* 1998). Redd superimposition may disproportionately affect early spawners and, therefore, potentially affect Chinook salmon exhibiting spring-run life history characteristics.

<u>Habitat Degradation</u>

Another major reason why spring-run Chinook salmon are in need of ESA protection is because the remaining spawning and rearing habitat for this species is severely degraded (63 FR 11482, March 9, 1998; Myers *et al*. 1998; Good *et al*. 2005; NMFS 2011b). Threats to spring-run Chinook salmon habitat include, but are not limited to: (1) operation of antiquated fish screens, fish ladders, and diversion dams on streams throughout the Sacramento River Basin including on Deer, Mill, Butte, and Antelope creeks; (2) levee construction and maintenance projects that have greatly simplified riverine habitat and have disconnected rivers from the floodplain; and (3) water delivery and hydroelectric operation on the main-stem Sacramento River (Central Valley Project), and the Feather River (State Water Project).

General degradation of rearing and migrating habitat includes elevated water temperatures, agricultural and municipal diversions and returns, restricted and regulated flows, entrainment of migrating fish into unscreened or poorly screened diversions, predation by nonnative species, and the poor quality and quantity of remaining habitat (NMFS 1998). Hydropower dams and water diversions in some years have greatly reduced or eliminated in-stream flows during spring-run migration periods (NMFS 1998b).

Overutilization of Spring-run Chinook Salmon for Commercial, Recreational, Scientific, or Educational Purposes

Overutilization of spring-run Chinook salmon for commercial, recreational, scientific, or educational purposes was not identified as an important risk to spring-run Chinook salmon when the species was listed in 1999 (63 FR 11482; March 9, 1998). The spring-run Chinook salmon status review that informed the 1999 listing determination stated that, "*Harvest rates* [of spring-run Chinook salmon] *appear to be moderate*. (Myers *et al*. 1998)." No spring-run Chinook salmon ocean harvest rate data were available to support that statement. Some limited information obtained since spring-run Chinook salmon were listed suggests that harvest in the ocean fisheries may be more of a risk to the species than originally thought. An analysis done by Grover *et al*. (2004) indicated that Butte Creek spring-run Chinook salmon are vulnerable to the commercial and recreational ocean salmon fisheries with an estimated 36 percent of brood year 1998 and 42 percent of brood year 1999 harvested in the ocean, respectively. Those harvest rates are about twice that of winter-run Chinook salmon (NMFS 2010c). Grover *et al*. (2004) cautioned the interpretation of their own results because of the low number of coded wire tag recoveries and the analysis covered just two cohorts. Further analysis of spring-run Chinook salmon harvest rates is needed to better understand the ocean fisheries' impacts on this ESU.

Disease or Predation

Disease

Disease was not an important factor in the listing of spring-run Chinook salmon (63 FR 11482, March 9, 1998; Myers *et al*. 1998). There is no evidence that spring-run Chinook salmon have experienced unusual levels of disease in the wild. There have been numerous outbreaks of infectious hematopoietic necrosis virus (IHNV) in Chinook salmon at CNFH and the FRFH. Although the virus had been detected in stream salmonids, there have been no reported epizootics of IHNV in Central Valley stream populations (i.e., the virus was detected but the fish themselves were asymptomatic of the disease) (DWR 2009). It appears that IHNV is not readily transmitted from hatchery fish to salmon and other fish in streams, estuary or the ocean (DWR 2009).

Predation

Predation was not identified as an important factor in the listing of spring-run Chinook salmon (63 FR 11482, March 9, 1998; Myers *et al*. 1998), but more recently it has gained attention as a potentially significant source of mortality (Moyle 2002; Vogel

2011). See section 2.1.6 above for information on predators of juvenile Chinook salmon in the Central Valley and their potential impact.

The Inadequacy of Existing Regulatory Mechanisms

Laws relevant to the protection and restoration of spring-run Chinook salmon are the ESA, the Magnuson-Stevens Fishery Conservation and Management Act, the CVPIA, the Federal Power Act, the Fish and Wildlife Coordination Act, the Clean Water Act, the National Environmental Policy Act, and numerous State laws administered by CDFW, DWR, or the SWRCB. These laws and associated regulations provide adequate mechanisms for recovering spring-run Chinook salmon; however some of the goals of these existing mechanisms have not yet been achieved. The effectiveness of applying the regulatory mechanisms is to some extent controlled by societal values. The people of California will need to place a higher value on improving natural ecosystems in order for existing regulatory mechanisms to be most effective at recovering anadromous salmonids in the Central Valley.

Other Natural or Manmade Factors Affecting the Continued Existence of Spring-run Chinook Salmon

<u>Reduced Genetic Integrity</u>

Threats to the genetic integrity of spring-run Chinook salmon was identified as a serious concern to the species when it was listed in 1999 (63 FR 11482, March 9, 1998; Myers *et al*. 1998). Three main factors compromised the genetic integrity of spring-run Chinook salmon: (1) the lack of reproductive isolation following dam construction throughout the Central Valley resulting in introgression with fall-run Chinook salmon in the wild; (2) within basin and inter-basin mixing between spring- and fall- broodstock for artificial propagation, resulting in introgression in hatcheries; and (3) releasing hatchery-produced juvenile Chinook salmon in the San Francisco estuary, which contributes to the straying of returning adults throughout the Central Valley.

In the 1940s, trapping of adult Chinook salmon that originated from areas above Keswick and Shasta dams may have resulted in stock mixing, and further mixing with fall-run Chinook salmon apparently occurred with fish transferred to the CNFH. Deer Creek, one of the locations generally believed most likely to retain essentially native spring-run Chinook salmon, was a target of adult outplants from the 1940s trapping operation, but the success of those transplants is uncertain (Myers *et al*. 1998).

Much of the Central Valley Chinook salmon production is of hatchery origin, and over the years hatchery fish have interbred with wild populations of both fall-run and spring-run Chinook salmon. This problem has been exacerbated by the continued practice of trucking juvenile Chinook salmon to the Delta for release, contributing to the straying of returning adults throughout the Central Valley.

The FRFH spring-run Chinook salmon program releases half its production near the hatchery and the other half is released far downstream of the hatchery (CDFW 2001a). Given the large number of juveniles released off station, the potential contribution of straying adults to rivers throughout the Central Valley is considerable (Myers *et al*. 1998). Cramer (1996) reported that up to 20 percent of the Feather River spring-run Chinook salmon are recovered in the

American River sport fishery. From 2004 through 2010 on the Yuba River, hatchery origin Chinook salmon accounted for an average of 21.4% of the total annual run of spring-run Chinook salmon passing upstream of Daguerre Point Dam (USACE 2012). Analysis of coded wire tags suggests that most of those hatchery fish originated from the FRFH (USACE 2012).

Catastrophic Environmental Disturbance

Although not identified as a reason for listing spring-run Chinook salmon under the ESA, the potential for a catastrophic environmental disturbance has more recently been recognized as a key threat to the species. Lindley *et al.* (2007) report that the current distribution of viable populations makes the Central Valley spring-run Chinook salmon ESU vulnerable to catastrophic disturbance. All three extant independent populations are in basins whose headwaters lie within the debris and pyroclastic flow radii of Lassen Peak, an active volcano that USGS views as highly dangerous. Additionally, a fire with a maximum diameter of 30 km, big enough to burn the headwaters of Mill, Deer, and Butte creeks simultaneously, has roughly a 10 percent chance of occurring somewhere in the Central Valley each year. Impacts on salmon and their habitat from fires include potential death during a fire that goes through a drainage, reduced water quality from fire suppression activities and associated chemicals, increased water temperatures from lost canopy, increased sedimentation, and reduced habitat complexity and large woody debris. A catastrophic environmental disturbance affecting Mill, Deer, and Butte creeks would greatly reduce the abundance and distribution of the spring-run Chinook salmon ESU.

2.2.7 Threats Assessment

A detailed threats assessment was conducted for the Central Valley spring-run Chinook salmon ESU, and followed the same general procedure previously described for winter-run Chinook salmon. The threats/stressors affecting each spring-run Chinook salmon diversity group and population are described in Appendix B.

The completed stressor matrix sorted by normalized weight is a prioritized list of the life stage-specific stressors affecting the ESU. For spring-run Chinook salmon, threats were prioritized within each diversity group, as well as within each population. Specific information explaining the individual steps taken to generate these prioritized lists are provided in Appendix B.

Some major stressors to the entire Central Valley spring-run Chinook salmon ESU include passage impediments/barriers, ocean harvest, warm water temperatures for holding and rearing, limited quantity and quality of rearing habitat, predation, and entrainment. The complete prioritized list of life stage-specific stressors to this ESU is presented in Appendix B.

Some of the most important specific stressors to each diversity groups within the ESU are described below.

Northern Sierra Nevada Diversity Group

- Agricultural diversions, diversion dams, and/or weirs on Deer, Mill, Antelope, and Butte creeks impeding or blocking access to upstream spawning habitat;
- Warm water temperatures in Antelope, Butte, and Big Chico creeks during the adult immigration

and holding life stage, especially in dry or extreme years;

- Englebright Dam blocking access to habitat historically used by Yuba River spring-run Chinook salmon;
- Oroville Dam blocking access to habitat historically used by Feather River spring-run Chinook salmon;
- Entrainment in Antelope Creek resulting from terminal diversions and loss of channel connectivity;
- Loss of rearing habitat in the lower and middle sections of the Sacramento River and in the Delta;
- Ocean harvest on all populations; and
- Predation on juveniles from all populations rearing and migrating through the Sacramento River and Delta.

Basalt and Porous Lava Diversity Group

- Keswick and Shasta dams blocking access to habitat historically used by spring-run Chinook salmon in the upper Sacramento River watershed;
- Passage impediments and flow fluctuations resulting from hydropower operations on the North and South Forks of Battle Creek;
- Loss of rearing habitat in the Sacramento River and Delta;
- Ocean harvest on all populations; and
- Predation on juveniles from all populations rearing and migrating through the Sacramento River and Delta.

Northwestern California Diversity Group

- Warm water temperatures in all three watersheds during the adult immigration and holding life stage;
- Limited spawning habitat availability in all three watersheds;
- Loss of rearing habitat in the lower and middle sections of the Sacramento River and in the Delta;
- Whiskeytown Dam blocking access to habitat potentially historically used by Clear Creek spring-run Chinook salmon;
- Ocean harvest on all populations; and
- Predation on juveniles from all populations rearing and migrating through the Sacramento River and Delta.

2.2.8 Conservation Measures

ERP and CVPIA actions in the Sacramento River tributaries have focused on riparian and shaded riverine aquatic habitat restoration, improved access to available upstream habitat, improved instream flows, and reduced loss of juveniles at diversions, particularly for spring-run Chinook salmon and steelhead. For a description of ERP, CVPIA and other actions, refer to the previous discussion of Conservation Measures for winter-run Chinook salmon.

The Delta Pumping Plant Fish Protection Agreement (Delta Agreement) signed in 1986 was intended to mitigate for SWP and pumping plant impacts. From 1986 through 2007, approximately $60 million from the Delta Agreement has been spent on over 40 fish mitigation projects. These funds resulted in the screening of water diversions, enhanced law enforcement efforts to reduce illegal fish harvest, installation of seasonal barriers to guide fish away from undesirable spawning habitat or migration corridors, salmon habitat restoration, and removal of four dams to improve fish passage on Butte Creek for Chinook and steelhead. Approximately one-third of the approved funding for salmon projects specifically targeted spring-run Chinook salmon and steelhead in the upper Sacramento River tributaries. Projects implemented under the agreement that have most directly benefited spring-run Chinook salmon include water exchange projects to improve passage flows on Mill and Deer creeks, and fish screens and fish ladder improvements on Butte Creek.

Harvest protective measures benefiting spring-run Chinook salmon include seasonal constraints on sport and commercial fisheries south of Point Arena. In addition, the State has listed spring-run Chinook under the CESA, and has thus established specific in-river fishing regulations and no-retention prohibitions designed to protect this ESU (e.g., fishing method restrictions, gear restrictions, bait limitations, seasonal closures, and zero bag limits), in tributaries such as Deer, Big Chico, Mill, and Butte creeks.

2.3 Steelhead

2.3.1 ESA Listing Status

NMFS proposed to list Central Valley steelhead (anadromous *O. mykiss*), which is currently listed as threatened, as endangered on August 9, 1996 (61 FR 41541). NMFS concluded that the California Central Valley steelhead ESU was in danger of extinction because of habitat degradation and destruction, blockage of freshwater habitats, water allocation problems, the pervasive opportunity for genetic introgression resulting from widespread production of hatchery steelhead and the potential ecological interaction between introduced stocks and native stocks. Moreover, NMFS proposed to list steelhead as endangered because steelhead had been extirpated from most of their historical range.

On March 19, 1998, NMFS listed the Central Valley steelhead as a threatened species (63 FR 13347). NMFS concluded that the risks to Central Valley steelhead had diminished since the completion of the 1996 status review based on a review of existing and recently implemented State conservation efforts and Federal management programs (e.g., CVPIA AFRP, CALFED) that address key factors for the decline of this species. In addition, NMFS noted that additional actions benefiting Central Valley steelhead included efforts to enhance fisheries monitoring and conservation actions to address artificial propagation.

On September 8, 2000, pursuant to a July 10, 2000, rule issued by NMFS under Section 4(d) of the ESA (16 USC § 1533(d)), the take restrictions that apply statutorily to endangered species began to apply with specific limitations to Central Valley steelhead (65 FR 42422). On January 5, 2006, NMFS reaffirmed the threatened status of the Central Valley steelhead and applied the DPS policy to the species because the resident and anadromous life forms of steelhead remain "markedly separated" as a consequence of physical, ecological and behavioral factors, and may therefore warrant delineation as a separate DPS (71 FR 834). NMFS (1998) based its conclusion on conservation and protective efforts that, "*mitigate the immediacy of extinction risk facing the Central Valley steelhead DPS*." **Figure 2-9** depicts the California Central Valley steelhead DPS.

2.3.2 Species Description and Taxonomy

Steelhead and rainbow trout are the same species. In general, steelhead refers to the anadromous form of the species. Normally, adult steelhead reach a larger size than resident rainbow trout. Sacramento River Basin steelhead immigrants range in size from 12 to 18 inches (30.5 to 45.7 cm) FL for adults returning after 1 year in the ocean, to 18 to 23 inches (45.7 to 58.4 cm) FL for adults returning after 2 years in the ocean (S.P. Cramer & Associates 1995).

Steelhead can be identified by the numerous black spots on the caudal fin, adipose fin, dorsal fin and back (Moyle 2002). When in freshwater, steelhead often display the pinkish to red lateral band and cheeks typical of resident rainbow trout. The back is normally an iridescent blue to brown, the sides and belly are silver, white or yellowish (Moyle 2002). The resident forms are usually darker than the sea-run. Juvenile coloration is similar to adults except that juveniles often have 8 to 13 widely spaced parr marks centered on the lateral line, 5 to 10 dark marks on the back between the head and dorsal fin, white to orange tips on the dorsal and anal fins, and few, if any, dark spots on the tail (Moyle 2002).

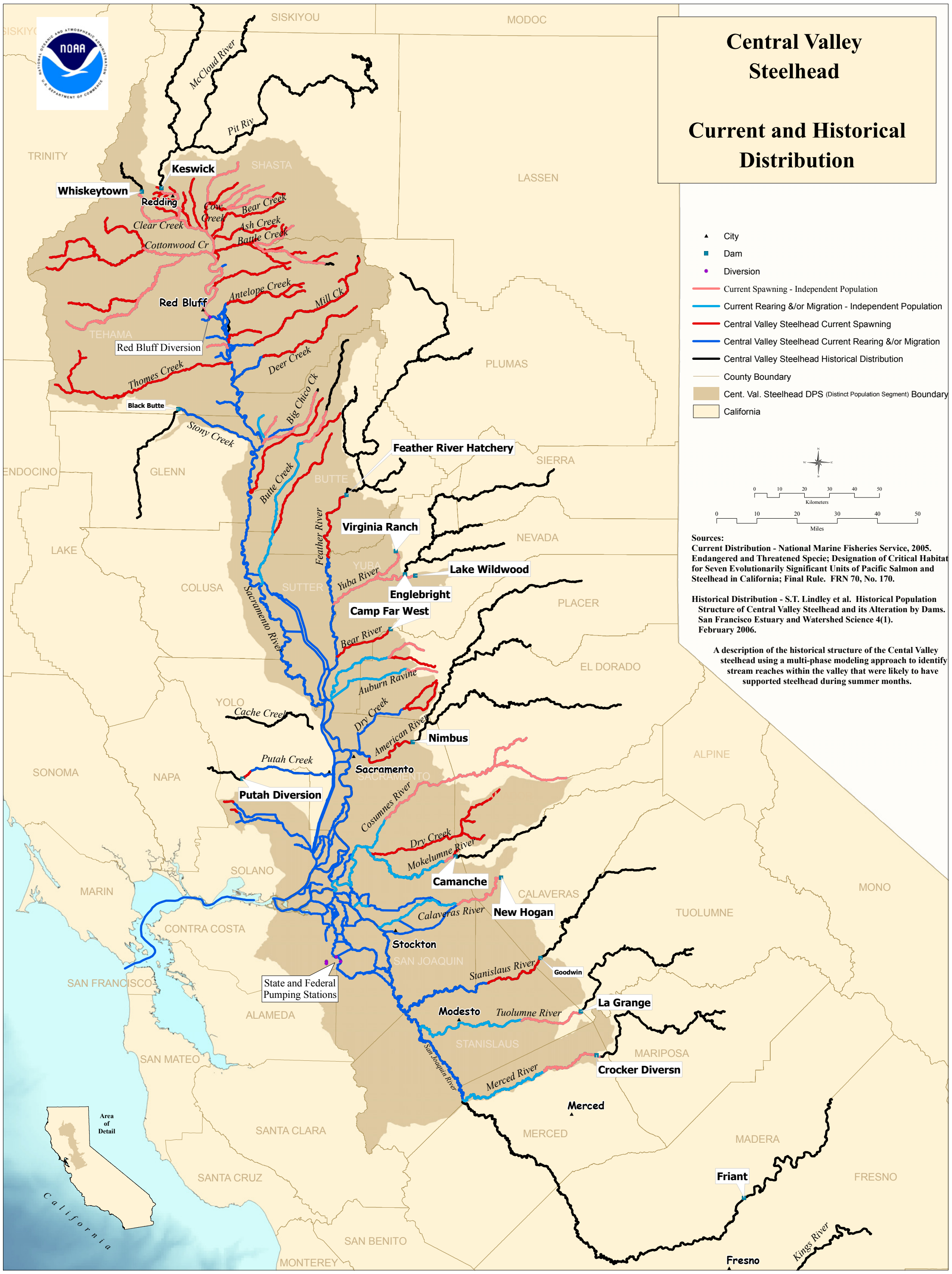


Figure 2-9. California Central Valley Steelhead Distinct Population Segment, and Current and Historical Distribution. See Lindley *et al.* 2006 (Table 1) in Appendix C for a list of the 81 historic independent steelhead populations in the Central Valley. Note: this figure does not include populations in the Suisun Bay Tributaries diversity group, the Central Western diversity group, or populations in the southern Sierra Nevada diversity group that are south of the upper San Joaquin River.

2.3.3 Life History/Habitat Requirements

Life History

Oncorhynchus mykiss may exhibit anadromy or freshwater residency. Resident forms are usually referred to as rainbow trout, while anadromous life forms are termed ‘‘steelhead.’’ Zimmerman *et al.* (2008) demonstrated that resident rainbow trout can produce anadromous smolts and anadromous steelhead can produce resident rainbow trout in the Central Valley. That study indicated that the proportion of resident rainbow trout to anadromous steelhead in the Central Valley is largely in favor of the resident form with 740 of 964 *O. mykiss* examined being the progeny of resident rainbow trout (Zimmerman *et al.* 2008).

Steelhead typically migrate to marine waters after spending two years in fresh water. They reside in marine waters for typically two or three years prior to returning to their natal stream to spawn as four- or five-year-olds. Unlike Pacific salmon, steelhead are capable of spawning more than once before they die. However, it is rare for steelhead to spawn more than twice before dying, and most that do so are females (Moyle 2002).

Currently, Central Valley steelhead are considered “ocean-maturing” (also known as winter) steelhead, although summer steelhead may have been present prior to construction of large dams (Moyle 2002). Ocean maturing steelhead enter fresh water with well-developed gonads and spawn shortly after river entry. Central Valley steelhead enter fresh water from August through April. They hold until flows are high enough in tributaries to enter for spawning (Moyle 2002). Steelhead adults typically spawn from December through April, with peaks from January through March in small streams and tributaries where cool, well oxygenated water is available year-round (Hallock *et al.* 1961; McEwan 2001). Depending on water temperature, steelhead eggs may incubate in redds for over one month before hatching as alevins. Following yolk sac absorption, alevins emerge from the gravel as young juveniles or fry and begin actively feeding (Moyle 2002).

In the Sacramento River, juvenile steelhead generally migrate to the ocean in spring and early summer at 1 to 3 years of age and 10 to 25 cm FL, with peak migration through the Delta in March and April (Reynolds *et al.* 1993). Hallock *et al.* (1961) found that juvenile steelhead in the Sacramento River Basin migrate downstream during most months of the year, but the peak emigration period occurred in the spring, with a much smaller peak in the fall.

Table 2-4 depicts the temporal occurrence of steelhead life stages in the Sacramento River. Steelhead may remain in the ocean from one to four years, growing rapidly as they feed in the highly productive currents along the continental shelf (Barnhart 1986). Oceanic and climate conditions such as sea surface temperatures, air temperatures, strength of upwelling, El Niño events, salinity, ocean currents, wind speed, and primary and secondary productivity affect all facets of the physical, biological and chemical processes in the marine environment. Some of the conditions associated with El Niño events include warmer water temperatures, weak upwelling, low primary productivity (which leads to decreased zooplankton biomass), decreased southward transport of subarctic water, and increased sea levels (Pearcy 1997). For juvenile steelhead, warmer water and weakened upwellings are possibly the most important of the ocean conditions associated with El Niño. Because of the weakened upwelling during an El Niño year, juvenile California steelhead would need to migrate more actively offshore through possibly stressful warm waters with numerous inshore predators.

Strong upwelling is probably beneficial because of the greater transport of smolts offshore, beyond major concentrations of inshore predators (Pearcy 1997).

Habitat Requirements

A description of freshwater habitat requirements for steelhead is presented in the following sections. Habitat requirements are organized by the species life stage.

Adult Immigration and Holding

Adult steelhead immigration into Central Valley streams typically begins in August and continues into March (McEwan 2001; NMFS 2004). Steelhead immigration generally peaks during January and February (Moyle 2002). Optimal immigration and holding temperatures have been reported to range from 46°F to 52°F (CDFW 1991b).

Central Valley steelhead are known to use the Sacramento River as a migration corridor to spawning areas in upstream tributaries. Historically, steelhead likely did not utilize the mainstem Sacramento River downstream from the Shasta Dam site except as a migration corridor to and from headwater streams. Likewise, the Feather River below the current site of Oroville Dam was likely used only as a migration corridor to upstream reaches.

Adult Spawning

Central Valley steelhead spawn downstream of dams on every major tributary within the Sacramento and San Joaquin River systems. The female steelhead selects a site with good intergravel flow, digs a redd with her tail, usually in the coarse gravel of the tail of a pool or in a riffle, and deposits eggs while an attendant male fertilizes them. Water velocities over redds are typically 20 to 155 cm/sec, and depths are 10 to 150 cm (Moyle 2002). The preferred water temperature range for steelhead spawning is reported to be 30°F to 52°F (CDFW 2000).

Embryo Incubation

Following deposition of fertilized eggs in the redd, they are covered with loose gravel. Central Valley steelhead eggs can reportedly survive at water temperature ranges of 35.6°F to 59°F (Myrick and Cech 2001). However, steelhead eggs reportedly have the highest survival rates at water temperature ranges of 44.6°F to 50.0°F (Myrick and Cech 2001). The eggs hatch in three to four weeks at 50°F to 59°F, and fry emerge from the gravel four to six weeks later (Shapovalov and Taft 1954).

Juvenile Rearing and Outmigration

Regardless of life history strategy, for the first year or two of life rainbow trout and steelhead are found in cool, clear, fast-flowing permanent streams and rivers where riffles predominate over pools, there is ample cover from riparian vegetation or undercut banks, and invertebrate life is diverse and abundant (Moyle 2002). The smallest fish are most often found in riffles, intermediate size fish in runs, and larger fish in pools. Steelhead can be found where daytime water temperatures range from nearly 32°F to 81°F in the summer, although mortality may result at extremely low (i.e.,

<39°F) or extremely high (i.e., > ~73°F) water temperatures if the fish have not been gradually acclimated (Moyle 2002). Juvenile steelhead in northern California rivers reportedly exhibited increased physiological stress, increased agonistic activity, and a decrease in forage activity after ambient stream temperatures exceeded 71.6°F (Nielsen *et al*. 1994).

When water temperatures become stressful in streams, juvenile steelhead are faced with the increased energetic costs of living at high water temperatures. Hence, juvenile steelhead will move into fast flowing riffles to feed because of the increased abundance of food, even though there are costs associated with maintaining position in fast water. At higher water temperatures, steelhead are more vulnerable to stress which can be fatal (Moyle 2002). Predators also have a strong effect on microhabitats selected by steelhead. Small steelhead select places to live based largely on proximity to cover in order to hide from predators.

Optimal water temperatures for growth of steelhead have been reported to be 59°F to 64.4°F (Moyle 2002). Many factors affect choice of water temperatures by steelhead, including the availability of food. As steelhead grow, they establish individual feeding territories. Some juvenile steelhead utilize tidal marsh areas, non-tidal freshwater marshes, and other shallow water areas in the Delta as rearing areas for short periods prior to their final emigration to the ocean.

2.3.4 Abundance Trends and Distribution

Prior to dam construction, water development and watershed perturbations, Central Valley steelhead were distributed throughout the Sacramento and San Joaquin rivers (Busby *et al.* 1996; NMFS 1996b, McEwan 2001). Steelhead were found from the upper Sacramento and Pit rivers (now inaccessible due to Shasta and Keswick dams) south to the Kings and possibly the Kern River systems, and in both east- and west-side Sacramento River tributaries (Yoshiyama *et al.* 1996). Lindley *et al.* (Lindley *et al.* 2006) estimated that historically there were at least 81 independent Central Valley steelhead populations distributed primarily throughout the eastern tributaries of the Sacramento and San Joaquin rivers (**see Appendix C**). Presently, impassable dams block access to 80 percent of historically available habitat, and block access to all historical spawning habitat for about 38 percent of historical populations (Lindley *et al.* 2006).

The current and historical distribution of Central Valley steelhead was presented in **Figure 2-9**. Existing wild steelhead populations in the Sacramento River basin occur in the upper Sacramento River and its tributaries, including Cottonwood, Antelope, Deer, and Mill creeks and the Yuba River. Other Sacramento River basin populations may exist in Big Chico and Butte creeks, and a few wild steelhead are produced in the American and Feather rivers (McEwan 2001). Snorkel surveys conducted from 1999 to 2008 indicate that steelhead are present in Clear Creek (Giovannetti and Brown 2009; Good *et al.* 2005). Monitoring data from 2005 to 2009 shows that steelhead are also present in Battle Creek (Newton and Stafford 2011).

A hatchery supported population of steelhead also occurs in the Mokelumne River, which flows directly into the Delta in between where the Sacramento and San Joaquin rivers enter the Delta.

Central Valley steelhead were thought to be extirpated from the San Joaquin River system, until recent monitoring detected small populations of *O.mykiss* in the Stanislaus, Mokelumne, and Calaveras rivers, and other streams previously thought to be devoid of steelhead (McEwan 2001). It is uncertain whether the *O.mykiss* in those rivers are predominantly resident or anadromous *O.mykiss*; presumably, both the anadromous and resident life history form of *O.mykiss* are present. On the Stanislaus River, small numbers of steelhead smolts have been captured in rotary screw traps at Caswell State Park and Oakdale each year since 1995 (S.P. Cramer and Associates Inc. 2000, 2001). Steelhead also currently occur in the Stanislaus, Calaveras, Merced, and Tuolumne rivers.

It is possible that naturally-spawning populations exist in many other streams but are undetected due to lack of monitoring programs (IEP Steelhead Project Work Team 1999). Incidental catches and observations of steelhead juveniles also have occurred on the Tuolumne and Merced Rivers during fall-run Chinook salmon monitoring activities, indicating that *O.mykiss* are widespread, throughout accessible streams and rivers in the Central Valley (Good *et al.* 2005).

Table 2-4. The Temporal Occurrence of Adult and Juvenile Steelhead in the Sacramento River

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult												
Sacramento River[1,3]												
Sacramento River at Red Bluff[2,3]												
Mill, Deer Creeks[4]												
Sacramento River at Fremont Weir[6]												
Sacramento River at Fremont Weir[6]												
San Joaquin River[7]												
Juvenile												
Sacramento River[1,2]												
Sacramento River at Knights Landing[2,8]												
Sacramento River at KL[9]												
Chipps Island (Wild)[10]												
Mossdale[8]												
Woodbridge Dam[11]												
Stanislaus River at Caswell[12]												
Sacramento River at Hood[13]												

Sources: [1]Hallock et al. 1961; [2]McEwan 2001; [3]USFWS unpublished data; [4]CDFW 1995; [5](Hallock et al. 1957); [6]Bailey 1954; [7]CDFW Steelhead Report Card Data; [8]CDFW unpublished data; [9]Snider and Titus 2000; [10]Nobriga and Cadrett 2003; [11]Jones & Stokes Associates, Inc., 2002; [12]S.P. Cramer and Associates, Inc. 2000 and 2001; [13]Schaffter 1980

Relative Abundance: = High = Medium = Low

Note: NMFS recognizes that CDFW Steelhead Report Card Data provides a small sample size and involves some known sampling bias, but these data represent the best information available for the temporal distribution of adult steelhead in the San Joaquin River.

Historic Central Valley steelhead run sizes are difficult to estimate because of the lack of data, but may have approached one to two million adults annually (McEwan 2001). By the early 1960s the steelhead run size had declined to about 40,000 (CDFW 1996). Over the last 30 years the steelhead populations in the upper Sacramento River have declined substantially. In 1996, NMFS estimated the Central Valley total run size based on dam counts, hatchery returns, and past spawning surveys was probably fewer than 10,000 fish. Both natural and hatchery runs have declined since the 1960s. Counts at RBDD averaged 1,400 fish from 1991 to 1993, compared to counts in excess of 10,000 fish in the late 1960. Because of adverse impacts on winter-run Chinook salmon, the operation of RBDD was changed so that the dam gates were raised earlier in the season, and this eliminated the ability to generate steelhead run-size estimates (McEwan 2001).

American River redd surveys and associated monitoring from 2002 through 2007 indicate that only a few hundred steelhead spawn in the river and the majority of those spawners originated from Nimbus Hatchery (Hannon and Deason 2008).

In analyzing flow-habitat relationships for anadromous salmonids in the upper Sacramento River upstream of the Battle Creek confluence and downstream of Keswick Dam, USFWS (2003) reported that it was not possible to differentiate between steelhead and resident rainbow trout. Specific information regarding steelhead spawning within the mainstem Sacramento River is limited due to lack of monitoring (NMFS 2004). Currently, the number of steelhead spawning in the Sacramento River is unknown because redds cannot be distinguished from a large resident rainbow trout population that has developed as a result of managing the upper Sacramento River for coldwater species.

2.3.5 Critical Habitat

When designating critical habitat, NMFS focuses on "Primary Constituent Elements" (PCEs), which are the principal biological or physical constituent elements within the defined area that are essential to the conservation of the listed species (50 CFR 424.12(b)). PCEs considered essential for the conservation of the California Central Valley steelhead DPS are those sites and habitat components that support one or more life stages (50 CFR 226.211(c)), including:

- Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation and larval development.

- Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.

- Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival.

- Estuarine areas free of obstruction and excessive predation with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.

NMFS proposed[5] critical habitat for Central Valley steelhead on December 10, 2004 (69 FR 71880) and published a final rule designating critical habitat for this species on September 2, 2005 (70 FR 52488). **Figure 2-10** depicts the designated critical habitat and distribution for Central Valley steelhead.

2.3.6 Reasons for Listing

Section 4 of the ESA requires the Secretary of the Interior or Commerce, depending upon the species involved, to determine if any species is an endangered or threatened species for any of the following listing factors: (1) present or threatened destruction, modification or curtailment of its habitat or range; (2) overutilization for commercial, recreational. scientific or educational purposes; (3) disease or predation; (4) inadequacy of existing regulatory mechanisms; or (5) other natural or manmade factors affecting its continued existence. Each of these listing factors with respect to Central Valley steelhead are summarized below.

The Present or Threatened Destruction, Modification, or Curtailment of Central Valley Steelhead's Habitat or Range.

The widespread degradation, destruction, and blockage of freshwater habitats within the Central Valley, and the continuing impacts to habitat resulting from water management were identified as key reasons why Central Valley steelhead were listed under the ESA (61 FR 41541, August 9, 1996; 63 FR 13347, March 19, 1998). These reasons are briefly discussed below under two categories – (1) habitat loss, and (2) habitat degradation.

Habitat Loss

About 80% of habitat identified by the TRT that was historically available to anadromous *O. mykiss* is now behind impassable dams, and 38% of the populations identified by the TRT have lost all of their habitat (Lindley *et al.* 2006). Anadromous *O. mykiss* populations may have been extirpated from their entire historical range in the San Joaquin Valley and most of the larger basins of the Sacramento River. The roughly 52% of watersheds with at least half of their historical area below impassable dams are all small, low elevation systems (Lindley *et al*. 2006).

[5] NMFS proposed critical habitat for Central Valley steelhead on February 5, 1999 (64 FR 5740) in compliance with Section 4(a)(3)(A) of the ESA, which requires that, to the maximum extent prudent and determinable, NMFS designates critical habitat concurrently with a determination that a species is endangered or threatened (NMFS 1999). On February 16, 2000 (65 FR 7764), NMFS published a final rule designating critical habitat for Central Valley steelhead. Critical habitat was designated to include all river reaches accessible to listed steelhead in the Sacramento and San Joaquin rivers and their tributaries in California. Also included were river reaches and estuarine areas of the Delta, all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait, all waters of San Pablo Bay westward of the Carquinez Bridge, and all waters of San Francisco Bay (north of the San Francisco/Oakland Bay Bridge) from San Pablo Bay to the Golden Gate Bridge.

In response to litigation brought by the National Association of Homebuilders (NAHB) (NAHB v. Evans, 2002 WL 1205743 No. 00–CV–2799 (D.D.C.)), NMFS sought judicial approval of a consent decree withdrawing critical habitat designations for 19 Pacific salmon and *O. mykiss* ESUs. The District Court in Washington DC approved the consent decree and vacated the critical habitat designations by Court order on April 30, 2002 (NAHB v. Evans, 2002 WL 1205743 (D.D.C. 2002)).

Habitat Degradation

The habitat in the Central Valley that remains accessible to anadromous *O. mykiss* has been drastically altered and degraded. Reynolds *et al.* (1993) reported that declines in Central Valley steelhead stocks are "*due mostly to water development, inadequate instream flows, rapid flow fluctuations, high summer water temperatures in streams immediately below reservoirs, diversion dams which block access, and entrainment of juveniles into unscreened or poorly screened diversions.*" Other problems related to land use practices (agriculture and forestry) and urbanization also have certainly contributed to the decline of Central Valley steelhead (McEwan 2001).

Overutilization of Steelhead for Commercial, Recreational, Scientific, or Educational Purposes

The overutilization of Central Valley steelhead was not identified as an important reason for the species' listing (61 FR 41541; 63 FR 13347).

Commercial or Recreational Fishery Impacts on Central Valley Steelhead

Because there is no commercial fishery for Central Valley steelhead and the recreational fishery is regulated to protect wild steelhead, there is some reason to think that fishing impacts would not be a significant problem for this species. However, because the sizes of Central Valley steelhead populations are largely unknown, it is difficult to make conclusions about the impact of the recreational fishery (Good *et al*. 2005).

Scientific or Educational Utilization of Central Valley Steelhead

NMFS issues permits under the ESA for scientific research that stipulate specific conditions to minimize take of steelhead. These permitted studies provide information about steelhead in the Central Valley that is useful for management and conservation of the DPS and are not considered a factor for the decline of this species (NMFS 2011c).

Disease or Predation

Disease

Infectious disease is one of many factors which can influence adult and juvenile steelhead survival. Steelhead are exposed to numerous bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, hatcheries, migratory routes, and the marine environments. Specific diseases such as bacterial kidney disease (BKD), ceratomyxosis, columnaris, Furunculosis, infectious hematopoietic necrosis (IHNV), redmouth and black spot disease, Erythrocytic Inclusion Body Syndrome (EIBS), and whirling disease among others are present and are known to affect steelhead and salmon (NMFS 1996).

Although disease was recognized as a potential factor in the decline of west coast steelhead (NMFS 1996), it was not specifically identified as an important reason why Central Valley steelhead were listed under the ESA (61 FR 41541; 63 FR 13347).

The Inadequacy of Existing Regulatory Mechanisms

The inadequacy of existing regulatory mechanisms was not identified as a key factor in the listing of Central Valley steelhead. Although there is a lengthy discussion of this listing factor in the Final Rule listing Central Valley steelhead as threatened, most of the discussion applies to other steelhead ESUs, which were also considered for listing at that time (63 FR 13347).

Other Natural or Manmade Factors Affecting the Continued Existence of Central Valley Steelhead

Hatchery Management/Reduced Genetic Integrity

Along with habitat loss and habitat degradation, hatchery management was identified as a key factor in the listing of Central Valley steelhead (61 FR 41541; 63 FR 13347). Over the past several decades, the genetic integrity of Central Valley steelhead has been diminished by increases in the proportion of hatchery fish relative to naturally produced fish, the use of out-of-basin stocks for hatchery production, and straying of hatchery produced fish (CDFW and NMFS 2001; California Hatchery Scientific Review Group 2012). Four hatcheries in the Central Valley produce steelhead, and each hatchery has specific production targets, as identified in Table 2-5. Currently there is still great concern about the ecological and genetic impacts of steelhead hatchery management in the Central Valley (California Hatchery Scientific Review Group 2012). These concerns continue to be related to the proportion of hatchery fish relative to naturally produced fish, the predominance of Eel River steelhead genetics in the Nimbus Hatchery steelhead program, and straying of hatchery produced steelhead.

Potential adverse effects to wild steelhead populations associated with hatchery production are similar to those described above for winter-run Chinook salmon. Research has indicated that approximately 63 to 92 percent of steelhead smolt production is of hatchery origin (NMFS 2003). Overall, hatchery-origin fish appear to comprise the majority of the DPS (Lindley *et al*. 2007)

Habitat fragmentation and population declines resulting in small, isolated populations also pose genetic risk from inbreeding, loss of rare alleles, and genetic drift.

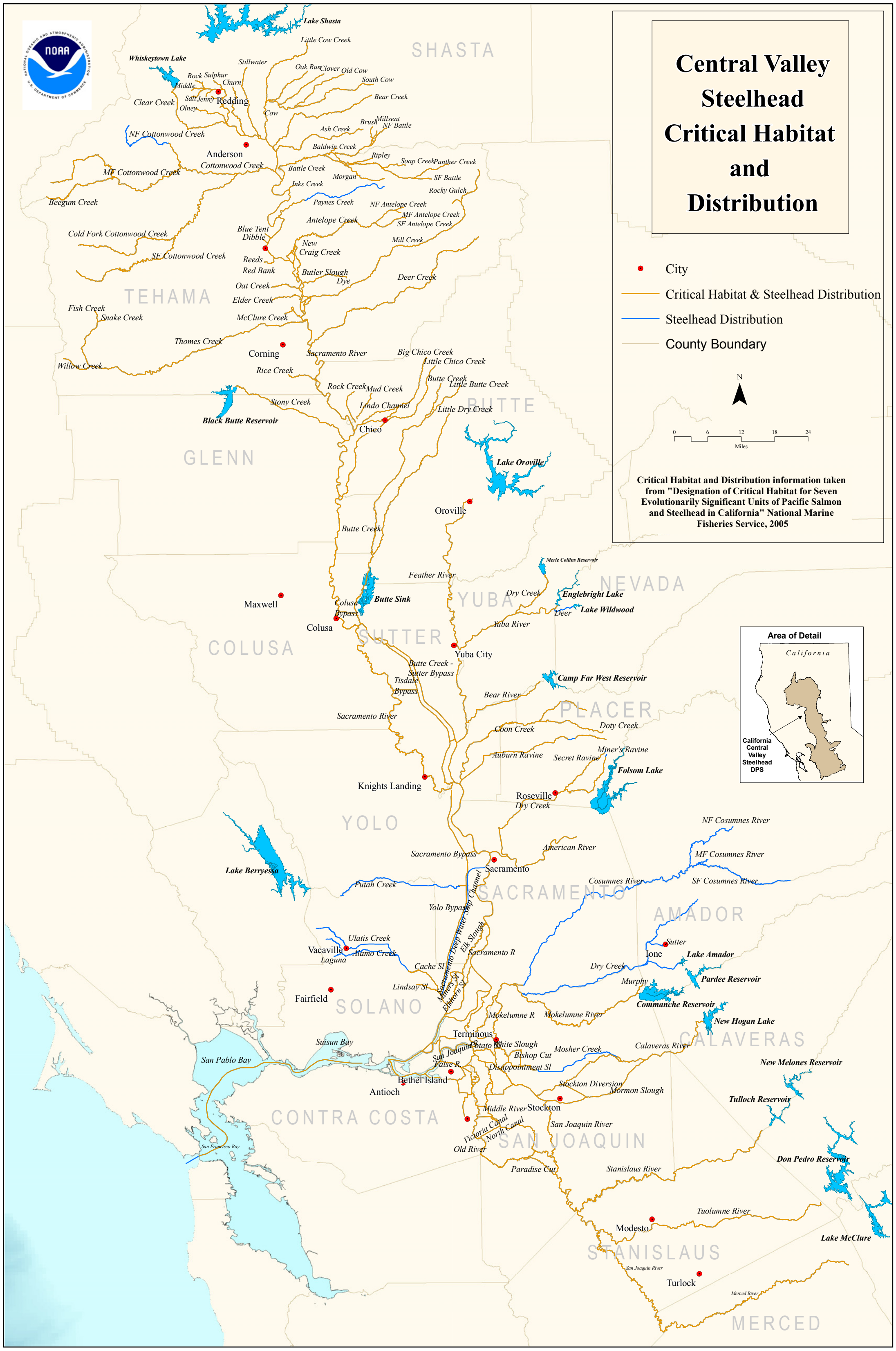


Figure 2-10. Central Valley Steelhead Designated Critical Habitat and Distribution

Table 2-5. Annual Steelhead Production Targets for Central Valley Hatcheries

Hatchery	Production Target
Coleman National Fish Hatchery	600,000
Feather River Fish Hatchery	500,000
Nimbus Hatchery	430,000
Mokelumne Fish Hatchery	100,000

There is still significant local genetic structure to Central Valley steelhead populations. Hatchery effects appear to be localized – for example, Feather River and the FRFH steelhead are closely related, as are American River and Nimbus Hatchery fish (DWR 2002). The Coleman National Fish Hatchery steelhead program was derived from the endemic stock of steelhead in the upper Sacramento River. Early-returning (October – December) steelhead in Battle Creek are similar genetically to the Coleman NFH adults and late-returning (March –May) natural-origin steelhead in Battle Creek are similar genetically to mainstem Sacramento River steelhead (Capton *et al*. 2004).

In general, although genetic structure was found, all naturally-spawned *O. mykiss* populations within the Central Valley basin were closely related, regardless of whether they were sampled above or below a known barrier to anadromy. This is due to some combination of pre-impoundment historic shared ancestry, downstream migration and, possibly, limited, anthropogenic upstream migration. However, lower genetic diversity in above-barrier populations indicates a lack of substantial genetic input upstream and highlights lower effective population sizes for above-barrier populations. Above-barrier populations clustered with one another and below-barrier populations are most closely related to populations in far northern California, specifically the genetic groups that include the Eel and Klamath rivers. Since Eel River origin broodstock were used for many years at Nimbus Hatchery on the American River, it is likely that Eel River genes persist there and have also spread to other basins by migration, and that this is responsible for the clustering of the below-barrier populations with northern California ones. This suggests that the below-barrier populations in this region appear to have been widely introgressed with hatchery fish from out of basin broodstock sources. The consistent clustering of the above-barrier populations with one another, and their position in the California-wide trees, indicate that they are likely to most accurately represent the ancestral population genetic structure of steelhead in the Central Valley (Garza and Pearse 2008).

A significant transfer of genetic material has occurred among hatcheries within the Central Valley, as well as some transfer from systems outside the Central Valley. For example, an Eel River strain of steelhead was used as the founding broodstock for the Nimbus Hatchery (DWR 2002). Additionally, eyed eggs from the Nimbus Hatchery were transferred to the FRFH several times in the late 1960s and early 1970s (DWR 2002). There have also been transfers of steelhead from the FRFH to the Mokelumne Hatchery. In the late 1970s, a strain of steelhead was brought in from Washington State for the FRFH (DWR 2002).

Environmental Variability

Variability in natural environmental conditions has both masked and exacerbated the problems associated with degraded and altered riverine and estuarine habitats. Floods and persistent drought conditions have periodically reduced steelhead spawning, rearing, and migration habitats.

El Nino events and periods of poor ocean conditions can threaten the survival of steelhead populations already reduced to low abundance levels due to the loss and degradation of freshwater and estuarine habitats. Alternatively, periods of favorable ocean conditions can offset the poor condition of inland habitats and result in increased population abundance and productivity by increasing the size and correlated fecundity of returning adults (NMFS 1996).

2.3.7 Threats Assessment

A detailed threats assessment was conducted for the California Central Valley steelhead DPS, and followed the same general procedure previously described for winter-run Chinook salmon. The threats/stressors affecting each steelhead diversity group and population are described by life stage in Appendix B.

Some major stressors to the entire California Central Valley steelhead DPS include passage impediments and barriers, warm water temperatures for rearing, hatchery effects, limited quantity and quality of rearing habitat, predation, and entrainment. The complete prioritized list of life stage-specific stressors to the DPS is presented in Appendix B.

Many of the most important stressors specific to the steelhead diversity groups correspond to the diversity group-specific stressors described for the Central Valley spring-run Chinook salmon ESU in section 2.2.7. The only diversity group (i.e., area) unique to the California Central Valley steelhead DPS, relative to the diversity groups in the Central Valley spring-run Chinook salmon ESU is the southern Sierra Nevada diversity group. Some of the most important stressors to steelhead in the southern Sierra Nevada diversity group include:

- Friant Dam blocking access to habitat historically used by San Joaquin River steelhead;
- Passage impediments on Calaveras River including Bellota Weir and flash board dams;
- Limited habitat availability in each watershed and in the mainstem San Joaquin River for spawning and juvenile rearing;
- La Grange and Don Pedro dams blocking access to habitat historically used by Tuolumne River steelhead;
- Goodwin and New Melones dams blocking access to habitat historically used by Stanislaus River steelhead;
- McSwain and Crocker Huffman dams blocking access to habitat historically used by Merced River steelhead;
- Camanche and Pardee dams blocking access to habitat historically used by Mokelumne River steelhead;
- Entrainment at the Jones and Banks Pumping Plants and associated losses from predation; and
- Inadequate summer flow on the Tuolumne River.

2.3.8 Conservation Measures

Conservation measures that have been taken to improve habitat for steelhead include, activities under the Clear Creek Restoration Program, the Battle Creek Salmon and Steelhead Restoration Project, several actions taken by the AFRP and the ERP, the Lower Yuba River Habitat Restoration Project, and actions under the San Joaquin River

Restoration Program. Specific information on how each of these programs and projects has benefited steelhead is described in the 5-year status review published in 2011 (NMFS 2011c).

Other ongoing measures to protect steelhead in the State of California include 100 percent adipose fin-clipping of all hatchery steelhead, although they are not coded-wire tagged and, therefore, determination of hatchery of origin, as well as straying rates, remain problematic for stock identification.

The State also works closely with NMFS to review and improve inland fishing regulations. As a result, zero bag limits for unmarked steelhead, gear restrictions, closures, and size limits designed to protect smolts are additional inland harvest measures that protect Central Valley steelhead.

While some conservation measures have been successful in improving habitat conditions for Central Valley steelhead, access to historic habitat remains blocked in many cases and fundamental problems still remain with the quality of the species' remaining habitat (see Lindley *et al*. 2009 and Cummins *et al*. 2008) and it continues to be highly degraded. The loss of historical habitat and the degradation of remaining habitat both continue to be major threats to this DPS.

3.0 Recovery Strategy

"The wide-ranging migration patterns and unique life histories of anadromous salmonids take them across ecosystem and management boundaries in an increasingly fragmented world, which creates the need for analyses and strategies at similarly large scales."

- Good *et al.* 2007. Recovery Planning for Endangered Species Act-listed Pacific Salmon: Using Science to Inform Goals and Strategies

3.1 INTRODUCTION

A broad strategic framework is necessary to serve as a strategic planning guide to integrate the actions contributing to the overarching goal of recovery of the two Chinook salmon ESUs and the steelhead DPS, which contain a mixture of hatchery and wild fish, and resident and anadromous fish. To address the complexity associated with the multi-faceted considerations for recovery efforts within the Central Valley Domain, San Francisco Estuary, and Pacific Ocean, this recovery strategy: explains the connection between the biological needs and situational background of the ESUs/DPS and the recovery program; and, presents the most effective means to achieve the individual recovery criteria and objectives, and, in turn, the delisting of the ESUs/DPS.

This chapter describes where we want to get to in terms of the number and spatial distribution of viable and dependent populations. Eliminating differences between the current viability and the desired viability is at the core of the recovery strategy. Having a strong rationale for, and understanding of, what a recovered Central Valley ESU/DPS will look like is critical to developing an effective strategy.

To convey this rationale and understanding, the chapter first describes the key facts and assumptions upon which the recovery plan is based. These facts and assumptions cover salmonid conservation principles, recovery implementation principles, and specific watershed classifications for recovery. Next, the primary objectives of the recovery plan are described. Lastly, adaptive management and monitoring are discussed because both will play a critical role in recovering the Chinook salmon ESUs and steelhead DPS.

3.2 FACTS AND ASSUMPTIONS

3.2.1 Salmonid Conservation Principles

Recovery of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead across such vast and altered ecosystems as the Central Valley, the San Francisco Estuary, and the Pacific Ocean, will require a broadly focused, science-based strategy. The scientific rationale for the strategy in this plan focuses on two key salmonid conservation principles. The first is that functioning, diverse, and interconnected habitats are necessary for a species to be viable.

That is, we cannot achieve salmon and steelhead recovery without providing sufficient habitat. Anadromous salmonids persisted in the Central Valley for thousands of years because the available habitat capacity and diversity allowed species to withstand and adapt to environmental changes including catastrophes such as prolonged droughts, large wildfires, and volcanic eruptions. The second salmonid conservation principle guiding the recovery strategy is that a species' viability is determined by its spatial structure, diversity, productivity, and abundance (McElhany *et al*. 2000). Life history diversity, genetic diversity, and metapopulation organization are ways that salmonids adapt to their complex and connected habitats. These factors are the basis of salmonid productivity and contribute to the ability of salmonids to cope with environmental variation that is typical of freshwater and marine environments.

Habitat Capacity and Diversity

A purpose of the ESA is to provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved, so that these species no longer require the protections of the ESA (i.e., can be delisted).

The availability and quality of habitat is fundamental to species viability; viable ESUs/DPSs and populations require a network of complex and interconnected habitats that are created, altered, and maintained by natural physical processes in freshwater, the estuary, and the ocean. Restoration of Central Valley anadromous salmonids must address the entire natural and cultural ecosystem, which encompasses the continuum of freshwater, estuarine, and ocean habitats where salmonid fishes complete their life histories. This consideration includes human developments, as well as natural habitats.

These diverse and high-quality habitats, which have been extensively degraded by human activities, are crucial for salmonid spawning, rearing, migration, maintenance of food webs, and predator avoidance. Ocean conditions, which are variable, are important in determining the overall patterns of productivity of salmon populations.

Unfortunately, habitat for Central Valley salmonids has been extensively altered. Dams have disconnected fish from their historic habitats and altered flow regimes downstream by storing winter and spring runoff and releasing higher–than-historic flows during summer for agricultural and municipal uses. More than 1,600 miles of levee construction in the Central Valley have constricted river channels, disconnected floodplains from active river channels, reduced riparian habitat, and reduced natural channel function, particularly in the Delta and the lower reaches of the Sacramento and San Joaquin Rivers. Thousands of water diversions within the Central Valley reduce instream flows, and the state and federal pumping facilities in the south Delta reverse natural river flows, disrupt natural tidal patterns, and alter the migration patterns and survival of salmonid individuals and populations.

Habitat conservation and enhancement efforts should focus on the sites and areas identified in NMFS's critical habitat designations for each of the three species. Additionally, consideration should be given to the PCEs and other relevant habitat conditions as summarized below.

<u>Freshwater Spawning Sites</u>

- have good water quality and quantity
- have substrate for spawning, incubation, and larval development

Freshwater Rearing Sites

- have good water quality and quantity and floodplain connectivity to maintain habitat conditions
- have forage for juvenile development
- have natural cover to provide refuge (such as submerged and overhanging large wood, log jams, beaver dams, aquatic vegetation, large rocks or boulders, side channels, undercut banks, etc.)

Freshwater Migration Corridors

- are unobstructed
- have good water quality and quantity
- have natural cover to provide refuge to support juvenile and adult mobility and survival
- afford safe passage conditions for migrations

Estuarine Areas

- are unobstructed
- have good water quality and quantity, with salinity conditions to support juvenile and adult physiological transitions between freshwater and saltwater
- have natural cover to provide refuge to support migrations among systems
- have forage for juvenile and adult migrating fish
- are free from overabundance of non-native predators

Nearshore Marine Areas[6]

- are unobstructed
- have good water quality and quantity conditions
- have forage to support growth and maturation of fish
- have natural cover to provide refuge

Offshore Marine Areas[6]

- have good water quality conditions
- have prey to support growth and maturation

Population Viability

Recovery planning seeks to ensure the viability of protected species. In the short term, viability of populations (and ESU/DPS) depends on the demographic properties of the population or ESU/DPS, such as population size, growth rate, the variation in growth rate, and carrying capacity (Tuljapurkar and Orzack 1980), all of which depend largely on the quality and quantity of habitat. In the longer term, genetic diversity, and the diversity of habitats that support genetic diversity, become increasingly important (McElhany

[6] For winter-run Chinook salmon marine areas are not explicitly included as physical biological features in the final rule designating critical habitat for that ESU (58 FR 33212; June 16, 1993); however, marine areas are important as the species spends the majority of its life cycle in the ocean. The preamble to the final rule designating critical habitat for CV spring-run Chinook salmon and CV steelhead discussed marine areas as primary constituent elements for the ESUs addressed in the final rule (70 FR 52488, 52521; September 2, 2005); however, the final rule did not include marine areas as primary constituent elements for CV spring-run Chinook salmon and CV steelhead (50 CFR 226.211(c); 70 FR 52488, 52537, September 2, 2005), and there are no marine areas designated as critical habitat for these species..

et al. 2000; Kendall and Fox 2002; Williams and Reeves 2003).

NMFS has developed guidelines to apply the four Viability of Salmon Population (VSP) parameters (abundance, productivity, spatial structure, and diversity). Application of the guidelines determines whether or not a population is viable (McElhany *et al.* 2000). The four parameters and their associated attributes are presented in **Figure 3-1.** The rationale applies these factors to define viable populations.

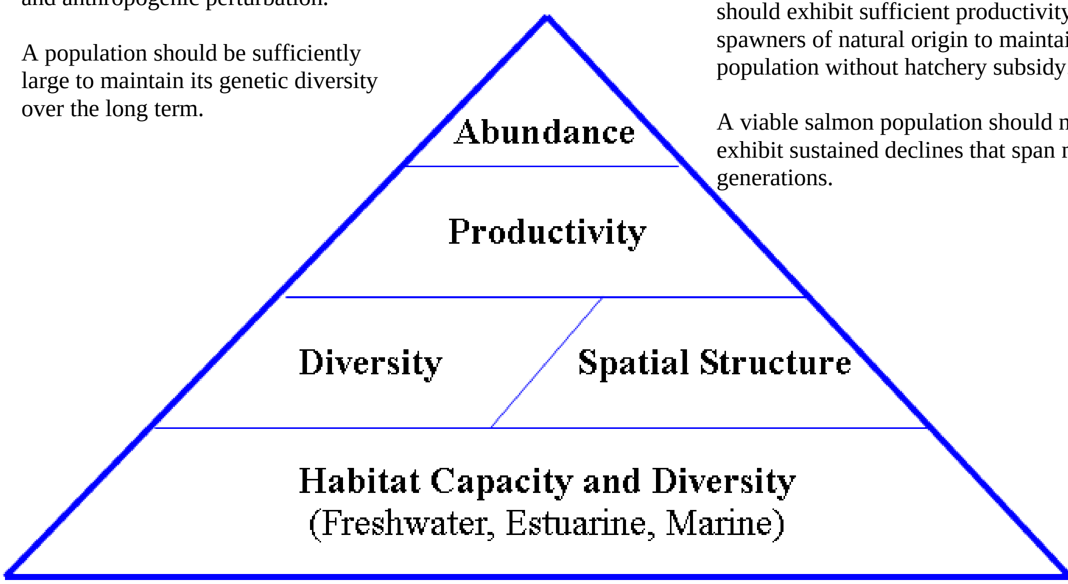
As presented in Good *et al.* (2005), criteria for VSP are based on population characteristics that reasonably predict extinction risk and reflect processes important to populations. Abundance is critical, because small populations are generally at greater risk of extinction than large populations. Stage-specific or lifetime productivity (i.e., population growth rate) provides information on important demographic processes. Abundance and productivity data are used to assess the status of populations of threatened and endangered ESUs (Good *et al.* 2005). Genotypic and phenotypic diversity are important in that they allow species to use a wide array of environments, respond to short-term changes in the environment, and survive long-term environmental change. Spatial structure reflects how abundance is distributed among available or potentially available habitats.

ABUNDANCE
A population should be large enough to have a high probability of surviving environmental variation of the patterns and magnitudes observed in the past and expected in the future.
A population should have sufficient abundance for compensatory processes to provide resilience to environmental and anthropogenic perturbation.

A population should be sufficiently large to maintain its genetic diversity over the long term.

PRODUCTIVITY (POPULATION GROWTH RATE)
Natural productivity should be sufficient to reproduce the population at a level of abundance that is viable.
Productivity should be sufficient throughout freshwater, estuarine, and nearshore life stages to maintain viable abundance levels, even during poor ocean conditions.
A viable salmon population that includes naturally spawning hatchery-origin fish should exhibit sufficient productivity from spawners of natural origin to maintain the population without hatchery subsidy.

A viable salmon population should not exhibit sustained declines that span multiple generations.



DIVERSITY

Human-caused factors such as habitat changes, harvest pressures, artificial propagation, and exotic species introduction should not substantially alter variation in traits such as run timing, age structure, size, fecundity (birth rate), morphology, behavior, and genetic characteristics.
The rate of gene flow among populations should not be altered by human caused factors.

Natural processes that cause ecological variation should be maintained.

SPATIAL STRUCTURE

Habitat patches should not be destroyed faster than they are naturally created.
Human activities should not increase or decrease natural rates of straying among salmon sub-populations.
Habitat patches should be close enough to allow the appropriate exchange of spawners and the expansion of population into underused patches.

Some habitat patches may operate as highly productive sources for population production and should be maintained.

Due to the time lag between the appearance of empty habitat and its colonization by fish, some habitat patches should be maintained that appear to be suitable, or marginally suitable, even if they currently contain no fish.

Figure 3-1. Viable salmonid population (VSP) parameters and their attributes. The quality and diversity of habitat (habitat capacity and diversity) available to the species in each of its three main habitat types (freshwater, estuarine and marine environments) are critical factors to VSP.

ESU Viability

Good *et al.* (2007) reported that viability of Pacific salmon ESUs depends on the status and distribution of populations within the entire ESU. In general, the ESU is more likely to be viable if it contains multiple populations (metapopulations), some of which meet viability criteria. Viability of the ESU is also more likely if: (1) populations are geographically widespread but some are close enough together to facilitate connectivity; (2) populations do not all share common catastrophic risks; and (3) populations display diverse life-histories and phenotypes (McElhany *et al.* 2000).

Considerations regarding ESU viability are discussed in ISAB (2005), and are generally adopted herein for application to the two Chinook salmon ESUs and the steelhead DPS in the Central Valley Domain. To be viable, an ESU needs more than simple persistence over time; it needs to be in an ecologically and evolutionarily functional state. Evaluation of ESU viability depends not only on the numbers of component populations and the abundance and productivity of those individual populations, but also on the integration of population dynamics within the ecosystem as a whole. For an ESU to fulfill the entire complement of ecological and evolutionary interactions and functions (ISAB 2005), it needs to contain viable populations inhabiting a variety of different habitats, interconnected as a metapopulation.

A viable ESU consists of a group of populations existing as a metapopulation that is self-sustaining for the foreseeable future. Populations within a viable ESU need to exhibit the abundance, productivity, diversity, and spatial distribution of natural spawners, sufficient to accomplish the following: avoid the loss of genetic and/or life history diversity during short-term reductions in abundance that are expected parts of environmental cycles; fulfill key ecological functions that are attributable to the species, such as nutrient cycling and food web roles; and provide for long-term evolutionary adaptability to changing environmental conditions.

This Recovery Plan endeavors to avoid loss of currently small, peripheral, or in any way seemingly less-valuable populations. The importance of these populations is not well understood, but it is likely they contribute significantly to ESU and DPS scale viability by providing increased life history diversity. They also are likely to buffer against local catastrophic occurrences.

In addition to the considerations presented by ISAB (2005), the Central Valley TRT addressed ESU viability for the Central Valley Domain, using two other approaches. The goal of these two approaches is to distribute risk and maximize future potential for adaptation.

In the first approach, the Central Valley TRT assessed ESU viability by examining the number and distribution of viable populations across the landscape, and their proximity to sources of catastrophic disturbance. Risk-spreading examines how viable populations are distributed among geographically-defined regions within an ESU. For example, the Puget Sound, Willamette/Lower Columbia and Interior Columbia TRTs have used the idea of dividing ESUs into subunits (Myers *et al.* 2003; Ruckelshaus *et al.* 2002; Interior Columbia Basin Technical Recovery Team 2003), and of requiring population presence and redundancy in the subunits (The Central Valley TRT referred to this approach as the “representation and redundancy” rule). ESU subunits are intended to capture geographically important components of habitat, life history, or genetic diversity that contribute to the viability of salmonid ESUs (Hilborn *et al.* 2003; Bottom *et al.* 2005).

In practice, this approach holds that if extinction risks are not strongly correlated, two populations, each with low risk of extinction, would be extremely unlikely to go extinct simultaneously (McElhany *et al.* 2003). Should a catastrophic event cause one of the populations to go extinct, the other(s) could serve as a source of colonists to re-establish the extirpated population.

In the second approach, the TRT attempted to account explicitly for the spatial structure of the ESU and the spatial structure of various catastrophic risks, including volcanoes, wildfires, and droughts. The product of this approach is a set of diversity groups. A diversity group is a geographically-distinct portion of the ESU/DPS which is ecologically or otherwise identifiable and which is essential to the recovery of the entire listed entity (e.g., to conserve genetic robustness, demographic robustness, and important life history stages).

To meet the objective of representation and redundancy, diversity groups need to contain multiple populations to survive in a dynamic ecosystem subject to unpredictable stochastic events, such as pyroclastic events or wild fires.

As discussed in Lindley *et al.* (2004), the Central Valley Basin is characterized by a wide range of climatological, hydrological, and geological conditions. The Central Valley TRT used the Jepson floristic ecoregions defined by Hickman (1993) as a starting point for salmon ecoregions, but modified them to account for geologic characteristics that produce spring-dominated base flow. Such conditions strongly influence salmonid habitat, but not upland plants. The resulting ecoregions for salmon and steelhead consider geology and are referred to herein as "Diversity Groups".

Delineation of Recovery Units

The four diversity groups listed below serve as recovery units, in that each one that was historically occupied by a species is essential for the recovery of that species. The diversity group structure is presented in **Figure 3-2** for the Chinook salmon ESUs and in **Figure 3-3** for the steelhead DPS in the Central Valley Domain.

The Central Valley Domain Diversity Groups are:

The **basalt and porous lava diversity group** composed of the upper Sacramento River (including watersheds upstream of Shasta Dam), Cow Creek and Battle Creek watersheds

The **northwestern California diversity group** composed of streams that enter the mainstem Sacramento River from the northwest, such as Clear Creek

The **northern Sierra Nevada diversity group** composed of streams tributary to the Sacramento River from the east, from Antelope Creek to the Mokelumne River, and

The **southern Sierra Nevada diversity group** composed of streams tributary to the San Joaquin River from the east.

The diversity groups reflect the historic distribution of each species. As a result, the number (and geographic range) of diversity groups differs by species. For winter-run Chinook salmon, all populations required for recovery are located in a single diversity group. This is the northernmost area called the "basalt and porous lava" diversity group. This recovery unit includes the streams that historically supported winter-run Chinook salmon, spring-run Chinook salmon, and steelhead. All of these streams receive large inflows of cold water from springs throughout the summer, upon which winter-run Chinook salmon depend. This region includes part of the upper Sacramento drainage (currently blocked by Shasta Dam), part of the Modoc Plateau region, and extends south to the Battle Creek watershed.

Three additional recovery units have been identified for spring-run Chinook salmon and steelhead. Though the southern part of the Cascades region (i.e., the drainages of Mill, Deer and Butte creeks) also contain some geology that results in spring-fed baseflows, these streams are included in the northern Sierra Nevada diversity group. The Sierra Nevada watersheds are divided into northern and southern diversity groups (split at the Mokelumne River watershed). This division reflects the greater importance of snowmelt runoff in the southern Sierra, and also places tributaries to the Sacramento and San Joaquin rivers in different diversity groups. The fourth diversity group includes tributaries that drain the watersheds on the west side of the northern Sacramento watershed and extends from Shasta Dam in the north to Willow Creek and Black Butte Reservoir in the south.

Lindley *et al.* (2006) report that historically steelhead populations were located in tributaries to Suisun Bay and to the San Joaquin River from the west (i.e., Central Western California diversity group). Recovery of Central Valley steelhead can be achieved without the presence of populations in either the Suisun Bay or Central Western California diversity groups. This conclusion is based on the fact that the four Chinook salmon diversity groups, which did not include the Suisun Bay or Central Western California regions, supported abundant and diverse Chinook salmon populations for thousands of years. As such, the extent and diversity of habitats historically available in those four diversity groups would likely also support a viable steelhead DPS, if the quantity and quality of habitat currently available in those regions was sufficiently increased. Additionally, based on the quantity and quality of available steelhead habitat, the Central Western California diversity group, which drains the relatively low elevation watersheds along the west side of the San Joaquin River, likely contributed little to the abundance of Central Valley steelhead. The Sacramento River basin was the source of most steelhead production (Lindley *et al.* 2006).

Because recovery can be reached without them, the Suisun area and the Central Western California diversity groups are not considered to be steelhead recovery units in this plan.

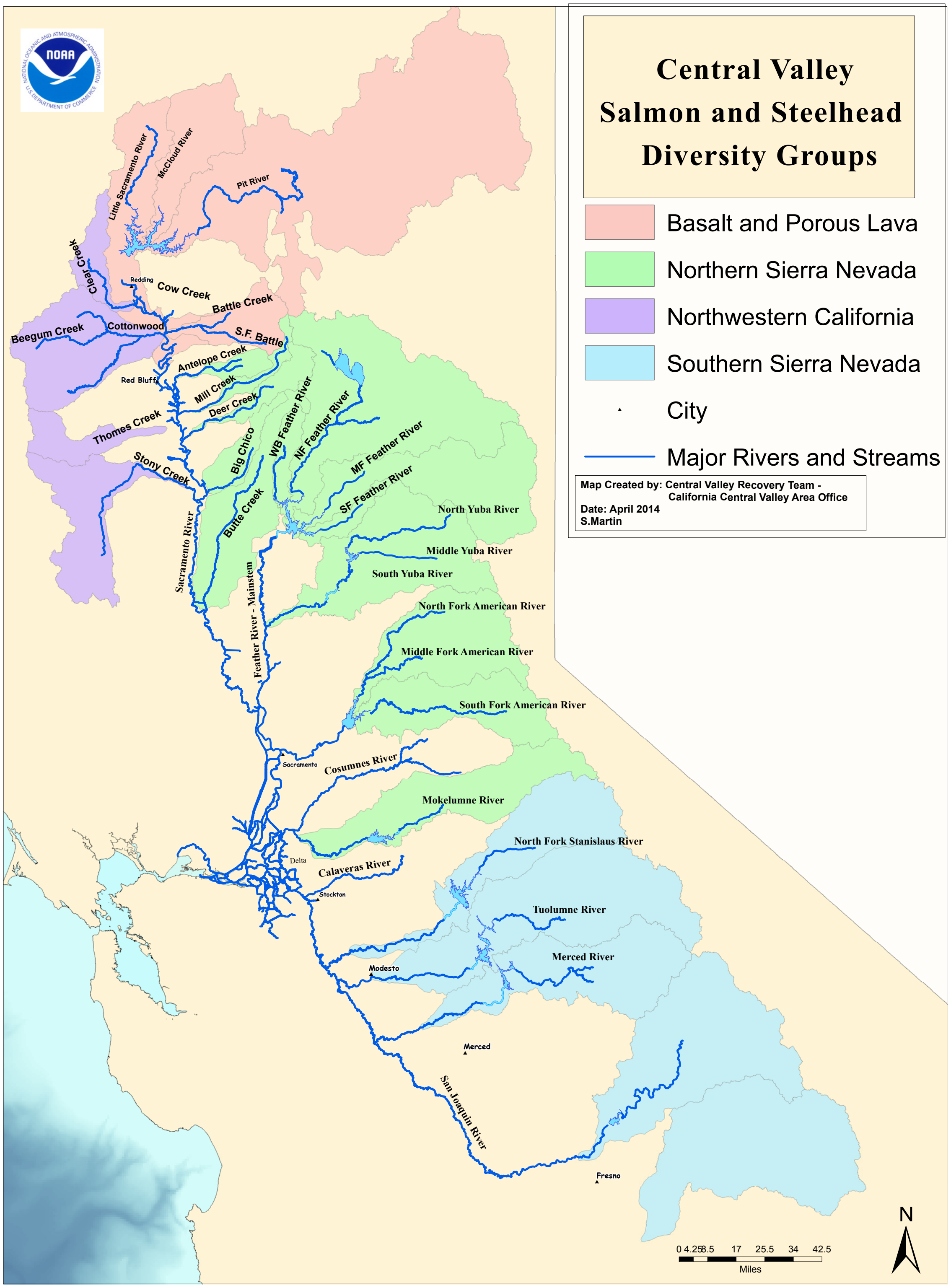


Figure 3-2. Diversity Groups for the Sacramento River Winter-run Chinook salmon and Central Valley Spring-run Chinook salmon ESUs in the Central Valley Domain. The Sacramento River Winter-run Chinook Salmon ESU Historically Occurred in the Basalt and Porous Lava Diversity Group, while Spring-run Chinook Salmon Occurred in all of the Diversity Groups Shown.

Figure 3-3. Diversity Groups for the California Central Valley Steelhead DPS in the Central Valley Domain.

3.2.2. Recovery Implementation Principles

The Strategy is based on five foundational implementation principles. The principles take into account the magnitude of the actions required by the strategy and the significant investment of resources required. Success is dependent on actions throughout the range of the species, in freshwater, estuarine, and ocean habitats and will require public understanding and support. Key elements in sustaining public support are investing in the most cost-effective practices, and continually assessing and reporting recovery plan progress and effectiveness. The five principles are described briefly below.

System wide Approach

Because the listed species are wide-ranging, and depend on headwater, riverine, estuarine, and ocean habitats, recovery implementation should address this entire set of ecosystems.

Cost Effectiveness

To focus investments on those actions with the highest likelihood of success, implementation of the strategy should give priority to measures with a proven record of success within the ESUs and DPS, or in ecologically comparable environments. Prior to initiating actions, similar actions previously implemented in the ESUs or DPS should be reviewed for lessons learned. It will also be beneficial to review the success of actions undertaken in other locations.

Self-Sustaining Improvements

Due to the uncertainty of future budgets, priority will be given to measures that, once implemented, are self-sustaining. In cases in which necessary actions will need maintenance (e.g., reintroductions into habitat upstream of impassible dams), priority will be given to options that need the least intervention in the long term.

Stakeholder Cooperation and Public Support

Partnerships and collaboration between all stakeholders and regulatory agencies are necessary to accelerate actions, increase available resources, reduce duplication of effort, encourage innovative solutions, improve communication, and increase public involvement and support through shared authority and ownership of habitat restoration (USFWS 2001). The Department of the Interior AFRP and the ERP contain processes for building partnerships to pursue restoration actions. The AFRP and the ERP continue to build partnerships and provide funds to local agencies and watershed groups, as well as other Federal and State agencies, in order to implement specific restoration actions throughout the Central Valley Domain. NMFS is engaged in both of these efforts, as well as with local agency and stakeholder efforts.

NMFS recognizes the high cost, broad geographic scope, and the economic, social, and cultural implications of necessary actions. NMFS therefore encourages local agencies and stakeholder groups to share or lead implementation of recovery and habitat restoration actions within the Central Valley Domain, and views such involvement as essential to success of the Recovery Plan.

In addition to participation by local, state and other Federal agencies, public support is necessary for the acceptance and successful implementation of the Recovery Plan for the Central Valley Domain. As stated by USFWS (2001), public sentiment is an indicator of perceived economic and social effects of restoration actions, and public support for an action will facilitate implementation and attract partners for future actions. NMFS will continue to coordinate with public stakeholders to assist in identifying, planning, and implementing recovery actions.

Adaptive Management and Monitoring

The plan will incorporate adaptive management into all components and actions. The reduced distribution and abundance of the listed species necessitates immediate action, but some key data gaps exist. Incorporating effective monitoring into plan actions will assist in addressing data needs and in modifying recovery actions where necessary. Effective monitoring, evaluation, and reporting will also provide for accountability.

Recovery Plan implementation includes an adaptive management and monitoring component to increase the effectiveness of, and to address the scientific uncertainty associated with specific restoration actions. The adaptive management component allows NMFS, as well as local water agencies and irrigation districts, municipal and county governmental agencies, watershed groups, and state and other Federal agencies, to learn from past experiences and to alter actions based on their measured effectiveness. There will be a thorough review of the effectiveness of the recovery actions implemented, as reflected by population and habitat condition responses, at the 5-year status reviews of the Chinook salmon ESUs and the steelhead DPS.

Within the framework of the Recovery Plan, NMFS has the flexibility to work with partners. This includes support in developing and implementing recovery actions that address specific problems as they arise or intensify. As additional information becomes available regarding threats abatement, the links between threats and population responses, and the viability of Chinook salmon and steelhead in the Central Valley Domain, specific measures as well as the plan itself will be modified. The adaptive management and monitoring component provides a framework to obtain the appropriate types and amounts of data to evaluate the effectiveness of recovery actions and the progress toward recovery. Therefore, the adaptive management and monitoring program needs to address system-wide, watershed, population, and action-specific scales. The program is outlined in greater detail in at the end of this chapter in section 3.4.

3.2.3 Watershed Classifications (Core 1, 2, or 3)

A key element of this recovery strategy is focus of actions on watersheds that can support viable populations and contribute to meeting Diversity Group requirements for distribution and redundancy. To assess their potential to contribute to species recovery, watersheds in the four Diversity Groups that supported historic populations of any of the three listed species have been placed into three categories, based on their potential to support populations with low risk of extinction. The three categories are Core 1, Core 2, and Core 3. Watersheds that supported the three species, historic and current distribution, and watershed classifications are presented in Tables 3-1, 3-2 and 3-3.

Core 1 watersheds possess the known ability or potential to support a viable population. For a population to be considered viable, it must meet the criteria for low extinction risk for Central Valley salmonids (Lindley *et al.* 2007). The criteria include population size, population decline, catastrophic decline and hatchery influence (see Table 4-1). Only a few of the Core 1 populations meet the long-term objective of low extinction risk; the remaining Core 1 populations have the potential to do so.

Core 2 populations meet, or have the potential to meet, the biological recovery standard for moderate risk of extinction set out in Table 4-1. These watersheds have lower potential to support viable populations, due to lower abundance, or amount and quality of habitat. These populations provide increased life history diversity to the ESU/DPS and are likely to provide a buffering effect against local catastrophic occurrences that could affect other nearby populations, especially in geographic areas where the number of Core 1 populations is lowest.

Core 3 watersheds have populations that are present on an intermittent basis and require straying from other nearby populations for their existence. These populations likely do not have the potential to meet the abundance criteria for moderate risk of extinction. Core 3 watersheds are important because, like Core 2 watersheds, they support populations that provide increased life history diversity to the ESU/DPS and are likely to buffer against local catastrophic occurrences that could affect other nearby populations. Dispersal connectivity between populations and genetic diversity may be enhanced by working to recover smaller Core 3 populations that serve as stepping stones for dispersal.

Table 3-1. Population presence, risk of extinction and classification of watersheds with historic populations of winter-run Chinook salmon. Currently there is one population in the mainstem Sacramento River downstream of Keswick Dam. "Primary": top priority for reintroduction; "Candidate": possible area for reintroduction; "Non-candidate": reintroduction should not be attempted here. "NA": not applicable.

Diversity Group	River, Creek or sub-reach	Historic Population	Current Population	Population Extinction Risk (from Williams *et al*. 2011)	Classification
Basalt and Porous Lava	Battle Creek	Yes	No	NA	Primary
	Mainstem Sacramento River (below Keswick)	No	Yes	moderate	Core 1
	McCloud River	Yes	No	NA	Primary
	Pit River	Yes	No	NA	Non-Candidate
	Little Sacramento River	Yes	No	NA	Candidate

Table 3-2: Population presence, risk of extinction, and classification of watersheds with historic and current populations of spring-run Chinook salmon. "Primary": top priority for reintroduction; "Candidate": possible area for reintroduction; "Non-candidate": reintroduction should not be attempted here. "NA": not applicable

Diversity Group	River, Creek or Sub-reach	Historic Population	Current Population	Population Extinction Risk (from Williams *et al.* 2011)	Classification
Basalt and Porous Lava	Battle Creek	Yes	Yes	Moderate	Core 1
	Mainstem Sacramento River (blw Keswick)	No	Yes	High	Core 2
	Little Sacramento River	Yes	No	NA	Candidate
	McCloud River	Yes	No	NA	Primary
	Pit River	Yes	No	NA	Non-Candidate
Northwestern California	Stony Creek	Yes	No	NA	Core 3
	Thomes Creek	Yes	Yes	NA	Core 3
	Cottonwood/Beegum	Yes	Yes	High	Core 2
	Clear Creek	Yes	Yes	Moderate	Core 1
Northern Sierra Nevada	Mokelumne (below Comanche)	No	No	NA	Candidate
	Mokelumne (above Pardee)	Yes	No	NA	Candidate
	American River (above Folsom)	Yes	No	NA	Candidate
	American River (below Nimbus)	Yes	No	NA	Non-Candidate
	Feather River (below Oroville)	No	Yes	High	Core 2
	West Branch Feather (above Oroville)	Yes	No	NA	Non-Candidate
	North Fork Feather (above Oroville)	Yes	No	NA	Candidate
	Middle Fork Feather (above Oroville)	Yes	No	NA	Non-Candidate
	South Fork Feather (above Oroville)	Yes	No	NA	Non-Candidate
	Yuba River (below Englebright)	No	Yes	High	Core 2
	North Yuba River (above Englebright)	Yes	No	NA	Primary
	Middle Yuba River (above Englebright)	Yes	No	NA	Primary
	South Yuba River (above Englebright)	Yes	No	NA	Candidate
	Butte Creek	Yes	Yes	Low	Core 1
	Big Chico	Yes	Yes	High	Core 2
	Deer Creek	Yes	Yes	High	Core 1
	Mill Creek	Yes	Yes	High	Core 1
	Antelope Creek	Yes	Yes	High	Core 2
Southern Sierra Nevada	Stanislaus River (below Goodwin)	No	No	NA	Candidate
	Upper Stanislaus River (abv New Melones)	Yes	No	NA	Candidate
	Tuolumne River (below La Grange)	No	No	NA	Candidate
	Upper Tuolumne River (abv La Grange and Don Pedro)	Yes	No	NA	Candidate
	Merced River (below Crocker Huffman)	No	No	NA	Candidate
	Upper Merced River (abv New Exchequer)	Yes	No	NA	Candidate
	San Joaquin River (below Friant)	No	No	NA	Primary
	San Joaquin above Friant	Yes	No	NA	Candidate

Table 3-3. Population presence, risk of extinction, and classification of watersheds with historic and current populations of steelhead. "Primary": top priority for reintroduction; "Candidate": possible area for reintroduction; "Non-candidate": reintroduction should not be attempted here. "NA": not applicable

Diversity Group	River, Creek or Sub-reach	Historic Population	Current Population	Population Extinction Risk (from Williams *et al*. 2011, Lindley *et al*. 2007)	Classification
Basalt and Porous Lava	Battle Creek	Yes	Yes	High	Core 1
	Cow Creek	Yes	Yes	Uncertain	Core 2
	Mainstem Sacramento River (below Keswick)	No	Yes	Uncertain	Core 2
	Little Sacramento River	Yes	No	NA	Candidate
	McCloud River	Yes	No	NA	Primary
	Pit River	Yes	No	NA	Non-Candidate
	Redding Area Tributaries	Yes	Yes	Uncertain	Core 2
Northwestern California	Putah Creek	Yes	Yes	Uncertain	Core 2
	Stony Creek	Yes	Yes	Uncertain	Core 3
	Thomes Creek	Yes	Yes	Uncertain	Core 2
	Cottonwood/Beegum	Yes	Yes	Uncertain	Core 2
	Clear Creek	Yes	Yes	Uncertain	Core 1
Northern Sierra Nevada	Cosumnes River	Yes	Yes	Uncertain	Core 3
	Mokelumne River (below Comanche)	No	Yes	High	Core 2
	Mokelumne River (above Pardee)	Yes	No	NA	Candidate
	American River (below Nimbus)	No	Yes	High	Core 2
	Upper American (above Folsom)	Yes	No	NA	Candidate
	Auburn Ravine	No	Yes	Uncertain	Core 2
	Dry Creek	Yes	Yes	Uncertain	Core 3
	Feather River (below Oroville)	No	Yes	High	Core 2
	West Branch Feather (above Oroville)	Yes	No	NA	Non-Candidate
	North Fork Feather (above Oroville)	Yes	No	NA	Candidate
	Middle Fork Feather (above Oroville)	Yes	No	NA	Non-Candidate
	South Fork Feather (above Oroville)	Yes	No	NA	Non-Candidate
	Bear River	Yes	Yes	Uncertain	Core 3
	Yuba River (below Englebright)	No	Yes	Uncertain	Core 2
	North, Middle, South Yuba Rivers (above Englebright)	Yes	No	NA	Primary
	Butte Creek	Yes	Yes	Uncertain	Core 2
	Big Chico	Yes	Yes	Uncertain	Core 2
	Deer Creek	Yes	Yes	Uncertain	Core 1
	Mill Creek	Yes	Yes	Uncertain	Core 1
	Antelope Creek	Yes	Yes	Uncertain	Core 1
Southern Sierra Nevada	Calaveras River (below New Hogan)	No	Yes	Uncertain	Core 1
	Upper Calaveras River (above New Hogan)	Yes	No	NA	Non-Candidate
	Stanislaus River (below Goodwin)	No	Yes	Uncertain	Core 2
	Upper Stanislaus River (above New Melones)	Yes	No	NA	Candidate
	Tuolumne River (below La Grange)	No	Yes	Uncertain	Core 2
	Upper Tuolumne River (abv La Grange and Don Pedro)	Yes	No	NA	Candidate
	Merced River (below Crocker Huffman)	No	Yes	Uncertain	Core 2
	Upper Merced River (above New Exchequer)	Yes	No	NA	Candidate
	San Joaquin River (below Friant)	No	No	NA	Candidate
	Upper San Joaquin (above Friant)	Yes	No	NA	Non-Candidate

Factoring Climate Change into Watershed Classifications

Areas targeted for emphasis in the strategy were selected based on current population distribution and abundance, existing habitat, and the impacts of existing stressors. Obviously, conditions are not static. The best available projections indicate that the climate is likely to warm considerably in the future. Lindley *et al.* (2007) reported on three greenhouse gas emission scenarios. The scenario with lowest emissions projected a mean summer air temperature increase of at least 2°C (3.6°F) in the geographical area under consideration, the intermediate scenario predicts an increase of around 5°C (9°F), and the highest emissions scenario, which is the least-likely, but still possible, projects an increase of 8°C (14.4°F) by the year 2100. Because spring-run Chinook salmon and steelhead both exhibit juvenile over-summer rearing as part of their life history strategies, long-term climate change considerations are discouraging for both species, unless coldwater refugia at local and larger scales exist or can be provided (see Section 6.6.2).

To generalize, populations in low elevation habitats are more likely to be negatively affected by temperature increases. Vulnerability to adverse climate change effects is assumed to be buffered somewhat in higher elevations (less change in snowmelt and water temperature) and in geology that results in springs and groundwater. Specifically, hydrologic changes are likely to be buffered somewhat in the Basalt and Porous Lava and Southern Sierra Nevada Diversity Groups due to groundwater dominance and elevations high enough to retain snow, respectively. One additional factor is habitat located below reservoirs; the assumption is that releases of cold water could be made in support of listed species, and serve as a buffer.

By screening Core 1 and "primary" watersheds for these characteristics, a very rough assessment of vulnerability of habitats to climate change was done to help identify watershed priorities. Watersheds at the lower elevations, which do not have coldwater springs or other sources of coldwater (e.g., Thomes Creek, Big Chico Creek), were among the lower priority watersheds. By contrast, watersheds where salmon have access to coldwater via high elevation, springs, or releases from storage reservoirs were considered higher priority.

3.3 Primary Objectives of the Recovery Effort

Based on recommendations from the Central Valley TRT, this recovery effort has two primary objectives: (1) secure existing populations by addressing stressors; and (2) reintroduce populations into historically occupied or other suitable areas (Lindley *et al.* 2007). These objectives are considered equal in importance and both should be pursued simultaneously. Each objective is more fully described below.

3.3.1 Secure Existing Populations

All four historic winter-run Chinook salmon populations are extinct, with only one current population that is supplemented with hatchery production. Of the 18 or 19 populations of spring-run Chinook salmon, three remain. One (Butte Creek) has low risk of extinction; the other two (Deer Creek and Mill Creek) are at high risk of extinction. Of perhaps 81 historic steelhead populations, fewer than two dozen remain. These numbers reflect the perilous condition of these species, and underline the importance of the few remaining populations to the long term recovery of the species. From this current, limited pool must come the individuals and genetic composition to support broader future population distribution. Loss of any of these populations would further jeopardize chances for recovery.

The strategy is consistent with the TRT recommendation that every extant population be viewed as necessary for the recovery of the ESUs and DPS. Wherever possible, the status of extant populations should be improved. Further information on population status and watershed condition can be found in Appendix A- Watershed Profiles.

Protection and enhancement of habitat for existing Core 1 and Core 2 populations are both vitally important. The strategy emphasizes protections and improvements in watersheds that support these populations, as well as actions necessary to eliminate or reduce threats present in the rivers and bay delta that connect them with the ocean.

Actions that protect and improve populations in Core 1 and Core 2 watersheds are the highest priority for investment of limited resources. This does not mean actions should not be taken in watersheds that support Core 3 populations, and, in fact, local groups are encouraged to undertake appropriate actions. It simply means that agencies should not substitute action in Core 3 watersheds for efforts in the Core 1 and Core 2 watersheds.

Address Threats

The primary means of securing existing populations is to reduce or eliminate the threats to the species and their habitats. Therefore, it was necessary to first identify the threats to each of the three species covered in this recovery plan; this was accomplished with the threats assessment described in Appendix B. Next, specific actions that address each prioritized threat must be identified. Those threat abatement actions (i.e., recovery actions), and the steps taken to identify and prioritize them, are described in Chapter 5.

3.3.2 Reintroduce Populations in Historically Occupied or Suitable Habitat

Meeting objectives for redundancy and distribution will require reintroducing some populations to habitats that historically supported the species, but are currently inaccessible because of existing dams (e.g. McCloud River). Also necessary are reintroduction of fish into watersheds that are currently accessible, but not utilized (e.g., winter-run Chinook salmon in Battle Creek).

Efforts to reintroduce fish will be challenging and expensive, and will require tremendous effort. To focus efforts, the strategy sets priorities for redundancy and spatial distribution within the four diversity groups. Priorities, based on existing information for the three listed species, are shown in **Tables 3-4, 3-5, and 3-6**. The highest-priority watersheds (primary watersheds) for re-introduction have been identified based on the current understanding of habitat conditions and the fact that reintroduction planning efforts are already underway in those watersheds. Watersheds with less potential, or where potential has not been assessed are classified as “candidates.”

This classification is based on current information. As the availability of habitat in these areas is further assessed, and measures necessary to facilitate the re-introductions evaluated and compared, priorities may change.

Populations will need to be re-established in some areas now blocked by dams or that have insufficient flows. Assuming that most of these dams will remain in place for the foreseeable future, it will be necessary to provide fish passage around the dams in both directions. Near-term priority actions will include assessing habitat suitability and passage logistics. In the long-term reintroductions to high elevation habitats will need to be successful in at least a few watersheds, particularly as air temperatures increase and precipitation patterns change (see Chapter 6). Moving forward, information is needed to confirm that conditions are suitable for reintroduction in the priority watersheds, to determine which candidate watersheds have the highest likelihood of successful reintroduction, and to determine what measures are necessary to facilitate reintroductions.

A complete picture of the watershed priorities for each species are displayed in **Figures 3-4, 3-5, and 3-6**. These maps also provide a picture of what the distribution of a recovered ESUs/DPS would look like.

Table 3-4. Priorities for Winter-Run Chinook Salmon by Diversity Group.

Diversity Group	Current Core 1 Population	Diversity Group Objective*	Re-introduction Priorities	Current Core 2 Populations
Basalt and Porous Lava	Sacramento River	3	McCloud River (Primary)	None
			Battle Creek (Primary)	
*number of populations with low risk of extinction				

Table 3-5. Priorities for Spring-Run Chinook Salmon by Diversity Group.

Diversity Group	Current Core 1 Populations	Diversity Group Objective*	Re-introduction Priorities	Current Core 2 Populations
Basalt and Porous Lava	Battle Creek	2	McCloud River (Primary)	Sacramento River (below Keswick)
Northwestern California	Clear Creek	1	None	Cottonwood/Beegum
Northern Sierra Nevada	Mill Creek	4	Yuba River above Englebright (Primary)	Yuba River (below Englebright)
	Deer Creek			Antelope Creek
	Butte Creek			Feather River (below Oroville)
Southern Sierra Nevada	None	2	San Joaquin (below Friant) (Primary)	None Currently Identified
			One Candidate Watershed	
* number of populations with low risk of extinction				

Table 3-6. Priorities for Steelhead by Diversity Group.

Diversity Group	Current Core 1 Populations	Diversity Group Objective	Re-introduction Priorities	Current Core 2 Populations
Basalt and Porous Lava	Battle Creek	2	McCloud River (Primary)	Cow Creek
				Redding Area Tributaries
				Sacramento River (below Keswick)
Northwestern California	Clear Creek	1	None	Thomes Creek
				Putah Creek
				Cottonwood/Beegum
Northern Sierra Nevada	Antelope Creek	4	Yuba River above Englebright (Primary)	Yuba River (below Englebright Dam)
	Deer Creek			Butte Creek
				Feather River (below Oroville Dam)
	Mill Creek			Big Chico Creek
				Auburn Ravine
				American River
Southern Sierra Nevada	Calaveras River	2	One Candidate Watershed	Stanislaus River (below Goodwin)
				Merced River (below Crocker Huffman)
				Tuolumne River (below La Grange)

* number of populations with low risk of extinction

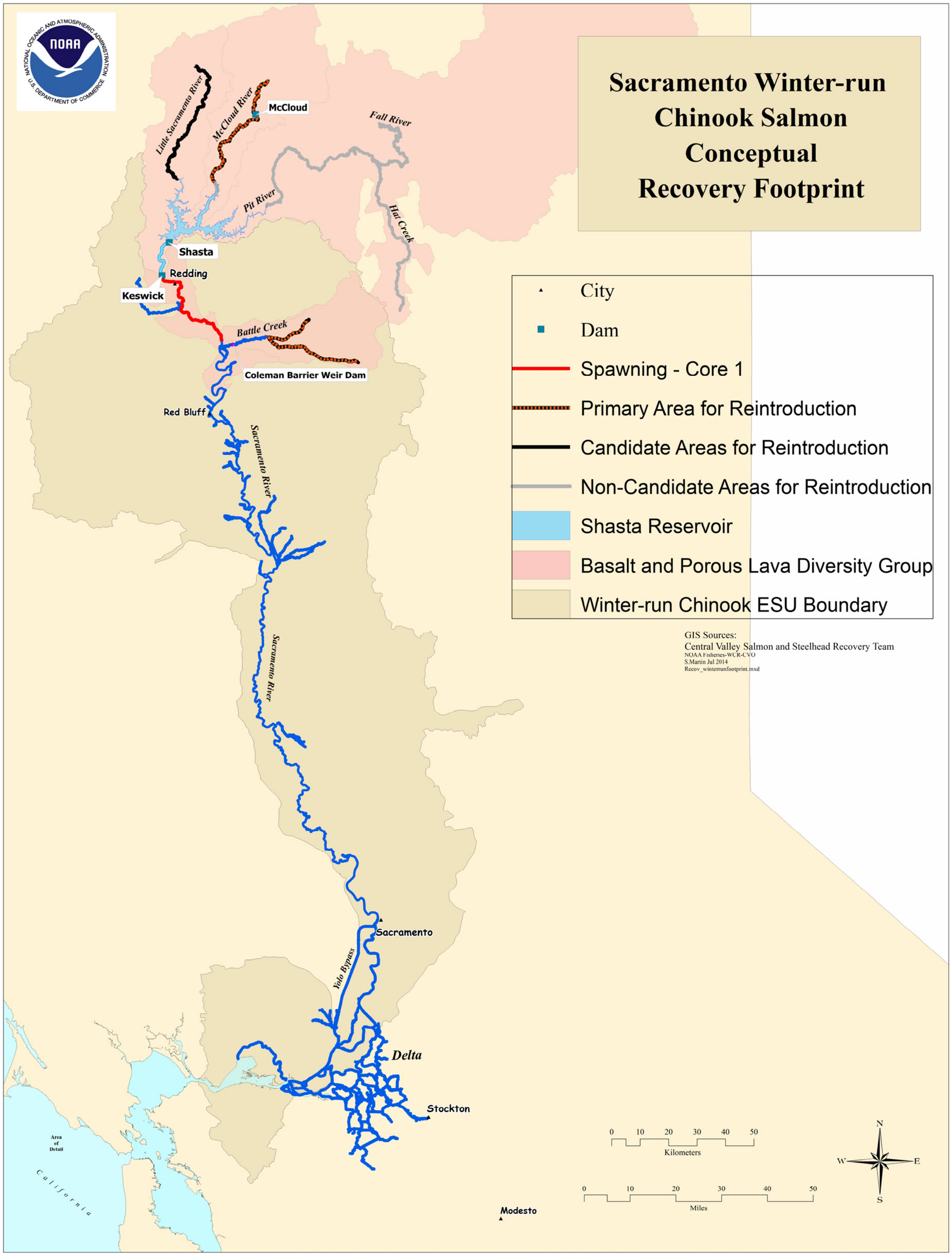


Figure 3-4. Sacramento River Winter-run Chinook Salmon Recovery Footprint. The primary and candidate areas for reintroduction depicted on this map are areas where, although dams block access, the primary constituent elements that are necessary to support freshwater migration, holding, spawning and rearing still exist or could be restored.

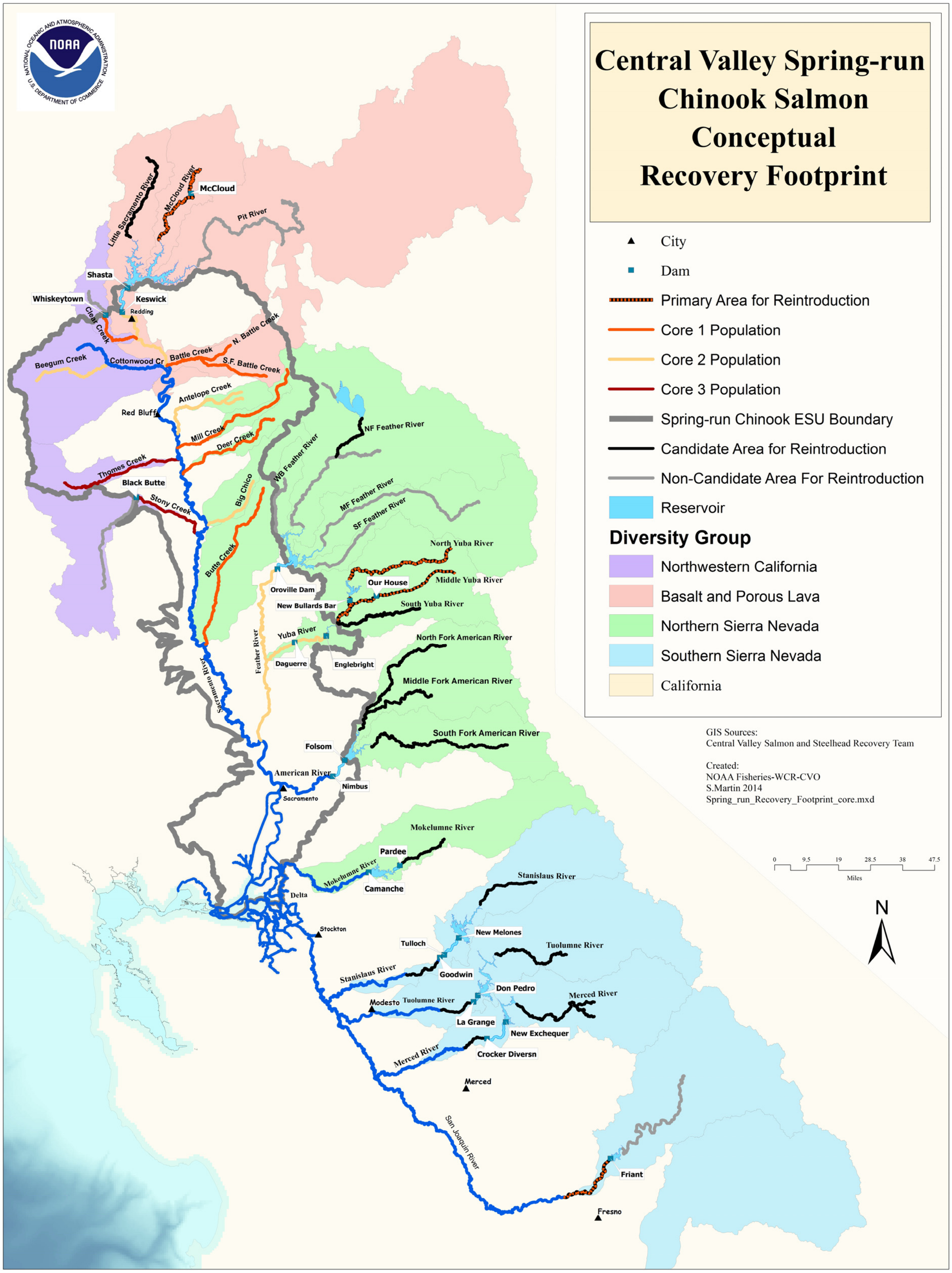


Figure 3-5. Central Valley Spring-run Chinook Salmon Recovery Footprint. The primary and candidate areas for reintroduction depicted on this map are areas where, although dams block access, the primary constituent elements that are necessary to support freshwater migration, holding, spawning and rearing still exist or could be restored.

Figure 3-6. California Central Valley Steelhead DPS Recovery Footprint. The primary and candidate areas for reintroduction depicted on this map are areas where, although dams block access, the primary constituent elements that are necessary to support freshwater migration, holding, spawning and rearing still exist or could be restored.

Re-introduction of anadromous fishes to historic habitats will require a new approach to watershed management, especially in regard to the operation and licensing of hydroelectric projects. Many of the keystone passage impediments to upstream habitat are regulated by the Federal Energy Regulatory Commission (FERC). In many watersheds, FERC also regulates upstream hydroelectric projects and facilities, and in most cases the licenses issued by FERC expire on different schedules, making the necessary, coordinated ecosystem-wide approach to relicensing difficult. Numerous hydroelectric licenses will come up for renewal in the next 20 years. Re-introduction of fish to historic habitats will require concerted watershed-scale approaches by FERC and other involved parties to align license schedules, develop new stream flow regimes, and facilitate comprehensive fish passage plans. This approach is especially necessary in the McCloud, upper Yuba, upper American, and other watersheds where hydroelectric projects influence areas identified for re-introduction, and affect downstream habitats that are essential for recovery. Re-introduction will require improved resource agency coordination, including joint filings under FERC proceedings, aligning regulatory schedules and products, and sharing biological, technical, and policy expertise on high priority projects.

The Sacramento River winter-run Chinook salmon ESU currently has one population, and that population spawns outside the species historic spawning range. For that reason, introductions into historically occupied habitat are necessary to meet requirements for redundancy. Re-introduction in the McCloud Rivers has the highest probability of success. Priority for the third population in the Diversity Group is introduction of the species in Battle Creek, which has suitable habitat for the species.

As with winter-run Chinook salmon, spring-run Chinook salmon will require re-introductions into historically occupied or currently suitable habitat in the Basalt and Porous Lava, Northern Sierra Nevada, and Southern Sierra Nevada Diversity Groups, in order to meet requirements for distribution and redundancy. Primary areas for spring-run Chinook salmon re-introduction into historic habitat include upstream of Shasta Dam in the Basalt diversity group and the Yuba River above Englebright Dam in the Northern Sierra Nevada. In the Southern Sierra Nevada, the strategy calls for reintroduction of spring-run Chinook salmon in the San Joaquin River below Friant Dam, and in one additional watershed in the Southern Sierra Nevada (Table 3-5).

Reintroductions of steelhead to historically occupied or currently suitable habitat will be necessary to meet objectives for distribution and redundancy in the Basalt and Porous Lava, Northern Sierra Nevada, and Southern Sierra Nevada Diversity Groups. Priorities for re-introduction are included in Table 3-6. These priorities include the McCloud River in the Basalt and Porous Lava Group and the Yuba River above Englebright in the Northern Sierra Nevada. Top priority areas for steelhead reintroductions in the Southern Sierra Nevada have yet to be established.

Reintroducing Chinook salmon and steelhead to historic habitats, particularly those habitats upstream of impassable barriers, will be extremely complicated and many questions will need to be answered as the projects progress. A few of the most important biological questions include:

- which donor populations should be used?;

- how will donor fish be collected, how many will be needed, and what life stages should be used?;
- how and where will juveniles produced upstream of a barrier be collected, and how will they be transported downstream of the barrier?; and
- where and when will adults and juveniles be released?

In addition to those questions, which apply to all three species, re-introducing steelhead upstream of impassable barriers comes with unique complications and associated questions. First, because steelhead are iteroparous (i.e., they spawn multiple times in their lifetime), the question of what to do with the adult steelhead that spawn upstream of the barrier arises. Assuming those adults should be allowed to carry out their natural life history strategy by returning to the ocean after spawning, an effective collection method will need to be implemented.

Another important issue related to steelhead re-introductions deals with the occurrence of resident *O.mykiss* upstream of the barriers, which, in some Central Valley locations, contain genetic material representative of ancestral *O.mykiss* (Garza and Pearse 2008). This adds additional considerations to the donor stock selection question raised above – should the ancestral stock be used or a below barrier stock? This question and others associated with integrating below and above barrier populations will need to be addressed.

Lastly, reintegrating *O.mykiss* below and above barriers does not guarantee an increase in steelhead abundance, at least in the short-term while the selection regime favors residency. There are more resident *O.mykiss* than anadromous *O.mykiss* in the Central Valley (McEwan 2001), indicating selection pressure in the favor of the resident form. If selection pressures on the anadromous and resident form were equal, then one would expect their relative abundances to be somewhat equal and likely biased to anadromous *O.mykiss* because anadromous fish attain a much larger size than resident fish, and thus are able to outcompete the resident fish for quality spawning habitat and are much more fecund, producing twice as many eggs per body weight (Moyle 2002). Hypotheses for why there are more resident than anadromous *O.mykiss* in the Central Valley include: (1) low survival of *O.mykiss* through the Delta; (2) cold water releases from dams providing thermally survivable habitat for *O.mykiss* to live in year-round; and (3) a combination of 1 and 2. Achieving a better understanding of the factors influencing the selection between anadromous and resident life history strategies is an important step for efforts to expand steelhead habitat upstream of impassable barriers.

In the face of all of the complications and questions related to anadromous salmonid reintroductions in the Central Valley, it is important to recognize that recovering winter-run Chinook salmon, spring-run Chinook salmon, and steelhead is highly unlikely without significant habitat expansion (Lindley *et al.* 2007; Cummins *et al.* 2008; Moyle *et al.* 2008).

Role of Hatcheries in Securing Existing Populations and Reintroducing Populations in Historically Occupied or Suitable Habitat

The principal strategy of salmonid conservation and recovery continues to be through the protection and restoration of the healthy ecosystems upon which they depend, in line with the ESA's stated purpose to conserve "the ecosystems upon which endangered and threatened species depend" (ESA section 2(b)). However, a natural recovery of local extinctions depends on one or more recolonization events, a process that operates on an indefinite timescale. Likewise, the viability of a depressed population, characterized by small size, fragmented structure, and impacted genetics (e.g., bottlenecks, inbreeding, outbreeding depression, etc.), may be so compromised that its response to restored or increased availability of habitat is not sufficient to prevent imminent extinction. Either case may demand management intervention to attain viable salmonid populations. Conservation hatcheries may provide an appropriate means for establishing new populations and for allowing existing populations to recover. Two relevant examples from the Central Valley are the development of a conservation hatchery to help re-establish spring-run Chinook salmon in the San Joaquin River and the ongoing operation of the winter-run Chinook salmon conservation program at the Livingston Stone National Fish Hatchery.

There is considerable uncertainty regarding the ability of artificial propagation to increase population viability over the long-term, and it cannot be assumed that artificial augmentation will reduce extinction risk. There is a risk to natural recovery from increasing dependency on hatchery production. Conservation hatcheries must therefore monitor the effects of their programs on the natural population using criteria which would trigger modification to or cessation of the conservation program.

3.4 ADAPTIVE MANAGEMENT AND MONITORING

Successful adaptive management relies on accurate data provided by effective long-term monitoring programs. Past and current CV salmonid monitoring programs have suffered from inconsistent and/or inadequate funding. For successful species recovery and effective use of limited resources, a funding mechanism for long term effective monitoring of CV salmonids should be a fundamental top priority in the recovery plan.

Implementation of the Recovery Strategy will involve actions throughout the ESUs and DPS, conducted by a variety of agencies and stakeholders, addressing a multitude of site specific and systematic issues. These efforts are complicated by uncertainties, which include the actual abundance and distribution of the listed species, interactions between the species and their habitat, and the design and effectiveness of recovery actions. An effective means of gathering and sharing information on the condition of the resources, and the lessons learned during implementation of actions, is essential to bring accountability and efficiency to the process, and to allow for informed revisions to the recovery approach.

Adaptive management and monitoring will provide a framework to obtain the appropriate types and amounts of data to evaluate the effectiveness of recovery actions and progress toward recovery. The plan, outlined below, includes an approach to coordination of the numerous monitoring and research tasks required for implementation of the strategy.

Track Performance

This effort will document that recovery actions are implemented, as well as determine if they were implemented as intended and designed.

Monitor effectiveness of implemented actions

The goal of this component of the plan is to determine if actions, once implemented, meet their objectives. Because priority for future restoration efforts will be given to actions shown to be effective, this information will lead to adjustments in priority for actions. At the site level, it will assist in project design, to take advantage of lessons learned.

Review progress in meeting recovery criteria

This information is needed to assess progress toward the goal of delisting, and includes three parts: viability in each Diversity Group (population distribution and abundance), habitat monitoring, and evaluation of threats.

Viability

Existing adult salmonid escapement monitoring programs in the Central Valley are currently inadequate to estimate population status and evaluate population trends in a statistically valid manner for the following management purposes: (1) providing a sound basis for assessing recovery of listed stocks; (2) monitoring the success of restoration programs; (3) evaluating the contribution of hatchery fish to Central Valley populations; and (4) managing sustainable ocean and inland harvest (Allen 2005).

Numerous programs are underway to collect information on anadromous fish species in the Central Valley. Although each of these programs and monitoring activities provides important information about the overall status of the specific resources and their habitats in the Central Valley and Bay/Delta, they are generally implemented on a project-by-project basis. Other streams and associated populations within the Chinook salmon ESUs and the steelhead DPS within the Central Valley Domain have no existing monitoring surveys or programs. Clearly, a more coordinated and comprehensive system-wide watershed and population monitoring system is needed.

As previously noted, there is great need for the development and implementation of a comprehensive monitoring plan for steelhead populations throughout the Central Valley Domain. The Central Valley Domain TRT was unable to assess the status of the California Central Valley steelhead DPS because nearly all of its approximately 80 historic populations are classified as data-deficient, with a few exceptions that are closely associated with a hatchery (Lindley *et al.* 2007).

In addition to population status and trend evaluation, accurate estimation of adult Chinook salmon and steelhead spawner escapement is necessary for harvest management. Age and run-specific escapement data in the Central Valley are necessary to utilize more accurate models associated with ocean harvest management.

Habitat

Watershed-level monitoring, including selected habitat variables, is necessary to evaluate the effectiveness of multiple restoration actions. Watershed-specific monitoring evaluations will contribute to the assessment of threat abatement and population responses. Additionally, the long-term effects of habitat restoration actions need to be assessed throughout the Central Valley Domain. Components that require monitoring include long-term changes in the characteristics of targeted recovery/restoration components such as aquatic habitat, riverine channel configuration, riparian vegetation, and floodplain structure and function.

Long-term habitat monitoring will also include parameters useful in tracking trends of climate change effects, such that necessary modifications to recovery objectives can be made.

Evaluation of Threats

Actions included in the strategy are intended to address threats to the listed species and their habitats. Monitoring implementation and effectiveness of actions will help track progress and provide information necessary to guide adaptive management. This data, along with monitoring of watershed and habitat conditions outlined above, will provide the information necessary to evaluate the degree to which threats have been eliminated or reduced as well as to identify any new threats.

Coordination research and monitoring targeted to address information gaps

Recovering the Chinook salmon ESUs and steelhead DPS will require numerous investigations and studies. The majority of these will address a specific question (e.g., gravel movement) at a particular site, while some are fairly broad questions (e.g., assess reintroduction potential above a group of impoundments). Also necessary are the system wide habitat and population monitoring programs outlined above. Coordination of these efforts is necessary so that questions are addressed in a priority sequence, and so that information and approaches are shared and efforts are not duplicated. A consistent framework for research and monitoring will directly inform recovery objectives and goals.

Reporting

There is a need to effectively share information with the public, stakeholders, and cooperators. To this end, NOAA is in the process of developing an internet-based recovery action tracking system. The reporting will support the annual reporting for the Government Performance and Results Act, Bi-Annual Recovery Reports to Congress, and the 5-Year Status Review.

4.0 Recovery Goals, Objectives and Criteria

"Merely increasing a species' numbers, range and abundance does not ensure its long-term health and sustainability; only by alleviating threats can lasting recovery be achieved."

- Interim Endangered and Threatened Species Recovery Planning Guidance (NMFS 2010b)

This chapter describes the goals of this Recovery Plan and includes a brief discussion of the biological basis for meeting those goals for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead. This chapter also explains the objectives and criteria to be used to determine when recovery of the listed species has been achieved. Two main types of criteria are presented. First, biological criteria pertaining to both ESU/DPS and population viability are described. Next, threat abatement criteria are covered to determine when the threats that led to listing of the species have been eliminated or adequately reduced.

4.1 Recovery Goals

The overarching goal of this Recovery Plan is the removal of the Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, and California Central Valley steelhead DPS from the Federal List of Endangered and Threatened Wildlife (50 CFR 17.11; 50 CFR 224.101; 50 CFR 223.102). Because recovery plans are not regulatory documents, successful implementation and recovery of listed species will require the support, efforts and resources of many entities, from Federal and State agencies to individual members of the public. Another goal will be to encourage and support effective partnerships with regional stakeholders to meet the objectives and criteria of the Recovery Plan. The objectives and criteria to accomplish the overarching goal of species delisting build upon the technical input and guidance provided by the Central Valley TRT, and other information provided during public workshops and co-manager reviews. Much of the technical recovery discussion in this section is taken directly from information developed by the TRT (Lindley *et al.* 2004; 2006; 2007).

The Endangered and Threatened Species Recovery Planning Guidance (NMFS 2010b) describes the recovery planning goal as recovery and long-term sustainability of an endangered or threatened species and, therefore, delisting of the species. Further, NMFS (2010b) states that goals usually can be subdivided into discrete component objectives which, collectively, describe the conditions (criteria) necessary for achieving the goal. Simply stated, recovery objectives are the parameters of the goal, and criteria are the values for those parameters. The objectives and related criteria, representing the components of the recovery goal, identify mechanisms for pursuing the goal (including necessary recovery actions) and allow confirmation when the goal has been reached.

According to NMFS (2010b), recovery and long-term sustainability of an endangered or threatened species require:

- Adequate reproduction for replacement of losses due to natural mortality factors (including disease and stochastic events)
- Sufficient genetic robustness to avoid inbreeding depression and allow adaptation
- Sufficient habitat (type, amount, and quality) for long-term population maintenance
- Elimination or control of threats (this may also include having adequate regulatory mechanisms in place).

4.2 Integrating TRT Products into Recovery Objectives and Criteria

The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria which, when met, would result in a determination in accordance with the provisions of the ESA that the species be removed from the Federal List of Endangered and Threatened Wildlife; the criteria described herein fulfill that role with regard to the aforementioned species.

Population or demographic parameters are considered through the biological recovery criteria, while the threats criteria consider threats under the five ESA listing factors in ESA section 4(a)(1) (threats criteria). Together, these make up the "objective, measurable criteria" required under section 4(f)(1)(B).

These recovery criteria were derived from the TRT products (Appendix C), and as such, they represent the best scientific analysis incorporating the most current understanding of the ESUs and DPS and their populations.

4.2.1 Biological Basis for Recovery Criteria

For delisting, the ESU/DPS should meet the criteria for populations and diversity groups listed below in Sections 4.3.2 and 4.3.4. Downlisting (endangered to threatened) criteria for winter-run Chinook salmon are provided in Section 4.3.4.1. These delisting and downlisting criteria are based on population- and ESU-level considerations as discussed below in Sections 4.2.1.1 and 4.2.1.2.

Population Level Considerations

This plan includes both population-level and Diversity Group recovery criteria. The population-level criteria are used to determine whether a population is viable or not. A viable population is one with a low extinction risk in the wild over the long-term (McElhany *et al*. 2000).

The Central Valley TRT incorporated the four VSP parameters into assessments of population viability, and two sets of population viability criteria were developed, expressed in terms of extinction risk (Table 4-1). The first set of criteria deal with direct estimates of extinction risk from population viability analysis (PVA) models. If data are available and such analyses exist and are deemed reasonable for individual populations, such PVA assessments may be efficient for assessing extinction risk. The Central Valley TRT assumed that, for PVA results, a 5 percent or less risk of extinction in 100 years is an acceptably low extinction risk for populations (Lindley *et al.* 2007).

The second set of criteria are simpler and do not require PVA modeling results. These simpler extinction risk criteria are the basis of the population-level recovery criteria used in this Recovery Plan, with the low extinction risk levels defining what constitutes a viable population. The simpler criteria from Table 4-1 include population size (and effective population size), population decline, catastrophic rate and effect, and hatchery influence. Estimators for the various viability criteria are presented in Table 4-2.

Population Size (Abundance)

The effective population size criteria (second row of Table 4-1) relate to loss of genetic diversity. Very small populations, for example with *Ne* < 50, suffer severe inbreeding depression (Franklin 1980; Soulé 1980 *in* Lindley *et al.* 2007), and normally outbred populations with such low *Ne* have a high risk of extinction from this inbreeding. Somewhat larger, but still small, populations can be expected to lose variation in quantitative traits through genetic drift faster than it can be replaced by mutation. With future research, it may be possible to better define population size targets that conserve genetic variation and account for migration and genetic structuring within ESUs/DPS.

Census size N can be used if direct estimates of effective population size are not available. Census size is estimated as the product of the mean run size and the average generation time. The average spawning run size is computed as the mean of up to the three most recent generations, if that much data are available.

The general criteria for population size discussed below may be adjusted as further information is developed. Healthy populations should be at or near carrying capacity in most years. As such, a detailed and thorough assessment of each watershed's carrying capacity should be conducted, and the recovery criterion for abundance should be based on that estimated carrying capacity.

As recovery actions are implemented and habitats are restored and expanded, the low extinction risk abundance criterion (i.e., census size>2,500) may be too low for large watersheds or for abundant populations. For example, Butte Creek has supported spring-run Chinook salmon populations with a census size well in excess of 2,500 since 1998, suggesting that the carrying capacity of that system may be greater than that criterion.

Carrying capacity assessments could be accomplished by applying a consistent approach to measure habitat capacity throughout each ESU/DPS and then relating that capacity to assumed spawner density thresholds that correspond to varying levels of extinction risk (Williams *et al.* 2008). Until such population-specific abundance recovery criteria are developed, the low and moderate extinction risk abundance criterion (Table 4-1) serve as benchmarks for the developing population delisting criteria.

Population Decline (Productivity)

This criterion is intended to capture demographic risks. The rationale behind the population decline criteria are fairly straight forward: severe and prolonged declines to small run sizes are strong evidence that a population is at risk of extinction. Population growth (or decline) rate is estimated from the slope of the natural logarithm of spawners versus time for the most recent 10 years of spawner count data.

Catastrophic Rate and Effect (Productivity)

The overall goal of the catastrophe criterion is to capture a sudden shift from a low risk state to a higher risk state. Catastrophes are defined as instantaneous declines in population size due to events that occur randomly in time, in contrast to regular environmental variation. A high risk catastrophic event is one that causes a 90 percent decline in population size over one generation. A moderate risk catastrophic event is one that is smaller but biologically significant, such as a year-class failure.

Hatchery Influence (Diversity)

The spawning of hatchery fish in the wild is a potentially serious threat to the viability of natural populations. Population genetics theory predicts that hatchery fish can negatively impact wild populations when they spawn in the wild. In assessing the genetic impact of immigration on a population, considerations include the source of the immigrants, duration of the impact, the number of immigrants relative to the size of the recipient population, and how genetically divergent the immigrants are from the recipient population. Definitions of the manner in which different immigration scenarios relate to extinction risk for natural populations are summarized in Figure 4-1. Application of these definitions can result in a low-risk classification even with moderate amounts of straying from best-practices hatcheries, as long as other risk measures are acceptable (Lindley *et al.* 2007). The fraction of naturally-spawning hatchery origin fish is the mean fraction over one to four generations.

Table 4-1. Criteria for assessing the Level of Risk of Extinction for Populations of Pacific Salmonids, Applied to the Chinook Salmon ESUs and the Steelhead DPS in the Central Valley Domain (from Lindley et al. 2007).

	Risk of Extinction		
Criterion	High	Moderate	Low
Extinction risk from PVA	$>$ 20% within 20 years – or any ONE of –	$>$ 5% within 100 years – or any ONE of –	$<$ 5% within 100 years – or ALL of –
Population size[a]	$N_e \leq 50$ –or– $N \leq 250$	$50 < N_e \leq 500$ –or– $250 < N \leq 2500$	$N_e > 500$ –or– $N > 2500$
Population decline	Precipitous decline[b]	Chronic decline or depression[c]	No decline apparent or probable
Catastrophe, rate and effect[d]	Order of magnitude decline within one generation	Smaller but significant decline[e]	not apparent
Hatchery influence[f]	High	Moderate	Low

[a] Census size N can be used if direct estimates of effective size N_e are not available, assuming $N_e/N = 0.2$.
[b] Decline within last two generations to annual run size $\leq$ 500 spawners, or run size $>$ 500 but declining at $\geq$ 10% per year. Historically small but stable population not included.
[c] Run size has declined to $\leq$ 500, but now stable.
[d] Catastrophes occuring within the last 10 years.
[e] Decline $<$ 90% but biologically significant.
[f] See Figure 1 for assessing hatchery impacts.

Table 4-2 Estimation Methods and Data Requirements for Population Metrics. S_t denotes the number of spawners in year t; g is mean generation time, assumed as three years for California salmon (from Lindley et al. 2007).

Metric	Estimator	Data	Criterion
$\hat{S}_t$	$\sum_{i=t-g+1}^{t} S_i/g$	$\geq$ 3 years spawning run estimates	Population decline
N_e	$N \times 0.2$ or other	varies	Population size
N	$\hat{S}_t \times g$	$\geq$ 3 years spawning run estimates	Population size
Population growth rate (% per year)	slope of $\log(S_t)$ v. time $\times 100$	10 years S_t	Population decline
c	$100 \times (1 - \min(N_{t+g}/N_t))$	time series of N	Catastrophe
h	average fraction of natural spawners of hatchery origin	mean of 1-4 generations	Hatchery influence

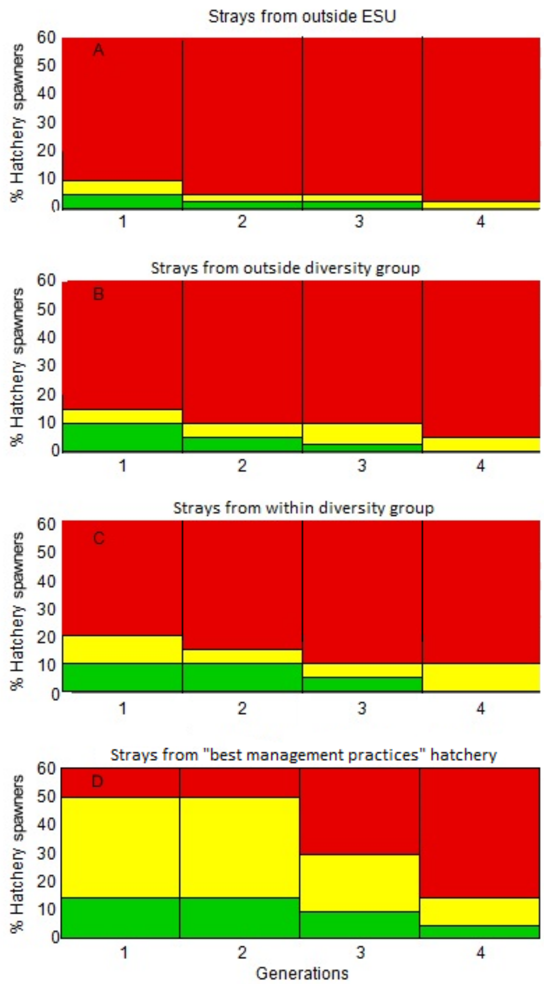


Figure 4-1. Extinction Risk Levels Corresponding to Different Amount, Duration and Source of Hatchery Strays.

Green bars indicate the range of low risk, yellow bars moderate risk, and red areas indicate high risk. Which chart to use depends on the relationship between the source and recipient populations. (A) hatchery strays are from a different ESU than the wild population. (B) Hatchery strays are from the same ESU but from a different diversity group within the ESU. (C) Hatchery strays are from the same ESU and diversity group, but the hatchery does not employ "best management practices." (D) Hatchery strays are from the same ESU and diversity group, and the hatchery employs "best management practices." (from Lindley *et al.* 2007)

Diversity Group and ESU/DPS Considerations

In order to delist the winter-run and spring-run Chinook salmon ESUs and the steelhead DPS, the TRT stated that there must be at least two viable populations in each diversity group (Lindley *et al.* 2007). This ESU/DPS-level recovery goal addresses the representation and redundancy rule for ESU/DPS viability.

The TRT recommendation of at least two viable populations is not applicable to the Northwestern California diversity group for spring-run Chinook salmon and steelhead, because this diversity group did not historically support viable populations. However due to management and restoration activities, the potential exists to support a viable population in Clear Creek.

As previously explained in Section 3.2.1, full steelhead recovery can be achieved without representation from either the Suisun Bay or Central Western California diversity groups.

4.3 Biological Objectives and Criteria at the Population, Diversity Group, and ESU/DPS Level

Implementation of the Recovery Plan is designed to ultimately achieve objectives for the ESUs/DPS at the Diversity Group level, and at the population level (i.e. watershed level) for the four VSP criteria of abundance, productivity, diversity, and spatial structure. Objectives addressing these requirements include demographic parameters, reduction or elimination of threats to the species (the listing factors), and any other particular vulnerability or biological needs inherent to the species.

4.3.1 Population Objectives

In general, viable populations should demonstrate a combination of population abundance, growth rate and genetic integrity that produces an acceptable probability of population persistence. Specifically, viable populations should meet the low extinction risk levels for the population decline and population size criteria described below in the following section.

4.3.2 Population Level Criteria

Consistent with the strategic approach to achieve recovery, this Recovery Plan establishes the following criteria for the viability of individual populations, similar to NMFS (2005b). The criteria are based on the VSP criteria for productivity and abundance, and diversity outlined in section 4.2.1

Low risk of extinction criteria

- Census population size is >2,500 adults -or- Effective population size is >500
- No productivity decline is apparent
- No catastrophic events occurring or apparent within the past 10 years
- Hatchery influence is low (see Figure 4-1).

Moderate risk of extinction criteria

- Census population size is 250 to 2,500 adults -or- Effective population size is 50 to 500 adults
- Productivity: Run size may have dropped below 500, but is stable
- No apparent decline in population growth rate resulting from catastrophic events within the past 10 years
- Hatchery influence is moderate

4.3.3 ESU/DPS Objectives

ESU/DPS viability depends on the number of populations within the ESU/DPS, their individual status, their spatial arrangement with respect to each other and sources of catastrophic disturbance, and the diversity of the populations and their habitats. In the most general terms, ESU/DPS viability increases with the number of populations (redundancy), the viability of these populations, spatial distribution of the populations, the diversity of the populations, and the diversity of habitats that they occupy.

For the ESUs and DPS to achieve recovery, each of the Diversity Groups should support both viable and dependent populations and meet goals for redundancy and distribution. Thus, an overall goal is to sustain populations in each of the Diversity Groups.

4.3.4 ESU/DPS Criteria

ESU Level Downlisting Criteria for Endangered Winter-run Chinook

Downlisting is the reclassification of a species from endangered to threatened. Two criteria have been identified with regard to downlisting of winter-run Chinook salmon from endangered to threatened:

- One population should meet each of the low extinction risk criteria described in section 4.3.2.; and
- In addition to the one viable population, the ESU should include one other spawning population that meets the moderate extinction risk criteria described in Table 4-1.

These winter-run Chinook salmon downlisting criteria were identified because, when achieved, the species' viability would be notably improved from its current status, but would still be far from recovered (i.e., delisted). Currently, there is one population of winter-run Chinook salmon. In order to achieve the downlisting criteria, the species would need to be composed of two populations – one viable and one at moderate extinction risk. Having a second population would improve the species' viability, particularly through increased spatial structure and abundance, but further improvement would be needed to reach the goal of recovery. As identified in the next section, to delist winter-run Chinook salmon, three viable populations are needed. Thus, the downlisting criteria represent an initial key step along the path to recovering winter-run Chinook salmon.

ESU/DPS Delisting Criteria

In order for the Chinook salmon ESUs and the steelhead DPS to achieve recovery, Diversity Groups should display the following characteristics:

For the Winter-run Chinook salmon ESU:

- Three populations in the Basalt and Porous Lava Diversity Group at low risk of extinction

For the Spring-run Chinook salmon ESU:

- One population in the Northwestern California Diversity Group at low risk of extinction
- Two populations in the Basalt and Porous Lava Diversity Group at low risk of extinction
- Four populations in the Northern Sierra Diversity Group at low risk of extinction
- Two populations in the Southern Sierra Diversity Group at low risk of extinction
- Maintain multiple populations at moderate risk of extinction

For the California Central Valley steelhead DPS:

- One population in the Northwestern California Diversity Group at low risk of extinction
- Two populations in the Basalt and Porous Lava Flow Diversity Group at low risk of extinction
- Four populations in the Northern Sierra Diversity Group at low risk of extinction
- Two populations in the Southern Sierra Diversity Group at low risk of extinction
- Maintain multiple populations at moderate risk of extinction

For context, these ESU/DPS recovery criteria are shown in relation to historic and current conditions in Table 4-3. Although Table 4-3 does show that much improvement in the number and distribution of viable populations is needed, an encouraging take-away point is that these species can be recovered without achieving the historic condition. For example, a recovered spring-run Chinook salmon ESU requires nine viable populations, not the 19 that historically occurred in the Central Valley.

Table 4-3: Number of independent, viable populations of winter-run and spring-run Chinook salmon and steelhead by diversity group under historic and current conditions, relative to the recovery criteria. The recovery criteria also include maintenance of all existing dependent populations.

Diversity Group	Historic, Current and Recovered Independent, Viable Populations - Total By Diversity Group								
	Winter-Run			Spring Run			Steelhead		
	Historic	Current	Recovery Criteria	Historic	Current	Recovery Criteria	Historic	Current	Recovery Criteria
Basalt and Porous Lava	4	0	3	4	0	2	12	Unknown	2
Northwestern California	0	0	0	0	0	1	14	Unknown	1
Northern Sierra	0	0	0	11	1	4	21	Unknown	4
Southern Sierra	0	0	0	4	0	2	26	Unknown	2

4.4 Threat Abatement

The underlying causes of species declines should be controlled prior to delisting. These causes include all threats identified at the time of listing, as well as any new factors identified since listing. Since listing, numerous additional threats have been identified and prioritized for the ocean, migratory corridors, and for each of the Diversity Groups and individual populations of the winter-run and spring-run Chinook salmon ESUs, and the steelhead DPS within the Central Valley Domain (Introduction, Appendix B).

NMFS believes that the condition of habitat in the ESUs/DPS will be directly affected by actions that address threats to the habitat. Therefore, changes to habitat condition will be inferred by monitoring progress and the degree to which threats to habitat are improved or removed, at both the watershed and system scale. Therefore, abatement of threats will also meet these habitat objectives:

- The spatial distribution and productive capacity of freshwater, estuarine, and marine habitats should be sufficient to maintain viable populations identified for recovery;

- The diversity of habitats for recovered populations should provide sufficient resilience and redundancy to withstand expected natural disturbance regimes such as wildfires, floods, droughts and volcanic eruptions. Historic conditions represent a reasonable template for a viable population; the closer the habitat resembles the historic diversity, the greater the confidence in its ability to support viable populations; and

- At a large scale, habitats should be protected and restored, with a trend toward an appropriate range of attributes for salmonid viability. Freshwater, estuarine, and marine habitat attributes should be maintained in a non-deteriorating state.

4.4.1 Threats

Sacramento River Winter-run Chinook Salmon

Several factors have contributed to the decline of winter-run Chinook salmon through degradation of spawning, rearing, and migration habitats. The primary factors included in the listing of winter-run Chinook salmon were blockage of historical habitat by Shasta and Keswick dams, warm water releases from Shasta Dam, juvenile and adult passage constraints at RBDD, water exports in the southern Delta, heavy metal contamination from Iron Mountain Mine, high ocean harvest rates and entrainment in a large number of unscreened or poorly screened water diversions (NMFS 1997). Other factors include smaller water manipulation facilities and dams, loss of rearing habitat in the lower Sacramento River and Delta from levee construction, marshland reclamation, interaction with and predation by introduced species, adverse flow conditions, high summer water temperatures and vulnerability to drought (NMFS 1997). Since listing, some of these threats have been addressed, although numerous additional threats have been identified and prioritized (Appendix B).

Central Valley Spring-run Chinook Salmon

Listing factors and threats to Central Valley spring-run Chinook salmon fall into three broad categories: loss of historical spawning habitat; degradation of remaining habitat; and threats to genetic integrity. The last threat is to wild spawning populations resulting from spawning with FRFH spring-run Chinook salmon and naturally- and hatchery produced fall-run Chinook salmon. A complete prioritized list of the life stage-specific threats to the ESU is presented in Appendix B.

Central Valley Steelhead

Threats to Central Valley steelhead are similar to those for Central Valley spring-run Chinook salmon: loss of historical spawning habitat, degradation of remaining habitat, and threats to the genetic integrity of the wild spawning populations from hatchery steelhead production programs in the Central Valley. A complete prioritized list of life stage-specific threats to the DPS is presented in Appendix B.

4.4.2 Listing Factors

All threats to a species can be categorized into one of the five ESA listing factors:

1. The present or threatened destruction, modification, or curtailment of its habitat or range;
2. Overutilization for commercial, recreational, scientific, or educational purposes;
3. Disease or predation;
4. The inadequacy of existing regulatory mechanisms;
5. Other natural or manmade factors affecting its continued existence.

NMFS proposes that, to determine that the affected ESU/DPS is recovered to the point that it no longer requires the protections of the ESA, these five ESA listing factors should be addressed according to specific criteria identified for each of them in order to ensure that the underlying causes for listing the species are addressed.

It is likely that current threats may diminish or increase in severity due to anthropogenic or natural changes to the environment. Indeed, successful implementation of the actions in this recovery plan will ameliorate threats to the ESUs/DPS. Consequently, NMFS expects that the significance of threats will change over time. It is also possible that new threats may be identified. To track changes in the threat regime, every five years during the status reviews of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead, NMFS will evaluate whether the five listing factors have substantially changed.

4.4.3 Threat Abatement Criteria

NMFS is providing the specific threat abatement criteria listed below for each of the relevant listing factors to help to ensure that underlying causes of decline have been addressed and mitigated prior to considering a species for delisting. These threat abatement criteria correspond to the listing factors identified for winter- and spring-run Chinook salmon and steelhead in this Recovery Plan, and are related to each of the threats described in Appendix B.

- Populations have unobstructed access to Core 1, 2, and 3 watersheds and assisted access to primary watersheds for reintroduction that are obstructed. Man-made structures (e.g., bridges and water diversions) affecting these watersheds and in migratory habitat should meet NMFS' salmonid passage guidelines for stream crossings and screening criteria for anadromous salmonids (Listing Factors 1, 4, and 5)
- Utilization for commercial, recreational, scientific and educational purposes is managed, such that all core 1 populations meet the low extinction risk categories for abundance, productivity, and diversity (see table 4-1) (Listing Factor 2)
- Hatchery programs are operated so that all core 1 populations meet the low extinction risk criteria for hatchery influence (see table 4-1) (Listing Factors 3 and 5)
- Migration and rearing corridors meet the life-history, water quality and habitat requirements of the listed species, such that the corridor supports multiple viable populations (Listing Factors 1, 3, 4, and 5)

5.0 Recovery Actions

"Once there is a firm commitment and a strategy alternative has been decided upon, the third and final pillar of an effective salmon recovery effort is that a number of specific actions will be required to achieve effective implementation."

- Jeffrey J. Dose. Commitment, Strategy, Action: The Three Pillars of Wild Salmon Recovery *in* Salmon 2100: the future of wild Pacific salmon

This Recovery Plan establishes a strategic approach to recovery, which identifies critical recovery actions for the Central Valley, as well as watershed- and site-specific recovery actions. Watershed-specific recovery actions address threats occurring in each of the rivers or creeks that currently support spawning populations of the Sacramento River winter-run Chinook salmon ESU, the Central Valley spring-run Chinook salmon ESU, or the California Central Valley steelhead DPS. Site-specific recovery actions address threats to these species occurring within a migration corridor (e.g., San Francisco Bay or the Delta).

This Recovery Plan maintains a consistent strategic framework for the establishment of recovery goals and criteria, the identification and prioritization of threats, and the identification of recovery actions. As described in the Recovery Strategy chapter, the framework for ESU or DPS recovery includes goals and criteria directed at the diversity group and population levels. Similarly, the threats assessment framework for each ESU or DPS also was organized by diversity groups and populations. For the winter-run Chinook salmon ESU, threats were prioritized for the one Sacramento River population; for spring-run Chinook salmon and steelhead, threats were prioritized within each diversity group as well as within each population.

Three steps were used to prioritize recovery actions as they are presented in this plan. First, results from the threats assessment and prioritization process (described in Appendix B) were used to guide the identification of watershed- and site-specific recovery actions for each diversity group and population. This step prioritized recovery actions separately for each species. The second step was undertaken through consideration of specific actions that benefit multiple species and populations. Results from the second step included tables of recovery actions listed in descending order of priority by geographic region (e.g., Delta, mainstem Sacramento River, Battle Creek) based on multiple species benefits (see Appendix C). These first two steps were the only steps taken to prioritize recovery actions that were presented in the Co-Manager Review Draft Recovery Plan. Based on feedback from co-managers, it was apparent that the priority with which recovery actions should be undertaken was not clear.

To address this, we implemented a third step and prioritized each of the area- or watershed-specific recovery actions according to three categories. Priority 1 actions address the most important threats within an area (e.g., Pacific Ocean or Delta) or watershed; priority 2 actions address threats of moderate importance, and priority 3 actions are of lower importance to implement[7].

Actions were identified as priority 1, 2, or 3 based on the first two prioritization steps and on the best professional judgment of agency co-managers, including biologists from CDFW, DWR, USFWS, USFS, and NMFS.

A number of ecosystem and/or anadromous fish enhancement plans for the Central Valley, as well as input received from two recovery planning public workshops, held May 22nd and 24th, 2007 in Sacramento and Redding, respectively, have been used to identify recovery actions. These documents include:

- Final Restoration Plan for the AFRP (USFWS 2001)
- AFRP Planning Documents (AFRP Website 2005; AFRP Website 2006a; AFRP Website 2006b)
- Ecosystem Restoration Plan Planning Documents (CALFED 2006; CALFED 2007)
- Summary of Threats and Recovery Actions for Spring-run Chinook Salmon and Winter-run Chinook Salmon Recovery Actions. Sacramento Salmon and Steelhead Recovery Workshop (NMFS 2007c)
- Summary of Threats and Recovery Actions for Steelhead. Sacramento Salmon and Steelhead Recovery Workshop (NMFS 2007a)
- Steelhead Restoration and Management Plan for California (CDFW 1996)
- Lower Yuba River Revised Implementation Plan and Appendices (CALFED and YCWA 2005)
- Ecosystem Restoration Program Plan (ERPP) (CALFED 1999a)
- Restoring Central Valley Streams: A Plan for Action (CDFW 1993)
- Lower Yuba River Fisheries Management Plan (CDFW 1991a)

[7] In NMFS' Public Draft Recovery Plan for the Evolutionarily Significant Units of Sacramento Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead, October 2009, Appendix C, we described how we applied the recovery action priorities 1-3 described in NMFS recovery planning guidelines (55 FR 24296; June 15, 1990), which are also described in NMFS' Recovery Planning Guidance (NMFS 2010b), in developing recovery actions for each species addressed in this recovery plan. The recovery actions priorities 1-3 described here in this final recovery plan are based on grouping the recovery actions for all three listed species addressed in this recovery plan by area or watershed and prioritizing those actions as described here.

- ❑ Initial Fisheries and In-Stream Habitat Management and Restoration Plan for the Lower American River (Water Forum 2001)
- ❑ CALFED Bay/Delta Program Multi-Species Conservation Strategy. Final Programmatic EIS/EIR Technical Appendix (CALFED 2000a)
- ❑ Potential for Re-establishing a Spring-Run Chinook Salmon Population in the Lower Feather River (MWD 2005)
- ❑ Central Valley Salmon – A perspective on Chinook and Steelhead in the Central Valley of California (Williams 2006)
- ❑ What caused the Sacramento River fall Chinook stock collapse? (Lindley *et al*. 2009)
- ❑ Insights into the Problems, Progress, and Potential Solutions for Sacramento River Basin Native Anadromous Fish Restoration (Vogel 2011).

The recovery actions for this plan are presented in the tables below according to the following geographic organization:

- Throughout California or the Central Valley
- Pacific Ocean
- San Francisco, San Pablo, and Suisun bays
- Delta
- Mainstem Sacramento River
- Northwestern California Diversity Group
- Basalt and Porous Lava Diversity Group
- Northern Sierra Nevada Diversity Group
- Mainstem San Joaquin River
- Southern Sierra Nevada Diversity Group.

The implementation schedules that follow outline actions for the recovery program for the Sacramento River winter-run Chinook salmon ESU, the Central Valley spring-run Chinook salmon ESU, and the California Central Valley steelhead DPS, as set forth in this recovery plan. The schedules are a guide for meeting the recovery goals outlined in this plan. They indicate action priorities, action numbers, action descriptions, and duration of actions; the parties potentially involved in either funding or carrying out actions; and estimated costs. The listing of a party in an implementation schedule does not require the identified party to implement the action(s) or to secure funding for implementing the action(s).

Cost estimates are provided wherever practicable. In some cases, information essential to the development of even the roughest of estimates is unavailable, as described in detail below:

- There is no available information to estimate, even in the roughest of terms, the appropriate extent of an action:

- The essential quality or quantity of a determinative feature of an action can only be estimated after site-specific investigations are completed; NMFS is unaware of any existing site-specific investigations. This includes:

Gravel Augmentation	Estimate of amount of necessary gravel augmentation (if any) unavailable. Per unit cost is $11 to $72/cubic yard (Appendix D).
Wetland Habitat Restoration	Estimate of amount of habitat to be restored unavailable. Per unit cost is $75 to $100,000/acre (Appendix D Table HI-7).
Riparian Habitat Restoration	Estimate of amount of habitat to be restored unavailable. As identified in Appendix D, per unit costs vary depending on whether fencing, planting, irrigation, or invasive week control are needed.
Floodplain Habitat Restoration	Estimate of amount of habitat to be restored unavailable. Per unit cost is $5,000 to $80,000/acre (Appendix D Table HI-4)
Side Channel Habitat Restoration/Re-connection	Estimate of amount of habitat to be restored unavailable. Per unit cost is $20,000 to $300,000/acre (Appendix D Table HI-5)
Sediment retention projects.	Extent and method of sediment retention unavailable. See Appendix D, tables HU-1 through HU-4 for per unit costs for road de-commissioning, road upgrades, landslide/gully stabilization, and planting in upland areas.
Habitat acquisition/easements	Estimate of amount of habitat for acquisition, lease, or easement unavailable. Land acquisition costs per acre for California are presented by county in Appendix D, Table HA-3, and generally range from $200 to $20,000/acre. Conservation easement costs range from $209 to $730/acre (Appendix D).
Water acquisition for instream flow	Estimate of amount of water to be purchased unavailable. Cost per unit ranges from $43 to $88/af/year for upstream of Delta water purchases (Appendix D)

- With regard to the Delta (DEL-2.31) and San Francisco Bay (SFB-2.4) actions designed to promote nitrification and retention of NH4 through marsh restoration, it is not scientifically practicable to estimate how much restoration is needed to achieve the appropriate NH4 concentrations.

    - For the actions calling for projects to minimize predation at weirs, diversions, and related structures outside of the Delta[8], it is impracticable to provide cost estimates given the unknown but likely large number of man-made structures in the bays, and the Sacramento and San Joaquin river systems, many of which will require site-specific studies and adaptive management to identify unique solutions. After initial investigation, it is likely that the solution at one structure may apply to other structures of the same type (e.g., boat docks), in which case the overall cost of identifying and implementing solutions will diminish. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013)[9].
    - For actions calling for fish passage improvements at small agricultural diversions on a particular river or creek, the total number of diversions is unknown, making it impracticable to provide a total cost. Per unit cost of providing passage at agricultural diversion dams ranges from $30,000 to $1,356,500 (see Appendix D, page 21, table HB-4).

- Information on the cost of an action is known only to a third party, but such information has not been provided to NMFS by the third party at time of this Recovery Plan's publication;
- The action is so novel that no comparable actions can be identified and the action involves development or application of a new technology for which it is impracticable to provide a reasonable guess at the action's cost;
- The recommended action is based on the broad directives/guidelines of existing government plans and goals, for which no cost-estimate currently exists, but, due to the breadth of the existing directives/guidelines and their lack of specificity, it is impracticable to estimate the cost of their implementation. Two actions that fall into this category are: (1) Implement recommended actions from the National Ocean Council's National Ocean Policy Implementation Plan dated April 2013 [action PAO-2.3]; and (2) Implement the USEPA's Action Plan for addressing water quality concerns in the Bay/Delta [DEL-1.25].

Under the aforementioned circumstances, NMFS is unable to estimate practicably the cost of the action; accordingly, costs are identified as "To Be Determined" ("TBD"). Cost estimates will be determined as the currently unavailable information becomes available. Wherever practicable, NMFS has attempted to identify the following: 1) per-unit costs (particularly where the

[8] The cost of minimizing predation at Delta structures was estimated at $50 million over 50 years (BDCP 2013). A similar type of cost analysis for which to base the cost of minimizing predation in San Francisco, San Pablo, and Suisun bays, and the Sacramento and San Joaquin river systems has not been conducted.

[9] BDCP (2013) estimated the annual cost of predator removal for 17 sites at roughly $640,000, therefore, each site would cost about $38,000 annually ($640,000/17).

unavailable quantum of information is the amount of habitat which must be addressed); 2) the cost of interim activities (including initial studies), which are the only estimable portion of an action and will help to provide the previously unavailable essential information, thereby ultimately leading to the action's ultimate cost estimate; and/or 3) a plan for determining the ultimate cost estimate.

In an effort to identify only the additional cost of species recovery, we considered what is already required under local, State, or Federal regulation, or settlement agreements, to be required actions, and thereby estimated them at $0. For example, the cost of an action required by a Reasonable and Prudent Alternative action which has already been adopted by an action agency is listed as $0. Also, actions were assumed to have no additional cost to recovery if the action would be accomplished under the existing work programs of government agencies and would not require an agency or group to acquire funding beyond their existing budgets. Because several federal and state agencies have significant budgets directed to natural resource protection in general, and anadromous salmonids in particular, many of the actions identified in this recovery plan will be implemented through those existing programs; as such, many actions are identified to cost $0, since the action will not cause agency budgets to expand.

The Southwest Fisheries Science Center (SWFSC) produced a Technical Memorandum providing information on costs associated with restoration activities. To help comply with the requirement to provide estimates of recovery costs, that Technical Memorandum has been appended to this recovery plan (Appendix D). Data from publicly available sources were used to obtain estimates of restoration costs for a variety of restoration activities. All costs described in Appendix D pertain to direct expenditures on restoration and do not include economic opportunity costs (e.g., foregone profits associated with restrictions on livestock grazing, timber harvest and other activities). Appendix D offers ranges of costs applicable at the ESU scale. Actual costs may vary widely from one watershed to another and across the extent of the Central Valley Domain due to potential differences in regional labor costs, property values, availability of expert contractors and materials, and permitting issues, etc. Many cost estimates for restoration activities in the Central Valley are specifically based on CALFED Ecosystem Restoration Program (ERP) implementation and/or contracted costs (most notably fish screening projects, gravel augmentation, channel restoration, bank stabilization, land acquisition, conservation easements, proposed watershed effectiveness monitoring, and a 5-dam decommissioning and removal project), so are specific to the Central Valley and are referenced as such in the Technical Memorandum. Also, levee-related and water purchase/lease activity cost estimates for the Central Valley were included in the report, based on information from DWR, county water agencies, and ERP. Irrigation ditch activity costs, including water control structures, were developed from information from county water agencies in the Central Valley. The rest of Appendix D contains data from the northernmost part of California, Oregon, Washington, and Idaho.

NMFS estimates that recovery for listed Central Valley salmon and steelhead, like for most of the ESA-listed Pacific Northwest salmon and steelhead, could take 50 to 100 years. Because there is an extensive list of actions that need to be undertaken to recover the listed Central Valley salmonids, there are many uncertainties involved in predicting the course of recovery and in estimating total costs and time to recovery. Such uncertainties include biological and ecosystem responses to recovery actions. Obtaining and evaluating cost estimates for recovery actions can be challenging, and projecting costs into the future becomes increasingly imprecise. NMFS believes it is impracticable to accurately estimate all projected actions and associated costs over 50 to 100 years, given the large number of economic, biological, and social variables involved, and that it is more appropriate to initially focus on the first 25 years of implementation. Because of these variables, cost projections become increasingly inaccurate with time. Most actions can be accomplished within this 25 year time frame. For actions that extend beyond 25 years (these actions are specifically identified in the description of the respective actions below), the cost over the first 25 years is provided, and it is assumed for lack of better information that those costs will continue for the remaining duration of the action. The cost estimates for actions in later years are likely much less accurate than estimates during earlier years of implementation.

The duration of an action in the implementation tables refers to how long the action will take to complete, as opposed to when the action will be initiated. When the exact number of years that it would take to complete an action could not be estimated, more general estimates were provided. The duration for most actions was identified using general estimates as short-term (i.e., roughly 10 years or less) or long-term (i.e., 11 to 25 years in most cases, up to 100 years where specifically noted).

Abbreviations key for the following tables:
ACWA: Association of California Water Agencies
AMR: American River
ANC: Antelope Creek
BAC: Battle Creek
BCC: Big Chico Creek
BLM: U.S. Bureau of Land Management
BUC: Butte Creek
CDFW: California Department of Fish and Wildlife
CEV: Central Valley
CLC: Clear Creek
COR: Cosumnes River
Corps: U.S. Army Corps of Engineers
CVP: Central Valley Project
CVRWQCB: Central Valley Regional Water Quality Control Board
DEC: Deer Creek
DEL: Delta
DRN: Delta Restoration Network
DSC: Delta Stewardship Council
DWR: California Department of Water Resources
FER: Feather River
FERC: Federal Energy Regulatory Commission
GCID: Glenn Colusa Irrigation District
HGMP: Hatchery and Genetic Management Plan
MER: Merced River
MIC: Mill Creek
MID: Merced Irrigation District

MOR: Mokelumne River
NGO: Non-governmental organization
NID: Nevada Irrigation District
NMFS: National Marine Fisheries Service
NFWF: National Fish and Wildlife Foundation
NRCS: Natural Resources Conservation Service
ODFW: Oregon Department of Fish and Wildlife
OID: Oakdale Irrigation District
PCWA: Placer County Water Agency
PG&E: Pacific Gas and Electric
PFMC: Pacific Fishery Management Council
PUC: Putah Creek
SAR: Sacramento River
SJR: San Joaquin River
SRCS: Spring-run Chinook salmon
STR: Stanislaus River
STC: Stony Creek
STE: Steelhead
SWP: State Water Project
SWRCB: State Water Resources Control Board
SWRFSC: NMFS Southwest Region Fisheries Science Center
SYRCL: South Yuba River Citizens League
TBD: To Be Determined
TCCA: Tehama-Colusa Canal Authority
THC: Thomes Creek
TID: Turlock Irrigation District
TNC: The Nature Conservancy
TUR: Tuolumne River
USBR: United States Bureau of Reclamation
USEPA: United States Environmental Protection Agency
USFS: United States Forest Service
USFWS: United States Fish and Wildlife Service
WRCS: Winter-run Chinook salmon
YCWA: Yuba County Water Agency
YUR: Yuba River

5.1 California and Central Valley Recovery Actions

Table 5-1. California and Central Valley Recovery Actions.

Action Area	Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
California	Implement Federal, State, and local initiatives and programs to improve water conservation in order to reduce state-wide water use by 20 percent per capita by 2020. This effort should take into account regional differences and find ways to improve agricultural and urban water use efficiency.	1	CA-1.1	WRCS ,SRCS, STE	Federal, State, County, and local governments	1,4,5	Short-term	TBD	TBD				TBD because the State Conservation Plan for the "20X2020" goal did not include an overall cost of the effort and the cost of the program can reasonably only be estimated by the state; numerous savings associated with investing in water conservation were provided, but an overall cost-benefit analysis was not conducted because of the large number of variables in play (DWR *et al.* 2010).
California	Implement the Global Warming Solutions Act (AB 32), the Sustainable Communities and Climate Protection Act (SB 375) and other smart growth measures to foster	1	CA-1.2	WRCS , SRCS, STE	Federal, State, County, and local governments	1,4,5	Long-term (beyond 25 years)	TBD	TBD	TBD	TBD	TBD	TBD because the number and scope of smart growth projects that will be implemented is indeterminate; it

Action Area	Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
	sustainable land use throughout California.												is assumed that smart growth and sustainable land use practices will need to be implemented in perpetuity in order to delist the species in this plan and keep them delisted.
Central Valley	Develop and implement an ecosystem based management approach that integrates harvest, hatchery, habitat, and water management, in consideration of ocean conditions and climate change (Lindley *et al*. 2009).	1	CEV-1.1	WRCS, SRCS, STE	NMFS, USFWS, CDFW, DWR, PFMC, SWRCB, USBR	1, 2, 5	Long-term	$1,086,360	$1,699,840	$1,965,015	$2,271,558	$2,625,921	$9,648,694
Central Valley	Support programs to provide educational outreach and local involvement in restoration and watershed stewardship, including programs like Salmonids in the Classroom, Aquatic Wild, Adopt a Watershed, school district environmental camps, and other programs teaching the effects of human land and water use on anadromous fish survival.	1	CEV-1.2	WRCS, SRCS, STE	NMFS, USFWS, USBR, USFS, CDFW, DWR	5	Long-term						Cost is provided in the education/outreach actions for specific watersheds.

Action Area	Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Central Valley	Provide additional funding for increased law enforcement to reduce illegal take of anadromous fish, ecologically harmful stream alterations, and water pollution and to ensure adequate protection for juvenile fish at pumps and diversions.	1	CEV-1.3	WRCS, SRCS, STE	CDFW, NMFS	4	Long-term	$12 million	$12 million	$12 million	$12 million	$12 million	$60 million
Central Valley	Implement the recommendations and guidelines of the California Hatchery Scientific Review Group (http://cahatcheryreview.com/).	1	CEV-1.4	WRCS, SRCS, STE	NMFS, USFWS, CDFW, USBR, DWR	5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD[10]
Central Valley	Implement a comprehensive Central Valley steelhead monitoring plan to better understand their abundance and distribution.	1	CEV-1.5	STE	NMFS, USFWS, CDFW, DWR, USBR	1	Long-term	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$7,500,000
Central Valley	Evaluate the relationship between resident and anadromous forms of O. mykiss to better understand the role that resident fish play in species maintenance and persistence.	1	CEV-1.6	STE	NMFS, USFWS, CDFW	1	Short-term	<$500,000	<$500,000				Cost will depend on study methodology, experimental design, number of samples needed, and other factors,

[10] The Hatchery Scientific Review Group Cost (HSRG) did not develop cost estimates for their recommendations and guidelines. To implement the HSRG recommendations, hatchery coordination teams for each hatchery will be established; those teams will identify implementation costs.

Action Area	Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
													but overall it is anticipated to cost <$1,000,000
Central Valley	Implement and evaluate actions to minimize the adverse effects of exotic (non-native invasive) species (plants and animals) on the aquatic ecosystems used by anadromous salmonids.	1	CEV-1.7	WRCS, SRCS, STE	Department of Boating and Waterways	1,2,4	Long-term	$51,000,000	$125,000,000	$125,000,000	$125,000,000	$125,000,000	$551,000,000
Central Valley	Develop and implement State and National levee vegetation policies to maintain and restore riparian corridors.	1	CEV-1.8	WRCS, SRCS, STE	Corps, DWR, CDFW, NMFS	1,4	Long-term	$0	$0	$0	$0	$0	$0
Central Valley	Incorporate ecosystem restoration including breaching and setting back levees into Central Valley flood control plans (i.e., FloodSafe Strategic Plan and the Central Valley Flood Protection Plan).	1	CEV-1.9	WRCS, SRCS, STE	NMFS, USFWS, Corps, USBR, CDFW, DWR,	1,4	Long-term	$0	$0	$0	$0	$0	$0
Central Valley	Establish partnerships and agreements that promote water transactions, water transfers, shared storage, and integrated operations that benefit both species needs and water supply reliability.	1	CEV-1.10	WRCS, SRCS, STE	SWRCB, NFWF, ACWA, DWR, USBR	1,4,5	Short-term	$2,500,000	$2,500,000	$0	$0	$0	$5,000,000
Central Valley	Annually evaluate the harvest rate of Central Valley spring-run Chinook salmon and Sacramento River winter-run Chinook salmon in the ocean salmon	1	CEV-1.11	WRCS, SRCS	NMFS, PFMC, CDFW, USFWS	2	Long-term	Up to $750,000 for genetic analysis and reporting (Garza	Up to 750,000 for genetic analysis and reporting (Garza	Up to 750,000 for genetic analysis and reporting (Garza	Up to 750,000 for genetic analysis and reporting (Garza	Up to 750,000 for genetic analysis and reporting (Garza	Up to $3,750,000 for genetic analysis and reporting (Garza 2013); Up to $3,450,000 for

Action Area	Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
	fisheries (commercial and recreational) and modify fishing regulations as necessary to ensure that the fisheries impacts allow for the ESUs to recover.							2013); Up to $690,000 for sampling assuming two FTEs are needed to expand the existing sampling program[11]	2013); Up to $690,000 for sampling assuming two FTEs are needed to expand the existing sampling program	2013); Up to $690,000 for sampling assuming two FTEs are needed to expand the existing sampling program	2013); Up to $690,000 for sampling assuming two FTEs are needed to expand the existing sampling program	2013); Up to $690,000 for sampling assuming two FTEs are needed to expand the existing sampling program	sampling assuming two FTEs are needed to expand the existing sampling program
Central Valley	Continue to implement and improve comprehensive Chinook salmon monitoring to assess the viability of winter-run and spring-run.	1	CEV-1.12	WRCS, SRCS	CDFW, USFWS, DWR, USBR, NMFS	5	Long-term	$0	$0	$0	$0	$0	$0
Central Valley	Conduct a Central Valley-wide assessment of anadromous salmonid passage opportunities at large rim dams including the quality and quantity of upstream habitat, passage feasibility and logistics, and passage-related costs.	2	CEV-2.1	WRCS, SRCS, STE	NMFS, USFWS, USBR, USFS, CDFW, DWR	1,5	Short-term	$2,500,000	$2,500,000	$0	$0	$0	$5,000,000
Central Valley	Develop a Fishery Management and Evaluation Plan for inland fisheries to ensure that impacts of those fisheries on winter-run	2	CEV-2.2	WRCS, SRCS, STE	CDFW, NMFS	2	Short-term	$0	$0	$0	$0	$0	$0

[11] Based on the May 2012 State Occupational Employment and Wage Estimates for California provided by the Bureau of Labor Statistics, the mean annual wage for a biologist is $69,000 (http://www.bls.gov/oes/current/oes_ca.htm#19-0000).

Action Area	Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
	Chinook salmon, spring-run Chinook salmon, and steelhead allow for these species to recover.												

5.2 Pacific Ocean Recovery Actions

Table 5-2. Pacific Ocean Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Re-evaluate and modify management measures, annual conservation objectives, harvest forecasting techniques, NMFS consultation standards for ESA listed salmon stocks, and consider implementing an ecosystem-based salmon fishery management plan that considers multi-trophic interactions, ocean currents, upwelling patterns, ocean temperatures, and other relevant factors.	1	PAO-1.1	WRCS, SRCS	NMFS, PFMC, CDFW	1,5	~ 10 years	$1,220,150	$1,410,493	$0	$0	$0	$2,630,643
Enhance water quality in the ocean and along the coast by continuing to promote and implement sustainable practices on land in ways that will improve the health of ocean water quality.	2	PAO-2.1	WRCS, SRCS, STE	NMFS, USFWS, PFMC, CDFW, WDFW, ODFW, county planning	1,5	Long-term	$0	$0	$0	$0	$0	$0
CDFW and National Marine Sanctuary Program should consider the ecological requirements of salmon and steelhead when designating sanctuaries	2	PAO-2.2	WRCS, SRCS, STE	CDFW, NMFS	4	Long-term	$0	$0	$0	$0	$0	$0
Implement recommended actions from the National Ocean Council's National Ocean Policy Implementation Plan dated April 2013	2	PAO-2.3	WRCS, SRCS, STE	NMFS, USFWS, PFMC, CDFW, WDFW, ODFW, county planning	4	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, the Ocean Policy Implementation Plan contains broad directives/guidelines, for which no cost-estimate currently exists, but, due to the breadth of the existing

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												directives/guidelines and their lack of specificity, it is impracticable to estimate the cost of their implementation.

5.3 San Francisco, San Pablo, and Suisun Bay Recovery Actions

Table 5-3. San Francisco, San Pablo, and Suisun Bay Reocery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement projects that improve wastewater and stormwater treatment throughout Suisun, San Pablo, and San Francisco bays and surrounding residential and commercial areas.	1	SFB-1.1	WRCS, SRCS, STE	SWRCB	1,5	Short-term	$1,545,000,000	$1,786,020,000	$0	$0	$0	$3,331,020,000
Protect, enhance, and restore a complex portfolio of habitats throughout Suisun, San Pablo, and San Francisco bays to provide cover and prey resources for migrating salmonids.	1	SFB-1.2	WRCS, SRCS, STE	NMFS, USFWS, Corps, DWR, CDFW	1, 3	Long-term						>$100 million (San Francisco Estuary Partnership 2007)
Improve the timing and extent of freshwater flow to the San Francisco Bay region to the	1	SFB-1.3	WRCS, SRCS, STE	USBR, DWR, CDFW, USFWS, NMFS, SWRCB, DSC	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
benefit of juvenile and adult salmonids by modifying water operations in the Central Valley to support flows that mimic the natural hydrograph.												
Fund and implement San Francisco Estuary Program's Comprehensive Conservation and Management Program aimed at the Estuary's aquatic resources.	1	SFB-1.4	WRCS, SRCS, STE	San Francisco Estuary Partnership	1, 4	Short-and Long-term components						$60-$80 million[12]
Cities, counties, districts, joint powers authority or other political subdivisions of the State involved with water management in Suisun, San Pablo, and San Francisco bays should	2	SFB-2.1	WRCS, SRCS, STE	CVRWQCB, Agriculture industry	1, 5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on the number of farmed acres that need drainage improvements in order to comply with CVRWQCB regulations. The cost estimates for management

[12] The cost range of $60-$80 million was derived from the 2007 Comprehensive Conservation and Management Plan's Aquatic Resources section. The cost range was identified by summing the cost of actions that were not already covered by actions in this Recovery Plan.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
implement agricultural drainage management projects to treat, store, convey, and/or dispose of agricultural drainage.												practices may range from less than $20/acre to greater than $110/acre per year (CVRWQCB 2012)
Develop a long-term strategy for monitoring and regulating discharges from agricultural lands entering Suisun, San Pablo, and San Francisco bays.	2	SFB-2.2	WRCS, SRCS, STE	SWRCB	1,5	5 Years	$0	$0	$0	$0	$0	$0
Implement projects that would reduce anthropogenic inputs of NH4 to help achieve concentrations below 4 µmol L-1 in order to promote increased primary and secondary production (Dugdale *et al*. 2007).	2	SFB-2.3	WRCS, SRCS, STE	NMFS, USFWS, SWRCB, DWR, CDFW, Local agriculture groups	1,4,5	Long-term						$1 - $2 billion by 2020 to upgrade Sacramento County Regional Water Treatment Plant to reduce discharge limits for nitrogen, ammonia and pathogens[13].

[13] Source: Sacramento Business Journal; http://www.bizjournals.com/sacramento/news/2012/12/05/state-water-sacramento-waste-water-treat.html

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement tidal marsh restoration projects to promote nitrification and retention of NH4 (Dugdale *et al*. 2007).	2	SFB-2.4	WRCS, SRCS, STE	NMFS, USFWS, Corps, CDFW, DWR, Various NGOs	1, 5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD because it is not scientifically practicable to estimate how much restoration is needed to achieve the appropriate NH4 concentrations
Evaluate whether predator control actions (e.g., fishery management or directed removal programs) can be effective at minimizing predation on juvenile salmon and steelhead in Suisun, San Pablo, and San Francisco bays; continue implementation if effective.	2	SFB-2.5	WRCS, SRCS, STE	USFWS, NMFS, USBR, CDFW, DWR, Various NGOs	3	Long-term	$0-$15,000,000[14]	$0-$15,000,000	$0-$15,000,000	$0-$15,000,000	$0-$15,000,000	$0-$75,000,000

[14] If the action is limited to angling regulation changes, the cost is $0; the upper bound ($15,000,000) is based on the cost of the Columbia River pikeminnow bounty program (i.e., $3,000,000/year on average) as identified in NMFS (2011). This recovery plan is not calling for a predator bounty program in the Central Valley, but for the purposes of cost estimation, the Columbia River program's cost is assumed to represent an upper bound for what predator control could cost in the Central Valley.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement studies to develop quantitative estimates of predation on juvenile salmonids by non-native species throughout Suisun, San Pablo, and San Francisco bays.	2	SFB-2.6	WRCS, SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	3	Short-term	$200,000-$400,000	$0	$0	$0	$0	$200,000-$400,000
Implement projects to identify predation "hot spots" throughout Suisun, San Pablo, and San Francisco bays and minimize losses of juvenile salmonids at those locations.	2	SFB-2.7	WRCS, SRCS, STE	DWR, USBR, CDFW, NMFS, USFWS	1,3	Long-term	$5,000-$50,000 for initial hot spot identification ; see total cost for potential site-specific costs	TBD	TBD	TBD	TBD	$5,000-$50,000 for initial hot spot identification. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												(BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013).
Prevent in-bay disposal of contaminated sediments known to be detrimental to aquatic life.	2	SFB-2.8	WRCS, SRCS, STE	NMFS, Corps, USEPA	5	Long-term	$0	$0	$0	$0	$0	$0
Evaluate, and if feasible implement restoration projects that integrate upland, intertidal, and subtidal habitats; consider the following locations (from California State Coastal Conservancy *et al*. 2010): 1) San Pablo Bay: study potential resources and restoration activities in areas offshore from Sears Point, San Pablo	2	SFB-2.9	WRCS, SRCS, STE	California State Coastal Conservancy, CDFW, Corps, NMFS, USFWS	1	Long-term	TBD	TBD	TBD	TBD	TBD	$5,000-$50,000 for initial scoping and feasibility; total project cost TBD based on the type and amount of habitat that is restored. See Appendix D for unit costs.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Bay National Wildlife Refuge and Tubbs Island, and other restoration sites; 2) Corte Madera area: Muzzi Marsh, Corte Madera Ecological Reserve, Heard Marsh: existing wetlands and restored eelgrass, link to living shoreline project; 3) Richardson Bay: wetland restoration linked to existing oyster/eelgrass populations; 4) Breuner Marsh and Point Molate: link to Point San Pablo eelgrass bed; 5) Eastshore State Park: wetland restoration linked with oyster and eelgrass restoration, creek daylighting; 6) Central and North Bay Islands: link rocky habitat with eelgrass												

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
and oyster beds; and 7) South Bay Salt Pond sites; Eden Landing and other sites: link to southernmost eelgrass population, native oyster restoration.												
Develop and implement education and outreach programs to encourage stewardship of Suisun, San Pablo, and San Francisco bay habitats.	2	SFB-2.10	WRCS, SRCS, STE	NMFS, USFWS, CDFW, DWR	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Develop and implement studies to identify the significance and spatial distribution of marine mammal predation on	3	SFB-3.1	WRCS, SRCS, STE	NMFS, USFWS, USBR, Corps, CDFW, DWR	1,3	Short-term	$1.5 million - TBD					$1.5 million minimum up to TBD [15].

[15] Based on an internet search, no projects have studied pinniped predation on juvenile salmon; as such there is no cost estimate to base the cost of this action on. The cost of studying pinniped predation on adult salmon is roughly estimated at $300,000 annually (Rub 2013); we assume that studying pinniped predation on juvenile salmon is more complicated than adults and thus will be at least as expensive. If the project were conducted for five years, the cost would be at least $1.5 million.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
adult and juvenile anadromous salmonids in Suisun, San Pablo, and San Francisco bays.												
On an annual basis, update the Office of Oil Spill Prevention and Response's Environmental Sensitivity Index maps and GIS maps to include the most current information on locations of sensitive or valued existing or restored subtidal habitats	3	SFB-3.2	WRCS, SRCS, STE	CDFW	3	Long-term	$0	$0	$0	$0	$0	$0

5.4 Delta Recovery Actions

Table 5-4. Delta Recovery Actions. Adaptively manage these suite of actions to achieve, at a minimum, through-Delta survival objectives of 57% for winter-run, 54% for spring-run, and 59% for steelhead originating from the Sacramento River; and 38% for spring-run and 51% for steelhead originating from the San Joaquin River (NMFS 2012b).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop, implement, and enforce new Delta flow objectives that mimic historic natural flow characteristics, including increased freshwater flows (from both the Sacramento and San Joaquin rivers) into and through the Delta and more natural seasonal and interannual variability.	1	DEL-1.1	WRCS, SRCS, STE	BDCP agencies and stake holders	1	Long-term, beginning in year 5	$0	$0	$0	$0	$0	$0
Reduce hydrodynamic and biological impacts of exporting water through Jones and Banks pumping plants.	1	DEL-1.2	WRCS, SRCS, STE	USBR, DWR, CDFW, NMFS	1	Long-term						$8.6 billion to $14.5 billion in capital costs (Stapler 2013); $85 million/year operating cost (Medellín-Azuara *et. al* 2013)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Provide pulse flows of approximately 17,000 cfs or higher as measured at Freeport periodically during the winter-run emigration season (i.e., December-April) to facilitate outmigration past Chipps Island.	1	DEL-1.3	WRCS, SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR, SWRCB	1	Long-term	$0	$0	$0	$0	$0	$0
Conduct landscape-scale restoration of ecological functions throughout the Delta to support native species and increase long-term overall ecosystem health and resilience (Whipple *et al*. 2012).	1	DEL-1.4	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	Long-term						$600 million to $13 billion

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop and implement a targeted research and monitoring program to better understand the behavior, movement, and survival of steelhead, spring-run Chinook salmon, and winter-run Chinook salmon emigrating through the Delta from the Sacramento and San Joaquin rivers.	1	DEL-1.5	WRCS, SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	5	Long-term, up to 50 years						$627 million over 50 years[16].

[16] This number is derived from the total estimated cost of monitoring and research as identified in the May 2013 administrative draft of BDCP. It is assumed that the cost estimate provided for BDCP research and monitoring provides a very rough approximation of the cost of action DEL-1.7.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Provide access to new floodplain habitat in the South Delta for migrating salmonids from the San Joaquin system.	1	DEL-1.6	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~20 years						~$950,000,000 [17]
Restore, improve and maintain salmonid rearing and migratory habitats in the Delta and Yolo Bypass to improve juvenile salmonid survival and promote population diversity.	1	DEL-1.7	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	Long-term						Cost of this action is covered by actions DEL – 1.5 and DEL – 1.6.
Restore 17,000 to 20,000 acres of floodplain habitat (NMFS 2009b).	1	DEL-1.8	WRCS, SRCS, STE	USBR, DWR	1	Year 1 through 25	$0	$0	$0	$0	$0	$0

[17] Assumes relocation of approximately 40 miles of existing lower San Joaquin River area levees over 50 years; cost estimate and associated assumptions taken from BDCP revised administrative draft dated May 2013

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Restore Liberty Island, Cache Slough, and the lower Yolo bypass (NMFS 2009b).	1	DEL-1.9	WRCS, SRCS, STE	USBR, DWR	1	Year 1 through 25	$0	$0	$0	$0	$0	$0
Enhance floodplain habitat in lower Putah Creek and along the toe drain (NMFS 2009b).	1	DEL-1.10	WRCS, SRCS, STE	USBR, DWR	1	Year 1 through 25	$0	$0	$0	$0	$0	$0
Implement the Putah Creek Enhancement Project (NMFS 2009b).	1	DEL-1.11	WRCS, SRCS, STE	USBR, DWR	1	Year 1 through 25	$0	$0	$0	$0	$0	$0
Implement the Lisbon Weir Fish Passage Enhancement Project (NMFS 2009b).	1	DEL-1.12	WRCS, SRCS, STE	USBR, DWR	1	Year 1 through 25	$0	$0	$0	$0	$0	$0
Implement the Prospect Island Tidal Habitat Restoration Project.	1	DEL-1.13	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	$16 million	$16 million				$32 million (Riordan 2013) Cost covered by Fish Restoration Program Agreement between CDFW and DWR.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement the Chipps Island Tidal Marsh Restoration Project.	1	DEL-1.14	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	TBD	TBD				<= $15 million[18]
Implement the Eastern Decker Island Tidal Marsh Restoration Project.	1	DEL-1.15	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	TBD	TBD				TBD, based on area of restoration and whether cost can be offset by re-use of excavated material[19]

[18] Chipps Island has 732 acres available for restoration; assuming $20,100/acre for tidal marsh restoration, the maximum cost estimate is roughly $15 million.

[19] Decker Island was formed in the early 1900s when dredged material from the Sacramento River was deposited there. As such, the island is one of the highest places above sea level in the Delta. Restoration of Decker Island to provide fish habitat will involve considerable excavation, and there may or may not be value associated with the excavated material.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement the Southport Floodplain Restoration Project.	1	DEL-1.16	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	$55-$160 million (West Sacramento Area Flood Control Agency 2011)					$55-$160 million (West Sacramento Area Flood Control Agency 2011)
Implement the Dutch Slough Tidal Marsh Restoration Project.	1	DEL-1.17	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	$25 - $30 million in 2005 dollars (California State Coastal Conservancy 2006)					$25 - $30 million in 2005 dollars (California State Coastal Conservancy 2006)
Minimize the frequency, magnitude, and duration of reverse flows in Old and Middle River to reduce the likelihood that fish will be diverted from the San Joaquin or Sacramento rivers into the southern or central Delta (NMFS 2009b).	1	DEL-1.18	WRCS, SRCS, STE	USBR, DWR	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Continue to evaluate head of Old River barrier operations to identify and then implement the best alternative for maximizing survival of juvenile steelhead and spring-run Chinook salmon emigrating from the San Joaquin River.	1	DEL-1.19	WRCS, SRCS, STE	USBR, DWR	1	Short-term	$0	$0	$0	$0	$0	$0
Modify Delta Cross Channel gate operations and evaluate methods to control access to Georgiana Slough and other migration routes into the Interior Delta to reduce diversion of listed juvenile fish from the Sacramento River and the San Joaquin River into the southern or central Delta (NMFS (2009b).	1	DEL-1.20	WRCS, SRCS, STE	USBR, DWR	1	Year 1 through 25	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Through additional releases in the San Joaquin River system, augment flows in the southern Delta and curtail exports during critical migration periods (April-May), consistent with a ratio or similar approach.	1	DEL-1.21	WRCS, SRCS, STE	USBR, DWR, MID, Turlock Irrigation District, SWRCB	1	Long-term	$0	$0	$0	$0	$0	$0, no additional cost because additional releases will likely occur via SWRCB water quality objectives; and the export curtailments already occur through the RPA in the CVP/SWP Biological Opinion (NMFS 2009b)
Curtail exports when protected fish are observed at the export facilities to reduce mortality from entrainment and salvage (NMFS (2009b).	1	DEL-1.22	WRCS, SRCS, STE	USBR, DWR	1,5	Year 1 through 25	$0	$0	$0	$0	$0	$0
Improve fish screening and salvage operations to reduce mortality from entrainment and salvage (NMFS (2009b).	1	DEL-1.23	WRCS, SRCS, STE	USBR, DWR	1,5	Year 1 through 25	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Establish a Delta operations technical group to assist in determining real-time operational measures, evaluating the effectiveness of the actions, and modifying them if necessary (NMFS (2009b).	1	DEL-1.24	WRCS, SRCS, STE	USBR, DWR	1,5	Year 1 through 25	$0	$0	$0	$0	$0	$0
Implement the USEPA's Action Plan for addressing water quality concerns in the Bay/Delta (USEPA 2012).	1	DEL-1.25	WRCS, SRCS, STE	USEPA, SWRCB	1,5	Long-term						TBD[20]
Design and implement a project(s) to: (1) allow adult salmonids (and sturgeon) from the Sacramento Deep Water Ship Channel	1	DEL-1.26	WRCS, SRCS, STE	Corps	1	Short-term	TBD; this action requires a yet to be determined unique engineering solution. Initial feasibility	TBD				TBD; this action requires a yet to be determined unique engineering solution. Initial feasibility

[20] The action plan contains seven components, six of which have dedicated funding and would result in no additional cost. A component calling for advanced water quality monitoring and assessment will require some additional funding, but it was not practicable until the multiple entities involved in this component have coordinated to conduct a funding assessment; a funding assessment for this component is planned.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
(SDWSC) to pass the channel gates and enter the Sacramento River (or block adult salmonids from entering the SDWSC); and (2) minimize fish passage from the Sacramento River into the SDWSC.							study is assumed to cost at least $50,000.					study is assumed to cost at least $50,000.
Identify and implement projects designed to improve passage and habitat conditions in the Stockton Deep Water Ship Channel.	1	DEL-1.27	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1	Long-term	$0	$0	$0	$0	$0	$0
Implement projects to minimize predation at weirs, diversions, and related structures in the Delta.	1	DEL-1.28	WRCS, SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	3	Long-term	$5 million	$5 million	$5 million	$5 million	$5 million	$50 million over 50 years (BDCP 2013)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Establish Vernalis flow criteria that incorporate the flow schedules of the San Joaquin River and tributaries in order to increase juvenile salmonid outmigration survival.	1	DEL-1.29	WRCS, SRCS, STE	USBR, DWR, CDFW, NMFS, USFWS, MID, TID, SWRCB	1	Long-term	$0	$0	$0	$0	$0	$0
Implement integrated flood control improvements along McCormack-Williamson Tract that benefit flood management, aquatic and terrestrial habitats, and species and ecological processes.	2	DEL-2.1	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	$5,000,000	$5,000,000	$0	$0	$0	$10,000,000
Implement restoration projects for Lindsey and Barker sloughs.	2	DEL-2.2	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	$400,000 to $3,400,000 (Solano Land Trust *et al*. 2006)					$400,000 to $3,400,000 (Solano Land Trust *et al*. 2006)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Evaluate the potential effects of reconnecting Elk Slough to the Sacramento River, and if the evaluation suggests that habitat conditions for salmonids would improve, then implement a project to carry out the reconnection (Siegel 2007).	2	DEL-2.3	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	$2,600,000	$2,600,000	$0	$0	$0	$5,200,000
Improve habitat for juvenile salmonids in Elk, Sutter, and Steamboat sloughs (Siegel 2007).	2	DEL-2.4	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	TBD, based on type and extent of habitat improvements ; initial study is expected to cost at least $50,000.	TBD				TBD, based on type and extent of habitat improvements; initial study is expected to cost at least $50,000.
Re-establish hydrologic connectivity between historical Stone Lakes floodplain and the Sacramento River with a design that minimizes juvenile stranding.	2	DEL-2.5	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	TBD; unaware of similar projects to base cost on; initial feasibility study would cost at least $50,000	TBD				TBD; unaware of similar projects to base cost on; initial feasibility study would cost at least $50,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Restore tidal wetlands and associated habitats at Brannan Island State Park, northeast tip of Sherman Island, along Seven-Mile slough, and the southwest tip of Twitchell Island.	2	DEL-2.6	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	TBD, based on type and extent of habitat improvements; initial study is expected to cost at least $50,000.	TBD				TBD, based on type and extent of habitat improvements; initial study is expected to cost at least $50,000.
Implement the Grizzly Slough Floodplain and Riparian Habitat Restoration Project.	2	DEL-2.7	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years						$250,000 - $4,000,000[21]

[21] DWR website identifies 50 additional acres for floodplain restoration at Grizzly Slough (http://www.water.ca.gov/floodsafe/fessro/environmental/dee/grizzlyslough.cfm).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement the Meins Landing Tidal Habitat Restoration Project.	2	DEL-2.8	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	TBD, based on extent and type of habitat restoration; initial study is expected to cost at least $50,000.	TBD				TBD, based on extent and type of habitat restoration; initial study is expected to cost at least $50,000.
Implement the Hill Slough Tidal Habitat Restoration Project.	2	DEL-2.9	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	TBD, based on extent and type of habitat restoration; initial study is expected to cost at least $50,000.	TBD				TBD, based on extent and type of habitat restoration; initial study is expected to cost at least $50,000.
Implement the Tule Red Restoration Project.	2	DEL-2.10	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	TBD, based on extent and type of habitat restoration; initial study is expected to cost at least $50,000.	TBD				TBD, based on extent and type of habitat restoration; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement the Rush Ranch Tidal Habitat Restoration Project.	2	DEL-2.11	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS	1	~10 years	TBD, based on extent and type of habitat restoration; initial study is expected to cost at least $50,000.	TBD				TBD, based on extent and type of habitat restoration; initial study is expected to cost at least $50,000.
Evaluate whether predator control actions (e.g., fishery management or directed removal programs) can be effective at minimizing predation on juvenile salmon and steelhead in the Delta.	2	DEL-2.12	WRCS, SRCS, STE	CDFW, Sport fishing community	3	Long-term						Cost covered by the cost of SFB-2.5 ($0-$75,000,000).
Modify existing water control structures to maintain flows through isolated ponds in the Yolo Bypass to minimize fish stranding, particularly following the cessation of flood flows over the Fremont Weir.	2	DEL-2.13	WRCS, SRCS, STE	TCCA, USBR, DWR, CDFW, NMFS, USFWS	1	Short-term	TBD, based on type and number of modifications; initial study is expected to cost at least $50,000.	TBD				TBD, based on type and number of modifications; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Modify Reclamation District 2068 levees to provide rearing and predator refuge habitat for juvenile salmonids.	2	DEL-2.14	WRCS, SRCS, STE	Corps	1	~10 years	TBD	TBD				TBD based on the amount and type of habitat to be restored.
Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap.	2	DEL-2.15	WRCS, SRCS, STE	Corps	1	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement to stop illegal rip rap applications in the Delta.	2	DEL-2.16	WRCS, SRCS, STE	CDFW, NMFS, Corps	1,4	Long-term						Cost is covered under action # COC-2.9 ($1,750,000)
Curtail further development in active Delta floodplains through zoning restrictions, county master plans and other Federal, State, and county planning and regulatory processes, and land protection agreements.	2	DEL-2.17	WRCS, SRCS, STE	Contra Costa, Solano, Yolo, Sacramento, and San Joaquin counties. DRN, DSC	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Prioritize and screen Delta diversions.	2	DEL-2.18	WRCS, SRCS, STE	DSC, DRN, Corps, DWR, USBR, USFWS, CDFW, NMFS, local counties	1	Long-term	$100,000 for monitoring program; screening costs for Delta Diversions are TBD.	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).
Implement management actions for addressing invasive aquatic species including those described in the California Aquatic Invasive Species Management Plan.	2	DEL-2.19	WRCS, SRCS, STE	Departme nt of Boating and Waterway s	1	Long-term	$51,000,000	$125,000,000	$125,000,000	$125,000,000	$125,000,000	$551,000,000
Implement projects that improve wastewater and stormwater treatment throughout the Delta and surrounding residential and commercial areas.	2	DEL-2.20	WRCS, SRCS, STE	NMFS, USFWS, SWRCB, CVRWCB , DWR, CDFW, Local governme nts	1, 5	Long-term						Cost is covered under action SFB-2.3 ($1 - $2 billion by 2020 to upgrade Sacramento County Regional Water Treatment Plant to reduce discharge limits for

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												nitrogen, ammonia and pathogens[22]).
Review and potentially update the through-Delta survival rate objectives included in this recovery plan as new information is obtained.	2	DEL-2.21	WRCS, SRCS, STE	NMFS, CDFW, DSC, USFWS	1	Long-term	$0	$0	$0	$0	$0	$0
Develop regional agreements on geographic boundaries for estimating through-Delta survival, and appropriate technologies for collecting the required empirical data.	2	DEL-2.22	WRCS, SRCS, STE	NMFS, CDFW, DSC, USFWS	5	Long-term	$0 for agreement development; TBD for technology development	$0 for agreement development; TBD for technology development	$0 for agreement development; TBD for technology development	$0 for agreement development; TBD for technology development	$0 for agreement development; TBD for technology development	$0 for agreement development; TBD for technology development

[22] Source: Sacramento Business Journal; http://www.bizjournals.com/sacramento/news/2012/12/05/state-water-sacramento-waste-water-treat.html

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Explore and support the development of existing or innovative approaches and tools for centralized tracking of restoration efforts in the Delta.	2	DEL-2.24	WRCS, SRCS, STE	Delta Conservancy, DWR, USBR, CDFW, NMFS Delta land owners	1,5	Long-term	$0	$0	$0	$0	$0	$0
Coordinate efforts to identify and highlight funding needs for restoration planning, monitoring, tracking, synthesis and adaptive management in the near and long term.	2	DEL-2.25	WRCS, SRCS, STE	Delta Conservancy, DWR, USBR, CDFW, NMFS Delta land owners	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop outreach strategies and mechanisms to ensure the Delta community, the legislature, appropriate agencies and the public are regularly updated on actions related to restoration and recovery.	2	DEL-2.26	WRCS, SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR, Various NGOs	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop and implement education and outreach programs to encourage river stewardship.	2	DEL-2.27	WRCS, SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR, Various NGOs	1,5	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Cities, counties, districts, joint powers authority or other political subdivisions involved with water management should implement agricultural drainage management projects to treat, store, convey, and/or dispose of agricultural drainage.	2	DEL-2.28	WRCS, SRCS, STE	CVRWQ CB, Delta farmers	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on the number of farmed acres that need drainage improvements in order to comply with CVRWQCB regulations. The cost estimates for management practices may range from less than $20/acre to greater than $110/acre per year (CVRWQCB 2012)
Continue development of a long-term strategy for monitoring and regulating discharges from agricultural lands to protect waters within the Central Valley, including	2	DEL-2.29	WRCS, SRCS, STE	CVRWQ CB	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
enforcing the regulations.												
Increase monitoring and enforcement in the Delta to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants (SWRCB 2007).	2	DEL-2.30	WRCS, SRCS, STE		1,5	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)
Implement projects that would reduce anthropogenic inputs of NH4 to help achieve concentrations below 4 µmol L-1 in order to promote increased primary and secondary production (Dugdale *et al*. 2007).	2	DEL-2.31	WRCS, SRCS, STE	Sacramento Regional County Sanitation District	1	Long-term						Cost is covered under action SFB-2.3 ($1 to $2 billion by 2020).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Continue to operate the Suisun Marsh Salinity Control Structure with the boat lock open in order to allow fish passage in and out of Suisun Marsh.	3	DEL-3.1	WRCS, SRCS, STE	DWR and USBR	1,5	Long-term	$0	$0	$0	$0	$0	$0

5.5 Mainstem Sacramento River Recovery Actions

Table 5-5. Mainstem Sacramento River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop and implement a program to reintroduce winter-run Chinook salmon, spring-run Chinook salmon, and steelhead to historic habitats upstream of Shasta Dam. The program should include feasibility studies, habitat evaluations, fish passage design studies, and a pilot reintroduction phase prior to implementation of the long-term reintroduction program.	1	SAR-1.1	WRCS, SRCS, STE	USBR, NMFS, CDFW, DWR, USFWS, PG&E, FERC	1,5	Long-term:	$200,000	$4,000,000	$15,000,000	$17,000,000	$14,000,000	$50,200,000
Restore and maintain riparian and floodplain ecosystems along both banks of the Sacramento River to provide a diversity of habitat types including riparian forest, gravel bars and bare cut banks, shady vegetated banks, side	1	SAR-1.2	WRCS, SRCS, STE	USBR, NMFS, CDFW, DWR, USFWS	1,4	~10 years	$19,532,500	$22,579,570	$0	$0	$0	$42,112,070

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
channels, and sheltered wetlands, such as sloughs and oxbow lakes following the guidance of the Sacramento River Conservation Area Handbook (Resources Agency of the State of California 2003).												
Identify and implement any required projects to assure the M&T Ranch water diversion is adequately screened to protect winter-run Chinook salmon, spring-run Chinook salmon, and steelhead.	1	SAR-1.3	WRCS, SRCS, STE	NMFS, USBR, USFWS, and M&T Ranch	1,5	< 5 years	$9,500,000	$0	$0	$0	$0	$9,500,000
Develop and implement a river flow management plan for the Sacramento River downstream of Shasta and Keswick dams that considers the effects of climate change and balances beneficial uses with the flow and water temperature	1	SAR-1.4	WRCS, SRCS, STE	NMFS, USBR, USFWS, DWR, CDFW	1,5	Short-term	$740,150	$0	$0	$0	$0	$740,150

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
needs of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead. The flow management plan should consider the importance of instream flows as well as the need for floodplain inundation (Williams *et al*. 2009).												
Install NMFS-approved, state-of-the-art fish screens at the Tehama Colusa Canal diversion. Implement term and condition 4c from the biological opinion on the Red Bluff Pumping Plant Project, which calls for monitoring, evaluating, and adaptively managing the new fish screens at the Tehama Colusa Canal diversion to ensure the screens are working properly and impacts to listed species are minimized (NMFS	1	SAR-1.5	WRCS, SRCS, STE	DWR, USBR, TCCA	1,4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
2009c).												
Develop and implement a long-term gravel augmentation plan consistent with CVPIA to increase and maintain spawning habitat for winter-run Chinook salmon, spring-run Chinook salmon, and steelhead downstream of Keswick Dam.	1	SAR-1.6	WRCS, SRCS, STE	CDFW, NMFS, USBR, USFWS	1,5	Long-term	$380,000	$439,280	Up to ~$500,000	Up to ~$500,000	Up to ~$500,000	Up to ~$2,319,280
Develop and implement a secondary fish trapping location for the Livingston Stone NFH winter-run Chinook salmon supplementation	1	SAR-1.7	WRCS, SRCS, STE	NMFS, USFWS, USBR	1,5	Long-term						Up to $27,400,000 to build secondary facility[23]; Assuming the facility will require two to ten FTE's, operational costs

[23] The Minto Salmon and Steelhead Collection Facility on western Oregon's North Santiam River was rebuilt at a cost of $27,400,000 (http://www.cbbulletin.com/426310.aspx).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
program to provide increased opportunity to capture a spatially representative sample and target numbers of broodstock.												will range from approximately $138,600 to $693,000 per year[24]
Study the merits and investigate feasibility of modifying the altered channel morphology at Turtle Bay in Redding to eliminate the gravel "sink" created by historic gravel mining activities. If the study suggests that it is feasible to modify the channel morphology such that it is beneficial to spawning gravel augmentation efforts, then implement the channel modification project.	1	SAR-1.8	WRCS, SRCS, STE	USFWS, NMFS, DFG, USBR	1	Long-term	>$110,000					>$110,000[25]

[24] Based on the May 2012 State Occupational Employment and Wage Estimates for California provided by the Bureau of Labor Statistics, the mean annual wage for a biologist is $69,000 (http://www.bls.gov/oes/current/oes_ca.htm#19-0000).

[25] A channel morphology study on the Yuba River was estimated at between $110,000 and $150,000; because action SAR-1.8 calls for studying the channel morphology and potentially modifying the channel, the Turtle Bay action will be at least as expensive as the Yuba project.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Investigate mechanisms to influence/stimulate anadromy in *O. mykiss* in the upper Sacramento River.	1	SAR-1.9	STE	NMFS SWRFSC, CDFW	1,5	~5 years	$100,000 - $1,000,000	$0	$0	$0	$0	$100,000 - $1,000,000
Operate and maintain temperature control curtains in Lewiston and Whiskeytown Reservoirs to minimize warming of water from the Trinity River and Clear Creek.	1	SAR-1.10	WRCS, SRCS, STE	USBR	1,5	Long-term	$150,000 for inspections. Up to $~17,000 to repair one rip in the curtain; repair cost TBD based on inspections	$150,000 for inspection. Up to $~17,000 to repair one rip in the curtain; repair cost TBD based on inspections	$150,000 for inspection. Up to $~17,000 to repair one rip in the curtain; repair cost TBD based on inspections	$150,000 for inspection. Up to $~17,000 to repair one rip in the curtain; repair cost TBD based on inspections	$150,000 for inspection. Up to $~17,000 to repair one rip in the curtain; repair cost TBD based on inspections	$750,000 for inspection; repair costs TBD based on inspections. Whiskeytown curtain was replaced in 2012 at a cost of $3.5 million. Replacement needed roughly every 15 years. Lewiston curtain is less susceptible to damage than Whiskeytown, but if it needs to be replaced, cost would be ~$1.5 million.
Avoid full power peaking at Trinity and Carr Power plants during sensitive periods for water temperatures to reduce water temperatures in the Sacramento River. Evaluate impacts of power	1	SAR-1.11	WRCS, SRCS, STE	USBR, USFWS, NMFS	5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD; NMFS is in the process of obtaining the information from USBR.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
peaking operations in the Trinity River, Sacramento River and Clear Creek.												
In an adaptive management context, implement short- and long-term solutions to minimize the loss of adult Chinook salmon and steelhead in the Yolo bypass, and Colusa and Sutter-Butte basins. Solutions include: • Re-operating, to the extent feasible, the Knights Landing outfall gates to help prevent listed fish from entering the Colusa Basin (short-term); • Monitoring the Colusa and Sutter-Butte basins during winter and spring for adult salmon presence, and conducting fish rescues as necessary (short-term);	1	SAR-1.12	WRCS, SRCS, STE	CDWF, DWR, USFWS, NMFS, USBR, GCID, RD 108	1	Short- and long-term components	If fish rescues are needed, cost is estimated at ~$100,000 based on the 2013 rescue. Providing and/or improving fish passage through the Yolo Bypass and Sutter Bypass is required by the 2009 CVP/SWP biological opinion and therefore is estimated at $0. NMFS is in the process of obtaining cost information for this	Same as for FY1-5.	Same as for FY1-5.	Same as for FY1-5.	Same as for FY1-5.	If fish rescues are needed, cost is estimated at ~$100,000 based on the 2013 rescue. Providing and/or improving fish passage through the Yolo Bypass and Sutter Bypass is required by the 2009 CVP/SWP biological opinion and therefore is estimated at $0. NMFS is in the process of obtaining cost information for this action from DWR

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
• Evaluating other potential Colusa Basin Drain entry points for adult salmon along the Sacramento River above Knights Landing, and implementing fish exclusion solutions if necessary (short-term); • Providing and/or improving fish passage through the Yolo Bypass and Sutter Bypass allowing for improved adult salmonid re-entry into the Sacramento River (long-term); and • Installing fish exclusion devices at strategic locations to reduce migration of listed, adult salmonids into the Colusa Basin Drain complex (long-term); locations include,							action from DWR					

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
but are not limited to: • in the Yolo Bypass Tule Canal or Knights Landing Ridge Cut, downstream of Wallace Weir; • just upstream of the Knights Landing outfall gates (Colusa Basin side), provided that the reoperation of the Knights Landing outfall gates and/or the exclusionary device downstream of Wallace Weir fail to block migration of adults into the Colusa Basin Drain; and • at the Knights Landing outfall gates (Sacramento River side), provided that the reoperation of the Knights Landing outfall gates is ineffective.												
Identify management targets for Yolo and Sutter bypass inundation timing,	1	SAR-1.13	WRCS, SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR,	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
frequency, magnitude, and duration that will maximize the growth and survival of juvenile winter-run Chinook salmon and spring-run Chinook salmon; and then manage the bypasses to those targets.				SWRCB								
Ensure that river bank stabilization projects along the Sacramento River utilize bio-technical techniques that restore riparian habitat, rather than solely using the conventional technique of adding rip rap.	2	SAR-2.1	WRCS, SRCS, STE	Corps, USBR, NMFS, USFWS, DWR, CDFW,	1,5	Long-term	$0	$0	$0	$0	$0	$0
Curtail further development in active Sacramento River floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	2	SAR-2.2	WRCS, SRCS, STE	Corps, NMFS, USFWS, DWR, CDFWS, Local governments	1,4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Increase monitoring and enforcement to minimize illegal streambank alterations along the Sacramento River.	2	SAR-2.3	WRCS, SRCS, STE	Corps, SWRCB, CDFW	1,5	Long-term						Cost is covered under action # COC-2.9
Develop and implement education and outreach programs to encourage river stewardship along the Sacramento River. Implement outreach projects to educate the public regarding the salmon life cycle including how to identify a salmon redd.	2	SAR-2.4	WRCS, SRCS, STE	USBR, NMFS, USFWS, CDFW, DWR, Various NGOs	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Improve wastewater and stormwater treatment in residential, commercial, and industrial areas within the Sacramento River watershed.	2	SAR-2.5	WRCS, SRCS, STE	NMFS, USFWS, SWRCB, CVRWCB, DWR, CDFW, Local governments	1, 5	Long-term						Cost partially covered in DEL-2.20 ($1-$2 billion). Other costs TBD based on site-specific evaluations, each of which could range up to $100,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Increase monitoring and enforcement to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants entering the Sacramento River.	2	SAR-2.6	WRCS, SRCS, STE	Corps, SWRCB, USBR, CDFW	4,5	Long-term	$350,000[26]	$350,000	$350,000	$350,000	$350,000	$1,750,000
Develop a long-term strategy for reducing water quality impacts to the Sacramento River from agricultural lands. The strategy should include incentive-based projects to promote implementation of best management practices as well as enforcement actions to ensure compliance with existing regulations.	2	SAR-2.7	WRCS, SRCS, STE	SWRCB, CVRWQCB, USEPA	5	Long-term	$0	$0	$0	$0	$0	$0

[26] Assuming 1 new full time equivalent at $70,000/year, based on the average salary for a California Fish and Game warden as identified on the Bureau of Labor statistics website (http://www.bls.gov/oes/current/oes_ca.htm#19-0000).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement projects that promote native riparian (e.g., willows) species including eradication projects for non-native species (e.g., Arundo, tamarisk).	2	SAR-2.8	WRCS, SRCS, STE	NMFS, USBR Districts, DWR, Corps	5	Long-term	$0	$0	$0	$0	$0	$0
Implement studies designed to quantify the amount of predation on winter-run Chinook salmon, spring-run Chinook salmon, and steelhead by non-native species in the Sacramento River. If the studies identify predator species and/or locations contributing to low salmonid survival, then evaluate whether predator control actions (e.g., fishery management or directed removal programs) can be effective at minimizing predation on juvenile salmon and steelhead in	2	SAR-2.9	WRCS, SRCS, STE	NMFS SWRFSC, CDFW	2	Long-term						Cost covered by the cost of SFB-2.5 ($0-$75,000,000).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
the Sacramento River; continue implementation if effective.												
Implement projects to minimize predation at weirs, diversions, and related structures in the Sacramento River.	2	SAR-2.10	WRCS, SRCS, STE	NMFS, CDFW, DWR, USFWS, USBR, Corps	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												cost about $38,000 annually (BDCP 2013).
Improve instream refuge cover in the Sacramento River for salmonids to minimize predatory opportunities for striped bass and other non-native predators.	2	SAR-2.11	WRCS, SRCS, STE	USCOE, DWR, NMFS	1,3,4	Long-term	TBD, based on the # of sites, # of miles, type of material, location of source material (onsite vs. imported), and placement method. Initial scoping to address those issues would cost at least $50,000. See Table H1-2 in Appendix D for cost per unit for various projects.	TBD	TBD	TBD	TBD	TBD, based on the # of sites, amount of material needed, type of material, location of source material (onsite vs. imported), and placement method. Initial scoping to address those issues would cost at least $50,000. See Table H1-2 in Appendix D for cost per unit for various projects.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop an incentive-based entrainment monitoring program in the Sacramento River designed to work cooperatively with diverters to develop projects or actions in order to minimize pumping impacts.	2	SAR-2.12	WRCS, SRCS, STE	USFWS, USBR, Family Alliance, DWR, CDFW, farmers, local govt, Northern California Water Association	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop and apply alternative diversion technologies that reduce entrainment.	2	SAR-2.13	WRCS, SRCS, STE	USBR and agricultural interests	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD. •This action involves development of a new technology such that is impracticable to provide a reasonable estimate of the action's cost.
Maintain remedial actions to reduce heavy metal containments from Iron Mountain Mine.	2	SAR-2.14	WRCS, SRCS, STE	USEPA, NMFS, DFG, USBR	5	Long-term	$0	$0	$0	$0	$0	$0
Restore the current Lake Red Bluff footprint to riparian habitat, consistent with flood control needs.	2	SAR-2.15	WRCS, SRCS, STE	USFS, USBR, USFWS	1	Short-term	$5,000-$6,750,000, depending on whether just a small portion or the entire footprint is restored.	$0	$0	$0	$0	$5,000-$6,750,000, depending on whether just a small portion or the entire footprint is restored.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop criteria and a process for phasing out the Livingston Stone winter-run Chinook salmon hatchery program as winter-run recovery criteria are reached. This hatchery program is expected to play a continuing role as a conservation hatchery to help recover winter-run Chinook salmon.	2	SAR-2.16	WRCS, SRCS, STE	USFWS, NMFS, CDFW	5	Short-term	$0	$0	$0	$0	$0	$0
Evaluate and reduce stranding of juvenile Chinook in side channels in the reach from Keswick Dam to Colusa, due to flow reductions from Keswick Reservoir, by increasing or stabilizing releases from the reservoir.	2	SAR-2.17	WRCS, SRCS, STE	USBR, USFWS, DFG	1,5	Short-term	$0	$0	$0	$0	$0	$0
Using an adaptive approach and pilot studies, determine if instream habitat for juvenile rearing is limiting salmonid populations, by placing juvenile-rearing-enhancement	2	SAR-2.18	WRCS, SRCS, STE	NMFS SWRFSC, DFG, USFWS	1	Short-term	TBD based on the scope of pilot and full studies; pilot study is assumed to cost at least $50,000; overall cost	TBD	$0	$0	$0	TBD based on the scope of pilot and full studies; pilot study is assumed to cost at least $50,000; overall cost will also depend on the amount and type of instream habitat that is

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
structures in the Sacramento River. If found to be limiting, add large woody debris / coarse organic material to the upper, middle and lower reaches of Sacramento River to increase the quantity and quality of juvenile rearing habitat.							will also depend on the amount and type of instream habitat that is restored, if any.					restored, if any.
Assess the impacts to development, migration, and predation on juvenile salmonids from artificial light sources (e.g., Sundial Bridge) and take appropriate action based on the findings.	2	SAR-2.19	WRCS, SRCS, STE	DFG, local govt.	1,5	Short-term	$0	$0	$0	$0	$0	$0

5.6 Northwestern California Diversity Group Recovery Actions

5.6.1 Clear Creek Recovery Actions

Table 5-6. Clear Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration (years)	~Cost FY 1-5	~Cost FY 6-10	~Cost FY 11-15	~Cost FY 16-20	~Cost FY 21-25	Total ~Cost
Operate the Clear Creek segregation weir to create reproductive isolation between fall-run Chinook salmon and spring-run Chinook salmon.	1	CLC -1.1	SRCS STE	USFWS	1,4	Long-term	$0	$0	$0	$0	$0	$0
Develop a new spawning gravel budget and implement a long-term gravel augmentation plan in Clear Creek, including acquisition of a long-term gravel supply (per CVPIA and RPA action I.1.3 of the 2009 Biological Opinion for the long-term operations of the CVP and SWP (NMFS 2009b).	1	CLC -1.2	SRCS STE	USBR, USFWS	1,5	Long-term	$0	$0	$0	$0	$0	$0
Manage releases from Whiskeytown Dam with instream flow schedules and criteria to provide suitable water temperatures for all life stages, reduce stranding and isolation, protect incubating eggs from being dewatered, and promote habitat quality and availability as described in RPA action I.1.6 of the 2009 Biological Opinion for the long-term operations of the CVP and SWP (NMFS 2009b).	1	CLC -1.3	SRCS STE	USBR, USFWS, Clear Creek Technical Team	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration (years)	~Cost FY 1-5	~Cost FY 6-10	~Cost FY 11-15	~Cost FY 16-20	~Cost FY 21-25	Total ~Cost
Develop water temperature models to improve Clear Creek water temperature management as described in RPA action I.1.5 of the 2009 Biological Opinion for the long-term operations of the CVP and SWP (NMFS 2009b).	1	CLC -1.4	SRCS STE	USBR, USFWS, NMFS	5	Short-term	$0	$0	$0	$0	$0	$0
Adaptively manage Whiskeytown Reservoir releases and water temperatures to evaluate whether anadromy in *O. mykiss* can be increased, without causing adverse impacts to other species.	1	CLC -1.5	STE	USBR, USFWS, NMFS	1	Long-term	$0	$0	$0	$0	$0	$0
Implement channel maintenance flows in Clear Creek called for in the CVP/SWP biological opinion (NMFS 2009b, Action I.1.2).	1	CLC -1.6	SRCS STE	USBR, USFWS, NMFS	1	Long-term	$0	$0	$0	$0	$0	$0
Enhance watershed resiliency in Clear Creek by identifying and implementing projects that would reduce the potential for, and magnitude of wildfires, including projects to restore meadows and forested areas.	2	CLC -2.1	STE	NMFS, USFWS, USBR, CDFW, BLM	1,5	Long-term	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBE	TBD	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.
Implement the Clear Creek pulse flows called for in the CVP/SWP biological opinion (NMFS 2009b, Action I.1.1), utilizing adaptive management to adjust pulse timing, magnitude, and/or duration, as needed, to be most effective at attracting adult spring-run Chinook salmon.	2	CLC -2.2	SRCS STE	USBR and Clear Creek Technical Team	1,4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration (years)	~Cost FY 1-5	~Cost FY 6-10	~Cost FY 11-15	~Cost FY 16-20	~Cost FY 21-25	Total ~Cost
Implement floodplain restoration projects, potentially including the Lower Clear Creek Floodway Rehabilitation Project (Phase 3C).	2	CLC -2.3	SRCS STE	Shasta Resource Conservation District, BLM, Lower Clear Creek Watershed Group, City of Redding	1,5	Part of the Lower Clear Creek Floodway Rehabilitation Project has been completed. Additional projects could occur over the next 10 years.	TBD, based on amount of floodplain habitat restored; initial study is expected to cost at least $50,000.	TBD	$0	$0	$0	TBD, based on amount of floodplain habitat restored; initial study is expected to cost at least $50,000.
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in Clear Creek.	2	CLC -2.4	SRCS STE	NMFS, Corps, USBR, Resource Conservancy, CDFW, DWR, BLM, Landowners, Local governments, NGOs	1,4,5	Short-term	$62,400	$0	$0	$0	$0	$62,400
Develop programs and implement projects for Clear Creek that promote natural river processes, including projects that restore floodplain habitat (e.g., Cloverview project and Paige Bar floodplain lowering project), add riparian habitat and instream cover, and control non-native invasive plant species.	2	CLC -2.5	SRCS STE	Corps, USFWS, DWR, CDFW, BLM, Local agencies, NGOs	1,5	Long-term	<$5,000,000	<$5,000,000	<$5,000,000	<$5,000,000	$0	<$20,000,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration (years)	~Cost FY 1-5	~Cost FY 6-10	~Cost FY 11-15	~Cost FY 16-20	~Cost FY 21-25	Total ~Cost
Develop education and outreach programs to encourage river stewardship in Clear Creek.	2	CLC-2.6	SRCS STE	USFWS, USFS, USEPA, Resource Conservation District, BLM, CDFW, Landowners	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Continue to minimize sources of sediment delivered to Clear Creek from roads and other near stream development by out-sloping roads, constructing diversion prevention dips, replacing under-sized culverts and applying other erosion prevention guidelines.	2	CLC-2.7	SRCS STE	NMFS, USFWS, USFS, CDFW, BLM	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop a long-term operation and maintenance agreement for the segregation weir in Clear Creek.	2	CLC-2.8	SRCS STE	NMFS, USFWS, SWRCB, BLM, CDFW, Local governments	1,5	Short-term	$0	$0	$0	$0	$0	$0
Ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met in Clear Creek for all potential pollutants.	3	CLC-3.1	SRCS STE	SWRCB, CVRWQCBs, Local agriculture groups	1,4	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration (years)	~Cost FY 1-5	~Cost FY 6-10	~Cost FY 11-15	~Cost FY 16-20	~Cost FY 21-25	Total ~Cost
Utilize bio-technical techniques that integrate riparian restoration into bank stabilization projects that may be implemented in the future, instead of conventional rip rap.	3	CLC -3.2	SRCS STE	Corps, USBR, NMFS, USFWS, BLM, CDFW, CBDA	1,5	Long-term	$0	$0	$0	$0	$0	$0
Curtail further development in active Clear Creek floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	3	CLC -3.3	SRCS STE	Corps, NMFS, USFWS, USFS, BLM, CDFW, Local governments	1,4,5	Long-term	$0	$0	$0	$0	$0	$0
Permanently protect Clear Creek riparian and floodplain habitat through easements and/or land acquisition.	3	CLC -3.4	SRCS STE	County, BLM,. CDFW, Tribal, Local owners	1,5	Long-term	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Monitor and evaluate the sport fishing regulations for Clear Creek to ensure they are consistent with the recovery of spring-run Chinook salmon and steelhead. Work with the Fish and Game Commission to modify the regulations as needed.	3	CLC -3.5	SRCS STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration (years)	~Cost FY 1-5	~Cost FY 6-10	~Cost FY 11-15	~Cost FY 16-20	~Cost FY 21-25	Total ~Cost
Negotiate agreements with Federal and State agencies to provide additional instream flows in Clear Creek.	3	CLC-3.6	SRCS STE	NMFS, Corps, USBR, Resource Conservation Districts, CDFW, DWR, Water districts, Landowners, Local governments, NGOs	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of water. Cost per unit is $43 - $88/af/year for upstream of Delta water purchases (Appendix D)

5.6.2 Cottonwood/Beegum Creek Recovery Actions

Table 5-7. Cottonwood/Beegum Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY 6-10	~ Cost FY 11-15	~ Cost FY 16-20	~ Cost FY 21-25	Total ~ Cost
Enhance watershed resiliency in Beegum Creek and the greater Cottonwood watershed by identifying and implementing projects that would reduce the potential for, and magnitude of a catastrophic wildfire, restore meadows to potentially increase summer flows and reduce local water temperatures, or increase riparian shade.	2	CBC-2.1	SRCS STE	NMFS, USFWS, USFS, CDFW, DWR, Cottonwood Creek Watershed Group	1,5	Long-term	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBE	TBD	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.
Develop and implement a spawning gravel augmentation plan in Beegum Creek.	2	CBC-2.2	SRCS STE	NMFS, USFWS, USFS, CDFW, DWR, Cottonwood Creek Watershed Group	1,5	Long-term	$50,000 for plan development; gravel augmentation costs TBD	TBD	TBD	TBD	TBD	$50,000-TBD
Protect/enhance existing riparian habitat and corridors in Beegum Creek and the greater Cottonwood watershed .	2	CBC-2.3	SRCS STE	NMFS, USFWS, USFS, CDFW, DWR, Cottonwood Creek Watershed Group	1	Long-term	$5,000-$50,000 for initial scoping; habitat protection costs TBD	TBD	TBD	TBE	TBD	$5,000-$50,000 for initial scoping; habitat protection costs TBD, based on amount of habitat protected or enhanced. As identified in Appendix D, per unit

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY 6-10	~ Cost FY 11-15	~ Cost FY 16-20	~ Cost FY 21-25	Total ~ Cost
												costs vary depending on whether fencing, planting, irrigation, or invasive weed control are needed.
Apply NMFS gravel mining criteria to all gravel mining projects in Beegum Creek and the greater Cottonwood watershed.	2	CBC-2.4	SRCS STE	NMFS, USFWS, USFS, CDFW, DWR, Cottonwood Creek Watershed Group	1,5	Long-term	$0	$0	$0	$0	$0	$0
Integrate riparian habitat restoration into bank protection and other stream side development projects in Beegum Creek and the greater Cottonwood watershed.	2	CBC-2.5	SRCS STE	NMFS, USFWS, USFS, CDFW, DWR, Cottonwood Creek Watershed Group	1	Long-term	$0	$0	$0	$0	$0	$0
Implement a non-native plant (e.g. Arundo) eradication plan in Beegum Creek and the greater Cottonwood watershed.	3	CBC-3.1	SRCS STE	NMFS, USFWS, USFS, CDFW, DWR, Cottonwood Creek Watershed Group	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY 6-10	~ Cost FY 11-15	~ Cost FY 16-20	~ Cost FY 21-25	Total ~ Cost
Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap in Beegum Creek and the greater Cottonwood watershed.	3	CBC-3.2	SRCS STE	NMFS, USFWS, USFS, CDFW, DWR, Cottonwood Creek Watershed Group	1	Long-term	$0	$0	$0	$0	$0	$0
Curtail further development in active Beegum and the greater Cottonwood watershed floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	3	CBC-3.3	SRCS STE	NMFS, USFWS, USFS, CDFW, DWR, Cottonwood Creek Watershed Group, Local governments	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop education and outreach programs to encourage river stewardship in the Beegum and the greater Cottonwood Creek watershed.	3	CBC-3.4	SRCS STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, CDFW, DWR, Landowners, Cottonwood Creek Watershed Group	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY 6-10	~ Cost FY 11-15	~ Cost FY 16-20	~ Cost FY 21-25	Total ~ Cost
Permanently protect Cottonwood and Beegum Creek riparian habitat through easements and/or land acquisition	3	CBC-3.5	SRCS STE	NMFS, USFWS, USFS, CDFW, DWR, Cottonwood Creek Watershed Group	1,5	Long-term	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the Cottonwood and Beegum watersheds.	3	CBC-3.6	SRCS STE	NMFS, USFWS, USFS, CDFW, Cottonwood Creek Watershed Group	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop cooperative water use agreements with landowners and Federal and State agencies to provide additional instream flows or purchase water rights in Cottonwood Creek.	3	CBC-3.7	SRCS STE	NMFS, Corps, USBR, Resource Conservation Districts, CDFW, DWR, Water districts, Landowners, Local governments, NGOs	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of water. Cost per unit is $43 - $88/af/year for upstream of Delta water purchases (Appendix D)
Develop a baseline monitoring program for Beegum Creek to evaluate water quality throughout the watershed to identify areas of concern.	3	CBC-3.8	SRCS STE	NMFS, USFWS, SWRCB, DWR, CDFW, Local governments	1,5	3 Years	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY 6-10	~ Cost FY 11-15	~ Cost FY 16-20	~ Cost FY 21-25	Total ~ Cost
Encourage voluntary landowner participation in Beegum Creek in educational opportunities such as water quality short courses, field demonstrations and distribution of water quality "Fact Sheets".	3	CBC-3.9	SRCS STE	NMFS, USFWS, USEPA, Resource Conservation Districts, CDFW, DWR, Landowners	2	Long-term	$32,260	$32,260	$32,260	$32,260	$0	$129,040
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in Beegum Creek.	3	CBC-3.10	SRCS STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW, Landowners	1,5	Short-term	$62,400	$0	$0	$0	$0	$62,400
Implement projects to minimize predation at weirs, diversion dams, and related structures in Cottonwood/Beegum Creek.	3	CBC-3.11	SRCS STE	NMFS, CDFW, DWR, USFWS, USBR, Corps	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY 6-10	~ Cost FY 11-15	~ Cost FY 16-20	~ Cost FY 21-25	Total ~ Cost
												identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013).
Improve instream refuge cover for salmonids in Cottonwood/Beegum Creek to minimize predatory opportunities for striped bass and other non-native predators.	3	CBC-3.12	SRCS STE	NMFS, USFWS, CDFW, DWR	1,3	Short-term	TBD, based on the # of sites, # of miles, type of material, location of source material (onsite vs. imported), and placement method. Cost of initial study to address these issues is $5,000-$50,000. See Table H1-2 in Appendix D for cost per unit for various projects.	$0	$0	$0	$0	TBD, based on the # of sites, amount of material needed, type of material, location of source material (onsite vs. imported), and placement method. Cost of initial study to address these issues is $5,000-$50,000. See Table H1-2 in Appendix D for cost per unit for various projects.
Implement projects to increase floodplain habitat availability in Beegum Creek and the greater Cottonwood watershed to improve juvenile rearing habitat	3	CBC-3.13	SRCS STE	NMFS, USFWS, CDFW, DWR	1	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of floodplain habitat restored. $5,000-$50,000 for initial scoping study.

5.6.3 Thomes Creek Recovery Actions

Table 5-8. Thomes Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Conduct a feasibility study on potential channel modifications that would improve upstream migration conditions in Thomes Creek.	3	THC-3.1	STE, SRCS	NMFS, USFWS, CDFW	1,5	5 Years	$50,000-$200,000					$50,000-$200,000
Design and implement a Thomes Creek anadromous fish passage study.	3	THC-3.2	STE, SRCS	NMFS, USFWS, CDFW	1,5	5 Years	$0	$0	$0	$0	$0	$0
Evaluate and improve passage at the Corning Canal siphon and at the two small seasonal push-up diversion dams near Paskenta and Henlyville.	3	THC-3.3	STE, SRCS	NMFS, USFWS, CDFW, DWR, Irrigation districts	1	5 years	$80,000-$382,000/project (CDFW 2004b)					$80,000-$382,000/project (CDFW 2004b)
Flow consolidation through reduction of braided channels in Thomes Creek.	3	THC-3.4	STE, SRCS	NMFS, USFWS, CDFW	1,5	Short-term	$5,000-$50,000 for initial scoping and feasibility; full project cost TBD based on initial study.					$5,000-$50,000 for initial scoping and feasibility; full project cost TBD based on initial study.
Enhance watershed resiliency in Thomes Creek by identifying and implementing projects that	3	THC-3.5	STE, SRCS	NMFS, USFWS, CDFW	1,5	Long-term	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBE	TBD	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.

would reduce the potential for, and magnitude of a catastrophic wildfire, restore meadows to potentially increase summer flows and reduce local water temperatures, or increase riparian shade.												
Develop and implement a spawning gravel augmentation plan in Thomes Creek.	3	THC-3.6	STE, SRCS	NMFS, USFWS, USBR, CDFW, DWR	1,5	Long-term	$50,000 for plan development; gravel augmentation costs TBD	TBD	TBD	TBD	TBD	$50,000-TBD
Conduct West Tehama riparian and floodplain conditions inventory.	3	THC-3.7	STE, SRCS	NMFS, USFWS, Tehama County Resource Conservation Districts, CDFW	1	Complete	$0	$0	$0	$0	$0	$0
Implement projects to increase floodplain habitat availability in Thomes Creek to improve juvenile rearing habitat	3	THC-3.8	STE, SRCS	NMFS, USFWS, CDFW	1,4	Long-term	TBD, based on amount of floodplain habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD, based on amount of floodplain habitat restored; initial study is expected to cost at least $50,000.
Re-establish natural channel morphology in Thomes Creek by: (1) applying NMFS gravel mining criteria to all gravel mining projects; (2) integrating natural morphological	3	THC-3.9	STE, SRCS	NMFS, USFWS, Resource Conservation Districts, CDFW, DWR	1,5	Long-term	$0	$0	$0	$0	$0	$0

features and functions into bank protection and other stream side development projects; and (3) implementing non-native plant (e.g. Arundo) eradication plan.												
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the Thomes Creek watershed.	3	THC-3.10	STE, SRCS	NMFS, USFWS, USFS, CDFW, DWR	1,5	Long-term	$0	$0	$0	$0	$0	$0

5.6.4 Stony Creek Recovery Actions

Table 5-9. Stony Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Enhance watershed resiliency in Stony Creek by identifying and implementing projects that would reduce the potential for, and magnitude of a catastrophic wildfire, restore meadows to potentially increase summer flows and reduce local water temperatures, or increase riparian shade.	3	STC-3.1	STE	NMFS, USFWS, CDFW, DWR	1,5	Long-term	TBD based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBE	TBD	TBD based on amount and type of habitat restored; initial study is expected to cost at least $50,000.
Develop and implement a spawning gravel augmentation plan in Stony Creek, which includes habitats above Black Butte Dam after passage is provided.	3	STC-3.2	STE	NMFS, USFWS, USBR, CDFW, DWR	1,5	Long-term	$50,000 for plan development; gravel augmentation costs TBD	TBD	TBD	TBD	TBD	$50,000-TBD
Evaluate water releases from Black Butte Dam, water exchanges with the Tehama-Colusa Canal and interim and long term water diversion solutions at RBDD.	3	STC-3.3	STE	Yolo Basin Working Group	1,5	5 years	$0					$0
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the Stony Creek watershed.	3	STC-3.4	STE	NMFS, USFWS, USFS, CDFW	1	Long-term	$0	$0	$0	$0	$0	$0
Develop a baseline monitoring program for Stony Creek to evaluate water quality throughout the	3	STC-3.5	STE	NMFS, USFWS, USFS, CDFW	1	Short-term	$0	$0	$0	$0	$0	$0

watershed to identify areas of concern.												
Encourage voluntary landowner participation in Stony Creek in educational opportunities such as water quality short courses, field demonstrations and distribution of water quality “Fact Sheets”.	3	STC-3.6	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, CHS, DWR, CDFW	2	Long-term	$76,140	$76,140	$76,140	$76,140	$0	$304,560
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in Stony Creek.	3	STC-3.7	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, CHS, DWR, CDFW	1	Short-term	$62,400	$0	$0	$0	$0	$62,400
Improve water temperature conditions in Stony Creek by identifying and implementing projects that would increase stream flows and increase shaded riverine habitat.	3	STC-3.8	STE	NMFS, USFWS, CDFW, DWR	1,4	Short-term	TBD	$0	$0	$0	$0	TBD based on the amount of water acquired and/or the amount of shaded habitat restored. Estimate of amount of water to be purchased unavailable. Cost per unit ranges from $43 to $88/af/year for upstream of Delta water purchases (Appendix D). Estimate of amount shaded habitat to be restored unavailable. As identified in Appendix D, per unit costs vary depending on whether fencing, planting, irrigation, or invasive week control are needed. Initial scoping study to determine project details estimated at $5,000-$50,000.

Implement projects to increase floodplain habitat availability in Stony Creek to improve juvenile rearing habitat.	3	STC-3.9	STE	NMFS, USFWS, CDFW, DWR	1,4	Long-term	TBD, based on amount of floodplain habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD, based on amount of floodplain habitat restored; initial study is expected to cost at least $50,000.
Install water temperature recorders at select locations in Stony Creek; develop recommendations for minimum instream flow based on temperature needs.	3	SCT-3.10	STE	NMFS, USFWS, CDFW, DWR	1	5 Years	$0					$0
Monitor and evaluate sport-fishing impacts in Stony Creek to ensure that the fishery allows for the recovery of steelhead; modify regulations as necessary.	3	STC-3.11	STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0

5.6.5 Putah Creek Recovery Actions

Table 5-10. Putah Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Conduct an anadromous fish passage feasibility study in Putah Creek that assesses upstream habitat conditions and operational alternatives.	2	PUC-2.1	STE	NMFS, USFWS, USFS, CDFW, DWR, Yolo Basin Working Group	1,5	5 Years	$25,000-$200,000					$25,000-$200,000
Develop a cooperative program to provide water for target flows in Putah Creek from additional Lake Berryessa releases or reductions in water diversions at Solano Diversion Dam and in the creek downstream of the dam.	2	PUC-2.2	STE	NMFS, USFWS, USBR, CDFW, DWR	1,5	Long-term	$0	$0	$0	$0	$0	$0
Implement actions specified by the Putah Creek Council directed at restoring instream and riparian habitat.	2	PUC-2.3	STE	NMFS, USFWS, CDFW, DWR	1	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of habitat restored. As identified in Appendix D, per unit costs vary depending on whether fencing, planting, irrigation, or invasive weed control are needed.
Permanently protect Putah Creek riparian habitat through	2	PUC-2.4	STE	NMFS, USFWS, CDFW, DWR, NRCS	1,5	Long-term	TBD, based on specific easements and	TBD	TBD	TBD	TBD	TBD, based on specific easements and land

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
easements and/or land acquisition							land acquisitions; initial study is expected to cost at least $50,000.					acquisitions; initial study is expected to cost at least $50,000.
Implement projects that improve wastewater and stormwater treatment throughout the Putah Creek watershed.	2	PUC-2.5	STE	NMFS, USFWS, USEPA, SWRCB, DWR, CDFW, Local governments	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of water to be treated and whether existing treatment facilities need to be upgraded or new facilities are required.. $5,000-$50,000 for initial evaluation.
Implement projects to maintain and increase floodplain habitat availability in Putah Creek to improve juvenile rearing habitat	2	PUC-2.6	STE	NMFS, USFWS, USBR, CDFW, DWR, Yolo Basin Working Group	1,4	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of floodplain habitat restored; initial study is expected to cost at least $50,000.
Develop and implement a spawning gravel augmentation plan in Putah Creek.	2	PUC-2.7	STE	NMFS, USFWS, CDFW, DWR	1,5	Long-term	$50,000 for plan development; gravel augmentation costs TBD	TBD	TBD	TBD	TBD	$50,000-TBD (based on gravel augmentation costs)
Increase monitoring and enforcement in Putah Creek to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin	2	PUC-2.8	STE	SWRCB, RWQCBs, Local agriculture groups	1,5	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Plan) are met throughout the Putah Creek watershed for all potential pollutants (SWRCB 2007).												
Monitor and evaluate sport-fishing impacts in Putah Creek to ensure that the fishery allows for the recovery of steelhead; modify regulations as necessary.	3	PUC-3.1	STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0
Evaluate whether predator control measures can be effective at minimizing predation of juvenile steelhead in Putah Creek; implement measures found to be effective.	3	PUC-3.2	STE	USFWS, NMFS, USBR, CDFW, DWR, Various NGOs	1,3,4	Long-term	TBD	TBD	TBD	TBD	TBD	Cost covered by the cost of SFB-2.5 ($0-$75,000,000).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement projects to minimize predation at weirs, diversion dams, and related structures in Putah Creek.	3	PUC-3.3	STE	NMFS, CDFW, DWR, USFWS, USBR, Corps	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013).
Improve instream refuge cover for salmonids in Putah Creek to minimize predatory opportunities for striped bass and other non-native	3	PUC-3.4	STE	USFWS, NMFS, USBR, CDFW, DWR	1,3	Long-term	TBD, based on the # of sites, # of miles, type of material, location of source material (onsite vs. imported), and	TBD	TBD	TBD	TBD	TBD, based on the # of sites, # of miles, type of material, location of source material (onsite vs. imported), and placement

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
predators.							placement method. Initial scoping to address those issues would cost at least $50,000. See Table H1-2 in Appendix D for cost per unit for various projects.					method. Cost of initial study to address these issues is $5,000-$50,000. See Table H1-2 in Appendix D for cost per unit for various projects.
Encourage voluntary landowner participation in Putah Creek in educational opportunities such as water quality short courses, field demonstrations and distribution of water quality "Fact Sheets".	3	PUC-3.5	STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, DWR, CDFW, Landowners	2	Long-term	$76,140	$76,140	$76,140	$76,140	$0	$304,560
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in Putah Creek.	3	PUC-3.6	STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, DWR, CDFW, Landowners	1,5	Short-term	$62,400	$0	$0	$0	$0	$62,400

5.7 Basalt and Porous Lava Diversity Group Recovery Actions

5.7.1 Cow Creek Recovery Actions

Table 5-11. Cow Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop and implement actions to reduce or eliminate passage impediments in Cow Creek.	2	COC-2.1	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1	5 Years	TBD based on the number and type of impediments. Per unit cost of providing passage at agricultural diversion dams ranges from $30,000 to $1,356,500 (see Appendix D, page 21, table HB-4). Initial evaluation of passage impediments estimated to cost up to $50,000.	$0	$0	$0	$0	TBD based on the number and type of impediments. Per unit cost of providing passage at agricultural diversion dams ranges from $30,000 to $1,356,500 (see Appendix D, page 21, table HB-4). Initial evaluation of passage impediments estimated to cost up to $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Install water temperature recorders at select locations in Cow Creek; develop recommendations for minimum instream flow based on temperature needs.	2	COC-2.2	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1	5 Years	$0	$0	$0	$0	$0	$0
Conduct a Cow Creek diversion mapping study and install screens and ladders at agricultural diversions where necessary.	2	COC-2.3	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1,5	5 Years	$50,000 for mapping study; Per unit cost of providing passage at agricultural diversion dams ranges from $30,000 to $1,356,500 (see Appendix D, page 21, table HB-4)	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).
Develop and apply alternative diversion technologies that eliminate entrainment in Cow Creek.	2	COC-2.4	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD. This action involves development of a new technology such that is impracticable to provide a reasonable estimate of the action's cost.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Enhance watershed resiliency in Cow Creek by identifying and implementing projects that would reduce the potential for, and magnitude of, a catastrophic wildfire, and restore forested areas within the watershed including riparian areas.	2	COC-2.5	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1,5	Long-term	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.
Implement actions specified in the Cow Creek Watershed Management Plan directed at restoring riparian habitat.	2	COC-2.6	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1,4	Long-term	~$235,000 for restoring 10 acres and developing best management practices	$300,000 for monitoring and identification of new restoration sites; if new sites are identified, each is estimated to cost ~$213,000 /10 acres.	$300,000 for monitoring and identification of new restoration sites; if new sites are identified, each is estimated to cost ~$213,000 /10 acres.	$300,000 for monitoring and identification of new restoration sites; if new sites are identified, each is estimated to cost ~$213,000 /10 acres.	$300,000 for monitoring and identification of new restoration sites; if new sites are identified, each is estimated to cost ~$213,000 /10 acres.	>~$1,435,000
Identify stream reaches in Cow Creek that have been most altered by anthropogenic factors and reconstruct a natural channel geometry scaled to current channel forming flows.	2	COC-2.7	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1,5	Long-term	$4,217,625	$0	$0	$0	$0	$4,217,625

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Curtail further development in the active Cow Creek floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	2	COC-2.8	STE	NMFS, USFWS, Corps, CDFW, DWR, Local governments	1,5	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement of illegal rip rap applications in Cow Creek.	2	COC-2.9	STE	Corps, SWRCB	1,5	Long-term	$350,000[27]	$350,000	$350,000	$350,000	$350,000	$1,750,000
Develop education and outreach programs to encourage river stewardship in Cow Creek, such as water quality short courses, field demonstrations and distribution of water quality "Fact Sheets".	2	COC-2.10	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000

[27] Assuming 1 new full time equivalent at $70,000/year, based on the average salary for a California Fish and Game warden as identified on the Bureau of Labor statistics website (http://www.bls.gov/oes/current/oes_ca.htm#19-0000).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Cooperatively negotiate long-term agreements with local landowners to maintain and restore riparian communities along lower reaches of Cow Creek (CALFED 2000).	2	COC-2.11	STE	NMFS, USFWS, Corps, USBR, Resource Conservation Districts, CDFW, DWR, Water districts, Landowners, Local governments	1,5	Long-term	$0	$0	$0	$0	$0	$0
Permanently protect Cow Creek riparian habitat through easements and/or land acquisition	2	COC-2.12	STE	NMFS, USFWS, Corps, USBR, Resource Conservation Districts, CDFW, DWR, Water districts, Landowners, Local governments	1,5	Long-term	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Develop and implement a spawning gravel augmentation plan in Cow Creek.	2	COC-2.13	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1,4	Long-term	$50,000 for plan development; gravel augmentation costs TBD	TBD	TBD	TBD	TBD	$50,000-TBD (gravel augmentation costs)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Monitor, evaluate, and adaptively manage the Cow Creek rainbow trout stocking program to minimize the potential for adverse impacts to steelhead.	2	COC-2.14	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1,5	3 Years	$0	$0	$0	$0	$0	$0
Implement projects to increase floodplain habitat availability in Cow Creek to improve juvenile rearing habitat	2	COC-2.15	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, Cow Creek Watershed Management Group	1	Long-term	TBD, based on amount of floodplain habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD, based on amount of floodplain habitat restored; initial study is expected to cost at least $50,000.
Implement projects to increase flows in Cow Creek and tributaries.	2	COC-2.16	STE	NMFS, USFWS, Western Shasta Resource Conservation, CDFW, DWR, SWRCB, Cow Creek Watershed Management Group	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD because the estimate of amount of water to be purchased is unavailable. Cost per unit for upstream of Delta water purchases ranges from $43 to $88/af/year (Appendix D). Cost of an initial study to determine the amount of water needed is at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement the water quality action options described in the Cow Creek Watershed Management Plan.	2	COC-2.17	STE	USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW, Cow Creek Watershed Management Group	1	Long-term	$0	$0	$0	$0	$0	$0
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the Cow Creek watershed.	2	COC-2.18	STE	NMFS, USFWS, USFS, CDFW, Cow Creek Watershed Management Group	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop a baseline monitoring program for Cow Creek to evaluate water quality throughout the watershed to identify areas of concern.	2	COC-2.19	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW, Cow Creek Watershed Management Group	1	2 Years	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in Cow Creek.	2	COC-2.20	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW, Landowners, Cow Creek Watershed Management Group	1,5	Short-term	$62,400	$0	$0	$0	$0	$62,400
Decommission the Kilarc-Cow Creek hydroelectric project (FERC Project No. 606).	2	COC-2.21	STE	PG&E, FERC, NMFS, CDFW, Cow Creek Watershed Management Group	1	Short-term	$0					$0
Monitor and evaluate sport-fishing impacts in Cow Creek to ensure that the fishery allows for the recovery of steelhead; modify regulations as necessary.	2	COC-3.1	STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0

5.7.2 Battle Creek Recovery Actions

Table 5-12. Battle Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Fully fund and implement the Battle Creek Restoration Project through Phase 2	1	BAC-1.1	WRCS, SRCS, STE	USBR, CDFW, NMFS, PG&E, USFWS	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop and implement a winter-run Chinook salmon reintroduction plan to re-colonize historic habitats made accessible by the Battle Creek Restoration Project.	1	BAC-1.2	WRCS	CDFW, USFWS, NMFS, watershed stakeholders, USBR	1,5	15	$1,000,000-$1,333,333	$1,000,000-$1,333,333	$1,000,000-$1,333,333	$0	$0	$3,000,000-$3,999,999
Implement the Battle Creek Salmon and Steelhead Restoration Project Adaptive Management Plan.	1	BAC-1.3	WRCS, SRCS, STE	CDFW, USFWS, NMFS, watershed stakeholders, USBR	1,5	Short-term	$0	$0	$0	$0	$0	$0
Enhance watershed resiliency in Battle Creek by developing a strategy to identify and prioritize vegetation and fuels treatments that would reduce the potential extent and/or the magnitude of high severity wildfires.	1	BAC-1.4	WRCS, SRCS, STE	USBR, NMFS, USFWS, CDFW	1,5	Long-term	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBE	TBD	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Ensure that timber cutting operations on private lands in the Battle Creek watershed follow the State Forest Practice rules.	1	BAC-1.5	WRCS, SRCS, STE	USBR, NMFS, USFWS, FERC, CDFW, SWRCB, SPI	1,5	Long-term	$0	$0	$0	$0	$0	$0
Implement a water quality monitoring program throughout the Battle Creek watershed to identify areas of concern. The program should monitor for sediment loading and include detection of chemical/nutrient inputs from illegal plant cultivation operations.	1	BAC-1.6	WRCS, SRCS, STE	USBR, NMFS, USFWS, FERC, CDFW, SWRCB	1,5	5	$0	$0	$0	$0	$0	$0
Develop an Adaptive Management Plan for Coleman National Fish Hatchery and continue to integrate hatchery operations with Battle Creek Salmon and Steelhead Restoration Project activities.	1	BAC-1.7	WRCS, SRCS, STE	CDFW, USFWS, NMFS, watershed stakeholders, USBR	1,4,5	Short-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Evaluate the scientific merits of moving Coleman National Fish Hatchery operations for the production of steelhead and late-fall Chinook salmon to minimize adverse impacts to listed species. If warranted, then follow with an assessment of the feasibility of moving the programs.	1	BAC-1.8	WRCS, SRCS, STE	CDFW, USFWS, NMFS, watershed stakeholders, USBR	1,3,5	Short-term evaluation; long-term implementation	TBD	TBD	TBD	TBD	TBD	TBD; The cost of the evaluation and, if necessary, the feasibility assessment will be identified by the Coleman Hatchery Coordination Team that will be formed according to the recommendation from the Hatchery Scientific Review Group.
Finalize the Biological Opinion for the artificial propagation at Coleman National Fish Hatchery.	1	BAC-1.9	WRCS, SRCS, STE	FWS, NMFS	1,5	1 year	$0	$0	$0	$0	$0	$0
Evaluate the need to upgrade PG&E facilities in order to reduce the potential for outages and harmful flow fluctuations. If outages and flow fluctuations are important stressors after completion of the Battle Creek Salmon and Steelhead Restoration	1	BAC-1.10	WRCS, SRCS, STE	Corps, USFWS, NMFS, CDFW, PG&E	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD based on whether or not facilities need to be upgraded. Evaluation of facilities estimated to cost up to $100,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Project, then PG&E facilities should be upgraded.												
Develop and utilize the Battle Creek Fisheries Management Plan.	1	BAC-1.11	WRCS, SRCS, STE	CDFW, USFWS, NMFS	1,5	Short-term	$0	$0	$0	$0	$0	$0
Improve fish passage at natural (rock or wood) fish barriers in the watershed including the ones immediately upstream and downstream of Eagle Canyon, and at the mouth of Digger Creek.	1	BAC-1.12	WRCS, SRCS, STE	CDFW, USFWS, NMFS	1,5	Short-term	$500,000					$500,000
Develop and apply alternative water diversion technologies that eliminate entrainment in Battle Creek.	2	BAC-2.1	WRCS, SRCS, STE	FWS, CDFW	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD. This action involves development of a new technology such that is impracticable to provide a reasonable estimate of the action's cost.
Implement a study designed to evaluate the impact of predation on spring-run Chinook salmon and steelhead in	2	BAC-2.2	WRCS, SRCS, STE	FWS, CDFW, NMFS	1,3,5	Long-term						Cost covered by the cost of SFB-2.5 ($0-$75,000,000).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Battle Creek. If the study suggests that predation is an important stressor in Battle Creek, then implement projects to minimize predation, potentially including predator removal and/or harvest management.												
Implement projects to minimize predation at weirs, diversion dams, and related structures in Battle Creek.	2	BAC-2.3	WRCS, SRCS, STE	NMFS, CDFW, DWR, USFWS, USBR, Corps, PG&E	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												site will cost about $38,000 annually (BDCP 2013).
The Corps, DWR, CDFW, BLM, USFWS, NMFS, private land owners, and Resource Conservation Districts should continue to focus on retaining, restoring and creating continuous riparian corridors within their jurisdictions in Battle Creek in order to improve natural river function and provide predator refuge habitat.	2	BAC-2.4	WRCS, SRCS, STE	DWR, BLM, TNC, USFWS, CDFW	1,5	Long-term	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$150,000 -$675000
Increase monitoring and enforcement in order to eliminate/minimize illegal plant cultivation operations and anadromous fish poaching in the Battle Creek watershed.	2	BAC-2.5	WRCS, SRCS, STE	CDFW	1,5	Long-term						Cost is covered under action # COC-2.9
Permanently protect Battle Creek riparian habitat through	2	BAC-2.6	WRCS, SRCS, STE	DWR, BLM, TNC, USFWS, CDFW	1,5	Long-term	TBD, based on specific easements and land	TBD	TBD	TBD	TBD	TBD, based on specific easements and land acquisitions; initial

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
easements and/or land acquisition.							acquisitions; initial study is expected to cost at least $50,000.					study is expected to cost at least $50,000.
Ensure through the FERC process and monitoring that the hydroelectric project at Lassen Lodge on the South Fork of Battle Creek avoids or minimizes any adverse impacts to listed anadromous salmonids.	2	BAC-2.7	WRCS, SRCS, STE	FERC, USFS, NMFS, CDFW	1,3,5	Short-term	$0	$0	$0	$0	$0	$0
Utilize bio-technical techniques for river bank stabilization instead of conventional rip rap in Battle Creek.	3	BAC-3.1	WRCS, SRCS, STE	Corps, USFWS	1,5	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement to minimize illegal streambank alterations in Battle Creek.	3	BAC-3.2	WRCS, SRCS, STE	CDFW, Corps, USFWS	1,5	Long-term						Cost is covered under action # COC-2.9

5.8 Northern Sierra Nevada Diversity Group Recovery Actions

5.8.1 Antelope Creek Recovery Actions

Table 5-13. Antelope Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Restore instream flows during upstream and downstream migration periods through water exchange agreements and provide alternative water supplies to Edwards Ranch and Los Molinos Mutual Water Company in exchange for instream fish flows.	1	ANC-1.1	SRCS, STE	NMFS, USFWS, CDFW, Edwards Ranch, Los Molinos Mutual Water Company	1	Long-term	$0	$0	$0	$0	$0	$0
Restore connectivity of the migration corridor during upstream and downstream migration periods by implementing Edwards and Penryn fish passage and entrainment improvement projects and identify and	1	ANC-1.2	SRCS, STE	CDFW, Edwards Ranch	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
construct a defined stream channel for upstream and downstream fish migration												
Create and restore side channel habitats to increase the quantity and quality of off-channel rearing (and spawning) areas in Antelope Creek.	2	ANC-2.1	SRCS, STE	NMFS, CDFW	1	Short-term	TBD based on the amount of side channel habitat restoration. Unit cost is $20,000 to $300,000/acre (Appendix D). $5,000-$50,000 for initial evaluation.	TBD based on the amount of side channel habitat restoration. Unit cost is $20,000 to $300,000/acre (Appendix D). $5,000-$50,000 for initial evaluation.	TBD based on the amount of side channel habitat restoration. Unit cost is $20,000 to $300,000/acre (Appendix D). $5,000-$50,000 for initial evaluation.	TBD based on the amount of side channel habitat restoration. Unit cost is $20,000 to $300,000/acre (Appendix D). $5,000-$50,000 for initial evaluation.	TBD based on the amount of side channel habitat restoration. Unit cost is $20,000 to $300,000/acre (Appendix D). $5,000-$50,000 for initial evaluation.	TBD based on the amount of side channel habitat restoration. Unit cost is $20,000 to $300,000/acre (Appendix D). $5,000-$50,000 for initial evaluation.
Federal, State, and local agencies should use their authorities to develop and implement programs and projects that focus on retaining, restoring and creating riparian and floodplain habitat in Antelope Creek.	2	ANC-2.2	SRCS, STE	NMFS, USFWS, CDFW, DWR, Irrigation districts	1	Short-term	TBD based on type and amount of habitat restored; initial study is expected to cost at least $50,000.	TBD	$0	$0	$0	TBD based on type and amount of habitat restored; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Improve passage conditions at Paynes crossing to allow upstream passage during low flows.	2	ANC-2.3	SRCS, STE	NMFS, USFWS, USFS, CDFW, DWR	1	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement of illegal rip rap applications in Antelope Creek.	2	ANC-2.4	SRCS, STE	Corps, SWRCB	1	Long-term						Cost is covered under action # COC-2.9
Develop education and outreach programs to encourage river stewardship in Antelope Creek.	2	ANC-2.5	SRCS, STE	NMFS, USFWS, USFS, CDFW, DWR, NGOs	5	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Evaluate the quality and quantity of spawning habitat in Antelope Creek and rehabilitate spawning habitat as needed.	2	ANC-2.6	SRCS, STE	NMFS, USFWS, CDFW, DWR	1	Long-term	$50,000 for plan development; rehabilitation costs TBD	TBD	TBD	TBD	TBD	$50,000-TBD
Develop and implement TMDL's for all pollutants in Antelope Creek	2	ANC-2.7	SRCS, STE	NMFS, USFWS, USFS, CDFW	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Increase monitoring and enforcement in the Antelope Creek watershed to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants.	2	ANC-2.8	SRCS, STE	SWRCB, RWQCBs, Local agriculture groups	1	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)
Develop a baseline monitoring program in Antelope Creek to evaluate water quality throughout the watershed to identify areas of concern.	2	ANC-2.9	SRCS, STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW	1	3 Years	$0	$0	$0	$0	$0	$0
Enhance watershed resiliency in Antelope Creek by developing a strategy to identify and prioritize vegetation and fuels treatments that would reduce the potential extent and/or the	2	ANC-2.10	SRCS, STE	NMFS, USFWS, USFS, CDFW	1	Long-term	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBE	TBD	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
magnitude of high severity wildfires.												
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the Antelope Creek watershed.	2	ANC-2.11	SRCS, STE	NMFS, USFWS, USFS, CDFW	1	Long-term	$0	$0	$0	$0	$0	$0
Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap in Antelope Creek.	2	ANC-2.12	SRCS, STE	NMFS, USFWS, Corps, USBR, DWR, CDFW, CBDA	1	Long-term	$0	$0	$0	$0	$0	$0
Implement projects that cooperatively work with landowners to modify existing diversions in Antelope Creek so that fish do not become entrained in agricultural fields.	2	ANC-2.13	SRCS, STE	NMFS, USFWS, CDFW, DWR, Landowners, Irrigation districts	1,5	Short-term	TBD	TBD	$0	$0	$0	TBD, based on the type of diversion modification. If a fish screen is the solution, the cost will generally range from $2 to $10 thousand per cfs (Appendix D). $5,000-$50,000 for initial evaluation.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Monitor and evaluate the sport fishing regulations for Antelope Creek to ensure they are consistent with the recovery of spring-run Chinook salmon and steelhead, and work with the Fish and Game Commission to modify the regulations as needed.	2	ANC-3.1	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	2	Long-term	$0	$0	$0	$0	$0	$0

5.8.2 Mill Creek Recovery Actions

Table 5-14. Mill Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Modify Ward, Upper, and Cemetery Ditch Siphon diversions and associated structures in Mill Creek in order to minimize entrainment and provide unimpeded passage for adult and juvenile Chinook salmon and steelhead. The modifications should meet the fish passage design criteria developed by NMFS as well as the criteria developed by CDFW.	1	MIC-1.1	SRCS, STE	NMFS, CDFW, Los Molinos Mutual Water Company, DWR, USFWS, Mill Creek Conservancy, TNC	1,5	Short-term	$2,672,672	$0	$0	$0	$0	$2,672,672
Analyze previous Mill Creek flow studies (i.e., Alley 1996; Harvey-Arrison 2009) to identify the flow regime in the flow control reach (i.e., downstream of Upper Diversion to the confluence with the Sacramento River) that best supports the life stages of spring-run Chinook salmon and steelhead that occur in that reach; conduct an additional flow study if necessary.	1	MIC-1.2	SRCS, STE	NMFS, CDFW, Los Molinos Mutual Water Company, DWR, USFWS, Mill Creek Conservancy, TNC, NFWF	1,5	Short-term	$200,000	$0	$0	$0	$0	$200,000
Develop and implement instream flow agreements with Mill Creek diverters designed to provide flows that best support the life stages of spring-run Chinook salmon and steelhead that occur in the flow control reach (i.e., downstream of Upper Diversion to the confluence with the Sacramento River).	1	MIC-1.3	SRCS, STE	NMFS, CDFW, Los Molinos Mutual Water Company, DWR, USFWS, Mill Creek Conservancy, TNC, NFWF	1,5		TBD	TBD	TBD	TBD	TBD	TBD, based on amount of water. Cost per unit is $43 - $88/af/year for upstream of Delta water purchases (Appendix D)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
The agreements can include approaches such as groundwater exchange, water leases, acquiring water rights, and other water management options.												
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the upper Mill Creek watershed. On National Forest Service (NFS) lands, this action should follow the prioritization criteria and strategies identified in the Long-term Strategy for Anadromous Fish-producing Watersheds in the Lassen National Forest (USFS 2001).	1	MIC-1.4	SRCS, STE	USFS, NMFS, USFWS, CDFW, DWR, Mill Creek Conservancy, TNC	1,4,5	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement in order to eliminate/minimize illegal plant cultivation operations and anadromous fish poaching in the Mill Creek watershed.	1	MIC-1.5	SRCS, STE	NMFS, CDFW, SWRCB	2,4							Cost is covered under action # COC-2.9
Conduct real time flow and water temperature monitoring in Mill Creek in order to inform real time management decisions.	1	MIC-1.6	SRCS, STE	CDFW, USGS, DWR, Los Molinos Mutual Water Company	1,5		$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Build partnerships with land owners and/or permittees in the Mill Creek watershed to develop grazing strategies that promote meadow restoration, protect and improve streamside vegetation, and minimize bank disturbance.	2	MIC-2.1	SRCS, STE	NMFS, USFWS, CDFW, DWR, Mill Creek Conservancy, TNC	1,5		$47,520	$0	$0	$0	$0	$47,520
Implement a water quality monitoring program throughout the Mill Creek watershed to identify areas of concern.	2	MIC-2.2	SRCS, STE	NMFS, USFWS, CDFW, DWR, SWRCB, USEPA	1,4,5	Long-term	$0	$0	$0	$0	$0	$0
Develop education and outreach programs to encourage river stewardship in Mill Creek. Collaborate with the Mill Creek Watershed Conservancy in watershed management activities and any other public education events related to river stewardship.	2	MIC-2.3	SRCS, STE	CDFW, Mill Creek Conservancy, TNC, USFWS, NMFS, Los Molinos Mutual Water Company	2		$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Ensure that timber cutting operations in the Mill Creek watershed follow the State Forest Practice rules.	2	MIC-2.4	SRCS, STE	CDFW, CalFire, Board of Forestry, NMFS, USFWS, USFS	1,5		$0	$0	$0	$0	$0	$0
Enhance watershed resiliency in Mill Creek by developing a strategy to identify and prioritize vegetation and fuels treatments that would reduce the potential extent and/or the magnitude of high severity wildfires.	2	MIC-2.5	SRCS, STE	USFS, CalFire, NMFS, USFWS, , CDFW, Mill Creek Conservancy	1,5	Long-term	TBD based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBE	TBD	TBD based on amount and type of habitat restored; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Investigate whether there are areas in the Mill Creek valley reach where it would be feasible to implement floodplain restoration projects in order to improve habitat conditions for juvenile rearing. If there are floodplain restoration opportunities, those projects should be prioritized and implemented as funding becomes available.	2	MIC-2.6	SRCS, STE	NMFS, USFWS, CDFW, DWR, Mill Creek Conservancy, TNC	1,5	Short-term	$50,000 for investigation; cost of floodplain restoration TBD based on amount of habitat to be restored. Per unit cost of floodplain habitat restoration is $5,000 to $80,000/acre (Appendix D Table HI-4)	TBD	$0	$0	$0	$50,000-TBD
Monitor and evaluate the sport fishing regulations for Mill Creek to ensure they are consistent with the recovery of spring-run Chinook salmon and steelhead, and modify the regulations as needed. Establish and enforce hook size restrictions intended to allow trout fishing, but minimize angling impacts on salmon.	2	MIC-2.7	SRCS, STE	CDFW, Fish and Game Commission, NMFS	2,4		$0	$0	$0	$0	$0	$0
Identify stream reaches in Mill Creek that have been most altered by anthropogenic factors and develop restoration actions that restore natural river processes.	2	MIC-2.8	SRCS, STE	NMFS, USFWS, CDFW, DWR, Mill Creek Conservancy, TNC	1,5		$4,217,625	$0	$0	$0	$0	$4,217,625

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Curtail further development in the active Mill Creek floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	2	MIC-2.9	SRCS, STE	Local governments, NMFS, USFWS, CDFW, DWR, Mill Creek Conservancy, TNC	1,4	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement to minimize illegal streambank alterations in Mill Creek.	2	MIC-2.10	SRCS, STE	CDFW, NMFS, Corps, SWRCB	1,5	Long-term						Cost is covered under action # COC-2.9
Permanently protect riparian habitat along Mill Creek through easements and/or land acquisition.	2	MIC-2.11	SRCS, STE	CDFW, USFWS, NMFS, Mill Creek Conservancy, TNC	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Develop and implement actions to remove feral cows in the Black Rock area of Mill Creek.	2	MIC-2.12	SRCS, STE	CDFW, USFWS, NMFS, Mill Creek Conservancy, TNC	1,5	Short-term	TBD	$0	$0	$0	$0	TBD, based on number of cows. Cost per cow removed is $150 (Bratcher 2013).

5.8.3 Deer Creek Recovery Actions

Table 5-15. Deer Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop and implement instream flow agreements with the Deer Creek Irrigation District and the Stanford-Vina Ranch Irrigation Company designed to provide flows that best support all life stages of spring-run Chinook salmon and steelhead. The agreements can include approaches such as groundwater exchange, water leases, and other water management options.	1	DEC-1.1	SRCS, STE	Corps, SWRCB, DCID, SVRIC	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of water. Cost per unit is $43 - $88/af/year for upstream of Delta water purchases (Appendix D)
Modify the Cone-Kimball Diversion, Stanford-Vina Dam, and the Deer Creek Irrigation District Dam in order to provide unimpeded passage for adult and juvenile Chinook salmon and steelhead. The modifications should meet the fish passage design criteria developed by NMFS and CDFW.	1	DEC-1.2	SRCS, STE	NMFS, USFWS, USFS, CDFW, DWR, NGOs	1,5	Short-term	$10,925,000	$12,629,300	$0	$0	$0	$23,554,300

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
In coordination with technical advisors from the natural resource agencies, implement the Deer Creek Flood Improvement Project, and other projects to increase Deer Creek floodplain habitat availability.	1	DEC-1.3	SRCS, STE	NMFS, USFWS, CDFW, DWR	1,4	Short-term	$1,860,000	$0	$0	$0	$0	$1,860,000
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the upper Deer Creek watershed. On National Forest Service lands, this action should follow the prioritization criteria and strategies identified in the Long-term Strategy for Anadromous Fish-producing Watersheds in the Lassen National Forest (USFS 2001).	1	DEC-1.4	SRCS, STE	NMFS, USFWS, USFS, CDFW	1,4	Long-term	$0	$0	$0	$0	$0	$0
Conduct an instream flow study to identify the flow regime in lower Deer Creek that best supports migration and rearing of spring-run Chinook salmon and steelhead.	1	DEC-1.5	SRCS, STE	CDFW, Deer Creek Irrigation Company, Stanford-Vina, SWRCB, DWR, Deer Creek Watershed Conservancy	1,5	Long-term	$1,600,000	$0	$0	$0	$0	$1,600,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Based on instream flow study results, develop an adaptive management strategy to provide a flow regime in the lower watershed that best supports spring-run Chinook salmon and steelhead during fish migration and rearing periods.	1	DEC-1.6	SRCS, STE	CDFW, Deer Creek Irrigation Company, Stanford-Vina, SWRCB, DWR, Deer Creek Watershed Conservancy	1,5	Long-term	$0	$0	$0	$0	$0	$0
Conduct real time flow and water temperature monitoring in Deer Creek in order to inform real time management decisions.	1	DEC-1.7	SRCS, STE	NMFS, USFWS, USGS, CDFW, DWR	1,5	Long-term	$0	$0	$0	$0	$0	$0
Implement a Deer Creek monitoring program to identify the abundance and the temporal and spatial distributions of immigrating and holding spring-run Chinook salmon and steelhead. These data would help ensure that suitable flows and water temperatures are being provided when and where the fish are immigrating and holding. Additionally, the data would help estimate the abundance of both species.	1	DEC-1.8	SRCS, STE	CDFW, SPI	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Increase monitoring and enforcement in order to eliminate/minimize illegal plant cultivation operations and anadromous fish poaching in the Deer Creek watershed.	1	DEC-1.9	SRCS, STE	CDFW, Deer Creek Irrigation Company, Stanford-Vina, Deer Creek Watershed Conservancy	1,4,5	Long-term						Cost is covered under action # COC-2.9
Study feasibility of consolidating diversion points (e.g., Stanford Vina and Cone-Kimball diversions) to minimize the number of diversions on Deer Creek. Based on this study, consolidate diversions where feasible.	2	DEC-2.1	SRCS, STE	NMFS, CDFW, Deer Creek Watershed Conservancy, Deer Creek Irrigation Company, Stanford-Vina, SWRCB, DWR	1,5	10 Years	$50,000	$750,000	$0	$0	$0	$800,000
Assess the feasibility and need for modifying the lower Deer Creek falls fish ladder, to improve its function for allowing upstream passage to the upper six miles of anadromous habitat. Implement modifications as needed.	2	DEC-2.2	SRCS, STE	NMFS, USFWS, USFS, CDFW	1,5	5 Years	$0	$0	$0	$0	$0	$0
Enhance watershed resiliency in Deer Creek by developing and implementing a strategy to identify and prioritize vegetation and fuels treatments that would reduce the potential extent and/or the magnitude of high severity wildfires.	2	DEC-2.3	SRCS, STE	SWRCB, RWQCBs, Local agriculture groups	1,4,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount and type of habitat restored; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Build partnerships with land owners and/or permittees in the Deer Creek watershed to develop grazing strategies that promote meadow restoration, protect and improve streamside vegetation, and minimize bank disturbance.	2	DEC-2.4	SRCS, STE	NMFS, CDFW, Deer Creek Watershed Conservancy, USFWS	1,5	Long-term	$47,520	$0	$0	$0	$0	$47,520
Maintain an up-to-date Highway 32 Contingency Spill Plan to ensure immediate emergency response strategy and continue to develop alternatives to reduce the potential for hazardous material spills along Deer Creek.	2	DEC-2.5	SRCS, STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW	4,5	Long-term	$0	$0	$0	$0	$0	$0
Work with California Department of Transportation (Caltrans) to ensure that proposed changes to the existing Highway 32 road alignment would not contribute to potentially unacceptable effects to anadromous fish and/or their habitat (e.g. increases in fine grained sediment, increased risk of hazardous spills).	2	DEC-2.6	SRCS, STE	NMFS, USFWS, USFS, CDFW	4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop education and outreach programs to encourage river stewardship in Deer Creek. Continue educational outreach and support and assist Deer Creek Watershed Conservancy (DCWC) in watershed management activities (AFRP Website 2005).	2	DEC-2.7	SRCS, STE	NMFS, USFWS, USFS, CDFW	2,5	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Continue implementing a water quality monitoring program throughout the Deer Creek watershed to identify areas of concern. The monitoring program should include detection of chemical/nutrient inputs from illegal plant cultivation operations.	2	DEC-2.8	SRCS, STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW	1,4	2 Years	$0	$0	$0	$0	$0	$0
To recruit and provide a continuous supply of spawning gravels into Deer Creek, re-design the Highway 32 culvert crossing at the South Fork of Calf Creek to allow for unimpeded bedload transport.	2	DEC-2.9	SRCS, STE	Caltrans, NMFS, CDFW, Deer Creek Watershed Conservancy, Deer Creek Irrigation Company, Stanford-Vina	1,5	Long-term	$50,000	$0	$0	$0	$0	$50,000
Ensure that timber cutting operations on private lands in the Deer Creek watershed follow the State Forest Practice rules.	2	DEC-2.10	SRCS, STE	Board of Forestry, Deer Creek Watershed Conservancy, SPI, Collins Pine Timber Co	1,4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Monitor and evaluate the sport fishing regulations for Deer Creek to ensure they are consistent with the recovery of spring-run Chinook salmon and steelhead, and work with the Fish and Game Commission to modify the regulations as needed. Work with CDFW and the Fish and Game Commission to establish and enforce hook size restrictions intended to allow trout fishing, but minimize angling impacts on salmon.	2	DEC-2.11	SRCS, STE	CDFW, NMFS, Deer Creek Watershed Conservancy	2,4	Long-term	$0	$0	$0	$0	$0	$0
Identify stream reaches in Deer Creek that have been most altered by anthropogenic factors and promote development of actions that contribute to the restoration of riparian vegetation and natural river processes.	2	DEC-2.12	SRCS, STE	CDFW, NMFS, Deer Creek Watershed Conservancy, SPI, Collins Pine Timber Co	1,5	Long-term	$0	$0	$0	$0	$0	$0
Curtail further development in the active Deer Creek floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	2	DEC-2.13	SRCS, STE	Local governments, Corps, NMFS, CDFW, grazing interests, Deer Creek Watershed Conservancy	1,4	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Increase monitoring and enforcement to minimize illegal streambank alterations in Deer Creek.	2	DEC-2.14	SRCS, STE	CDFW, Corps, SWRCG, NMFS	1,4,5	Long-term						Cost is covered under action # COC-2.9
Permanently protect Deer Creek riparian habitat through easements and/or land acquisition.	2	DEC-2.15	STE	NMFS, USFWS, DWR, CDFW	1,5	Long-term	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Monitor, evaluate, and adaptively manage the upper Deer Creek rainbow trout stocking program to minimize the potential for adverse impacts to spring-run Chinook salmon or steelhead.	2	DEC-2.16	SRCS, STE	CDFW, NMFS	4,5	5 Years	$0	$0	$0	$0	$0	$0
Evaluate the scientific merits of improving the Upper Falls fish ladder on Deer Creek to allow steelhead access to the upper watershed. The existing ladder will remain closed and improvements to it will not be undertaken unless Deer Creek habitat modeling verifies that: (1) steelhead spawning and rearing habitats below the Upper Falls are limiting steelhead recovery; and (2)	2	DEC-2.17	SRCS, STE	CDFW, NMFS, USBR (Shasta Mitigation)	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
spawning and rearing habitats above the Upper Falls are suitable and necessary to recover the Deer Creek steelhead population.												
Ensure that through the FERC relicensing process for the Fire Mountain Lodge Hydroelectric Project, detailed mitigation and design criteria are implemented to reduce the potential for impacts into downstream anadromous habitat.	3	DEC-3.1	SRCS, STE	FERC, NMFS, USFS	1,5	Long-term	$0	$0	$0	$0	$0	$0

5.8.4 Big Chico Creek Recovery Actions

Table 5-16. Big Chico Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement fish passage improvement projects at the recreational pools in Bidwell Park.	1	BCC-1.1	SRCS, STE	NMFS, USFWS, CDFW, DWR, Big Chico Watershed Alliance	1	5 Years	$500,000	$0	$0	$0	$0	$500,000
Re-establish spring-run Chinook salmon and steelhead passage at low and moderate flows through Iron Canyon.	1	BCC-1.2	SRCS, STE	City of Chico, USFWS, CDFW, NMFS, Big Chico Creek Ecological Reserve, Chico State University, Butte County, Sierra Nevada Conservancy	1	5 years	$1,000,000					$1,000,000
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the Big Chico Creek watershed.	2	BCC-2.1	SRCS, STE	NMFS, USFWS, USFS, CDFW	1,5	Long-term	$0	$0	$0	$0	$0	$0
Enhance watershed resiliency in Big Chico Creek by identifying and implementing projects that would reduce the potential for, and magnitude of, a catastrophic wildfire, and restore forested areas within the watershed including riparian areas.	2	BCC-2.2	SRCS, STE	NMFS, USFWS, CDFW, DWR, Big Chico Watershed Alliance	1,5	Long-term	TBD based on amount and type of habitat restored; initial study is expected to cost at least	TBD	TBD	TBE	TBD	TBD based on amount and type of habitat restored; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
							$50,000.					
Implement projects to increase Big Chico Creek floodplain habitat availability to improve habitat conditions for juvenile rearing	2	BCC-2.3	SRCS, STE	NMFS, USFWS, CDFW, DWR, Big Chico Watershed Alliance	1	Long-term	TBD based on amount of habitat restored; initial study is expected to cost at least $50,000. Per unit cost is $5,000 to $80,000/acre (Appendix D Table HI-4)	TBD	TBD	TBD	TBD	TBD based on amount of habitat restored; initial study is expected to cost at least $50,000. Per unit cost is $5,000 to $80,000/acre (Appendix D Table HI-4)
Identify stream reaches in Big Chico Creek that have been most altered by anthropogenic factors and reconstruct a natural channel geometry scaled to current channel forming flows.	2	BCC-2.4	SRCS, STE	NMFS, USFWS, CDFW, DWR, Big Chico Watershed Alliance	1,5	5 Years	$4,217,625	$0	$0	$0	$0	$4,217,625
Curtail further development in the active Big Chico Creek floodplains through zoning restrictions, county master plans, HCPs, and other Federal, State, and county planning and regulatory processes.	2	BCC-2.5	SRCS, STE	NMFS, USFWS, USFS, Corps, CDFW, DWR, Local governments	1,3, 5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Increase monitoring and enforcement of illegal rip rap applications in Big Chico Creek.	2	BCC-2.6	SRCS, STE	Corps, SWRCB	1,5	Long-term						Cost is covered under action # COC-2.9
Develop education and outreach programs to encourage river stewardship in Big Chico Creek.	2	BCC-2.7	SRCS, STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, Landowners, Local Schools	1	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Increase monitoring and enforcement in Big Chico Creek to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants (SWRCB 2007).	2	BCC-2.8	SRCS, STE	SWRCB, RWQCBs, Local agriculture groups	1,5	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)
Develop a baseline monitoring program to evaluate water quality throughout the watershed to identify areas of concern.	2	BCC-2.9	SRCS, STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, CDFW	1,5	3 Years	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts.	2	BCC-2.10	SRCS, STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, CDFW, DWR, Landowners	1,5	Long-term	$62,400	$0	$0	$0	$0	$62,400

5.8.5 Butte Creek Recovery Actions

Table 5-17. Butte Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Identify and establish minimum instream flow requirements for Butte Creek that support all life stages of spring-run Chinook salmon and steelhead.	1	BUC-1.1	SRCS, STE	SWRCB, RWQCBs, Local agriculture groups	1	Long-term	$0	$0	$0	$0	$0	$0
Install and maintain real-time flow and water temperature monitoring gages in Butte Creek in order to help make real-time management decisions.	1	BUC-1.2	SRCS, STE	CDFW, DWR, USFWS, NMFS, SWRCB	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop an entrainment monitoring program in Butte Creek to determine the level of take at individual diversions. Prioritize diversions based on this monitoring and screen those	1	BUC-1.3	SRCS, STE	NMFS, USFWS, CDFW, DWR	1,3,5	5 years	$100,000 for monitoring program; costs of screens for Butte Creek TBD	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
that are determined to have substantial impacts.												
Implement projects that consolidate and screen existing diversions in Butte Creek where feasible.	1	BUC-1.4	SRCS, STE	NMFS, USBR, CDFW, DWR, Irrigation districts, Water districts	1,3,5	Long-term	$50,000	$750,000	$0	$0	$0	$800,000
Develop information to better understand the interaction between surface water and groundwater in the Butte Creek watershed in order to evaluate the potential impacts of water management options (e.g., groundwater sales; conjunctive use) in the watershed on the Butte Creek flow regime.	1	BUC-1.5	SRCS, STE	SWRCB, CDFW, DWR Irrigation districts	4,5	Short-term	$0	$0				$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement projects that improve water temperature management in Butte Creek, including facility modifications to the DeSabla-Centerville Hydroelectric Project.	1	BUC-1.6	SRCS, STE	PG&E, NMFS, CDFW, FERC, SWRCB	1	Short-term	TBD. NMFS is in the process of obtaining the cost from PG&E.					TBD. NMFS is in the process of obtaining the cost from PG&E.
Improve the segregation of Butte Creek spring-run and fall-run Chinook salmon during spawning by development and installation of a more robust separation device or removable weir at or near the Parrott-Phelan diversion dam. The segregation device should allow adult steelhead passage.	1	BUC-1.7	SRCS	CDFW, NMFS, USFWS, PG&E	1	Short-term	< $500,0000					<$500,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement programs and measures designed to control non-native predatory fish in Butte Sink and the Sutter Bypass, including harvest management techniques and programs for non-native predators (e.g., striped bass, largemouth bass, and smallmouth bass).	2	BUC-2.1	SRCS, STE	NMFS, USFWS, CDFW, DWR	2,3	Long-term	TBD	TBD	TBD	TBD	TBD	Cost covered by the cost of SFB-2.5 ($0-$75,000,000).
Increase instream cover in Butte Creek in order to minimize predatory opportunities for striped bass and other non-native predators on anadromous salmonids.	2	BUC-2.2	SRCS, STE	Corps, USFWS, NMFS, CDFW	1,3	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on the # of sites, amount of material needed, type of material, location of source material (onsite vs. imported), and placement method. Cost of initial study to address these issues is $5,000-$50,000. See Table H1-2 in Appendix D for cost per unit for various projects
Implement flow ramping protocols in Butte Creek to protect all life	2	BUC-2.3	SRCS, STE	NMFS, USFWS, CDFW, DWR, PG&E, FERC	1,4	Long-term	TBD	TBD	TBD	TBD	TBD	TBD in the FERC licensing process

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
stages of spring-run Chinook salmon and steelhead.												
Develop and implement a strategy that prioritizes projects with the intent of promoting Butte Creek watershed resiliency and reducing the potential for wildfires.	2	BUC-2.4	SRCS, STE	NMFS, USFWS, CDFW, Butte Creek Watershed Conservancy, PG&E	1,4	Long-term	$0	$0	$0	$0	$0	$0
Identify stream reaches in Butte Creek that have been most altered by anthropogenic factors and develop and implement actions that restore natural river processes; conduct associated public outreach projects. One specific issue that should be addressed by this action is the number of temporary passage	2	BUC-2.5	SRCS, STE	NMFS, USFWS, CDFW, DWR	1	Long-term	$4,217,625	$0	$0	$0	$0	$4,217,625

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
impediments installed to create swimming holes in Butte Creek near Chico.												
Develop and implement programs and projects that focus on maintaining and restoring riparian corridors within the Butte Creek watershed.	2	BUC-2.6	SRCS, STE	NMFS, USFWS, USFS, CDFW, DWR, Local governments	1,4	Long-term	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$150,000 -$675000
Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap in Butte Creek.	2	BUC-2.7	SRCS, STE	Corps, USBR, NMFS, USFWS, DWR, CDFW, CBDA	1	Long-term	$0	$0	$0	$0	$0	$0
Curtail further development in active Butte Creek floodplains through zoning restrictions, county master plans, and	2	BUC-2.8	SRCS, STE	Corps, NMFS, USFWS, DWR, CDFW, Local governments	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
other Federal, State, and county planning and regulatory processes.												
Develop education and outreach programs to encourage river stewardship in the Butte Creek watershed.	2	BUC-2.9	SRCS, STE	NMFS, USFWS, CDFW, DWR, CSU Chico, Landowners, schools	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Permanently protect riparian habitat in Butte Creek through easements and/or land acquisition	2	BUC-2.10	SRCS, STE	CDFW, Landowners, USFWS	1	Long-term	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Increase monitoring and enforcement in order to minimize illegal streambank alterations in Butte Creek, including high bank gold mining.	2	BUC-2.11	SRCS, STE	Corps, DWR, SWRCB	1,4,5	Long-term						Cost is covered under action # COC-2.9

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Increase water quality monitoring and enforcement in Butte Creek to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants (SWRCB 2007).	2	BUC-2.12	SRCS, STE	SWRCB, RWQCBs, Local agriculture groups	5	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in Butte Creek.	2	BUC-2.13	SRCS, STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Dist, SWRCB, DWR, CDFW, Landowners	5	Long-term	$62,400	$0	$0	$0	$0	$62,400
Implement projects to increase Butte Creek floodplain habitat availability to improve habitat	2	BUC-2.14	SRCS, STE	NMFS, USFWS, CDFW, DWR	1,4	Long-term	TBD based on amount of habitat restored; initial study is expected to cost at least $50,000. Per unit cost is $5,000 to $80,000/acre (Appendix D Table	TBD	TBD	TBD	TBD	TBD based on amount of habitat restored; initial study is expected to cost at least $50,000. Per unit cost is $5,000 to $80,000/acre (Appendix D Table

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
conditions for juvenile rearing							HI-4).					HI-4).
Monitor and evaluate the sport fishing regulations for Butte Creek to ensure they are consistent with the recovery of spring-run Chinook salmon and steelhead, and work with the Fish and Game Commission to modify the regulations as needed.	2	BUC-2.15	SRCS, STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0
Develop, implement and evaluate a Butte Creek water management option for the PG&E DeSabla-Centerville Hydroelectric Project to determine the flow conditions that optimize coldwater holding habitat and spawning	2	BUC-2.16	SRCS, STE	CDFW, PG&E, FERC, NMFS	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD in the FERC licensing process

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
distribution for spring-run Chinook salmon.												
Maintain state-of-the-art fish passage facilities at diversions in Butte Creek and DWR weir 2 to meet NMFS and CDFW fish passage criteria.	2	BUC-2.17	SRCS, STE	Irrigation districts, DWR	1,4	Long-term	$100,000	$100,000	$100,000	$100,000	$100,000	$500,000 over 25 years; ~$20,000 for each year after that. Estimate of $20,000/year is based on DWR (2004b).
Implement projects to minimize predation at weirs, diversion dams, and related structures in Butte Creek.	3	BUC-3.1	SRCS, STE	NMFS, CDFW, DWR, USFWS, USBR, Corps	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013).

5.8.6 Feather River Recovery Actions

Table 5-18. Feather River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Establish reproductive isolation between fall-run Chinook salmon and spring-run Chinook salmon naturally spawning in the Feather River.	1	FER-1.1	SRCS	DWR, USFWS, NMFS, CDFW, FERC	1	Long-term	$0	$0	$0	$0	$0	$0 because this is an action required by a settlement agreement in FERC relicensing proceedings for DWR's Oroville Facilities hydroelectric project.
Develop and implement hatchery and genetic management plans for the spring-run Chinook salmon, steelhead, and fall-run Chinook salmon hatchery programs at the Feather River Fish Hatchery.	1	FER-1.2	SRCS, STE	DWR, USFWS, NMFS, CDFW, SWRCB, CVRWQCB, FERC	1,5	Long-term	$0	$0	$0	$0	$0	$0 because this is an action required by a settlement agreement in FERC relicensing proceedings for DWR's Oroville Facilities hydroelectric project.
Identify and implement actions intended to minimize straying of Feather River Hatchery salmon and steelhead.	1	FER-1.3	SRCS, STE	DWR, YCWA, USFWS, NMFS, CDFW, SWRCB, CVRWQCB, and FERC	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	The cost of hatchery measures are included in FER-1.2; the cost of any flow management measures are TBD in FERC licensing proceedings for projects on the Feather and Yuba Rivers.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop a spawning gravel budget, identify gravel depleted areas, and implement an augmentation plan in the Feather River.	1	FER-1.4	SRCS, STE	DWR, CDFW, USFWS, NMFS, SWRCB, and FERC	1	Long-term	$0	$0	$0	$0	$0	$0 because this is an action required by a settlement agreement in FERC relicensing proceedings for DWR's Oroville Facilities hydroelectric project.
Implement and maintain projects to increase side channel habitats in order to improve steelhead spawning habitat availability and quality.	1	FER-1.5	STE	DWR, CDFW, USFWS, NMFS, and FERC	1,4	Long-term	$0	$0	$0	$0	$0	$0 because this is an action required by a settlement agreement in FERC relicensing proceedings for DWR's Oroville Facilities hydroelectric project.
Operate the Feather River Hatchery programs for spring-run Chinook salmon and steelhead as conservation hatchery programs, and develop criteria and a process for phasing out the programs as recovery criteria are reached.	1	FER-1.6	SRCS, STE	NMFS, USFWS, CDFW, DWR	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement projects to minimize predation at weirs, diversion dams, and related structures in the Feather River.	1	FER-1.7	SRCS, STE	NMFS, CDFW, DWR, USFWS, USBR, Corps	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013).
Implement the lower Feather River Corridor Management Plan and other projects that promote natural river processes (e.g., floodplain and riparian restoration). Federal, State, and local agencies should	1	FER-1.8	SRCS, STE	DWR, CDFW, Corps	1,4	Long-term	TBD	TBD	TBD	TBD	TBD	TBD. NMFS is in the process of obtaining the cost information from DWR.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
use their authorities to develop and implement programs and projects that focus on retaining, restoring and creating active floodplain and riparian corridors within their jurisdiction in the Feather River watershed.												
Implement projects to improve near shore refuge cover for salmonids in the Feather River to minimize predatory opportunities for striped bass and other non-native predators.	1	FER-1.9	SRCS, STE	DWR, CDFW, Corps	1,3,4	Short-term	TBD	TBD				TBD, based on the # of sites, amount of material needed, type of material, location of source material (onsite vs. imported), and placement method. Cost of initial study to address these issues is $5,000-$50,000. See Table H1-2 in Appendix D for cost per unit for various projects
Manage releases from Oroville Dam with instream flow schedules and criteria to provide suitable water temperatures for all life	1	FER-1.10	SRCS, STE	NMFS, USFWS, CDFW, DWR, SWRCB, FERC	1,5	Long-term	$0	$0	$0	$0	$0	$0, because this is an action required by a settlement agreement in FERC relicensing proceedings for DWR's Oroville Facilities hydroelectric project.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
stages, reduce stranding and isolation, protect incubating eggs from being dewatered, and promote habitat availability.												
Implement a habitat expansion plan that meets the criteria of the Habitat Expansion Agreement, or develop and implement a program to reintroduce spring-run Chinook salmon and steelhead to historic habitats upstream of Oroville Dam in the North Fork Feather River. The program should include feasibility studies, habitat evaluations, fish passage design studies, and a pilot reintroduction phase prior to implementation of the long-term	2	FER-2.1	SRCS, STE	NMFS, USFWS, CDFW, DWR, PG&E, USFS, FERC	1,5	Long-term	$200,000	$4,000,000	$15,000,000	$17,000,000	$14,000,000	$50,200,000 (Cost estimate is for reintroducing spring-run Chinook salmon and steelhead to the North Fork Feather River.)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
reintroduction program.												
Implement a habitat expansion plan that meets the criteria of the Habitat Expansion Agreement, or implement actions to enhance habitat conditions and improve access within the north fork Feather River upstream of Oroville Dam, including increasing minimum flows, providing passage at upstream dams, and assessing feasibility of passage improvement at natural barriers.	2	FER-2.2	SRCS, STE	NMFS, USFWS, CDFW, DWR, PG&E, USFS, FERC	1,4,5	Long-term	TBD	TBD	TBD	TBD	TBD	$50,000 for habitat evaluation and identification of specific enhancement actions; cost of actions TBD
Implement a study designed to develop quantitative estimates of	2	FER-2.3	SRCS, STE	NMFS, USFWS, CDFW, DWR	3,4	5 Years	$200,000-$400,000	$0	$0	$0	$0	$200,000-$400,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
predation on spring-run Chinook salmon and steelhead in the Feather River.												
Implement programs and measures designed to minimize predation on juvenile salmonids in the Feather River, including harvest management techniques and programs for non-native predators (e.g., striped bass, largemouth bass, and smallmouth bass).	2	FER-2.4	SRCS, STE	NMFS, USFWS, CDFW, DWR	2,3,4	Long-term						Cost covered by the cost of SFB-2.5 ($0-$75,000,000).
Curtail further development in the active Feather River floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	2	FER-2.5	SRCS, STE	Corps, NMFS, USFWS, DWR, CDFW, Local governments	1,4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Utilize fish friendly designs (e.g., levee setbacks, inclusion of riparian vegetation) for levee construction and maintenance.	2	FER-2.6	SRCS, STE	Corps, SWRCB	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop education and outreach programs to encourage river stewardship in the Feather River, including how to identify and avoid damaging salmon and steelhead redds.	2	FER-2.7	SRCS, STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, DWR, CDFW, CSU Chico, Landowners, schools, Feather River Nature Center	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Permanently protect Feather River riparian and floodplain habitat through easements and/or land acquisition.	2	FER-2.8	SRCS, STE	NMFS, CDFW, DWR, Corps	1,5	Long-term	TBD based on amount specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on amount specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Monitor and evaluate the sport fishing regulations for the Feather River to ensure they are consistent with the recovery of	2	FER-2.9	SRCS, STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
spring-run Chinook salmon and steelhead.												
Negotiate agreements with landowners and Federal and State agencies to provide additional instream flows or purchase water rights in the Feather River.	2	FER-2.10	SRCS, STE	USFWS, NMFS, Corps, USBR, Resource Conservation Districts, CDFW, DWR, Water districts, Landowners, Local governments, NGOs	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of water. Cost per unit is $43 - $88/af/year for upstream of Delta water purchases (Appendix D)
Evaluate pulse flow benefits in the Feather River for adult immigration and juvenile outmigration during peak migration periods for years with low water availability; if pulse flows are determined to be effective for attracting adult spring-run Chinook salmon and steelhead or for improving survival during juvenile	2	FER-2.11	SRCS, STE	DWR, USFWS, NMFS, CDFW, FERC, YCWA, PG&E, NID	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD in FERC license proceedings.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
outmigration, implement the most beneficial pulse flow regime.												
Develop an entrainment and predator monitoring program in the Feather River to determine the level of take at individual diversions and screen those with the highest take level relative to screen cost.	2	FER-2.12	SRCS, STE	NMFS, CDFW, Irrigation districts, Water districts	1,3,5	5 years	$100,000 for monitoring program; screening costs are TBD.	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).
Modify Sunset Pumps to provide unimpeded upstream passage of adult steelhead and Chinook salmon (and sturgeon) and to minimize predation of juveniles moving downstream.	2	FER-2.13	SRCS, STE	DWR	1,3,5	Short-term	$50,000 to identify and design a preferred modification; cost of modification TBD after the initial study.	$0	$0	$0	$0	$50,000 to identify and design a preferred modification; cost of modification TBD after the initial study.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop a baseline monitoring program in the Feather River to evaluate water quality throughout the watershed to identify areas of concern and disseminate the information to resource managers.	2	FER-2.14	SRCS, STE	DWR, CDFW	1,5	3 Years	$0	$0	$0	$0	$0	$0
Develop and apply alternative diversion technologies that eliminate entrainment in the Feather River.	3	FER-3.1	SRCS, STE	NMFS, CDFW, Irrigation districts, Water districts	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD. This action involves development of a new technology such that is impracticable to provide a reasonable estimate of the action's cost.
Implement pollution control programs and projects to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met in the Feather River for all potential pollutants.	3	FER-3.2	SRCS, STE	SWRCB, CVRWQCB, Local agriculture groups	1,5	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Pursue grant funding or cost-share payments for landowners to prepare plans and implement best-management practices to reduce water quality impacts in the Feather River watershed.	3	FER-3.3	SRCS, STE	USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW	1,5	Long-term	$62,400	$0	$0	$0	$0	$62,400

5.8.7 Yuba River Recovery Actions

Table 5-19. Yuba River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop and implement a program to reintroduce spring-run Chinook salmon and steelhead to historic habitats upstream of Englebright Dam. The program should include feasibility studies, habitat evaluations, fish passage design studies, and a pilot reintroduction phase prior to implementation of the long-term reintroduction program.	1	YUR-1.1	SRCS, STE	NMFS, USFWS, USFS, CDFW, Corps, PG&E, NIC, YCWA, FERC	1, 4	Long-term: Evaluations beginning in year 1 , Pilot	$200,000	$4,000,000	$15,000,000	$17,000,000	$14,000,000	$50,200,000
Improve spawning habitat in the Englebright Dam Reach (Englebright Dam [RM 24] downstream to the Deer Creek confluence	1	YUR-1.2	SRCS, STE	NMFS, USFWS, Corps, CDFW	1	Long-term	$5.9 million for spawning rehabilitation (DWR and PG&E 2010)	$800,000 for maintenance	$800,000 for maintenance	$800,000 for maintenance	$800,000 for maintenance	$9, 900,000 over 25 years; $800,000 for each additional 5-year block.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
[RM 23]) through habitat rehabilitation and a long-term gravel injection program (Pasternack 2009).												
Develop programs and implement projects that promote natural river processes, including projects that add riparian habitat and instream cover.	1	YUR-1.3	SRCS, STE	YCWA, Corps, CDFW, SYRCL, USFS, USFWS	1	Long-term	$4,217,625	$0	$0	$0	$0	$4,217,625
Modify Daguerre Point Dam to provide unobstructed volitional upstream passage of adult steelhead and Chinook salmon (and sturgeon) and to minimize predation of juveniles moving downstream.	1	YUR-1.4	SRCS, STE	YCWA, Corps, CDFW, SYRCL, USFWS	1,4	Long-term	Cost estimates for fish passage alternatives range from $2.5 million to construct an engineered channel to $97 million to remove the dam (DWR and Corps 2003).	Operation and maintenance costs range from $50,000 to $2,000,000 per year (DWR and Corps 2003)	Operation and maintenance costs range from $50,000 to $2,000,000 per year (DWR and Corps 2003)	Operation and maintenance costs range from $50,000 to $2,000,000 per year (DWR and Corps 2003)	Operation and maintenance costs range from $50,000 to $2,000,000 per year (DWR and Corps 2003)	$3.5 million to $137 million based on DWR and Corps (2003) estimates, and assuming construction during years 1-5 and operation and maintenance costs during years 6-25.
Develop and implement a large woody material restoration	2	YUR-2.1	SRCS, STE	NMFS, USFWS, Corps, USBR, DWR, CDFW	1	Long-term	$750,000 - $2,000,000	$750,000 - $2,000,000	$750,000 - $2,000,000	$750,000 - $2,000,000	$750,000 - $2,000,000	$3,750,000 - $10,000,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
program along the lower Yuba River utilizing sources of wood that enter upstream reservoirs.												
Increase floodplain habitat availability in the lower Yuba River.	2	YUR-2.2	SRCS, STE	CDFW, USFWS, NMFS, YCWA	1	Long-term	TBD	TBD	TBD	TBD	TBD	TBD based on several factors including: (1) how much floodplain habitat is to be restored; (2) the amount of material that needs to be removed; (3) whether the removed material can be sold and at what price; and (4) whether the newly available floodplain is planted or vegetation is allowed to colonize naturally. Initial evaluation to address these factors estimated at up to $200,000.
Curtail further development in active Yuba River floodplains through zoning restrictions, county master plans, and other Federal, State, and	2	YUR-2.3	SRCS, STE	YCWA, Corps, CDFW, SYRCL, USFS, FERC, USFWS	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
county planning and regulatory processes.												
Create and restore side channel habitats to increase the quantity and quality of off-channel rearing and spawning areas in the Yuba River.	2	YUR-2.4	SRCS, STE	YCWA, Corps, CDFW, SYRCL, USFS, FERC, USFWS	1	Short-term	TBD	TBD				TBD based on the amount of side channel habitat restoration. Unit cost is $20,000 to $300,000/acre (Appendix D). Initial evaluation estimated at $5,000-$50,000
Federal, State, and local agencies should use their authorities to develop and implement programs and projects that focus on retaining, restoring and creating river riparian corridors within their jurisdiction in the Yuba River watershed.	2	YUR-2.5	SRCS, STE	NMFS, USWS, FERC, CDFW, DWR, YCWA	1	Long-term	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$150,000 - $675000
Permanently protect Yuba River riparian and floodplain habitat through easements and/or land	2	YUR-2.6	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR, Yuba Watershed Council	1	Long-term	TBD based on specific easements and land acquisitions; initial study is expected	TBD	TBD	TBD	TBD	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
acquisition.							to cost at least $50,000.					
Implement flow fluctuation and ramping rates found to be protective of embryos and juveniles.	1	YUR-2.7	SRCS, STE	YCWA, NMFS, USFWS, Corps, CDFW, DWR, PG&E, NID, SYRCL, Yuba Watershed Council	1	Long-term	Costs TBD in FERC licensing proceedings	Costs TBD in FERC licensing proceedings	Costs TBD in FERC licensing proceedings	Costs TBD in FERC licensing proceedings	Costs TBD in FERC licensing proceedings	Costs TBD in FERC licensing proceedings
Implement programs and measures designed to minimize predation by non-native fish in the Yuba River, including harvest management techniques and programs for non-native predators (e.g., striped bass, largemouth bass, and smallmouth bass).	2	YUR-2.8	SRCS, STE	NMFS, USFWS, CDFW, DWR, YCWA, South Yuba and Brophy Water Districts	2,3	Long-term						Cost covered by the cost of SFB-2.5 ($0-$75,000,000).
Improve efficiency of screening devices at Hallwood-Cordua and Brophy-South Yuba water diversions, and	2	YUR-2.9	SRCS, STE	NMFS, CDFW, YCWA, South Yuba and Brophy Water Districts	1,4	Short-term	$200,000	$0	$0	$0	$0	$200,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
construct screens at unscreened diversions												
Evaluate whether salmonid straying between the Feather and Yuba rivers can be minimized through flow management.	2	YUR-2.10	SRCS, STE	NMFS, USFWS, Corps, DWR, YCWA	1,4	Short-term	$5,000 for initial study to develop goals, objectives, experimental design, and statistical analysis; cost of the evaluation is TBD based on the initial study.	TBD	TBD	TBD	TBD	$5,000 for initial study to develop goals, objectives, experimental design, and statistical analysis; cost of the evaluation is TBD based on the initial study.
Monitor and evaluate the sport fishing regulations for the Yuba River to ensure they are consistent with the recovery of spring-run Chinook salmon and steelhead.	2	YUR-2.11	SRCS, STE	NMFS, CDFW,SYRCL, Yuba Watershed Council	2	Short-term	$0	$0	$0	$0	$0	$0
Relocate the riverside motocross recreation area outside of the Yuba River's active floodplain.	3	YUR-3.1	SRCS, STE	CDFW, Yuba County, Yuba Watershed Council	2	5 Years	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap in the Yuba River.	3	YUR-3.2	SRCS, STE	NMFS, USFWS, USBR, DWR, CDFW, CBDA	1	Long-term	$0	$0	$0	$0	$0	$0
Identify the benefits, risks, and costs associated with various techniques and locations for spatially segregating spring-run Chinook salmon and fall-run Chinook salmon during spawning in the Yuba River. If the benefits sufficiently outweigh the risks and costs, then implement a project to segregate spring- and fall-run Chinook salmon.	3	YUR-3.3	SRCS, STE	NMFS, CDFW, YCWA, Yuba Watershed Council, PG&E	1	Short-term	$10,000 for benefit, risk, and cost evaluation. Cost of segregation TBD based on the evaluation.	$0	$0	$0	$0	$10,000 for benefit, risk, and cost evaluation. Cost of segregation TBD based on the evaluation.

5.8.8 Dry Creek Recovery Actions

Table 5-20. Dry Creek Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Conduct an anadromous fish passage assessment in Dry Creek and implement projects to fix any obstructions.	3	DRC-3.1	STE	NMFS, USFWS, USFS, CDFW, DWR, Yuba Watershed Council, Bear River Watershed Group	1	5 Years	$50,000-$200,000, fish passage project(s) cost TBD by the assessment.	$0	$0	$0	$0	$50,000-$200,000, fish passage project(s) cost TBD by the assessment.
Enhance watershed resiliency in Dry Creek by identifying and implementing projects that would reduce the potential for, and magnitude of, a catastrophic wildfire, and restore forested areas within the watershed including riparian areas.	3	DRC-3.2	STE	NMFS, USFWS, USFS, CDFW, DWR, Yuba Watershed Council, Bear River Watershed Group	1	Long-term	TBD based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBE	TBD	TBD based on amount and type of habitat restored; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the Dry Creek watershed.	3	DRC-3.3	STE	NMFS, USFWS, National Park Service, SWRCB, DWR, CDFW, Dry Creek Conservancy, Placer County, Sierra College	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop education and outreach programs to encourage river stewardship in Dry Creek.	3	DRC-3.4	STE	NMFS, USFWS, National Park Service, SWRCB, DWR, CDFW, Dry Creek Conservancy, Placer County, Sierra College	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in the Dry Creek watershed.	3	DRC-3.5	STE	NMFS, USFWS, National Park Service, SWRCB, DWR, CDFW, Dry Creek Conservancy, Placer County, Sierra College	1,5	Long-term	$62,400	$0	$0	$0	$0	$62,400
Develop a long-term strategy for monitoring and regulating discharges from agricultural lands in the Dry Creek watershed to protect waters within the Central Valley, including enforcing the regulations.	3	DRC-3.6	STE	SWRCB, NRCS, Placer County	1,5	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement in Dry Creek to ensure that the water quality criteria established in the Central	3	DRC-3.7	STE	SWRCB, CVRWQCB, Local agriculture groups	1,5	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants.												
Conduct a hydrologic analysis of the Dry Creek watershed that explores conjunctive use opportunities to reduce water allocations that are dependent on surface water.	3	DRC-3.8	STE	NMFS, USFWS, National Park Service, SWRCB, DWR, CDFW, Dry Creek Conservancy, Placer County, Sierra College	1	Long-term	$275,550	$0	$0	$0	$0	$275,550
Evaluate gravel resources on Dry Creek and provide gravel at any identified locations.	3	DRC-3.9	STE	NMFS, USFWS, National Park Service, SWRCB, DWR, CDFW, Dry Creek Conservancy, Placer County, Sierra College	1,5	Short-term	$5,000-$50,000 for evaluation; gravel augmentation costs TBD based on the evaluation.	$0	$0	$0	$0	$5,000-$50,000 for evaluation; gravel augmentation costs TBD based on the evaluation.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Curtail further development in the active Dry Creek floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	3	DRC-3.10	STE	NMFS, USFWS, National Park Service, SWRCB, DWR, CDFW, Dry Creek Conservancy, Placer County, Sierra College	1,5	Long-term	$0	$0	$0	$0	$0	$0
Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap in Dry Creek.	3	DRC-3.11	STE	NMFS, USFWS, Corps, USBR, CDFW, DWR, CBDA	1	Long-term	$0	$0	$0	$0	$0	$0
Permanently protect Dry Creek riparian habitat through easements and/or land acquisition	3	DRC-3.12	STE		1,5	Long-term	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Monitor and evaluate the sport fishing regulations for Dry Creek to ensure they are consistent with the recovery of steelhead.	3	DRC-3.13	STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0
Implement programs and measures designed to control non-native predatory fish in Dry Creek (NMFS 2007b), including harvest management techniques and programs for non-native predators (e.g., striped bass, largemouth bass, and smallmouth bass).	3	DRC-3.14	STE	NMFS, USFWS, CDFW, DWR	1,3	Long-term						Cost covered by the cost of SFB-2.5 ($0-$75,000,000).
Implement projects to minimize predation at weirs, diversion dams, and related structures in Dry Creek.	3	DRC-3.15	STE	NMFS, CDFW, DWR, USFWS, USBR, Corps	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
							site-specific costs.					specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013).
Improve instream refuge cover for salmonids in Dry Creek to minimize predatory opportunities for striped bass and other non-native predators.	3	DRC-3.16	STE	NMFS, USFWS, CDFW, DWR	1,3	Long-term	TBD, based on the # of sites, # of miles, type of material, location of source material (onsite vs. imported), and placement method. Initial scoping to address those issues would cost at least $50,000. See Table H1-2 in Appendix D for cost per unit for various projects.	TBD	TBD	TBD	TBD	TBD, based on the # of sites, amount of material needed, type of material, location of source material (onsite vs. imported), and placement method. Cost of initial study to address these issues is $5,000-$50,000. See Table H1-2 in Appendix D for cost per unit for various projects

5.8.9 Auburn Ravine Recovery Actions

Table 5-21. Auburn Ravine Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Install a fish ladder at Gold Hill Dam and screen the diversion canal.	2	AUR-2.1	SRCS, STE	SWRCB, CVRWQCB, Local farmers, SARSAS	1,5	5 Years	<$1 million	$0	$0	$0	$0	<$1 million
Develop an entrainment monitoring program in Auburn Ravine and Coon Creek to determine the level of take at individual diversions. Prioritize diversions based on this monitoring and screen those that are determined to have substantial impacts at the population level.	2	AUR-2.2	STE	NMFS, USFWS, CDFW, DWR, Placer County, Irrigation districts, SARSAS	1,3,5	5 years	$100,000 for monitoring program; screening costs for Auburn Ravine are TBD.	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).
Develop and apply alternative diversion technologies that eliminate entrainment in Auburn Ravine and Coon Creek.	2	AUR-2.3	STE	NMFS, USFWS, CDFW, DWR, Placer County, Irrigation districts, SARSAS	1	Long-term	TBD	TBD	TBD	TBD	TBD	TBD. •This action involves development of a new technology such that is impracticable to provide a reasonable estimate of the action's cost.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement projects that consolidate and screen existing diversions in Auburn Ravine and Coon Creek where feasible.	2	AUR-2.4	STE	NMFS, USBR, CDFW, DWR, Irrigation districts, Water districts, SARSAS	1,3,5	Long-term	$200,000	$200,000	$0	$0	$0	$400,000
Conduct a hydrologic analysis of the Auburn/Coon Creek watershed that explores conjunctive use opportunities to reduce water allocations that are dependent on surface water.	2	AUR-2.5	STE	NMFS, USFWS, Corps, USBR, CDFW, DWR, SARSAS, PCWA	5	Long-term	$275,550	$0	$0	$0	$0	$275,550
Enhance watershed resiliency in Auburn Ravine and Coon Creek by identifying and implementing projects that would reduce the potential for, and magnitude of, a catastrophic wildfire, and restore forested areas within the watershed including riparian areas.	2	AUR-2.6	STE	NMFS, USFWS, USFS, CDFW, DWR, Placer County, SARSAS, PCWA	1	Long-term	TBD based on amount and type of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBE	TBD	TBD based on amount and type of habitat restored; initial study is expected to cost at least $50,000.
Continue to implement projects designed to minimize chronic road-related erosion on public and private lands in the	2	AUR-2.7	STE	NMFS, USFWS, USFS, CDFW, Placer County, SARSAS	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Auburn Ravine and Coon Creek watershed.												
Develop a baseline monitoring program in Auburn Ravine and Coon Creek to evaluate water quality throughout the watershed to identify areas of concern.	2	AUR-2.8	STE	NMFS, USFWS, USEPA, SWRCB, DWR, CDFW, Placer County, SARSAS	5	3 Years	$0	$0	$0	$0	$0	$0
Develop education and outreach programs to encourage river stewardship in the Auburn Ravine/Coon Creek watershed.	2	AUR-2.9	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW, Landowners, Placer County, SARSAS, PCWA	2	Long-term	$76,140	$76,140	$76,140	$76,140	$0	$304,560

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in the Auburn Ravine/Coon Creek watershed.	2	AUR-2.10	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW, Placer County, Local farmers	5	Long-term	$62,400	$0	$0	$0	$0	$62,400
Develop a long-term strategy for monitoring and regulating discharges from agricultural lands in the Auburn Ravine/Coon Creek watershed to protect waters within the Central Valley, including enforcing the regulations.	2	AUR-2.11	STE	SWRCB, Local farmers	5	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement in Auburn Ravine and Coon Creek to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met (SWRCB 2007).	2	AUR-2.12	STE	SWRCB, CVRWQCB, Local agriculture groups	1,5	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Identify stream reaches in Auburn Ravine and Coon Creek that have been most altered by anthropogenic factors and reconstruct a natural channel geometry scaled to current channel forming flows.	2	AUR-2.13	STE	NMFS, USFWS, CDFW, DWR, SARSAS	5	5 Years	$4,217,625	$0	$0	$0	$0	$4,217,625
Curtail further development in the active Auburn Ravine and Coon Creek floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	2	AUR-2.14	STE	NMFS, USFWS, Corps, USFS, DWR, CDFW, Local governments	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop State and national levee vegetation policies to maintain and restore riparian corridors in Auburn Ravine and Coon Creek (Corps vegetation management policy and FloodSAFE).	2	AUR-2.15	STE	NMFS, USFWS, Corps, USBR, CDFW, DWR	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement programs and projects that focus on retaining, restoring and creating river riparian corridors within their jurisdiction in the Auburn Ravine/Coon Creek watershed.	2	AUR-2.16	STE	NMFS, USFWS, Corps, USBR, USFS, DWR, CDFW, Local agencies, NGOs	1,5	Short-term	TBD	TBD	$0	$0	$0	TBD based on amount of riparian habitat to be restored. As identified in Appendix D, per unit costs vary depending on whether fencing, planting, irrigation, or invasive week control are needed. Initial scoping study estimated to cost $5,000-$50,000.
Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap in Auburn Ravine and Coon Creek.	2	AUR-2.17	STE	NMFS, USFWS, Corps, USBR, DWR, CDFW, CBDA	1	Long-term	$0	$0	$0	$0	$0	$0
Permanently protect Auburn and Coon Creek riparian habitat through easements and/or land acquisition	2	AUR-2.18	STE	NMFS, USFWS, CDFW, DWR, SARSAS	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Implement programs and measures in Auburn Ravine and Coon Creek designed to control non-native predators.	2	AUR-2.19	STE	NMFS, USFWS, CDFW, DWR, SARSAS	1,3	Long-term	Cost covered by the cost of SFB-2.5 ($0-$75,000,000).	TBD	TBD	TBD	TBD	Cost covered by the cost of SFB-2.5 ($0-$75,000,000).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement projects to minimize predation at weirs, diversion dams, and related structures in Auburn Ravine and Coon Creek.	2	AUR-2.20	STE	NMFS, CDFW, DWR, USFWS, USBR, Corps, SARSAS	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs. P	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013).
Improve instream refuge cover for salmonids in Auburn Ravine and Coon Creek to help minimize predation.	2	AUR-2.21	STE	NMFS, USFWS, CDFW, DWR, SARSAS	1,3	Long-term	TBD, based on the # of sites, # of miles, type of material, location of source material (onsite vs. imported), and placement method. Initial scoping to address those issues would cost at least $50,000. See Table H1-2 in Appendix D for cost per unit for various projects.	TBD	TBD	TBD	TBD	TBD, based on the # of sites, # of miles, type of material, location of source material (onsite vs. imported), and placement method. Initial scoping to address those issues would cost at least $50,000. See Table H1-2 in Appendix D for cost per unit for various projects.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Monitor and evaluate the sport fishing regulations for Auburn Ravine and Coon Creek to ensure they are consistent with the recovery of steelhead.	3	AUR-3.1	STE	NMFS, CDFW	1,2	Long-term	$0	$0	$0	$0	$0	$0

5.8.10 American River Recovery Actions

Table 5-22. American River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop and implement a steelhead reintroduction plan to re-colonize historic habitats above Nimbus and Folsom Dams: Conduct feasibility study; Conduct habitat evaluations; Conduct 3-5 year pilot testing program; and Implement long-term fish passage.	1	AMR-1.1	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW, FERC, PG&E, PCWA	1,5	Long-term: Evaluations beginning in year 1	$200,000	$4,000,000	$15,000,000	$17,000,000	$14,000,000	$50,200,000
Implement physical and structural modifications to the American River Division of the CVP in order to improve water temperature management (See RPA action II.3 in the 2009 Biological Opinion for the long-term operations of the CVP and SWP) (NMFS 2009b).	1	AMR-1.2	STE	NMFS, USFWS, Corps, USBR, DWR, CDFW, CBDA, Water Forum	1,4	Long-term	$0	$0	$00	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop an annual water temperature management plan for the lower American River (NMFS 2009b).	1	AMR-1.3	STE	USFWS, USBR, CDFW, DWR, Water Forum	1,5	Long-term	$0	$0	$0	$0	$0	$0
Implement the flow management related actions (i.e., RPA actions II.1 and II.4) identified in the reasonable and prudent alternative from the 2009 Biological Opinion for the long-term operations of the CVP and SWP (NMFS 2009b).	1	AMF-1.4	STE	USFWS, USBR, CDFW, DWR, Water Forum	1,4	Long-term	$0	$0	$0	$0	$0	$0
Implement a long-term gravel management program in the lower American River to provide suitable spawning habitat per CVPIA.	1	AMR-1.5	STE	USFWS, USBR, Water Forum	1,4	Long-term	$1,000,000[28]	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$5,000,000
Implement a long-term wood management program to provide habitat	1	AMR-1.6	STE	USFWS, USBR, CDFW, Water Forum	1,4,5	Long-term)	$100,000	$200,000	$250,000	$300,000	$300,000	$1,150,000

[28] Based on cost of 2013-2016 CVPIA funded gravel augmentation project for the American River.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
complexity and predator refuge habitat.												
Implement the recommendations of the 2012 California Hatchery Scientific Review Group Report regarding the steelhead program at Nimbus Hatchery.	1	AMR-1.7	STE	USBR, CDFW	4,5	Long-term	$0	$0	$0	$0	$0	$0
Develop and implement a HGMP for the steelhead program at Nimbus Hatchery (NMFS 2009b).	1	AMR-1.8	STE	USBR, CDFW	2,5	Long-term	$0	$0	$0	$0	$0	$0
Develop a baseline monitoring program in the American River watershed to evaluate water quality throughout the watershed to identify areas of concern.	2	AMR-2.1	STE	NMFS, USFWS, USEPA, SWRCB, DWR, CDFW	1,5	3 Years	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement in the American River watershed to ensure that the water quality	2	AMR-2.2	STE	SWRCB, CVRWQCB	1,4	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants.												
Implement projects that improve wastewater and stormwater treatment in residential, commercial, and industrial areas throughout the American River watershed.	2	AMR-2.3	STE	NMFS, CDFW, SWRCB, Water Forum, Sacramento County and cities germane to this issue.	4,5	Long-term	TBD	TBD	TBD	TBD	TBD	Cost partly covered in DEL-2.20 ($1-$2 billion). Other costs TBD based on site-specific evaluations, each of which could range up to $100,000.
Develop education and outreach programs to encourage river stewardship in the American River watershed.	2	AMR-2.4	STE	Corps, NMFS, USFWS, DWR, CDFW, American River Conservancy, Local government, Water Forum	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Develop and implement programs and projects that focus on retaining, restoring and creating river riparian corridors within their	2	AMR-2.5	STE	NMFS, USFWS, Corps, USBR, USFS, DWR, CDFW, Local agencies, NGOs	1,4	Long-term	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$150,000 -$675,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
jurisdiction in the American River watershed.												
Permanently protect American River riparian habitat through easements and/or land acquisition	2	AMR-2.6	STE	Local govt, Corps, SAFCA, CDFW	1,5	short-term	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap in the American River.	2	AMR-2.7	STE	Corps, USBR, NMFS, USFWS, DWR, CDFW, CBDA	1	Long-term	$0	$0	$0	$0	$0	$0
Curtail further development in active American River floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	2	AMR-2.8	STE	Corps, NMFS, USFWS, USFS, DWR, CDFW, Local governments	1,4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Inventory locations on the American River for creating shallow inundated floodplain habitat for multi-species benefits and implement where suitable opportunities are available (Water Forum 2001).	2	AMR-2.9	STE	NMFS, USFWS, USBR, Corps, CDFW, DWR, Water Forum	1	Long-term	$0	$0	$0	$0	$0	$0
Modify sport-fishing regulations to minimize "take" of wild steelhead and to minimize hatchery influence in the lower American River. This could include increased information in the regulations about not wading through redds and increasing the bag and possession limit for hatchery steelhead.	3	AMR-3.1	STE	NMFS, CDFW	2,5	short-term	$0	$0	$0	$0	$0	$0

5.8.11 Mokelumne River Recovery Actions

Table 5-23. Mokelumne River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Adaptively manage water releases in the Mokelumne River in consideration of the spatial and temporal distribution of steelhead life stages in the Mokelumne River.	1	MOR-1.1	STE	NMFS, USFWS, CDFW, DWR, Landowners, Irrigation districts	1	Long-term	$0	$0	$0	$0	$0	$0
Manage cold water pools in Camanche and Pardee reservoirs to provide suitable water temperatures in the Mokelumne River for all steelhead life stages.	1	MOR-1.2	STE	NMFS, USFWS, USBR, CDFW, EBMUD	1	Long-term	$278,030 for evaluation of alternative reservoir management practices; cost of any operational changes TBD based on the evaluation.	TBD	TBD	TBD	TBD	$278,030 for evaluation of alternative reservoir management practices; cost of any operational changes TBD based on the evaluation.
Implement the recommendations of the 2012 California Hatchery Scientific Review Group Report regarding the steelhead program at Mokelumne Hatchery.	1	MOR-1.3	STE	NMFS, USFWS, CDFW, DWR	4, 5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD; Specific actions to be taken and associated costs will be identified by the Mokelumne River Hatchery Coordination Team that will be formed according to the recommendation from the Hatchery Scientific Review Group.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Continue to develop and implement a spawning gravel augmentation plan for the Mokelumne River.	2	MOR-2.1	STE	NMFS, USFWS, USBR, CDFW, DWR	1,5	Long-term	$50,000 for plan development; gravel augmentation costs TBD	TBD	TBD	TBD	TBD	$50,000-TBD
Conduct feasibility studies for allowing steelhead access to habitat above Camanche and Pardee dams, including assessing habitat suitability and fish passage logistics.	2	MOR-2.2	STE	NMFS, USFWS, USBR, DWR, PG&E, FERC	1	Short-term	$720,000	$0	$0	$0	$0	$720,000
If the feasibility studies suggest that fish passage can be successful, then design and conduct an experimental fish passage program evaluating adult distribution, survival, spawning, and juvenile production in habitats above Camanche and Pardee dams.	2	MOR-2.3	STE	NMFS, USFWS, USBR, DWR	1	Short-term	$0	$9,000,000	$0	$0	$0	$9,000,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
If the experimental fish passage program demonstrates that passage above Camanche and Pardee dams can substantively contribute to the long-term viability of the DPS, then develop and implement long-term fish passage programs.	2	MOR-2.4	STE	NMFS, USFWS, USBR, DWR	1	Long-term	$0	$0	$3,500,000	$3,500,000	$3,500,000	10,500,000
Evaluate the adequacy of the existing flow regime through SWRCB processes, and dedicate flows as necessary.	2	MOR-2.5	STE	NMFS, USFWS, CDFW, SWRCB	1,5	Long-term	$0	$0	$0	$0	$0	$0
Negotiate agreements with landowners, water districts, and Federal and State agencies to provide additional instream flows or purchase water rights, and/or restore riparian habitat to promote shading in the Mokelumne River.	2	MOR-2.6	STE	USFWS, NMFS, Corps, USBR, Resource Conservation Districts, CDFW, DWR, Water Districts, Landowners, Local governments, NGOs	1, 5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on : (1) amount of water. Cost per unit is $43 - $88/af/year for upstream of Delta water purchases (Appendix D); and (2) amount of habitat restored. As identified in Appendix D, per unit costs for riparian restoration vary depending on whether fencing, planting, irrigation, or invasive weed control are needed. Evaluation of water available for acquisition and riparian habitat

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												restoration opportunities could range up to $100,000.
Evaluate pulse flow benefits for steelhead attraction and passage in the Mokelumne River; if pulse flows are determined to be effective for attracting steelhead, implement the most beneficial pulse flow regime.	2	MOR-2.7	STE	NMFS, USFWFS, USBR, CDFW, DWR	1	Long-term	$0	$0	$0	$0	$0	$0
Monitor and evaluate sport-fishing regulations to ensure that angling impacts on steelhead in the Mokelumne River are consistent with recovery.	2	MOR-2.8	STE	NMFS, CDFW	1, 2	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement outreach projects in the Mokelumne River basin to educate the public regarding the steelhead life cycle and watershed stewardship.	2	MOR-2.9	STE	NMFS, USFWS, USBR, CDFW, DWR	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in the Mokelumne River.	2	MOR-2.10	STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, CDFW, DWR, Landowners	1, 5	Long-term	$62,400	$0	$0	$0	$0	$62,400
Increase monitoring and enforcement in the Mokelumne River to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants.	2	MOR-2.11	STE	SWRCB, CVRWQCB, Local agriculture	1, 5	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Work with local land owners to restore riparian habitats in the Mokelumne River.	2	MOR-2.12	STE	NMFS, USFWS, Resource Conservation Districts, CDFW, DWR	1, 5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of habitat restored. As identified in Appendix D, per unit costs vary depending on whether fencing, planting, irrigation, or invasive weed control are needed.$5,000-$50,000 for initial scoping evaluation.
Permanently protect Mokelumne River riparian habitat through easements and/or land acquisition	2	MOR-2.13	STE	NMFS, USFWS, Resource Conservation Districts, CDFW, DWR	1, 5	Long-term	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Conduct research and monitoring to better understand the factors affecting the survival of steelhead downstream of Woodbridge Dam.	2	MOR-2.14	STE	EBMUD, CDFW, USFWS, NMFS	1,5	Short-term	$5,000 for initial study to develop goals, objectives, experimental design, and statistical analysis; cost of the research and monitoring is TBD based on the initial study.	TBD	$0	$0	$0	$5,000 for initial study to develop goals, objectives, experimental design, and statistical analysis; cost of the research and monitoring is TBD based on the initial study.
Implement projects to minimize predation in the Mokelumne River.	2	MOR-2.15	STE	EBMUD, CDFW, USFWS, NMFS	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
							for potential site-specific costs.					details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013).
Implement projects to minimize entrainment in the Mokelumne River.	2	MOR-2.16	STE	EBMUD, CDFW, USFWS, NMFS	1	Short-term	TBD based on number of diversions and site specific factors affecting screening costs. $5,000-$50,000 for initial scoping evaluation.	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).

5.8.12 Cosumnes River Recovery Actions

Table 5-24. Cosumnes River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop cooperative water use agreements (e.g., groundwater exchange agreements) with local water users to provide flows in the Cosumnes River.	3	COR-3.1	STE	CDFW, USFWS, NMFS, water districts	1	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of water. Cost per unit is $43 - $88/af/year for upstream of Delta water purchases (Appendix D)
Implement projects to minimize predation in the Cosumnes River	3	COR-3.2	STE	CDFW, USFWS, NMFS	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												assumed that each site will cost about $38,000 annually (BDCP 2013).
Implement projects to minimize entrainment in the Cosumnes River.	3	COR-3.3	STE	CDFW, USFWS, NMFS, water districts	1,5	Short-term	TBD based on number of diversions and site specific factors affecting screening costs. $5,000-$50,000 for initial scoping evaluation.	TBD	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).

5.9 Mainstem San Joaquin River Recovery Actions

Table 5-25. San Joaquin River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement the Exhibit B hydrographs providing interim and restoration flows as outlined in the San Joaquin River Stipulation of Settlement (available at http://www.restoresjr.net/).	1	SJR-1.1	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1,4	Long-term	$0	$0	$0	$0	$0	$0
Develop and implement a spring-run Chinook salmon reintroduction strategy as outlined in paragraph 14 of the San Joaquin River Stipulation of Settlement (available at http://www.restoresjr.net/).	1	SJR-1.2	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1,4	Long-term	$0	$0	$0	$0	$0	$0
Implement channel modifications as outlined in the San Joaquin River Stipulation of Settlement, including increasing the channel capacity to accommodate restoration flows up to 4,500 cfs (available at http://restoresjr.net/).	1	SJR-1.3	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1,4	Long-term	$0	$0	$0	$0	$0	$0
Minimize entrainment and fish losses to both adult and juvenile life stages to non-viable migration pathways as outlined in the San Joaquin River Stipulation of Settlement, including, placing temporary barriers at Mud and Salt Sloughs and other potential sources of adult entrainment, screening	1	SJR-1.4	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1,4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Arroyo Canal and other riparian diversions as they are identified, and modifying and screening the Chowchilla Bypass Bifurcation Structure (available at http://www.restoresjr.net/).												
Provide fish passage at existing structures as outlined in the San Joaquin River Stipulation of Settlement (available at http://restoresjr.net/) including: (1) modifications to the Sand Slough Control Structure; (2) modification of the Reach 4B head gate; (3) reconstruction of Sack Dam to ensure unimpeded fish passage; (4) construction of a Mendota Pool Bypass; (5) modifications to structures in the Eastside and Mariposa Bypasses channels; and (6) fixing other passage impediments including road crossings, drop structures, and others as identified in the DWR Passage Report (DWR 2012) for the San Joaquin River Restoration Area.	1	SJR-1.5	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1,4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Manage juvenile salmonid predation risk by filling and/or isolating high priority gravel pits as identified in paragraph 11(b) of the San Joaquin River Stipulation of Settlement (available at http://www.restoresjr.net/).	1	SJR-1.6	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1,4	Long-term	$0	$0	$0	$0	$0	$0
Develop and implement an ecologically based San Joaquin River flow regime to help restore natural river processes and support all life stages of steelhead and spring-run Chinook salmon (Poff *et al.*1997).	1	SJR-1.7	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR, SWRCB	1,4	Long-term	$4,217,625	$4,217,625	$4,217,625	$4,217,625	$0	$16,870,500
Implement projects that improve wastewater and stormwater treatment in residential, commercial, and industrial areas throughout the San Joaquin River watershed to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants.	1	SJR-1.8	SRCS, STE	NMFS, USFWS, CDFW, DWR, SWRCB, Local governments	1,4,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD based on amount of water to be treated and whether existing treatment facilities need to be upgraded or new facilities are required.. Site-specific evaluations could range up to $100,000 each.
Develop a long-term strategy for monitoring and regulating discharges from agricultural lands in the San Joaquin River basin to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan)	1	SJR-1.9	SRCS, STE	SWRCB	1,5	5 Years	TBD	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
are met for all potential pollutants.												
Complete Total Maximum Daily Load projects for all Clean Water Act Section 303(d) listed pollutants entering the San Joaquin River.	1	SJR-1.10	SRCS, STE	SWRCB	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop and implement a spawning gravel augmentation plan in the San Joaquin River.	1	SJR-1.11	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1	Long-term	$0	$0	$0	$0	$0	$0; covered under San Joaquin River Restoration Program
Develop and implement a program to reestablish steelhead upstream of Friant Dam. The program should include feasibility studies, habitat evaluations, fish passage design studies, and a pilot phase prior to implementation of the long-term program.	2	SJR-2.1	STE	NMFS, USFWS, USBR, CDFW, DWR	1,5	Long-term	$200,000	$4,000,000	$15,000,000	$17,000,000	$14,000,000	$50,200,000
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in the San Joaquin River.	2	SJR-2.2	SRCS, STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, CDFW, DWR, SWRCB, Landowners	1,5	Long-term	$62,400	$0	$0	$0	$0	$62,400

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop education and outreach programs and coordinate with local governments, communities, and conservation districts to encourage river stewardship in the San Joaquin River basin.	2	SJR-2.3	SRCS, STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, CDFW, DWR, SWRCB	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000
Permanently protect San Joaquin River riparian and floodplain habitat through easements and/or land acquisition.	2	SJR-2.4	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1,5	Long-term	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Implement projects to protect and restore riparian and floodplain habitats along the San Joaquin River, such as projects underway at the San Joaquin River National Wildlife Refuge to restore riparian habitat, expand the refuge, and breach deauthorized levees in order to increase floodplain habitat.	2	SJR-2.5	SRCS, STE		1,4	Long-term	TBD based on type and amount of habitat restored; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on type and amount of habitat restored; initial study is expected to cost at least $50,000.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Coordinate with county and other local planning processes to encourage protection of floodplain habitat along the San Joaquin River.	2	SJR-2.6	SRCS, STE	NMFS, USFWS, Corps, CDFW, DWR, Local governments	1,5	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement of illegal stream bank alterations and monitor permitted alterations in the San Joaquin River.	2	SJR-2.7	SRCS, STE	Corps, SWRCB	1,4	Long-term						Cost is covered under action # COC-2.9
Compile available data and/or conduct new habitat analyses to determine if instream cover is lacking in the San Joaquin River, and add instream cover as necessary.	2	SJR-2.8	SRCS, STE	NMFS, USFWS, CDFW	1	5 years	$0	$0	$0	$0	$0	$0
Implement studies designed to quantify the impact of predation on steelhead in the San Joaquin River and identify specific locations where predation is a problem.	2	SJR-2.9	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1,3,4	5 Years	$200,000-$400,000	$0	$0	$0	$0	$200,000-$400,000
Conduct studies to evaluate whether predator control actions (e.g., fishery management or directed removal programs) can be effective at minimizing predation on steelhead and spring-run Chinook salmon in the San Joaquin River; continue implementation if effective.	2	SJR-2.10	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR	1,3,4	5 Years						Cost covered by the cost of SFB-2.5 ($0-$75,000,000).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement habitat enhancement or augmentation actions designed to minimize predation on steelhead in the San Joaquin River.	2	SJR-2.11	SRCS, STE	NMFS, USFWS, USBR, CDFW, DWR, Various NGOs	1,3,4	Long-term	$0	$0	$0	$0	$0	$0
Develop and implement design criteria and projects to minimize predation at weirs, diversion dams, and related structures in the San Joaquin River.	2	SJR-2.12	SRCS, STE	NMFS, USFWS, USBR, Corps, CDFW, DWR	1,3,5	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												$38,000 annually (BDCP 2013).
Monitor and evaluate the sport fishing regulations for the San Joaquin River to ensure they are consistent with the recovery of steelhead and spring-run Chinook salmon, and work with the Fish and Game Commission to modify the regulations as needed.	2	SJR-2.13	SRCS, STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0
Develop information to better understand the interaction between surface water and groundwater in the San Joaquin watershed in order to evaluate the potential impacts of water management options (e.g., groundwater sales; conjunctive use) in the watershed on San Joaquin River flows.	2	SJR-2.14	SRCS, STE	SWRCB, DWR, NMFS, USFWS, USBR, Corps, CDFW,	1.4	Short-term	$0	$0	$0	$0	$0	$0
Develop information to better understand the potential impact of inter basin water management (i.e., Sacramento River water being pumped into and then running off the San Joaquin basin) on the migratory cues and fish response (e.g., straying) for returning adult Chinook salmon and	2	SJR-2.15	SRCS, STE	NMFS, USFWS, USBR, Corps, CDFW, DWR	1,4	Short-term	$5,000 for initial study to develop goals, objectives, experimental design, and statistical analysis; cost of the research and monitoring is TBD based on the initial	TBD	$0	$0	$0	$5,000 for initial study to develop goals, objectives, experimental design, and statistical analysis; cost of the research and monitoring is TBD based on the initial study.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
steelhead.							study.					
Develop an incentive-based entrainment monitoring program in the San Joaquin River designed to work cooperatively with diverters to develop projects or actions in order to minimize pumping impacts.	2	SJR-2.16	SRCS, STE	NMFS, USFWS, USBR, Corps, CDFW, DWR	1,4	Short-term	TBD based on number of diversions and site specific factors affecting screening costs. Entrainment monitoring program estimated at up to $300,000 annually.	TBD	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).

5.10 Southern Sierra Nevada Diversity Group Recovery Actions

5.10.1 Merced River Recovery Actions

Table 5-26. Merced River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop and implement a program to reestablish steelhead in historic habitat upstream of Crocker-Huffman, Merced Falls, McSwain, and New Exchequer dams. The program should include feasibility studies, habitat evaluations, fish passage design studies, and a pilot reintroduction phase prior to implementation of the long-term program.	1	MER-1.1	STE	NMFS, USFWS, USBR, CDFW, DWR, MID, PG&E, FERC	1,5	Long-term	$200,000	$4,000,000	$15,000,000	$17,000,000	$14,000,000	$50,200,000
Manage releases from New Exchequer Reservoir in order to provide the	2	MER-1.2	STE	NMFS, USFWS, MID, FERC, CDFW, DWR	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD in the FERC licensing process

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
most beneficial flow and water temperatures for all steelhead life stages.												
Supplement flows provided pursuant to the Davis-Grunsky Contract and FERC License Number 2179 with water acquired from willing land owners and water districts to provide additional instream flow.	1	MER-1.3	STE	NMFS, USFWS, USBR, CDFW, DWR	1,4	Long-term	$0	$0	$0	$0	$0	$0
Develop a Merced River steelhead team to help guide collection and evaluation of baseline data to help address hypotheses for why resident O.mykiss are more abundant than anadromous O.mykiss in the Merced River. This information could be used to identify the flow and water	1	MER-1.4	STE	NMFS, USFWS, CDFW, DWR	1,2,3,4,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
temperature conditions that are most beneficial to anadromous O. mykiss.												
Evaluate whether pulse flows in the Merced River are beneficial to adult steelhead immigration and juvenile steelhead emigration; if pulse flows are determined to be effective, implement the most beneficial pulse flow regime.	1	MER-1.5	STE	NMFS, USFWS, MID, FERC, CDFW, DWR	1,4	Long-term	TBD	TBD	TBD	TBD	TBD	TBD in the FERC licensing process
Identify and implement floodplain and side channel projects to improve river function and increase habitat diversity in the Merced River.	1	MER-1.6	STE	NMFS, USFWS, MID, FERC, CDFW, DWR	1,4,5	Short-term	TBD, based on amount of floodplain and side channel habitat restored. Floodplain restoration unit cost ranges from is $5,000 - $80,000/acre (Appendix D Table HI-4); side channel reconnection unit cost ranges from $20,000 to	TBD	$0	$0	$0	TBD, based on amount of floodplain and side channel habitat restored. Floodplain restoration unit cost ranges from is $5,000 - $80,000/acre (Appendix D Table HI-4); side channel reconnection unit cost ranges from $20,000 to $300,000/acre.. $5,000-$50,000 for initial scoping evaluation.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
							$300,000/acre.. $5,000-$50,000 for initial scoping evaluation.					
Develop and implement a long-term gravel management plan to increase and maintain steelhead spawning habitat downstream of Crocker-Huffman, Merced Falls, and New Exchequer dams.	1	MER-1.7	STE	NMFS, USFWS, , MID, PG&E, FERC, CDFW, DWR	1,4	Long-term	$50,000 for plan development; gravel augmentation costs TBD	TBD	TBD	TBD	TBD	$50,000-TBD
Prioritize Merced River diversions based on their level of entrainment and screen those with the highest benefit to cost ratio.	2	MER-2.1	STE	NMFS, USFWS, USBR, CDFW, DWR, MID	1,3,5	5 years	$50,000 for prioritization; screening costs are TBD.	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).
Work with water rights holders in the Merced River watershed to provide flows that are	2	MER-2.2	STE	NMFS, USFWS, USBR, Corps, CDFW, DWR, NRCS, Family Water Alliance, MID	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
protective of steelhead.												
Develop and implement ramping rate criteria for the Merced River that are protective of anadromous fishes.	2	MER-2.3	STE	NMFS, USFWS, Corps, MID, PG&E, FERC, CDFW, DWR	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD in the FERC licensing process
Continue to supply spawning-sized gravel to landowners for construction and maintenance of wing dam diversion structures in the Merced River; implement the Gravel Mining Reach Phase II projects.	2	MER-2.4	STE	NMFS, USFWS, CDFW, DWR	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD based on amount of gravel added; Per unit cost is $11 to $72/cubic yard (Appendix D).
Evaluate the potential benefits and feasibility of installing a water temperature control device on New Exchequer Dam in order to most efficiently	2	MER-2.5	STE	NMFS, USFWS, USBR, MID, FERC, CDFW, DWR	1	Short-term	<$50,000	$0	$0	$0	$0	<$50,000 for evaluation and feasibility study.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
utilize the volume of cold water in the reservoir.												
Federal, State, and local agencies should use their authorities to develop and implement programs and projects that focus on retaining, restoring and creating riparian corridors within their jurisdiction in the Merced River watershed.	2	MER-2.6	STE	USFWS, Corps, CDFW, DWR, Local agencies, NGOs	1,4	Long-term	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$30,000 - $135,000	$150,000 -$675000
Permanently protect Merced River riparian habitat through easements and/or land acquisition	2	MER-2.7	STE	NMFS, USFWS, CDFW, DWR, landowners, Resource Conservation Districts	1,5	Long-term	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Increase monitoring and enforcement of illegal rip rap applications in the Merced	2	MER-2.8	STE	Corps, SWRCB	1,4,5	Long-term						Cost is covered under action # COC-2.9

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
River.												
Implement studies designed to quantify the impact of predation on steelhead in the Merced River. If the studies identify predator species and/or locations contributing to low steelhead survival, then evaluate whether predator control actions (e.g., fishery management or directed removal programs) can be effective at minimizing predation on steelhead in the Merced River; continue implementation if effective.	2	MER-2.9	STE	NMFS, USFWS, CDFW, DWR	1,2,3	Long-term						Cost covered by the cost of SFB-2.5 ($0-$75,000,000).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement programs and measures designed to control predation in the Merced River, including actions to isolate "ponded" sections of the river.	2	MER-2.10	STE	NMFS, USFWS, CDFW, DWR	1,3,5	Long-term	$0	$0	$0	$0	$0	$0

5.10.2 Tuolumne River Recovery Actions

Table 5-27. Tuolumne River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Evaluate and, if feasible, develop and implement a steelhead and spring-run Chinook salmon passage program for La Grange and Don Pedro dams. The program should include feasibility studies, habitat evaluations, fish passage design studies, and a pilot reintroduction phase prior to implementation of the long-term reintroduction program.	1	TUR-1.1	STE	NMFS, CDFW, Modesto Irrigation District, Turlock Irrigation District, FERC	1,5	Long-term	$720,150	$9,000,000	$3,468,000	$0	$0	$13,188,150

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Manage releases from La Grange and Don Pedro dams to provide suitable flows and water temperatures for all downstream life stages of steelhead.	1	TUR-1.2	STE	NMFS, CDFW, Modesto Irrigation District, Turlock Irrigation District, FERC	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD in the FERC licensing process
Develop a Tuolumne River steelhead team to help guide collection and evaluation of baseline data to help address hypotheses for why resident O.mykiss are more abundant than anadromous O.mykiss in the Tuolumne River. This information could be used to identify the flow and water temperature conditions that are most	1	TUR-1.3	STE	USFWS, CDFW, NMFS	1	Short-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
beneficial to anadromous O. mykiss.												
Evaluate whether pulse flows in the Tuolumne River are beneficial to adult steelhead immigration and juvenile steelhead emigration; if pulse flows are determined to be effective, implement the most beneficial pulse flow regime.	1	TUR-2.1	STE	NMFS, USFWS, USBR, CDFW, DWR, Modesto and Turlock Irrigation Districts, FERC	1	Long-term	TBD	TBD	TBD	TBD	TBD	TBD in the FERC licensing process
Continue to implement projects to increase the availability and quality of spawning and rearing habitat in the Tuolumne	2	TUR-2.2	STE	NMFS, USFWS, USBR, CDFW, DWR, Modesto and Turlock Irrigation Districts	1,4	Long-term	TBD	TBD	TBD	TBD	TBD	TBD based on the amount of spawning gravel to be added and the type and amount of rearing habitat restored. Per unit cost for gravel augmentation is $11 to $72/cubic yard (Appendix D). See Appendix D for per unit costs of restoring various

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
River.												types of rearing habitats (e.g., riparian, floodplain, instream cover. $5,000-$50,000 for initial scoping of rearing habitat restoration opportunities and gravel needs.)
Evaluate the feasibility of moving water diversions lower in the Tuolumne River in order to provide higher flows in the upstream reaches. If feasible and cost effective, move water diversions lower in the Tuolumne River.	2	TUR-2.3	STE	NMFS, USFWS, USBR, CDFW, DWR, Modesto and Turlock Irrigation Districts	1	Long-term	<$200,000 for evaluation; cost of moving diversions TBD based on information obtained during the evaluation.	TBD	TBD	TBD	TBD	<$200,000 for evaluation; cost of moving diversions TBD based on information obtained during the evaluation.
Develop and implement flow fluctuation criteria for the Tuolumne River that are protective of anadromous	2	TUR - 2.4	STE	NMFS, USFWS, Corps, CDFW, DWR, Modesto and Turlock Irrigation Districts, FERC	1	Long-term	TBD	TBD	TBD	TBD	TBD	TBD in the FERC licensing process

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
fishes.												
Work with State and Federal water acquisition programs to dedicate instream water in the Tuolumne River.	2	TUR - 2.5	STE	NMFS, USFWS, USBR, CDFW, DWR, Modesto and Turlock Irrigation Districts	1	Long-term	$0	$0	$0	$0	$0	$0
Evaluate modifying current operation plans (e.g., flood control curves) for Don Pedro with the Corps and irrigation districts to reallocate instream flows for salmonids.	2	TUR - 2.6	STE	Corps, Modesto and Turlock Irrigation Districts, NMFS, USFWS, CDFW	1	Short-term	$0	$0	$0	$0	$0	$0
Identify and implement floodplain and side channel projects to improve river function and	2	TUR - 2.7	STE	NMFS, USFWS, CDFW, Modesto and Turlock Irrigation Districts	1	Short-term	TBD	TBD	$0	$0	$0	TBD, based on amount of floodplain and side channel habitat restored. Floodplain restoration unit cost ranges from is $5,000 - $80,000/acre (Appendix D Table HI-

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
increase habitat diversity in the Tuolumne River.												4); side channel reconnection unit cost ranges from $20,000 to $300,000/acre. $5,000-$50,000 for initial scoping of restoration opportunities.
Update the 2006 Water Quality Control Plan for the Bay-Delta in order to improve flow conditions for steelhead in the Tuolumne River.	2	TUR - 2.8	STE	SWRCB, CDFW, USFWS, NMFS, Modesto and Turlock Irrigation Districts	1,4	Long-term	$0	$0	$0	$0	$0	$0
Restore riparian habitat to promote shading and habitat diversity in the Tuolumne River.	2	TUR - 2.9	STE	Corps, Modesto and Turlock Irrigation Districts, NMFS, USFWS, CDFW, CV Flood Protection Board	1		TBD	TBD	TBD	TBD	TBD	TBD, based on amount of habitat restored. As identified in Appendix D, per unit costs vary depending on whether fencing, planting, irrigation, or invasive weed control are needed. $5,000-$50,000 for initial scoping of restoration opportunities.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Implement projects to minimize predation at weirs, diversion dams, and related structures in the Tuolumne River.	2	TUR - 2.10	STE	NMFS, CDFW, DWR, USFWS, Modesto and Turlock Irrigation Districts	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about $38,000 annually (BDCP 2013).
Improve instream refuge cover for salmonids in the Tuolumne River to minimize predatory opportunities for striped bass and other non-native	2	TUR - 2.11	STE	NMFS, USFWS, CDFW, DWR	1,3	Long-term	TBD, based on the # of sites, # of miles, type of material, location of source material (onsite vs. imported), and placement method. Initial scoping to address those	TBD	TBD	TBD	TBD	TBD, based on the # of sites, amount of material needed, type of material, location of source material (onsite vs. imported), and placement method. Cost of initial study to address these issues is $5,000-$50,000. See Table H1-2 in Appendix D for cost per unit for various

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
predators.							issues would cost at least $50,000. See Table H1-2 in Appendix D for cost per unit for various projects.					projects
Develop a baseline monitoring program for the Tuolumne River to evaluate water quality throughout the watershed to identify pollutants to be included on the Clean Water Act section 303(d) list.	2	TUR - 2.12	STE	SWRCB, CDFW, USFWS, NMFS, Modesto and Turlock Irrigation Districts	1,5	Short-term	$0	$0	$0	$0	$0	$0
Complete Total Maximum Daily Load projects for all Clean Water Act Section 303(d) listed pollutants entering the Tuolumne	2	TUR - 2.13	STE	SWRCB	1	Short-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
River.												
Encourage voluntary landowner participation in the Tuolumne River watershed in educational opportunities such as water quality short courses, field demonstrations and distribution of water quality "Fact Sheets".	2	TUR - 2.14	STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, CDFW, DWR, Landowners	2	Long-term	$76,140	$76,140	$76,140	$76,140	$0	$304,560
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in the Tuolumne River.	2	TUR - 2.15	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, CDFW, DWR, SWRCB	1,5	Long-term	$62,400	$0	$0	$0	$0	$62,400

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Increase monitoring and enforcement in the Tuolumne River to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants excluding water temperature.	2	TUR - 2.16	STE	SWRCB, CVRWQCB, Local agriculture groups	1,4	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)
Evaluate Tuolumne River O.mykiss genetics to inform management in the anadromous reach as well as planning for potential reintroductions to the upper river.	3	TUR - 3.1	STE	CDFW, USFWS, NMFS	1,5	Short-term	$25,000 - $50,000	$0	$0	$0	$0	$25,000 - $50,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Prioritize lower Tuolumne River diversions based on their level of entrainment and screen those with the highest benefit to cost ratio	3	TUR - 3.2	STE	CDFW, USFWS, NMFS, USBR, DWR, Modesto and Turlock Irrigation Districts	1,5	5 years	$50,000 for prioritization; screening costs are TBD.	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).

5.10.3 Stanislaus River Recovery Actions

Table 5-28. Stanislaus River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Evaluate and, if feasible, develop and implement a steelhead passage program for Tullock, Goodwin, and New Melones dams. The program should include feasibility studies, habitat evaluations, fish passage design studies, and a pilot reintroduction phase prior to implementation of the long-term reintroduction program.	1	STR-1.1	STE	NMFS, USFWS, USBR, CDFW, OID, South San Joaquin Irrigation District, TriDam, PG&E, FERC	1,5	Long-term	$720,150	$9,000,000	$3,468,000	$0	$0	$13,188,150

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Manage releases from Tulloch, Goodwin, and New Melones dams to provide suitable water temperatures and flows for all steelhead life stages. Suitable water temperatures for the Stanislaus River are specified on page 621 of the biological opinion for the long-term operations of the CVP/SWP (NMFS 2009b). Suitable minimum instream flow schedules for the Stanislaus River are described in Appendix 2-E of the biological opinion	1	STR-1.2	STE	NMFS, USFWS, USBR, Corps, CDFW, DWR, OID, South San Joaquin Irrigation District, Tridam	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
(NMFS 2009b).												
Develop a Stanislaus River steelhead team to help guide collection and evaluation of baseline data to help address hypotheses for why resident O.mykiss are more abundant than anadromous O.mykiss in the Stanislaus River. This information could be used to identify the flow and water temperature conditions that are most beneficial to anadromous O. mykiss.	1	STR-1.3	STE	NMFS, USFWS, USBR, CDFW	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Continue to implement projects to increase the availability and quality of spawning and rearing habitat in the Stanislaus River.	2	STR-2.1	STE	NMFS, USFWS, USBR, CDFW, DWR	1,4	Long-term	$0	$0	$0	$0	$0	$0
Evaluate whether pulse flows in the Stanislaus River are beneficial to adult steelhead immigration and juvenile steelhead emigration; if pulse flows are determined to be effective, implement the most beneficial pulse flow regime.	2	STR-2.2	STE	NMFS, USFWS, USBR, CDFW, DWR, Stanislaus River Fish Group, OID, South San Joaquin Irrigation District, TriDam, PG&E, FERC	1,5	Long-term	$0	$0	$0	$0	$0	$0. Pulse flows are required under the 2009 biological opinion for the long-term operations of the CVP/SWP.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Work with State and Federal water acquisition programs to dedicate instream water in the Stanislaus River.	2	STR-2.3	STE	NMFS, USFWS, USBR, CDFW, DWR, Stanislaus River Fish Group	1	Long-term	$0	$0	$0	$0	$0	$0
Negotiate agreements with landowners, water districts, and Federal and State agencies to provide additional instream flows or purchase water rights in the Stanislaus River.	2	STR-2.4	STE	NMFS, USFWS, USBR, Corps, Resource Conservation Districts, CDFW, DWR, Water districts, Landowners, Local governments, NGOs	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of water. Cost per unit is $162 - $246/af/year for south of Delta water purchases (Appendix D)
Utilize the SWRCB regulatory process of updating the 2006 Water Quality Control Plan for the Bay-Delta to	2	STR-2.5	STE	NMFS, SWRCB	1,4	Short-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
improve flow conditions for steelhead in the Stanislaus River.												
Identify and implement floodplain and side channel projects to improve river function and increase habitat diversity in the Stanislaus River.	2	STR-2.6	STE	NMFS, USFWS, USBR, Corps, CDFW, DWR	1	Short-term	TBD, based on amount of floodplain and side channel habitat restored. Floodplain restoration unit cost ranges from is $5,000 - $80,000/acre (Appendix D Table HI-4); side channel reconnection unit cost ranges from $20,000 to $300,000/acre.. $5,000-$50,000 for initial scoping evaluation.	TBD	$0	$0	$0	TBD, based on amount of floodplain and side channel habitat restored. Floodplain restoration unit cost ranges from is $5,000 - $80,000/acre (Appendix D Table HI-4); side channel reconnection unit cost ranges from $20,000 to $300,000/acre.. $5,000-$50,000 for initial scoping evaluation.
Work with local land owners to restore riparian habitats along the Stanislaus River.	2	STR-2.7	STE	NMFS, USFWS, USBR, CDFW, DWR, Stanislaus River Fish Group	1,5	Long-term	TBD, based on amount of floodplain and side channel habitat restored. Floodplain restoration unit cost ranges from is $5,000 - $80,000/acre	TBD	$0	$0	$0	TBD, based on amount of floodplain and side channel habitat restored. Floodplain restoration unit cost ranges from is $5,000 - $80,000/acre (Appendix D Table

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
							(Appendix D Table HI-4); side channel reconnection unit cost ranges from $20,000 to $300,000/acre.. $5,000-$50,000 for initial scoping evaluation.					HI-4); side channel reconnection unit cost ranges from $20,000 to $300,000/acre.. $5,000-$50,000 for initial scoping evaluation.
Permanently protect riparian habitat along the Stanislaus River through easements and/or land acquisition.	2	STR-2.8	STE	NMFS, USFWS, USBR, Corps, Resource Conservation Districts, CDFW, DWR, Water districts, Landowners, Local governments, NGOs	1,5	Long-term	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD, based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Monitor and evaluate the impact of the sport fishery on Stanislaus River steelhead to ensure the regulations are consistent with steelhead recovery, and work with the Fish and Game Commission to	2	STR-2.9	STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
modify the regulations as needed.												
Increase monitoring and enforcement in order to minimize steelhead poaching in the Stanislaus River.	2	STR-2.10	STE	NMFS, CDFW	2,4	Long-term						Cost is covered under action # COC-2.9
Implement outreach projects in the Stanislaus River to educate the public regarding the steelhead life cycle including how to identify steelhead redds. Encourage voluntary landowner participation in the Stanislaus River in educational opportunities such as water	2	STR-2.11	STE	NMFS, USFWS, USBR, CDFW, DWR, Stanislaus River Fish Group	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
quality short courses, field demonstrations and distribution of water quality "Fact Sheets".												
Evaluate programs and measures designed to minimize predation in the Stanislaus River.	2	STR-2.12	STE	NMFS, USFWS, CDFW, DWR, Stanislaus River Fish Group, OID	1,3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost about

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												$38,000 annually (BDCP 2013).
Implement projects to minimize predation in the Stanislaus River at mine pits and at deep pools caused by bank stabilization projects.	2	STR-2.13	STE	NMFS, USFWS, CDFW, DWR, Stanislaus River Fish Group	1,3,4	Long-term	Costs covered in action STR-2.12	Costs covered in action STR-2.12	Costs covered in action STR-2.12	Costs covered in action STR-2.12	Costs covered in action STR-2.12	Costs covered in action STR-2.12
Implement projects to increase instream habitat complexity and predator refuge cover in the Stanislaus River, including the addition of large woody material.	2	STR-2.14	STE	NMFS, USFWS, CDFW, DWR, Stanislaus River Fish Group	1,3,4	Long-term	$750,000 - $2,000,000	$750,000 - $2,000,000	$750,000 - $2,000,000	$750,000 - $2,000,000	$750,000 - $2,000,000	$3,750,000 - $10,000,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop a baseline monitoring program for the Stanislaus River to evaluate water quality throughout the watershed to identify areas of concern.	2	STR-2.15	STE	NMFS, USWFS, USEPA, Resource Conservation Districts, CDFW, DWR, SWRCB, Stanislaus River Fish Group	1,5	3 Years	$0	$0	$0	$0	$0	$0
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water quality impacts in the Stanislaus River.	2	STR-2.16	STE	NMFS, USFWS, USFS, USEPA, Resource Conservation Districts, CDFW, DWR, Landowners	1,5	Long-term	$62,400	$0	$0	$0	$0	$62,400
Increase monitoring and enforcement in the Stanislaus River to ensure that the water quality criteria	2	STR-2.17	STE	SWRCB, CVRWQCB, Local agriculture groups	1,4,5	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants.												
Complete Total Maximum Daily Load projects for all Clean Water Act Section 303(d) listed pollutants entering the Stanislaus River.	2	STR-2.18	STE	EPA, SWRCB, CVRWQCB, Local agriculture groups	1,5	Long-term	$0	$0	$0	$0	$0	$0
Evaluate Stanislaus River *O.mykiss* genetics to inform management in the anadromous reach as well as planning for potential reintroductions to the upper river.	2	STR-2.19	STE	NMFS, CDFW, Reclamation, USFWS	1,5	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop an entrainment monitoring program in the Stanislaus River to determine the level of take at individual diversions. Prioritize diversions based on this monitoring program and screen those that are determined to have substantial impacts.	3	STR-3.1	STE	NMFS, USFWS, CDFW	1,3,5	5 years	$100,000 for monitoring program; screening costs are TBD.	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is estimated at $20 million (San Francisco Estuary Partnership 2007).

5.10.4 Calaveras River Recovery Actions

Table 5-29. Calaveras River Recovery Actions.

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Develop and implement long-term year-round instream flow schedules and water temperature requirements that are protective of all steelhead life stages, including providing flows for upstream and downstream fish passage.	1	CAR - 1.1	STE	NMFS, USFWS, CDFW	1	Long-term	$594,090	$0	$0	$0	$0	$594,090
Establish a minimum carryover storage level at New Hogan Reservoir that meets the instream flow and water temperature requirements in the lower Calaveras River.	1	CAR - 1.2	STE	NMFS, USFWS, CDFW, Corps	1,5	Long-term	$1,144,240	$0	$0	$0	$0	$1,144,240
Remove or modify all fish passage impediments in the lower Calaveras River to meet NMFS and CDFW fish passage criteria.	1	CAR - 1.3	STE	NMFS, USFWS, CDFW, Corps	1	Long-term	$0	$15,000,000	$0	$0	$0	$15,000,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Monitor upstream and downstream fish passage through the existing Bellota weir fish ladder and operate the weir based on this monitoring information to provide timely and safe fish passage.	1	CAR-1.4	STE	NMFS, USFWS, USBR, CDFW, DWR, Fishery Foundation of California, Stockton East Water District	1,4	Long-term	$0	$0	$0	$0	$0	$0
Replace Bellota weir incorporating a permanent fish ladder and screened diversion as recommended in the Calaveras River Fish Screen Facilities Feasibility Study.	1	CAR-1.5	STE	NMFS, USFWS, USBR, CDFW, DWR, Fishery Foundation of California, Stockton East Water District	1	Short-term	$8-$10 million	$0	$0	$0	$0	$8-$10 million
Implement a Calaveras River monitoring program to identify the temporal and spatial distributions of migrating and holding steelhead. These data would help ensure that suitable flows, water temperatures, and passage conditions are	1	CAR-1.6	STE	NMFS, USFWS, USBR, CDFW, DWR, Fishery Foundation of California, Stockton East Water District	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
being provided when and where the fish are in the Calaveras River.												
Fully implement the Calaveras River fish passage improvement project in order to provide permanent upstream and downstream passage for salmonids between the mouth of the Calaveras River and Bellota weir.	2	CAR-2.1	STE	DWR, USFWS, USBR, Corps, CDFW, Fishery Foundation of California, Stockton East Water District	1	Long-term	TBD	TBD	TBD	TBD	TBD	TBD based on the number and type of fish passage impediments. NMFS is in the process of obtaining a cost estimate from DWR, the lead agency for the project.
Until year-round permanent fish passage improvements are made to preclude the need for flashboard weirs, operate Bellota and other weirs so that the flashboards are not in place from at least October through June.	2	CAR-2.2	STE	USFWS, USBR, Corps, CDFW, DWR, Fishery Foundation of California, Stockton East Water District	1	Long-term	$0	$0	$0	$0	$0	$0
Prioritize and screen unscreened diversions in the Calaveras River including Bellota weir.	2	CAR-2.3	STE	CDFW, NMFS, Stockton East Water District, Calaveras County Water District	1,3,5	5 years	$50,000 for prioritization; screening costs are TBD.	$0	$0	$0	$0	The cost of installing screens on all diversions in the Sacramento and San Joaquin river systems is

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												estimated at $20 million (San Francisco Estuary Partnership 2007).
Negotiate agreements with landowners, Stockton East Water District (SEWD), Calaveras County Water District (CCWD) and federal and state agencies to provide additional instream flows.	2	CAR-2.4	STE	SEWD, CCWD, NMFS, USFWS, Corps, USBR, Resource Conservation Districts, CDFW, DWR, Water Districts, Landowners, Local Governments, NGOs	1,5	Long-term	TBD	TBD	TBD	TBD	TBD	TBD, based on amount of water. Cost per unit is $162 - $246/af/year for south of Delta water purchases (Appendix D)
Purchase water rights from Calaveras River water diverters in order to increase flows.	2	CAR-2.5	STE	NMFS, USFWS, Corps, USBR, Resource Conservation Districts, CDFW, DWR, Water Districts, Landowners, Local Governments, NGOs	1,5	Short-term	TBD	TBD	$0	$0	$0	TBD based on the amount of water accounted for in the water right. Cost per unit is $162 - $246/af/year for south of Delta water purchases (Appendix D)
Continue implementing the recommendations from the lower Calaveras River Salmonid Life History Limiting Factor Analysis to assess flow requirements for anadromous salmonids and also develop and implement further specific	2	CAR-2.6	STE	NMFS, USFWS, USBR, CDFW, DWR, Stockton East Water District	1	Long-term	$0	$0	$0	$0	$0	$0

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
recommendations.												
Evaluate pulse flow benefits for steelhead attraction and passage in the Calaveras River; if pulse flows are determined to be effective for attracting steelhead, implement the most beneficial pulse flow regime.	2	CAR-2.7	STE	NMFS, USFWS, USBR, Corps, DWR, CDFW	1,5	Long-term	$0	$0	$0	$0	$0	$0
Develop a baseline monitoring program for the Calaveras River to evaluate water quality throughout the watershed to identify areas of concern.	2	CAR-2.8	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW	1	3 Years	$0	$0	$0	$0	$0	$0
Pursue grant funding or cost-share payments for landowners to inventory, prepare plans and implement best-management practices that reduce water	2	CAR-2.9	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW	1	Long-term	$62,400	$0	$0	$0	$0	$62,400

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
quality impacts in the Calaveras River.												
Increase monitoring and enforcement in the Calaveras River to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants.	2	CAR-2.10	STE	SWRCB, CVRWQCB, Local agriculture groups	1,4	Long-term						Cost is covered under the cost of action SAR-2.6 ($1,750,000)
Complete Total Maximum Daily Load projects for all Clean Water Act Section 303(d) listed pollutants entering the Calaveras River.	2	CAR-2.11	STE	NMFS, USFWS, USEPA, Resource Conservation Districts, SWRCB, DWR, CDFW	1	Long-term	$0	$0	$0	$0	$0	$0
Develop and implement a spawning gravel augmentation plan in the Calaveras River, including periodic evaluations of spawning gravel quality and quantity.	2	CAR-2.12	STE	NMFS, USFWS, Corps, DWR, CDFW	1	Long-term	$50,000 for plan development; gravel augmentation costs TBD	TBD	TBD	TBD	TBD	$50,000-TBD

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Curtail further development in active Calaveras River floodplains through zoning restrictions, county master plans, and other Federal, State, and county planning and regulatory processes.	2	CAR-2.13	STE	NMFS, USFWS, Corps, CDFW, DWR, Local governments	1,5	Long-term	$0	$0	$0	$0	$0	$0
Utilize bio-technical techniques that integrate riparian restoration for river bank stabilization instead of conventional rip rap in the Calaveras River.	2	CAR-2.14	STE	NMFS, USFWS, USBR, Corps, CDFW, DWR, CBDA	1	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement of illegal stream bank alterations and monitor permitted alterations in the Calaveras River.	2	CAR-2.15	STE	Corps, SWRCB	1,4	Long-term						Cost is covered under action # COC-2.9
Develop education and outreach programs to encourage river stewardship in the Calaveras River.	2	CAR-2.16	STE	NMFS, USFWS, USBR, CDFW, DWR, Various NGOs	2	Long-term	$75,000	$75,000	$75,000	$75,000	$75,000	$375,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
Monitor and evaluate the sport fishing regulations for the Calaveras River to ensure they are consistent with the recovery of steelhead, and work with the Fish and Game Commission to modify the regulations as needed.	2	CAR-2.17	STE	NMFS, CDFW	2	Long-term	$0	$0	$0	$0	$0	$0
Increase monitoring and enforcement in order to minimize anadromous fish poaching in the Calaveras River.	2	CAR-2.18	STE	CDFW	2	Long-term						Cost is covered under action # COC-2.9
Implement a study designed to quantify the amount of predation on steelhead by non-native species in the Calaveras River. If the study identifies predator species and/or locations contributing to low steelhead survival, then evaluate whether predator control actions (e.g., fishery management or	2	CAR-2.19	STE	NMFS, USFWS, CDFW, DWR	1,2	Long-term						Cost covered by the cost of SFB-2.5 ($0-$75,000,000).

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
directed removal programs) can be effective at minimizing predation on juvenile steelhead in the Calaveras River; continue implementation if effective.												
Develop and implement design criteria and projects to minimize predation at weirs, diversion dams, and related structures in the in the Calaveras River.	2	CAR-2.20	STE	NMFS, CDFW, DWR, USFWS, USBR, Corps	3	Long-term	$5,000-$50,000 for site identification and evaluation; project implementation costs TBD. See total cost for potential site-specific costs.	TBD	TBD	TBD	TBD	$5,000-$50,000 for site identification and evaluation. Total cost TBD. If structural modification is identified as a solution at a particular site, it is impracticable to provide a cost without knowing details of the specific structure and what type of modification is needed. If structural removal is identified as a solution, it is assumed that the average cost of removal will be roughly $8,300 per structure (BDCP 2013). If predator removal is identified as a solution, it is assumed that each site will cost

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
												about $38,000 annually (BDCP 2013).
Improve refuge cover for steelhead in the Calaveras River to minimize predatory opportunities for predators.	2	CAR-2.21	STE	NMFS, USFWS, CDFW, DWR	1,2	Short-term	TBD, based on the # of sites, # of miles, type of material, location of source material (onsite vs. imported), and placement method. See Table H1-2 in Appendix D for cost per unit for various projects.	$0	$0	$0	$0	TBD, based on the # of sites, amount of material needed, type of material, location of source material (onsite vs. imported), and placement method. Cost of initial study to address these issues is $5,000-$50,000. See Table H1-2 in Appendix D for cost per unit for various projects
Permanently protect riparian habitat through easements and/or land acquisition.	2	CAR-2.22	STE	NMFS, USFWS, CDFW, DWR	1,5	Long-term	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.	TBD	TBD	TBD	TBD	TBD based on specific easements and land acquisitions; initial study is expected to cost at least $50,000.
Examine the potential for re-establishing steelhead in historic habitats upstream of New Hogan Dam by conducting feasibility and habitat evaluations. If	3	CAR-3.1	STE	NMFS, USFWS, CDFW, DWR, Corps	1,5	Long-term	$200,000	$4,000,000	$15,000,000	$17,000,000	$14,000,000	$50,200,000

Recovery Action	Action Priority	Action ID	Species	Potential Collaborators	Listing Factor(s) Addressed	Duration	~ Cost FY1-5	~ Cost FY6-10	~ Cost FY11-15	~ Cost FY16-20	~ Cost FY21-25	Total ~Cost
these evaluations suggest that re-establishment can be successful, then develop a phased program intended to re-establish steelhead upstream of New Hogan Dam.												

6.0 Climate Change and Recovery of Salmon and Steelhead

"Climate variability plays a large role in driving fluctuations in salmon abundance by influencing their physical environment, the availability of food, the competitors for that food, and the predators that prey on small salmon. The complexity of influences on salmon, both climate and otherwise, combined with the scarcity of observations of factors important to salmon in estuaries and the ocean, make it challenging to identify the links between salmon and climate."

- Climate Impacts Group (2004)

6.1 Overview

The scientific basis for understanding the processes and sources of climate variability has grown significantly in recent years, and our ability to forecast human and natural contributions to climate change has improved dramatically. With consensus on the reality of climate change now established (Oreskes 2004; IPCC 2007), the scientific, political, and public priorities are evolving toward determining its ecosystem impacts, and developing strategies for adapting to those impacts. Climate forces directly influence regional temperature, wind, precipitation, snowpack and streamflow patterns, which may impact the habitat suitability for marine and anadromous species directly or indirectly (Schwing 2009).

Many salmon populations throughout the West Coast are at historically low levels due to stresses imposed by a variety of human activities including dam construction, logging, pollution, and over-fishing. Climate change affects salmon throughout their life cycle and poses an additional stress. Earlier peak flows flush young salmon from rivers to estuaries before they are physically mature enough for the transition, increasing a variety of stresses including the risk of being eaten by predators. Earlier snowmelt leaves rivers and streams warmer and shallower during the summer and fall (Thomas *et al*. 2009).

Increasing air temperatures, particularly during the summer, lead to rising water temperatures, which increase stress on coldwater fish such as salmon and steelhead. Projected temperatures for the 2020s and 2040s under a higher emissions scenario suggest that the habitat quality and quantity for these fish is likely to decrease dramatically (Mote *et al*. 2008; Salathé *et al*. 2005; Keleher *et al*. 1996; McCullough *et al*. 2001).

Warmer water temperatures and lower base flows will negatively affect salmonids in several ways. Fish metabolism increases with water temperature, reducing growth if more energy is devoted to searching for food. Warmer water causes salmonid eggs to hatch sooner. Resulting young may be smaller, and emerge at a time when their insect prey base is not available. (Thomas *et al*. 2009). In addition, diseases and parasites that infect salmon are more prevalent in warmer water.

Ocean conditions are also important to salmon populations, as they reside there for years. The oceans are also impacted by warmer temperatures. Warm coastal temperatures have been correlated with low salmon abundance; higher salmon abundance is associated with cooler ocean temperatures (Janetos *et al*. 2008; Crozier *et al*. 2008).

6.2 Climate Change and Environmental Variability

For ecosystem concerns (e.g., warming, wildfire, sea level rise, anthropogenic influences, El Niño) related to long-term climate changes, all regions under the management jurisdiction of NMFS are expected to experience environmental conditions that have not been experienced before. Warming over this century is projected to be considerably greater than over the last century (Thomas *et al.* 2009). Since 1900, the global average temperature has risen by about 1.5°F. By about 2100, it is projected to rise between 2°F and 10.5°F (**Figure 6-1**), but could increase up to 11.5°F (Thomas *et al*. 2009; California Climate Change Center 2006). In the United States, the average temperature has risen by a comparable amount and is very likely to rise more than the global average over this century, with some variation according to location. Several factors will determine future temperature increases. Increases at the lower end of this range are more likely if global heat-trapping gas emissions are substantially reduced.

If emissions continue to rise at or near current rates, temperature increases are more likely to be near the upper end of the range. Volcanic eruptions or other natural variations could temporarily counteract some of the human-induced warming, slowing the rise in global temperature, but these effects would only last a few years (Thomas *et al*. 2009).

Climate-related fire dynamics also will be affected by changes in the distribution of ecosystems across the landscape. Torn *et al*. (1998) project that there will be a doubling of catastrophic wildfires in some regions due to faster and more intense burning associated with warming, drying vegetation, and elevated wind speed. Increasing temperatures and shifting precipitation patterns also will drive declines in high elevation ecosystems such as alpine forests. As an example, under higher emissions scenarios (Figure 6-1), high-elevation forests in California are projected to decline by 60 to 90 percent before the end of the century. At the same time, grasslands are projected to expand, another factor likely to increase fire risk. Climate changes also could create subtle shifts in fire behavior, allowing more “runaway fires” – fires that are thought to have been brought under control, but then rekindle (Thomas *et al*. 2009).

Current climate trends predict a future of warmer oceans and melting glaciers and icecaps, all of which are expected to raise mean sea levels, leading to the inundation and displacement of many estuaries. A rise in sea level will most dramatically affect those estuaries that are confined by surrounding development, which prohibits their boundaries from naturally shifting in response to inundation. Projections for sea level rise by 2100 vary from 0.18 to 0.58

meters (m), to 0.5 to. 1.4 m (IPCC 2007a; Rahmstorf 2007; Raper and Braithwaite 2006). Paleoclimatic data suggest that the rate of future melting of Greenland and Antarctic ice sheets and related sea-level rise could be faster than currently projected (NMFS 2009). A projected 1 m rise in sea level could potentially inundate 65 percent of the coastal marshlands and estuaries in the United States. In addition, there could be shifts in the quality of the habitats in affected coastal regions. Prior to being inundated, coastal watersheds would become saline due to saltwater intrusion into the surface and groundwater. Regarding California's water supply, the largest effect of sea level rise would likely be in the Delta (DWR 2005c). Increased intrusion of salt water from the ocean into the Delta could lead to increased releases of water from upstream reservoirs or reduced pumping from the Delta to maintain compliance with Delta water quality standards (Anderson *et al*. 2008).

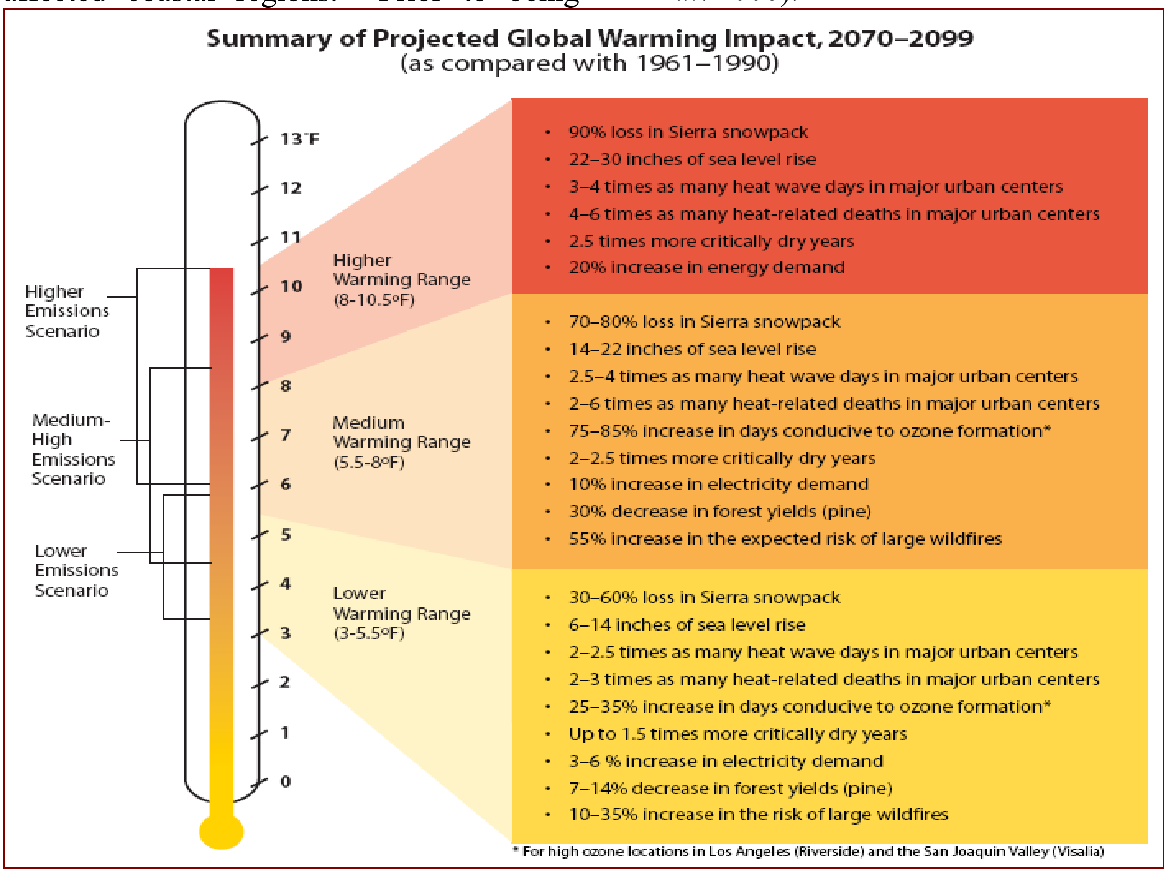


Figure 6-1. Summary of Projected Global Warming Impacts (2070 to 2099 compared to 1961 to 1990). ***(Source: California Climate Change Center 2006)***

Figure 6-2. Schematic of Coastal Upwelling Near the California Coast. Winds from the northwest during spring and summer drive surface water offshore, and it is replaced by cool water high in nutrients that is "upwelled" onto the continental shelf. ***(Source: NMFS 2009 - image from NOAA Cordell Bank National Marine Sanctuary).***

Anthropogenic influences on salmon and steelhead habitat play a primary role in climate influences on extinctions (Francis and Mantua 2003). Over the past 150 years, human activities have degraded, and in some cases completely eliminated, much of the historic stream and estuarine habitats for anadromous salmonids. In many ways, human actions have forced semi-permanent changes to the salmonid landscape that parallel those typically associated with climate change (Karr 1994). For example, stream temperatures, flow regimes, sediment transports, and pool-to-riffle ratios are all subject to anthropogenic and climate changes. Karr (1994) indicates that one major difference between perturbations due to natural climate events versus one caused by human activities is the time scale of the resulting impacts. A warm phase of the El Niño-Southern Oscillation generally impacts precipitation and flow over a single year, while hydropower dam construction alters flow for decades to centuries (Francis and Mantua 2003).

Because it affects the distribution of heat in the atmosphere and the oceans, climate change will affect winds and currents that move along the nation's coasts, such as the California Current that bathes the West Coast from British Columbia to Baja California (Thomas *et al*. 2009). Wind-driven upwelling of deeper ocean water along the coast in this area is vital to moderation of temperatures and the high productivity of Pacific Coast ecosystems (**Figure 6-2**). Warmer temperatures are likely to increase ocean stratification, yet possible increases in winds may counter that in ways that mitigate or even increase the wind-driven upwelling of nutrients that fuel a productive food web (CIG 2004).

Coastal currents are subject to periodic variations caused by the El Niño-Southern Oscillation and the Pacific Decadal Oscillation, which have substantial effects on the success of salmon and other fishery resources. Climate change is expected to affect such coastal currents, and possibly the larger scale natural oscillations as well, although these effects are not yet well understood (Thomas *et al*. 2009).

In addition to carbon dioxide's heat-trapping effect, the increase in its concentration in the atmosphere is gradually acidifying the ocean (Thomas *et al*. 2009). About one-third of the carbon dioxide emitted by human activities has been absorbed by the ocean, resulting in a decrease in the ocean's pH. Since the beginning of the industrial era, ocean pH has declined demonstrably and is projected to decline much more by 2100 if current emissions trends continue (Thomas *et al*. 2009). Because less dissolved carbon is available as carbonate ions at a lower pH (Feely *et al*. 2008; Janetos *et al*. 2008), further declines in pH are very likely to continue to affect the ability of living organisms to create and maintain shells or skeletons of calcium carbonate. Ocean acidification also is anticipated to affect important plankton species in the open ocean, mollusks and other shellfish, and corals (Feely *et al*. 2008; Janetos *et al*. 2008; Royal Society 2005; Orr *et al*. 2005). Reductions in pH also affect photosynthesis, growth, and reproduction. The upwelling of deeper ocean water, deficient in carbonate and thus potentially detrimental to the food chains supporting juvenile salmon, has recently been observed along the West Coast (Feely *et al*. 2008).

It is unclear how coastal ocean conditions will respond to long-term climate change and, in turn, affect Chinook salmon and steelhead populations during their marine life stages. Results of studies by Pearcy (1992),Francis and Hare (1994), and Francis and Mantua (2003) indicate that many climate-related biophysical linkages to salmonid populations occur very early in the salmon's marine life history - likely just months after juvenile fish enter the ocean. This hypothesis that cohort survival can be greatly impacted by climate driven conditions (e.g. upwelling and resultant prey availability) when juvenile salmon enter the ocean was also found to apply to Central Valley Chinook salmon (Lindley *et al*. 2009), further indicating that coastal and estuarine environments are key areas of biophysical interaction. While there is uncertainty regarding how coastal ocean conditions will respond to long-term climate change, it is likely that near-shore marine areas will remain important for salmon survival.

6.3 Climate Change Effects on Ocean Conditions

Most climate factors affect the entire West Coast complex of salmonids. This is particularly true in their marine phase, because the California populations are believed to range fairly broadly along the coast and intermingle, and climate impacts in the ocean occur over large spatial scales (Schwing 2009). Because ocean warming will be widespread, populations at the southern extreme of their ranges will be most susceptible to future warming. Salmon and steelhead residing in coastal areas where upwelling is the dominant process are more sensitive to climate-driven changes in the strength and timing of upwelling. Coastal sea level is generally not a major issue along the West Coast, but future sea level rise will be important to juvenile fish in the San Francisco Bay and Delta, as well as in lagoons and estuaries where the annual cycle of bar development and breaching are important to salmonid life history strategies. Perhaps the greatest uncertainty is how ocean acidification will affect salmonids and their marine ecosystem (Schwing 2009). The following is a general discussion of anticipated future changes in ocean conditions, as they may affect off-shore areas used by winter- and spring-run Chinook salmon, and steelhead during their marine life stages.

6.3.1 California Current Ecosystem

The California Current Ecosystem (CCE) is designated by NMFS as one of eight large marine ecosystems within the United States Exclusive Economic Zone. The California Current begins at the northern tip of Vancouver Island, Canada and ends somewhere between Punta Eugenia and the tip of Baja California Mexico (NMFS 2009). The northern end of the current is dominated by strong seasonal variability in winds, temperature, upwelling, plankton production and the spawning times of many fishes, whereas the southern end of the current has much less seasonal variability. For some groups of organisms, the northern end of the CCE is dominated by sub-arctic boreal fauna whereas the southern end is dominated by tropical and sub-tropical species. Faunal boundaries (i.e., regions where rapid changes in species composition are observed) are known for the waters between Cape Blanco Oregon/Cape Mendocino California, and in the vicinity of Point Conception California (**Figure 6-3**). Higher trophic level organisms often take advantage of the strong seasonal cycles of production in the north by migrating to the region during the summer to feed. Climate signals in this region are quite strong. During the past 10 years, the North Pacific has seen two El Niño events (1997/98, 2002/03), one La Niña event (1999), a four-year climate regime shift to a cold phase from 1999 until late 2002, followed by a four-year shift to warm phase from 2002 until 2006. The response of ocean conditions, plankton and fish to these events is well documented in the scientific literature. The biological responses are often so strong that the animals give early warning of events before such shifts are noticed in the physical oceanographic records (Osgood 2008). Numerous climate stressors (e.g., warming, sea level rise, freshwater flow) impact productivity and structure throughout the CCE. It is difficult to isolate the effect of individual stressors on most individual species, and most of these stressors impact many species at multiple trophic levels.

Five climate-related issues are of greatest concern in the CCE (Osgood 2008). The following provides a summary of these issues, based upon the analysis developed as part of NMFS' framework for a long-term plan to address climate impacts on living marine resources (Osgood 2008).

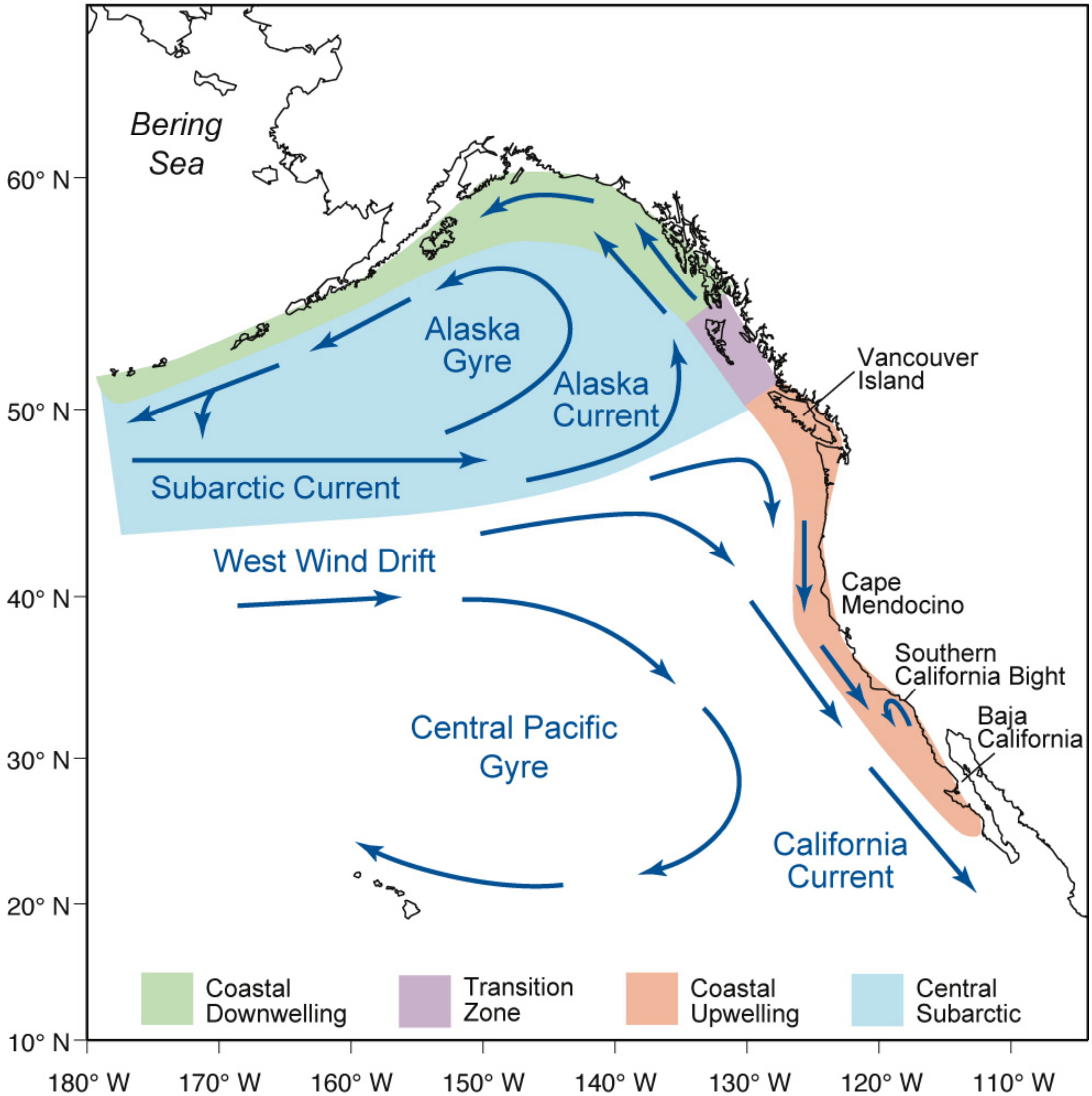


Figure 6- 3. The Principal Ocean Currents Affecting the Coastal Waters off of California. Eastward flow (West Wind Drift) bifurcates as it nears the west coast. The southward arm (the California Current) transports, cool, low salinity, nutrient-rich water along the U.S. west coast. (Source: Image from J.A. Barth, Oregon State University)

Increased Future Climate Variability

One of the likely consequences of global climate change will be a more volatile climate with greater extreme events on the intra-seasonal to inter-annual scales. For the CCE, more frequent and severe winter storms are expected to occur, with greater wind mixing, higher waves and coastal erosion, and more extreme precipitation events and years, which would impact coastal circulation and stratification. Some global climate models predict a higher frequency of El Niño events; others predict that the intensity of these events will be stronger. If true, primary and secondary production will be greatly reduced in the CCE, with negative effects transmitted up the food chain.

The Pacific Decadal Oscillation is a pattern of Pacific climate variability that shifts phases approximately every 20 to 30 years. During a "warm" or "positive" phase, the west Pacific becomes cool and part of the eastern ocean warms; during a "cool" or "negative" phase, the opposite pattern occurs. Most models project roughly the same timing and frequency of decadal variability in the North Pacific under the impacts of global warming. However, combined with the global warming trend, the CCE is expected to experience a greater frequency of years consistent with historical periods of lower productivity (e.g., positive Pacific Decadal Oscillation values). Based on ongoing observations, a positive Pacific Decadal Oscillation and a warmer ocean result in dominance of small warm-water zooplankton (which are lipid-depleted), which may result in food chains with lower bioenergetic content. By about 2030, it is expected that the minima in decadal regimes will be above the historical mean of the 20th Century (i.e., the greenhouse gas warming trend will be as large as natural variability).

The Extent and Timing of Freshwater Input

While variability in ocean conditions has substantial impacts on salmon survival and growth, future changes in freshwater and river conditions also will have a great effect on production of anadromous fish. Warmer air temperatures will result in more precipitation earlier in the year, and less snowpack. Changes in the seasonal and inter-annual timing and intensity of rainfall and snowpack, for example, are expected to increase winter and spring runoff and decrease summer runoff. These hydrologic changes may alter the way that water supplies from the Sacramento River are managed for hydropower generation and water storage, which may affect the manner in which Chinook salmon, steelhead and other estuarine-dependent species are managed.

Climate models project the 21st Century will feature greater annual precipitation in the Pacific Northwest, extreme winter precipitation events in California, and a more rapid spring snowmelt leading to a shorter, more intense spring period of river flow and freshwater discharge (Thomas *et al*. 2009). These changes are projected to considerably alter coastal stratification and mixing, riverine plume formation and evolution, and the timing of transport of anadromous fish populations to and from the ocean. A warmer and drier future also means that extra care will be needed in planning the allocation of water for the coming decades (Thomas *et al*. 2009). The current allocation of water resources between salmon and human requirements in the western United States has been a critical factor in the success of many salmon populations, and will be more so if future water availability is altered (Osgood 2008).

Changes in the Timing and Strength of the Spring Transition, and Their Resultant Effects on Marine Populations

The primary issue for the CCE is the onset and length of the upwelling season - when upwelling begins and ends (i.e., the "spring" and "fall" transitions). The biological transition date provides an estimate of when seasonal cycles of significant plankton and euphausiid production are initiated. At present, there is some evidence that coastal upwelling has become stronger over the past several decades due to greater contrasts between warming of the land (resulting in lower atmospheric pressure over the continent), relative to ocean warming. The greater cross-shelf pressure gradient will result in higher along-shore wind speeds and the potential for more upwelling (Bakun 1990). Regional climate models project that not only will upwelling-favorable winds will be stronger in summer, but that the peak in seasonal upwelling will occur later in the summer (Snyder *et al*. 2003).

Even though southward winds that cause coastal upwelling are likely to increase in magnitude, these winds may be less effective in driving vertical transport of nutrient-rich water because it is not known if these winds will be able to over-ride increased water column stratification (Osgood 2008; NMFS 2009). That is, the winds may not be able to mix this light buoyant water or transport it offshore resulting in the inability of the cold nutrient-rich water to be brought to the ocean surface. Thus, phytoplankton blooms may not be as intense, which may impact organisms up the food chain (Roemmich and McGowan 1995).

Given that the future climate will be warmer, the upper ocean at the watershed scale will almost certainly be, on average, more stratified (Osgood 2008). This will make it more difficult for winds and upwelling to mix the upper layers of the coastal ocean, and will make offshore Ekman pumping less effective at bringing nutrients into the photic zone. The result will be lower primary productivity throughout the salmon marine habitat (with the possible exception of the nearshore coastal upwelling zones) (Osgood 2008).

Should global warming result in shorter winters in the Pacific Northwest, areas where production is light limited (e.g., the northern California Current) may see higher productivity (Osgood 2008). During most years since 2002, phytoplankton blooms are initiated as early as February off northern California in years when storm intensity is low. These early blooms result in bursts in egg production by both copepods and euphausiids, initiating a cohort of animals that reach adulthood one to two months earlier than a cohort that is initiated with the onset of upwelling during March or April. The result would be a longer plankton production season. Alternatively, regional climate projections are for a later shift in the start time, peak times and end of the upwelling season, which could counter the idea of a longer upwelling season (Osgood 2008).

Ocean Warming and Increased Stratification, and Their Resultant Effects on Pelagic Habitat

This issue focuses on the central and southern California Current, and on the organisms that utilize the upper ocean habitat in this region. Generally warmer ocean conditions will cause a northward shift in the distribution of most species, and possibly the creation of reproductive populations in new regions. Existing faunal boundaries are likely to remain as strong boundaries, but their resiliency to shifts in ocean conditions due to global climate change is not known (Osgood 2008). Warmer water temperatures also will affect freshwater salmon and steelhead habitats by reducing habitat opportunity on both spatial and seasonal time scales. In coastal and oceanic regions, the southern boundaries of pelagic habitats used by many populations are expected to shift northward.

Warmer air temperatures may lead to increased stratification of the coastal CCE. The warmer temperatures will increase the heat flux into the ocean. Mixing and diffusion are not likely to redistribute this heat rapidly enough to prevent an increase in thermal stability and stratification of the upper ocean (Osgood 2008). The vertical gradient in ocean water temperature off of the California coast has intensified over the past several decades (Palacios *et al*. 2004). Areas with enhanced riverine input into the coastal ocean will also see greater vertical stratification. Moreover, increased melting of glaciers in the Gulf of Alaska coupled with warmer sea surface temperatures will result in increased stratification. Because some of the source waters that supply the northern California Current originate in the Gulf of Alaska, more stratified source waters will contribute to increased stratification of coastal waters of the northern California Current (Osgood 2008).

Changes to Ocean Circulation and Their Resultant Effects on Species Distribution and Community Structure

NMFS (2008) states that this is a climate-induced ecosystem concern primarily for the northern California Current, although changes in transport are known to have subtle effects on the entire Current. A particular biological concern is related to the variability in the transport of organisms, which impacts zooplankton species composition and regional recruitment patterns for demersal fish stocks.

As previously discussed, the California Current extends from the northern tip of Vancouver Island, Canada to southern Baja California, Mexico. As the current flows from north to south, the waters warm and mix with offshore waters such that both temperature and salinity increase gradually in a southward direction (Osgood 2008). Observations of the biota of the California Current show that there are pronounced latitudinal differences in the species composition of plankton, fish, and benthic communities, ranging from cold water boreal sub-arctic species in the north to warm water subtropical species in the south. Changes in abundance and species composition can be gradual in some cases, but it is widely accepted that faunal boundaries (zones of rapid change in species composition) are present in the waters in the vicinity of Capes Blanco and Mendocino, and at Point Conception. The strongest contrasts are observed during summer (Osgood 2008).

The strong contrast in species composition between shelf and offshore waters during summer is due to the upwelling process. A combination of upwelling itself, along with the sub-arctic water which feeds the inshore arm of the northern end of the CCE, create conditions favorable for development of a huge biomass of sub-arctic zooplankton. This pattern is slightly modified as a function of the phase of the Pacific Decadal Oscillation. During a cool phase, all of the northern CCE becomes more sub-Arctic in character (both shelf-slope-oceanic regions); during a warm phase of the Pacific Decadal Oscillation, the water masses and associated copepod community become far more similar to a sub-tropical community. Copepod biodiversity increases in coastal waters, due to shoreward movement of offshore waters onto the continental shelf, due to either weakening of southward wind stress in summer or strengthening of northward wind stress in winter. Thus, when Pacific Decadal Oscillation is in a positive phase, a greater proportion of the water entering the northern end of the current is sub-tropical in character rather than sub-Arctic.

Regardless of the season, the source waters that feed into the California Current from the north and from offshore can exert some control over the phytoplankton and zooplankton species that dominate the current (**Figure 6-4**).

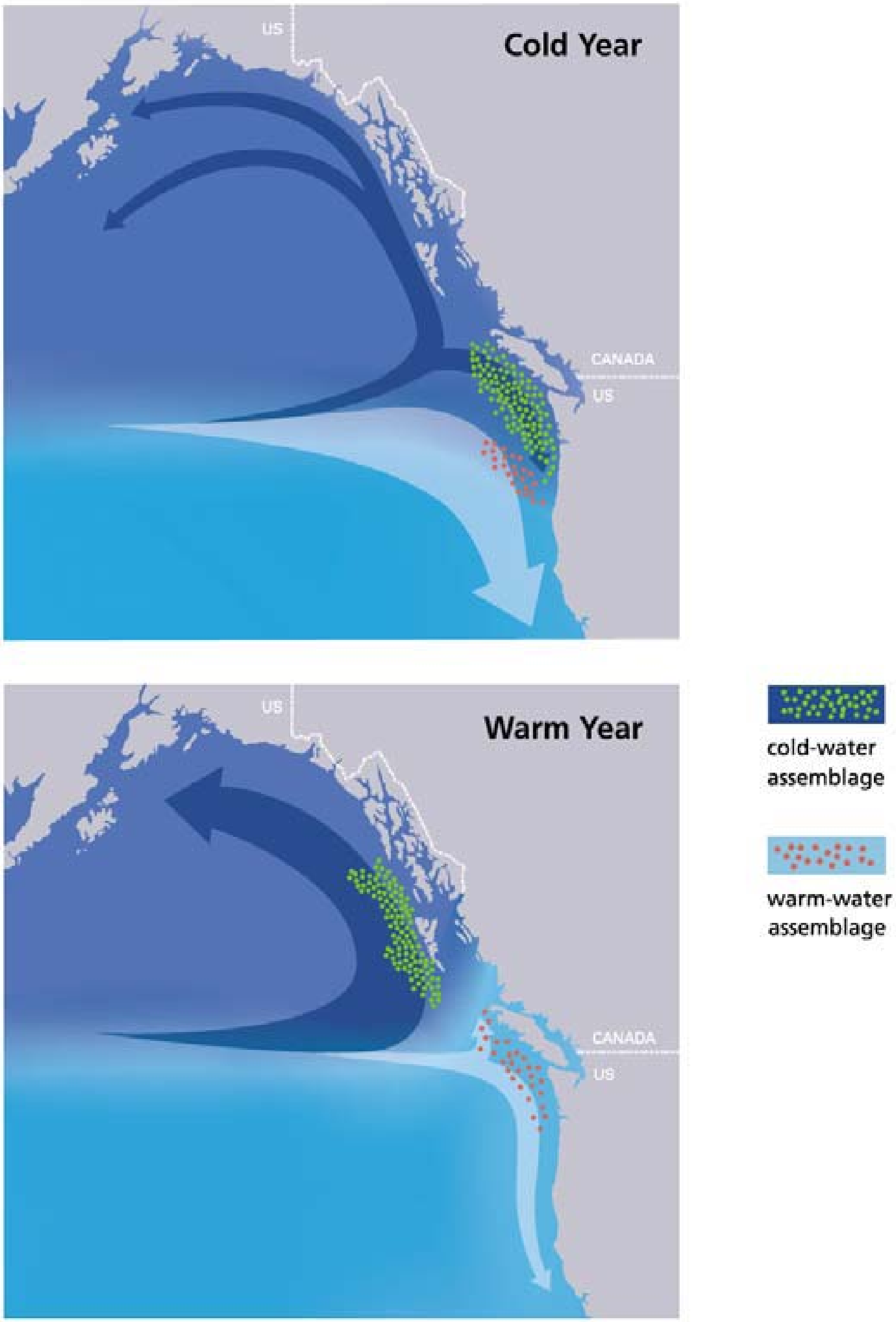


Figure 6-4. Schematic of the Flow of the North Pacific Current South into the California Current and North into the Gulf of Alaska. Cool years (such as La Niña and negative PDO years) are associated with greater flow into the California Current, which favors a southward displacement of coldwater and warmwater species. ***(Source: Osgood 2008)***

Hooff and Peterson (2006) suggest that knowledge of source waters is critical to understanding ecosystem dynamics in the shelf waters of the Northern CCE because waters from the Gulf of Alaska carry large, lipid-rich copepods to the shelf waters, whereas waters coming from an offshore source carry small, oceanic lipid-poor copepods to the shelf waters. Thus, changes reflected by Pacific Decadal Oscillation shifts may result in local food chains that have considerably different bioenergetic content. Given, for example, that: (a) salmon returns are low when the Pacific Decadal Oscillation is in a positive, warm water phase, but high when the Pacific Decadal Oscillation is in a negative, cold-water phase; and (b) salmon returns to Pacific Northwest rivers are highly correlated with copepod community structure (Peterson and Schwing 2003), variations in the bioenergetic content of the food web may represent a mechanistic link between Pacific Decadal Oscillation sign change and salmon survival (Osgood 2008). This mechanistic link may also apply to Chinook salmon originating from the Central Valley because some of the source waters that supply the Gulf of the Farallones, where Central Valley salmon first enter the ocean, originate in the Gulf of Alaska and Central Valley Chinook salmon abundance was found to be correlated with prey availability in the Gulf of the Farallones (Wells *et al*. 2012).

Northward shifts in distribution also are possible. Generally warmer conditions could result in a northward shift in the distribution of some species, and possibly the creation of reproductive populations in new regions. Alternatively, if upwelling strengthens due to global climate change, regardless of the sign of the Pacific Decadal Oscillation, cold-water species should still be favored in the coastal upwelling zones (Osgood 2008). However, the onshore-offshore gradients in temperature and species abundance should strengthen if offshore waters become warmer and upwelling becomes stronger, creating stronger upwelling fronts, and perhaps a greater level of mesoscale activity. It is unclear how faunal boundaries might be affected (Osgood 2008).

6.4 Climate Change Effects on Salmon and Steelhead in the Central Valley

In California, there have been observed changes in air temperatures, annual precipitation, runoff, and sea levels over the past century (Anderson *et al*. 2008). Regional-scale climate models for California are in broad agreement that temperatures in the future will warm significantly, total precipitation may decline, and snowfall will decline significantly (Lindley *et al*. 2007). Literature suggests that by 2100, mean summer temperatures in the Central Valley may increase by 2 to 8°C, precipitation will likely shift to more rain and less snow, with significant declines in total precipitation possible, and hydrographs will likely change, especially in the southern Sierra Nevada mountains. Thus, climate change poses an additional risk to the survival of salmonids in the Central Valley. As with their ocean phase, Chinook salmon and steelhead will be more thermally stressed by stream warming at the southern ends of their ranges (e.g., Central Valley Domain). For example, warming at the lower end of the predicted range (about 2°C) may allow spring-run Chinook salmon to persist in some streams, while making some currently utilized habitat inhospitable (Lindley *et al*. 2007). At the upper end of the range of predicted warming, very little spring-run Chinook salmon habitat is expected to remain suitable (Lindley *et al*. 2007).

The complex life history of salmonids as well as the complexity of their multiple aquatic habitats makes it difficult to isolate what environmental factors, or drivers, are responsible for variability in these populations

(Schwing 2009). Overall, the climate-species linkages for salmon are extremely complex. In a recent report to the Pacific Fishery Management Council, CDFW identified 46 possible reasons for the collapse of the 2004 and 2005 broods of Central Valley fall-run Chinook salmon. It is difficult to isolate the immediate effect of an individual stressor on a species, and most stressors impact many species at multiple trophic levels. Further, it is not likely that there is one single stressor, but a combination of several factors that drive ecosystem variability and change (Schwing 2009). Nevertheless, it is possible to focus on a relatively small number of factors that are sufficiently sensitive to climate change and impact the populations and freshwater and marine ecosystems of California anadromous salmonids.

This Recovery Plan addresses the California Central Valley steelhead DPS, and two Chinook salmon ESUs - Sacramento River winter-run Chinook salmon, and Central Valley spring-run Chinook salmon. Because of their extended use of the Sacramento and San Joaquin River systems, they are very dependent on runoff from the Sierra snowpack and the variability of precipitation affecting it (Osgood 2008), as previously discussed. The future climate of the freshwater habitats of the Central Valley Domain is expected to include:

- More frequent intense winter storms, high stream flow events, and floods
- Earlier snowmelt, with higher peak flows in winter, less spring runoff, and much lower summer flows
- Considerably warmer stream, river and ocean water temperatures during the summer
- Greater inter-annual precipitation variability, more frequent wet and drought years, and extended droughts
- Years with weaker fall storms, and delays in the onset of high stream flows
- More frequent wildfires and infestations, and increased erosion and sedimentation

The impacts of climate change on winter-run and spring-run Chinook salmon will differ due to differences in their life history. Winter-run Chinook salmon adults return and migrate upstream in winter through early spring, where they hold for several months before spawning in late spring and summer (Williams 2006). This spawning timing and subsequent fry emergence allows winter-run Chinook salmon juveniles to rear and move downstream during the cooler fall, winter, and spring months (Yoshiyama *et al*. 1998). That is, the juveniles can rear in freshwater for several months, without being exposed to stressful summer water temperatures. However, incubation, the most temperature-sensitive life stage, coincides with the time when river temperatures can exceed the lethal range for embryo incubation. Thus, winter-run Chinook salmon occur currently only in the Sacramento River, where summer water temperatures are cool enough to enable successful embryo incubation, but warm enough in winter to support juvenile rearing (Stillwater 2006 in Schwing 2009). They also spawn in deeper water than other populations (Moyle 2002). Juvenile winter-run Chinook salmon have historically exploited the floodplain habitat created by winter flooding in the Sacramento River Basin, which results in higher juvenile growth rates and presumably higher ocean survival (Sommer *et al*. 2001 in Schwing 2009).

The life history of spring-run Chinook salmon is to migrate upstream in spring, hold through the summer in deep pools, and then spawn in early fall, with juveniles emigrating after either a few months or a year in freshwater. However, they have considerable flexibility in their life history strategies. Age at spawning for spring-run Chinook salmon varies from two to four years.

Central Valley watersheds are fed predominantly by runoff from Sierra snowmelt, which has been historically highest during the late spring and early summer. The resulting high flow allows Chinook salmon to reach their summer holding areas, while the lower flow extending from the summer into early fall is cool enough for spawning. In the San Joaquin River drainage, snowmelt at high elevations produced a long runoff period that benefited spring-run Chinook salmon, making them the dominant run in the region. However, the recent trend toward an earlier seasonal runoff and lower flow in spring and summer has reduced the potential for survival in these watersheds, and will make the transit of adults returning to their spawning streams more difficult (see watershed profile information for individual rivers located in the Southern Sierra Nevada Diversity Group).

Because eggs and juveniles are less tolerant of warm water temperatures, spawning occurs during the fall, after streams cool. On their migration to the ocean, juvenile fish access temporary habitats with warmer water temperatures and abundant food in floodplain, tidal marsh, and estuarine habitats. These habitats are very important in smolt growth and survival - smolt size at ocean entry strongly affects survival during the first year at sea (Williams 2006). After reaching the ocean in the late spring and summer, smolts forage near the coast on crustaceans, euphausids, and prey fishes (MacFarlane and Norton 2002) that are associated with upwelling. Smolt survival over their first winter is dependent on a threshold of prey and the resultant smolt condition after the first summer at sea (Williams 2006).

Because of their close proximity, a relatively small wildfire could simultaneously burn the headwaters of all three remaining spring-run Chinook populations. Such a fire has a 10 percent chance of occurring in any given year in California (Lindley *et al*. 2007), but this probability will increase due to climate change. Prolonged drought due to lower precipitation shifts in snowmelt runoff, and greater climate extremes could also easily render most existing spring-run Chinook salmon habitat unusable, either through temperature increases or lack of adequate flows.

Increased water temperature, low flow, drought and other climate-related events will compound the threats to Chinook salmon due to human manipulation of their freshwater habitats. Because of these watersheds' great dependence on Sierra snowpack melt, the projected shift toward earlier runoff (Dettinger and Cayan 1995; Cayan *et al*. 2001) will exacerbate sensitivity to low flow and warm stream conditions at critical life stages. Winter-run Chinook salmon are especially vulnerable to climate warming, prolonged drought, and other catastrophic climate events, because they have only one remaining population that spawns in the hottest time of the year (also see the conceptual recovery scenario for winter-run Chinook salmon). Additionally, future ocean productivity will decline due to altered upwelling cycles, thus reducing prey availability and salmon ocean survival (NMFS 1997 in Schwing 2009).

Central Valley steelhead also exhibit a flexible life history, allowing them to compensate for the variable conditions and extremes of their habitat (McEwan 2001). Most juveniles remain in streams for one or two years before becoming smolts and emigrating out to the Delta and ocean (Hallock 1961 in Schwing 2009). Others may remain in the rivers their entire lives. Temperature and water quality are critical factors for fry and juvenile survival (Moyle 2002). Fry move into cooler, deeper, faster-flowing channels in the late summer and fall (Hartman 1965, Everest and Chapman 1972, and Fontaine 1988 in Schwing 2009). Juvenile steelhead prefer deep pools with heavy cover, as well as higher-velocity rapids (Bisson *et al*. 1982, 1988 and Dambacher 1991 in Schwing 2009).

The distribution of steelhead today is greatly reduced from the historical distribution. Dams and water diversions limit steelhead access to less than 20 percent of their historical spawning and rearing areas in the Central Valley (Yoshiyama *et al*. 2001; Lindley *et al*. 2006). Climate warming will further restrict access to cool water streams. Most of the same climate factors that affect other California steelhead populations are critical to Chinook salmon. The diversity and variability of their life history complicates their management. Yet this same attribute reduces their vulnerability to climate change.

Additionally, low flows during juvenile rearing and outmigration are associated with poor survival through the Delta (Kjelson and Brandes 1989; Baker and Morhardt 2001; and Newman and Rice 2002) and poor returns in subsequent years (Speed 1993). Climate change also may impact Central Valley salmonids through community effects. For example, warming may increase the activity and metabolic demand of predators, reducing the survival of juvenile salmonids (Vigg and Burley 1991).

6.5 Concepts for Buffering Climate Change Effects and Application in this Recovery Plan

The general concepts of resiliency and refugia discussed below have been used in the strategy (Chapter 3) of this recovery plan to identify a distribution of habitat in the Central Valley and habitat types that are most likely to allow winter-run Chinook salmon, spring-run Chinook salmon, and steelhead to withstand the effects of climate change. This distribution of habitat is reflected in the ESU/DPS level recovery criteria relating to population spatial structure. The types of habitats that these species will need in the face of climate change have been factored into the watershed prioritizations identified in the recovery strategy.

6.5.1 Resiliency

In ecology, resiliency carries the additional meaning of how much disturbance a system can "absorb" without crossing a threshold and entering an entirely different state of equilibrium (e.g., distinctly different physical habitat structure or conditions) (Bakke 2009**.** In regard to recovery, habitat restoration, and conservation of at-risk aquatic species, resiliency also requires that certain key habitat characteristics or processes will change little, or not at all, in response to climate change. When it comes to stream aquatic habitat, the most important elements to remain steady are temperature and disturbance regime (Bakke 2009). Resiliency is temporally dependent and given enough time, large disturbances are virtually certain to occur on the landscape and to the climate. Resiliency can only function on a landscape scale; there must be enough individual rivers available with the appropriate habitat and connectivity so that a disturbance to one portion of the system has a minimal impact on at-risk aquatic species because other parts of the system are able to support sensitive populations through the recovery and recolonization period (Bakke 2009).

In the long-term, there is no substitute for a landscape that offers redundancy of habitat opportunities. This recovery plan incorporates the resiliency concept by using the Central Valley diversity groups as recovery units (see Section 3.2.1) and generally calling for multiple viable populations within each of the units. Having an ESU or DPS spatial structure with each diversity group represented and population redundancy within each diversity group follows the historic population structure, which allowed the species to withstand extreme climactic events and persist for thousands of years. Because the biological recovery criteria for each of the three species covered in this plan (Section 4.3.4) are based on the species' historic spatial structure, it is assumed that an ESU/DPS that meets those criteria should be resilient to disturbances caused by climate change.

6.5.2 Refugia

Refugia are places in the landscape where organisms can go to escape extreme conditions (Bakke 2009). Typically, this refers to short-term conditions such as floods or high water temperatures. But in the context of climate change, refugia can also be places where a population may persist through decades and centuries of unfavorable climate conditions and instability. For coldwater obligate fish species, refugia will continue to be areas where groundwater emergence influences water temperature and volume. These refugia will exist on multiple scales: (1) local areas of cold water emergence within a reach otherwise insufficiently cold; (2) lower sections of rivers downstream of reservoirs with large amounts of coldwater storage; and (3) entire stream systems where groundwater hydrology is dominant or snowmelt hydrology is preserved due to high elevations. Thus, the same set of circumstances producing cold water conditions in the current landscape may, to varying degrees, produce thermal refugia against global warming.

The coldwater refugia concept has been applied in this recovery plan as a factor in the prioritization of watersheds. For example, Battle Creek, Mill Creek, and Deer Creek each were identified as core 1 watersheds for spring-run Chinook salmon, in part, because fish in those watersheds should be able to withstand warming air temperatures either by coldwater spring inputs (Battle Creek) or having access to holding and spawning habitat at relatively high elevation (Mill Creek and Deer Creek). As another example of how the refugia concept was applied in this recovery plan, the Sacramento River downstream of Shasta Dam was identified as a core 1 area for winter-run Chinook salmon, in part, because, in wetter year types, suitable water temperatures for spawning and incubation are provided during the summer via coldwater releases from the dam. Even with the projected effects of climate change, it is likely that suitable temperatures for winter-run Chinook salmon will be available downstream of Shasta Dam during wetter years. However, considering the expected increase in the frequency of dry years, which often result in mortality during egg incubation, it will be increasingly difficult to maintain the species without access to coldwater in the summer on a more consistent annual basis. As such, the McCloud River watershed, which receives coldwater from high elevation snowmelt and from springs, has been identified as a primary area for reintroduction. Reintroducing salmon and steelhead to historic high elevation habitats is a key part of the recovery strategy (see Section 3.3.2) because coldwater refugia will be needed to allow the species to withstand climate change.

7.0 Implementation

"Although recovery actions can, and should, start immediately upon listing a species as endangered or threatened under the ESA, prompt development and implementation of a recovery plan will ensure that recovery efforts target limited resources effectively and efficiently into the future."

NMFS 2010b. Interim Endangered and Threatened Species Guidance

7.1 Costs and Benefits of Salmon and Steelhead Recovery

Implementing the recovery actions in this recovery plan will be expensive, with a rough estimate ranging from $17 to $37 billion[29]. This investment in recovery of salmon and steelhead will result in economic, societal and ecosystem benefits. Monetary investments in watershed restoration projects can promote the economy in a myriad of ways. These include stimulating the economy directly through the employment of workers, contractors and consultants, and the expenditure of wages and restoration dollars for the purchase of goods and services. Habitat restoration projects have been found to stimulate job creation at a level comparable to traditional infrastructure investments such as mass transit, roads, or water projects (Oregon Watershed Enhancement Board 2010). In addition, viable salmonid populations provide ongoing direct and indirect economic benefits as a resource for fish, recreation, and tourist related activities. Dollars spent on salmon and steelhead recovery will promote local, State, Federal and tribal economies, and should be viewed as an investment with both societal (clean rivers, healthy ecosystems) and economic returns.

[29] Estimate derived by summing the costs of all recovery actions presented in Chapter 5.

The largest direct economic returns resulting from recovered salmon and steelhead are associated with sport and commercial fishing. On average 1.6 million anglers fish the Pacific region annually (Oregon, Washington and California) and 6 million fishing trips were taken annually between 2004 and 2006 (NMFS 2010a). Most of these trips were taken in California and most of the anglers lived in California. The California salmon fishery is estimated to generate $118 to $279 million in income annually, and provide roughly two to three thousand jobs (Michael 2010). With a revived sport and commercial fishery, an increase in economic gains and the creation of jobs would be realized across California, but most notably for river communities and rural coastal counties.

Many of the actions identified in this Recovery Plan are designed to improve watershed-wide processes which will benefit many native species of plants and animals (including other state and federally listed species) by restoring natural ecosystem functions. In addition, restoration of habitat in watersheds will provide substantial benefits for human communities. Some of these benefits are: improving and protecting the quality of important surface and ground water supplies; reducing damage from flooding resulting from floodplain development; and controlling invasive exotic animal and plant species which can threaten water supplies and increase flooding risk. Restoring and maintaining healthy watersheds also enhances important human uses of aquatic habitats, including outdoor recreation, ecological education, field based research, aesthetic benefits, and the preservation of tribal and cultural heritage.

The final category of benefits accruing to recovered salmon and steelhead populations are even more difficult to quantify and are related to the ongoing costs associated with maintaining populations that are at risk of extinction. Significant funding is spent annually by entities (Federal, State, local, private) in order to comply with the regulatory obligations that accompany populations that are listed under the ESA.

Important activities, such as water management for agriculture and urban use, are now constrained to protect ESA listed populations of salmon and steelhead. Recovering the salmonid populations so the protections of the ESA are no longer necessary will also result in elimination of the regulatory requirements imposed by the ESA, and allow greater flexibility for land and water managers to optimize their activities and reduce costs related to ESA protections. Salmon recovery is best viewed as an opportunity to diversify and strengthen the economy while enhancing the quality of life for present and future generations.

7.2 Integrating Recovery Implementation into NMFS Actions

It is a challenging undertaking to facilitate a change in practice and policy that reverses the path towards extinction of a species to one of recovery. This change can only be accomplished with effective outreach and education, strong partnerships, focused recovery strategies and solution-oriented thinking that can shift agency and societal attitudes, practices and understanding.

Implementation of the recovery plan by NMFS will take many forms and is generally and specifically described in the NMFS Protected Resources Division Strategic Plan 2006 (NMFS 2006). The Recovery Planning Guidance (NMFS 2010b) also outlines how NMFS will cooperate with other agencies regarding plan implementation. These documents, in addition to the ESA, will be used by NMFS to set the framework and environment for plan implementation. The PRD Strategic Plan asserts that species conservation (in implementing recovery plans) by NMFS will be more strategic and proactive, rather than reactive. To maximize existing resources with workload issues and limited budgets, the PRD Strategic Plan champions organizational changes and shifts in workload priorities to focus efforts towards "…*those activities or areas that have biologically significant beneficial or adverse impacts on species and ecosystem recovery*" (NMFS 2006).

NMFS actions to promote and implement recovery planning include:

- Formalizing recovery planning goals on a program-wide basis to prioritize work load allocation and decision-making (to include developing the mechanisms to make implementation (*e.g.*, restoration) possible).
- Conducting outreach and education.
- Facilitating a consistent framework for research, monitoring, and adaptive management that can directly inform recovery objectives and goals.
- Establishing an implementation tracking system that is adaptive and pertinent to support the annual reporting for the Government Performance and Results Act, Bi-Annual Recovery Reports to

Congress and the 5-Year Status Reviews.

To achieve recovery, NMFS will need to promote the recovery plan and provide needed technical information and assistance to other entities that implement actions that may impact the species' recovery. For example, NMFS intends to work with key partners on high priorities such as facilitating fish passage assessments and ensuring protective measures consistent with recovery objectives are included in County General Plans.

While recovery plans are guidance documents not regulatory documents, the intent is that they are used to prioritize and target necessary actions for the survival and recovery of the species. The Recovery Planning Guidance (NMFS 2010b) specifically outlines NMFS' obligations:

> "...the ESA clearly envisions recovery plans as the central organizing tool for guiding each species' recovery process. They should also guide Federal agencies in fulfilling their obligations under section 7(a)(1) of the ESA… and provide context and a framework for implementing other provisions of the ESA with respect to a particular species, such as section 7(a)(2) consultations on Federal agency activities, development of Habitat Conservation Plans or Safe Harbor agreements under section 10, special rules for threatened species under section 4(d), or the creation of experimental populations in accordance with section 10(j)."

As further discussed below, this recovery plan is intended to inform decisions made pursuant to or concerning critical habitat designation under section 4, land acquisition under section 5, take prohibitions through sections 4(d) and 9, cooperation with state(s) under section 6, needed research under section 10, and fishery management actions taken and Essential Fish Habitat (EFH) consultations conducted under the provisions of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

The approaches NMFS intends to use when implementing various sections of the ESA are discussed in detail and are summarized in **Table 7-1**. These approaches are intended to formalize the recovery plans in the daily efforts and decision-making at NMFS in the Southwest Region. Of necessity, some of these methods address the urgent issues of staffing and workload that NMFS faces. As a result, our commitment to implementing recovery plans extends to the ways in which we prioritize the many requests for consultations and permits we receive.

7.2.1 Working with Constituents and Stakeholders

NMFS commits to using recovery plans as a guiding mechanism for its daily endeavors. Successful implementation of this recovery plan will require the support, efforts and resources of many entities, from Federal and State agencies to individual members of the public. NMFS commits to working cooperatively with other individuals and agencies to implement recovery actions and to encourage other Federal agencies to implement actions where they have responsibility or authority.

7.2.2 ESA Section 4

Section 4 provides the mechanisms to list new species as threatened or endangered, designate critical habitat, develop protective regulations for threatened species, and develop recovery plans. Critical habitat designations may be revised as needed to reflect recovery strategies.

Sacramento River winter-run Chinook salmon critical habitat was designated on June 16, 1993, and includes the Sacramento River from Keswick Dam (RM 302) to Chipps Island (RM 0) at the westward margin of the Delta;

all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge; and all waters of San Francisco Estuary to the Golden Gate Bridge north of the San Francisco/Oakland Bay Bridge (58 FR 33212). CV spring-run Chinook salmon and CV steelhead critical habitat was designated on September 2, 2005, and includes stream reaches such as those of the Feather and Yuba rivers, Big Chico, Butte, Deer, Mill, Battle, Antelope, and Clear creeks, the Sacramento River, as well as portions of the northern Delta (70 FR 52488).

NMFS will reevaluate the designations in light of the data and criteria developed for this plan, and may propose the designation of additional habitat. The key recovery areas, special management considerations and recovery priorities identified in this recovery plan will inform future critical habitat designations. Certain unoccupied historic habitats that may be essential for recovery, and that are recommended for future critical habitat consideration include:

<u>Sacramento River winter-run Chinook salmon</u>

- Little Sacramento River
- McCloud River
- Battle Creek
- Non-natal rearing tributaries to the Sacramento River

Although these areas may provide sites and habitat components that are consistent with the physical and biological features that are essential for the conservation of Sacramento River winter-run Chinook salmon described in the final rule designating critical habitat for that ESU (58 FR 332112, 33216-17; June 16, 1993), a more detailed evaluation of habitat conditions will need to be undertaken when re-considering whether a system should be proposed for critical habitat. In the Little Sacramento and McCloud rivers and Battle Creek, these sites and habitat components include freshwater rearing, migration and spawning habitats. Although these habitats are currently blocked by dams, the many miles of relatively unimpaired cold water habitats and the fact that they historically supported winter-run Chinook salmon may make these areas highly valuable to the recovery of the species. Non-natal rearing tributaries to the Sacramento River include freshwater rearing habitat. Some non-natal rearing areas potentially have a high value because they provide critical and improved growing conditions, particularly during high winter flow events on the Sacramento River.

<u>CV spring-run Chinook salmon and CV steelhead</u>

- Little Sacramento River
- McCloud River
- North Fork Feather River
- North, Middle and South Yuba River
- Upper American River
- Mokelumne River
- North Fork Stanislaus River
- Tuolumne River
- Merced River
- San Joaquin River (CV spring-run Chinook salmon only)

This list represents the unoccupied historic habitat identified in the Conceptual Recovery Footprint maps presented in Chapter 3 (Figures 3-5 and 3-6). Although these areas may provide sites and habitat components consistent with the primary constituent elements (PCEs) essential for the conservation of CV spring-run Chinook salmon and CV steelhead that are included in the critical habitat designated for this ESU and DPS (50 C.F.R. § 226.211(c)), a more detailed evaluation of habitat conditions will need to be undertaken when re-considering whether a system should be proposed for critical habitat.[30]

Section 4(d) of the ESA directs the Secretary of Commerce (who has delegated such authority to NMFS) to issue regulations as deemed necessary and advisable to conserve species listed as threatened. ESA section 9 prohibits any take of species listed as endangered. Pursuant to regulations issued under section 4(d) of the ESA (commonly referred to as 4(d) rules), NMFS may also prohibit the take of threatened species. Section 4(d) of the ESA gives NMFS the discretion to customize prohibitions and regulate activities to provide for the conservation of threatened species when applying the take prohibitions that apply to endangered species under ESA section 9. A 4(d) rule is currently in place for Central Valley spring-run Chinook salmon and CV steelhead at 50 C.F.R. § 223.203. That 4(d) rule applies the endangered species prohibitions of section 9(a)(1) to threatened Central Valley spring-run Chinook salmon and CV steelhead, subject to certain limitations. Those limitations include limits on take prohibitions found in 50 C.F.R. § 223.203 (b).

Based on our review of the special management considerations necessary to implement recovery actions for spring-run Chinook salmon and steelhead, development of additional 4(d) limits on the take prohibitions for the following activities are recommended for consideration:

- Fish passage facilities that are consistent with NMFS fish passage criteria
- Levee construction or maintenance activities that meet the following requirements, provided they are applicable to the levee activity being considered:
    - Part of a comprehensive flood management program that has been approved by NMFS and includes a detailed conservation strategy for implementing recovery actions for floodplain and riparian habitat restoration
    - Levee relocations that create frequently activated floodplain areas (Williams *et al*. 2009), and minimize the potential for the stranding of juvenile fish
    - Slurry wall construction within urban river corridors
    - In-river repair and maintenance actions within urban flood corridors that meet NMFS design and maintenance criteria for urban levees
- Spawning gravel augmentation projects below dams
- Adult and juvenile fish collection and relocation actions that are part of a NMFS-approved fish reintroduction program

The above recommendations are made because the activities could provide for the conservation of threatened species, potentially without involving the additional time and cost involved with methods of ESA compliance that are currently available for these activities.

[30] As described in the Recovery Strategy (Chapter 3), it is important to note that it is not necessary to re-establish populations in all of these watersheds to meet the recovery criteria for CV spring-run Chinook salmon or CV steelhead. In fact, successful reintroductions into just a few areas will allow the recovery criteria to be met.

7.2.3 ESA Section 5

Section 5 of the ESA provides that the Secretary of the Interior and the Secretary of Agriculture, with respect to the National Forest System, shall establish and implement a program to conserve fish, wildlife, and plants, including listed endangered and threatened species. To carry out this program, the appropriate Secretary shall use certain land acquisition and other authority, and is given additional authority related to land and water acquisition. Multiple National Forests lands are present within the Central Valley domain.

7.2.4 ESA Section 6

Section 6 of the ESA describes protocols for consultation and agreements between NMFS and the states for the purpose of conserving threatened or endangered species. The current agreement under section 6 of the ESA between NMFS and California covers abalone and green sturgeon. NMFS will explore options with CDFW for including winter-run Chinook salmon, spring-run Chinook salmon, and steelhead in the existing or a new agreement under section 6 of the ESA.

Table 7-1. Summary of approaches NMFS intends to use when implementing various sections of the ESA and MSFCMA.

Authority	Description	Implementation Actions
ESA Section 7	Section 7(a)(1) Interagency Cooperation (Use of authorities)	Use threats assessments and recovery actions to guide Federal partners to further the conservation of listed Central Valley salmon and steelhead.
ESA Section 7	Section 7(a)(2) Interagency Cooperation (Consultation)	Continue to use the viable salmonid population concept described in this Recovery Plan to help determine effects of proposed actions on the likelihood of species' survival and recovery.
	Note: Permits issued under section 10(a)(1) of the ESA also undergo section 7 consultation prior to issuance.	Use threats assessments and recovery strategy as a guide to prioritizing consultations when making workload decisions.
		Place high priority on consultations for actions that implement recovery strategy or specific actions.
		Streamline consultations for those actions with little or no effect on recovery areas or priorities.
ESA Section 9	Section 9 Enforcement	Prioritize those actions and areas deemed of greatest threat or importance for focused efforts to halt illegal take of listed species.
ESA Section 10	Section 10(a)(1)(B) Incidental Take Permits	Prioritize permit applications that address identified research and monitoring needs in the recovery plan.
		Prioritize cooperation and assistance to landowners proposing activities or programs designed to achieve recovery objectives.
Magnuson-Stevens Fishery Conservatio	Fishery Management	Implement fishery regulations to maintain salmon harvest levels at or below those necessary to allow for the recovery of listed salmon and steelhead.

Authority	Description	Implementation Actions
n and Mana geme nt Act		Implement fishery regulations to reduce bycatch of salmon in federally-managed fisheries.

7.2.5 ESA Section 7

Section 7(a)(1) provides that all Federal agencies shall "…in consultation with and with the assistance of the Secretary, utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species…." "Conservation" is defined in the ESA as "the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to [the ESA] are no longer necessary." 16 U.S.C. § 1532(3). . Therefore, a key theme is *recovery*. To encourage Federal agencies to fulfill their section 7(a)(1) requirement to carry out conservation programs for listed Central Valley salmon and steelhead, NMFS will:

1. Encourage development of a West Coast Region California Central Valley Area Office or Regional Memorandum of Understanding (MOU) similar to a 1994 MOU [Daily Env't Rep. (BNA) No. 188, at E-1] between Agencies (which expired in 1999), establishing a framework for cooperation and participation to further the purposes of the ESA that specifically outlines a process for coordinating and implementing appropriate recovery actions identified in recovery plans.

2. Prepare, and send after recovery plan approval, a letter to all other appropriate Federal agencies outlining section 7(a)(1) obligations and meet with these agencies to discuss listed salmonid conservation and recovery priorities.

3. Encourage use of conservation bank credits when appropriate to contribute toward recovery of listed anadromous salmonids in the Central Valley.

4. In addition to minimization of incidental take or effects to habitat, encourage meaningful and focused mitigation, in alignment with recovery goals for restoration and threat abatement, for actions that incidentally take listed Central Valley salmon and steelhead or affect their habitat.

5. Encourage Federal partners to include recovery actions in project proposals.

6. Conduct outreach to Federal partners, and provide an outline of 7(a)(1) obligations.

Under section 7(a)(2), Federal agencies must consult with NMFS (and/or USFWS) when they determine an action may affect a listed species or its critical habitat. NMFS then conducts an analysis of potential effects of the action. In the process of consultation, NMFS currently expends considerable effort to assist agencies in avoiding and minimizing the potential effects of proposed actions to ensure agency actions do not jeopardize a species or destroy or degrade habitat. Consultations have helped prevent and minimize take.

To improve the section 7(a)(2) consultation process, NMFS will utilize its authorities to:

- ❑ Continue to use the viable salmonid population concept described in this Recovery Plan to help determine effects of proposed actions on the likelihood of species' survival and recovery.
- ❑ Place high priority on consultations for actions that implement recovery strategy or specific actions.
- ❑ Develop and maintain databases to track the amount of incidental take authorized and effectiveness of conservation and mitigation measures.
- ❑ Provide recommended actions in the recovery plan as section 7(a)(1) conservation recommendations as applicable.
- ❑ While still fulfilling all relevant statutory and regulatory requirements, focus staff priorities, to the extent possible, away from section 7 compliance in watersheds not designated as a priority for recovery and direct efforts to recovery implementation
- ❑ Streamline consultations for those actions with little or no effect on recovery areas or priorities.
- ❑ Prioritize staff efforts to carefully and consistently consider short-term and long-term impacts to watershed processes when conducting jeopardy analysis for Federal actions in key listed Central Valley salmon and steelhead watersheds.
- ❑ Apply the VSP framework and recovery priorities to evaluate population and area importance in jeopardy and adverse modification analysis.
- ❑ Encourage action agencies to purchase credits from a NMFS approved conservation bank whenever appropriate.

Within this framework NMFS will utilize its authorities to:

- ❑ Encourage the Federal Emergency Management Agency (FEMA) to fund upgrades for flood-damaged facilities to meet the requirements of the ESA and facilitate recovery.
- ❑ Encourage the U.S. Environmental Protection Agency (USEPA) to prioritize action on pesticides known to be toxic to fish and/or are likely to be found in fish habitat; and to take protective actions, such as restrictions on pesticide use near water.
- ❑ Encourage the Federal Highway Administration and Caltrans to develop pile driving guidelines, approved by NMFS, for all bridge construction projects in key Dependent, Independent, and other watersheds with extant listed Central Valley salmon and/or steelhead populations.
- ❑ Encourage the development of section 7 Conservation Recommendations to help prioritize Federal funding towards recovery actions (NMFS, USFWS, NRCS, USEPA, etc) during formal consultations.
- ❑ Encourage all Federal agencies, or their designated representatives, to field review projects and actions upon project

completion to determine whether or not the projects were implemented as planned and approved. Encourage all Federal agencies, or their designated representatives to report the initial findings of such field reviews to NMFS.

- Encourage Federal agencies to coordinate and develop programmatic consultations for activities that contribute to the recovery of listed Central Valley salmon and steelhead, to streamline their permitting processes.
- Encourage all consulting agencies to provide biological assessments that comport to 50 CFR 402.14(c) for all projects in all watersheds where listed Central Valley salmon and/or steelhead are present and/or with designated critical habitat.

7.2.6 ESA Section 9

Section 9 prohibits the taking of endangered species; these prohibitions may be extended through 4(d) rules to threatened species, as discussed above. The recovery plan will assist NMFS' Enforcement personnel by targeting key watersheds essential for species recovery. Core watersheds identified in this plan should be considered the highest priority areas. NMFS biologists will work closely with NMFS Enforcement regarding the identification of threats and other activities believed to place Chinook salmon and steelhead at high risk of take and/or extirpation. Actions will include the following:

- NMFS will conduct outreach and provide enforcement with a summary of the recovery priorities and threats.
- NMFS will prioritize those actions and areas deemed of greatest threat or importance for focused efforts to halt illegal take of listed species.
- NMFS will develop a plan to outline responsibilities and priorities to ensure activities by NMFS staff, when supporting enforcement, are focused on the highest recovery priorities.
- When a take has occurred, NMFS biologists will work with NMFS enforcement, to the extent feasible, with the development of a take case.
- NMFS enforcement will work with CDFW, in conjunction with the Joint Enforcement Agreement to increase patrols and landowner outreach in critical watersheds, particularly during droughts, when listed Central Valley salmon and steelhead are potentially at greater threat of unauthorized taking.
- Regular meetings between recovery staff and Enforcement will occur. NMFS Enforcement will place a high priority on identification and curtailment of threats in key watersheds identified for recovery.

7.2.7 ESA Section 10

Section 10(a)(1)(A) provides NMFS authority to issue permits to authorize take of listed species for scientific purposes, or to enhance the propagation or survival of listed species.

Section 10(a)(1)(B) provides NMFS authority to issue permits to authorize take of listed species that is incidental to otherwise lawful activities for non-federal entities. Requests for such a permit must be accompanied by a conservation plan that, among other things, describes the effects of the incidental taking and how the entity will minimize and mitigate those effects.

To improve the section 10 authorization process, NMFS will utilize its authorities to:

<u>Section 10(a)(1)(a) Research Permits</u>

- ❑ Prioritize permit applications that address identified research and monitoring needs in the recovery plan.
- ❑ Evaluate all proposed activities against the identified threats, recovery strategy, and recovery actions identified in the plan.
- ❑ Develop and maintain databases to track the amount of take authorized and the effectiveness of conservation and mitigation measures.

<u>Section 10(a)(1)(B) Habitat Conservation Plans (HCPs)</u>

The USFWS/NMFS Habitat Conservation Planning Handbook (USFWS and NMFS 1996) stresses the need for consistency of mitigation measures for a species and for specific standards. Although, not a preferred option (according to the USFWS/NMFS HCP Handbook), if offsite mitigation is necessary this recovery plan can be used to target watersheds for recovery actions. In some circumstances off-site mitigation may provide greater opportunity for recovery than onsite mitigation (*i.e.*, if an HCP's covered activities occur in a non-focus watershed).

Within the HCP framework NMFS will utilize its authorities to cooperate and assist landowners in proposing activities or programs designed to contribute to recovery objectives.

<u>Section 10(j) Experimental Populations</u>

Section 10(j) of the ESA provides for the designation of specific populations of species as "experimental populations" under certain circumstances and procedures. The potential use of section 10(j) of the ESA could facilitate reintroductions by helping to minimize regulatory requirements on land and water users. This regulatory approach has been taken in order to help facilitate the reintroduction of spring-run Chinook salmon into the San Joaquin River downstream of Friant Dam. However, the regulatory context for future fish reintroductions in the Central Valley will be determined on a case by case basis.

7.2.8 Fisheries Management and EFH

Much of listed Central Valley salmon and steelhead habitat is located in areas identified as Essential Fish Habitat (EFH) for the Pacific Coast Salmon Fishery Management Plan (FMP) under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). NMFS anticipates the objectives and recovery strategies will serve as a guide when providing conservation recommendations for actions that may adversely affect EFH. In addition, NMFS will implement fishery regulations, through coordination with PFMC, to maintain salmon harvest levels at or below those necessary to allow for the recovery of listed salmon; and NMFS will work to implement fishery regulations to reduce bycatch of listed salmon in federally-managed fisheries.

7.2.9 Coordination with other NMFS Divisions and the PFMC

Other divisions within NOAA can contribute significantly to recovery. NMFS staff will coordinate closely with the SWFSC and the NOAA Restoration Center, to assist in the development, review and funding of restoration projects.

In addition NMFS staff will need to coordinate closely with the PFMC for establishing an ecosystem-based fishery management plan to prevent overfishing of listed Chinook salmon.

7.2.10 Technical Assistance

In conjunction with NMFS' statutory authorities and obligations we are engaged in a significant amount of outreach to various constituencies where we provide technical assistance regarding listed salmon and steelhead, their habitat needs, and various life history requirements. Due to the large proportion of private lands and the limited contributions of ESA section 7, developing partnerships through providing technical assistance will be critical for recovery. Through this role NMFS will focus efforts in key areas critical for recovery through the following actions:

- ❑ Work with individual cities and counties throughout the Central Valley so they have sufficient information to develop city planning and land use policies protective of listed Central Valley salmon and steelhead.
- ❑ Continue working with the Natural Resource Conservation Service, Resource Conservation Districts, and Reclamation Districts, to encourage improved agricultural practices as well as land use practices of rural residential landowners.
- ❑ Prioritize cooperation and assistance to landowners proposing activities or programs designed to achieve recovery objectives.
- ❑ Work with the SWRCB to restore and maintain natural flow patterns of clean, cold water across the ESUs/DPS.

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Appendix A

Central Valley Watershed Profiles

Table of Contents

CENTRAL VALLEY SALMON AND STEELHEAD RECOVERY PLAN WATERSHED PROFILES

At first glance, California Central Valley's major watersheds might seem very similar in physical characteristics and to have redundant habitat types. However, the Sacramento and San Joaquin River Basins that make up the two main watersheds in the Central Valley are surprisingly diverse. As already mentioned in the Recovery Plan, the Central Valley is made up of four distinct geological zones which create different watershed systems, which in turn are the basis for diverse fisheries.

An example of this is that the large number of historic salmon runs present before the 1850's, were likely a result of the plethora of habitat types and geological formations found in the Central Valley. These varying habitats supported different life history strategies leading to genetically distinct populations of salmon and steelhead. Central Valley salmon and steelhead developed different life history strategies by evolving with habitat factors that reflected differences in these watersheds such as: the availability of cold water, adequate substrate, cover, and flow. Fish ecologists believe that the variability in life history traits was caused by the limitations or availability of habitat features between watersheds, and geographic isolation of populations, which led to genetic separation and to independent salmonid populations within the Central Valley.

With the many habitat changes, and impacts to salmonids discussed in the Recovery Plan, improving habitat quality and availability of different habitats within a watershed and increasing the number of Central Valley watersheds that could support independent or important dependent populations is a cornerstone for salmon and steelhead recovery. Improvement in genetic diversity is and will be a direct result of maintaining and improving habitat complexity within watersheds. Since salmon and steelhead evolve to the habitats that they reside in, the loss of these habitats, or access to these habitats has been one of the primary road blocks to species population differentiation, production, and thus to recovery. Therefore, the relationship of these watersheds to population recovery is one of the primary tasks for planners when tackling restoration actions within watersheds.

The following watershed profiles characterize current watershed conditions, summarize key threats, and identify factors affecting species. The watershed profiles are generally categorized by biogeographic diversity groups based on the Central Valley Technical Recovery Team's (TRT) identification of four groups that Chinook salmon and steelhead historically inhabited in the Central Valley (Figure 1). Diversity groups are intended to capture a wide variety of climatological, hydrological, and geological conditions; and important components of habitat, life history or genetic diversity that contribute to the viability of salmonid ESUs/DPSs (Lindley *et al*. 2007). The diversity groups are as follows:

- The **basalt and porous lava diversity group** composed of the upper Sacramento River and Battle Creek watersheds;
- The **northwestern California diversity group** composed of streams that enter the mainstem Sacramento River from the northwest;
- The **northern Sierra Nevada diversity group** composed of streams tributary to the Sacramento River from the east, and including the Mokelumne River; and
- The **southern Sierra Nevada diversity group** composed of streams tributary to the San Joaquin River from the east.

The basalt and porous lava region comprises the streams that historically supported winter-run Chinook salmon. All of these streams receive large inflows of cold water from springs through the summer, upon which winter-run Chinook salmon depended. This region excludes streams south of Battle Creek, but would include the part of the Upper Sacramento drainage used by winter-run, and part of the Modoc Plateau region. The Northern Sierra Nevada region includes the southern part of the Cascades region (i.e., the drainages of Mill, Deer, and Butte creeks) and extends south including the Mokelumne River. The Southern Sierra Region begins just south of the Mokelumne River and extends south to include the upper San Joaquin River. This split reflects the greater importance of snowmelt runoff in the southern part, and distinguishes tributaries to the Sacramento and San Joaquin Rivers. There are two additional diversity groups within the steelhead DPS (Central Western California and Suisun Bay) which are not described here in the watershed profiles as it is assumed that full recovery of the CV steelhead can be achieved without the presence of populations in those diversity groups.

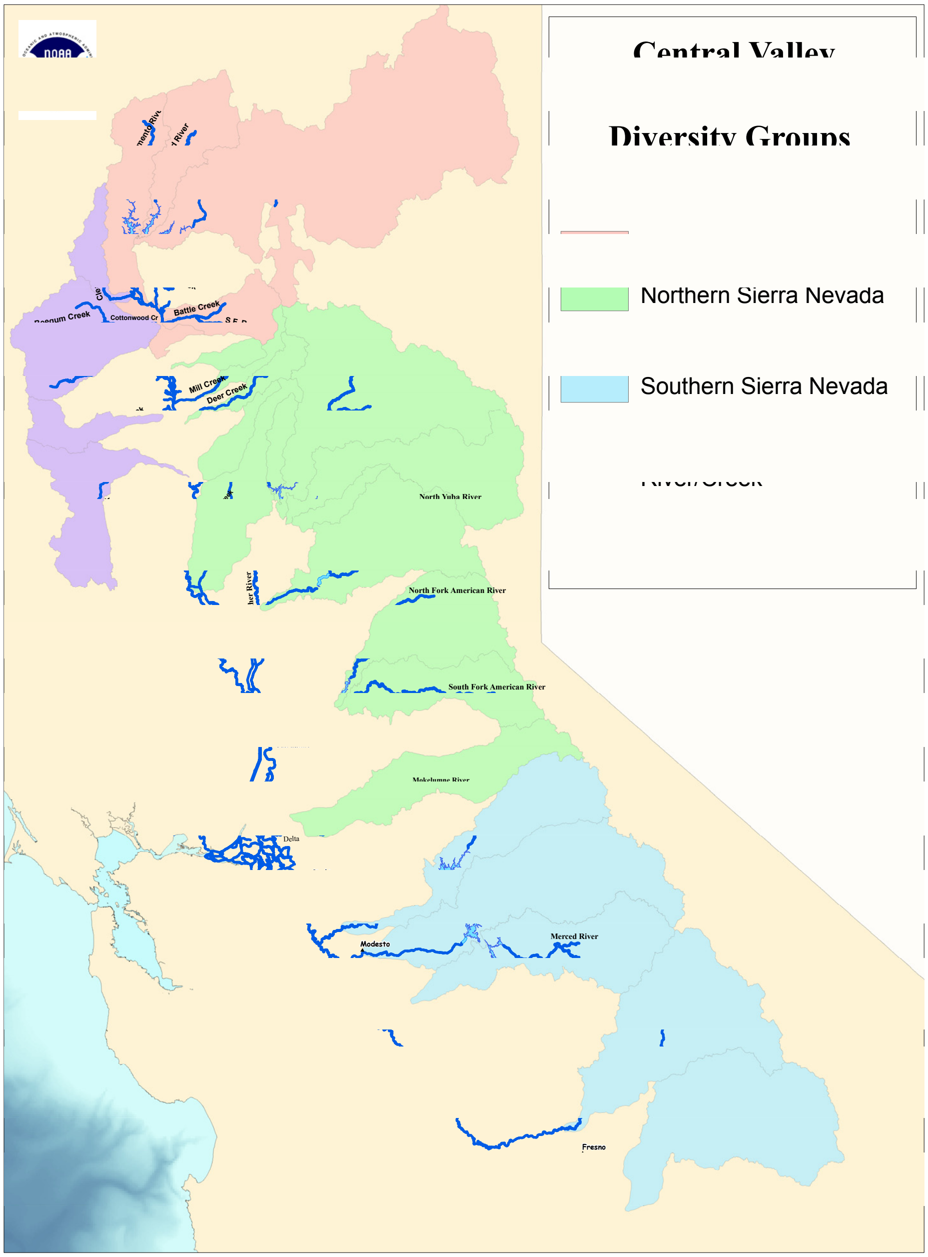

Figure 1. Central Valley Recovery Domain map of diversity groups and watersheds.
Source: Lindley *et al.* 2007

NORTHERN SIERRA NEVADA DIVERSITY GROUP

Cosumnes River Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead – *Oncorhynchus mykiss*

Species that Historically Occurred in the Watershed

Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to Central Valley steelhead in Cosumnes Creek include, but are not limited to the following:

- Water diversions and groundwater pumping resulting in low flows
- Loss of floodplain habitat, natural river morphology, and riparian habitat and instream cover affecting juveniles
- Predation in the lower intertidal reaches near the confluence with the Mokelumne River

Watershed Description

Originating at an elevation of 7,600 feet, the headwaters of the Cosumnes River flow through the El Dorado National Forest and support native trout fisheries and many other aquatic species. Descending towards the Central Valley, the river passes through blue oak, grassland, and vernal pool communities. The lower reaches of the river provide critical salmon spawning habitat and the broad floodplain of the lower river harbors valley oak riparian forest and freshwater wetlands used by thousands of resident and migratory birds.

Lands within the Cosumnes River Preserve are jointly owned by The Nature Conservancy, The Bureau of Land Management, Ducks Unlimited, the California Department of Fish and Wildlife, State Lands Commission, the California Department of Water Resources, Sacramento County and various private owners. The Preserve is reestablishing riparian forest and perennial grasslands through active and passive restoration efforts. Valley oak, Oregon ash, Fremont's cottonwood, box elder, willow, wild rose, and elderberry are planted to create the diverse understory of trees and shrubs found in mature riparian forest.

The Cosumnes River includes 35 miles river miles of anadromous habitat from Latrobe Falls at an elevation near 400 feet, downstream to the confluence with the Mokelumne River. Because of this low elevation, spawning is only likely to occur in wet water years, and the production of yearling emigrants is unlikely due to warm summer water temperatures. The Cosumnes River may provide important non-natal rearing habitat to CV steelhead from the Mokelumne River or other nearby steelhead-producing rivers. The most valuable portion of this habitat is within the 46,000 acres of the Cosumnes River Preserve, partnership with local landowners, private partners such as the Nature Conservancy, and federal, state and local government agencies. The Cosumnes River preserve is pursuing conservation strategies restore and protect the ecological processes within its boundaries.

Fisheries

The Cosumnes River Barrier Improvement project, funded in 1998, was a collaborative effort by the FFC, Department of Fish and Wildlife (DFG), The Nature Conservancy (TNC), AFRP, CALFED, Rancho Murieta Community Services District (RMCSD), Omochumnes/Hartnell Water district (OHWD), and a private landowner adjacent to the lower Cosumnes River. The focus of the project was fall-run Chinook salmon passage improvement, but is likely to include some ancillary benefits to steelhead, especially in wet years spawning may occur. The objectives of the project as originally proposed were to improve passage conditions at four low-flow barriers; two summer dams and a low flow crossing in the lower river beneath the historic spawning reach and a diversion dam in the middle of the spawning reach. During post project monitoring activities two additional potential barriers were discovered and included in the objectives. In total, improvements were made to six structures from river mile (RM) 6.75 through RM 34.5.

Mokelumne River Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon – *Oncorhynchus tshawytscha*
Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to Central Valley steelhead in the Mokelumne River watershed include, but are not limited to the following:

- ❖ Passage impediments/barriers at Camanche Dam and Pardee Reservoir Dam affecting adult immigration and holding
- ❖ Flow conditions (i.e., low flows) associated with attraction, migratory cues, flood flows and the attraction of non-natal fish into the Mokelumne River affecting adult immigration and holding
- ❖ Competition for spawning habitat, physical habitat alteration associated with limited supplies of instream gravel, habitat suitability and spawning habitat availability affecting adult spawning
- ❖ Hatchery effects associated with redd superimposition, competition for habitat, and genetic integrity affecting adult spawning
- ❖ Water temperatures affecting adult spawning and embryo incubation
- ❖ Flow conditions (i.e., flow fluctuations, changes in hydrology) affecting adult spawning, embryo incubation, juvenile rearing and outmigration
- ❖ Flow dependent habitat availability affecting juvenile rearing and outmigration
- ❖ Hatchery effects on juvenile rearing and outmigration

Watershed Description

With its headwaters at 10,000 feet on the crest of the Sierra Nevada mountains, the Mokelumne River drains approximately 661 square miles from four counties (i.e., Amador, Calaveras, Sacramento, and San Joaquin (USFWS and The Trust for Public Land 2009). It is a major tributary to the Sacramento-San Joaquin Delta, entering the lower San Joaquin River northwest of Stockton. The median historical unimpaired runoff is 696 taf, with a range of 129 taf to 1.8 maf (USFWS 1995). The landscape of the Mokelumne River watershed is typical of the lower

Sierra foothills, with rolling terrain interrupted by scattered rock outcrops and moderate to steep hillsides. The vegetation is predominantly grasslands and oak woodlands (EBMUD 2008).

The upper Mokelumne River watershed (upstream of Pardee Reservoir) measures about 570 square miles and is drained by numerous creeks (e.g., Jackson, Tiger and Sutter), feeding into the Mokelumne River (EBMUD 2009).

Chinook salmon and steelhead were once abundant in the Mokelumne River. The building of Comanche Dam, the Woodbridge diversion as well as other structures caused an 85% loss of habitat accessibility by these anadromous fish. Dams, sedimentation from gold mining and loss of habitat access were the main reasons that much of the steelhead and Chinook salmon runs have severely declined since the early 1900's (Reynolds *et al*. 1990 in USFWS 1995). Current efforts include improvements to fish passage and flows such as the recent improvement of passage at the Woodbridge diversion structure.

Recent monitoring in the San Joaquin River watershed has detected self-sustaining populations of steelhead in the Stanislaus, Mokelumne, and Calaveras rivers (McEwan 2001). Additionally, steelhead (and their progeny) from the artificially propagated stocks from the Coleman NFH and the Feather River Hatchery steelhead programs are considered part of the listed CCVS ESU. The Mokelumne River Hatchery uses steelhead stocks that originated from the Feather and Mokelumne River hatcheries and naturally produced Mokelumne River steelhead that enter the fish trap. The last time Nimbus origin eggs were used for the Mokelumne Hatchery program was in 1999-2000. Feather River steelhead eggs were imported from 2001-02 through 2006-07.

It is likely that the abundance of lower Mokelumne River steelhead would increase if water temperatures and flows for juvenile rearing and migration were improved, particularly in dry years. Lindley *et al*. (2007) recommend that in order to assess the risk of extinction or develop effective recovery actions for steelhead in the Central Valley, determining the distribution of steelhead and assessing the relationship between resident and anadromous forms of *O. mykiss* is a fundamental need. Lindley *et al*. (2007) stress that any quantitative assessment of population viability would be inadequate unless the role resident fish play in population maintenance and persistence of *O. mykiss* in the Central Valley is known.

Geology

The topography of the upper watershed varies from the gently sloping plain of the eastern San Joaquin Valley to the gentle and moderately rolling hills and ridges of the western-most Sierra Nevada foothills (EBMUD 2008). Elevations range from 235 feet above mean sea level (msl) to about 700 feet msl on the ridge-crests adjacent to Pardee Dam. Major soil groups in the upper watershed include well-drained stony clays to stony silt loams, well-drained gravelly to cobbly loams, well-drained clays occupying moderate slopes, relatively young overlying soil deposits consisting of well-developed alluvia with resistant hardpans, and unconsolidated to slightly consolidated alluvia. All exposed sedimentary rocks and soils are subject to erosion and transport into the downstream reservoirs (e.g., Pardee and Camanche), largely as a function of slope. Because rainfall in the watershed can mobilize contaminants and sediment in runoff, the presence of vegetation is a major factor in the prevention of erosion. Local sediments are the primary source of inorganic turbidity in Pardee and Camanche reservoirs (EBMUD 2008).

Hydrology

Almost 90 percent of precipitation occurs as rainfall during the months of November through April, and snowfall within the watershed is rare (EBMUD 2008).

Construction of Pardee Dam and Reservoir (1929) and Camanche Dam and Reservoir (1963) altered the hydrologic regime of the Mokelumne River, and the historic 100-year floodplain of the Mokelumne River is now within the area permanently flooded by Pardee and Camanche Reservoirs (EBMUD 2008). Watershed runoff is captured in three major impoundments (Camanche, Pardee, and Salt Springs Reservoirs) operated by East Bay Municipal Utilities District (EBMUD) and PG&E. These impoundments have a combined storage capacity of more than 750 taf. One other small impoundment in the watershed, the Lower Bear River Reservoir, stores 52 taf. Minimum flows below Camanche Dam range from between 100 to 325 cfs, as specified in FERC 2916-029, 1996 (Joint Settlement Agreement) (Reclamation 2008). Minimum flows below the Woodbridge Diversion Dam range from between 25 to 300 cfs (Reclamation 2008).

Land Use

The Mokelumne River watershed is a significant source of water for both consumption and energy production. The major land use in the upper watershed, owned both privately and publicly, is timber management. Much of the privately held land in the drainage area is undeveloped, and is currently left as open space or used for grazing (EBMUD 2008). Additionally, the Mokelumne River has a long history of water development. Within the watershed, East Bay Municipal Utility District (EBMUD) owns about 44 percent of the land area, which includes areas in the upper watershed extending from U.S. Highway 49 westward toward and including the Mokelumne River Day Use Area below Camanche Dam (EBMUD 2008a). Existing developments on the Mokelumne River upstream of Camanche Reservoir include facilities for hydroelectric, irrigation, and municipal use. Downstream of Camanche Reservoir, developments include both hydroelectric and irrigation facilities (USFWS 1995). EBMUD operates Camanche Reservoir together with Pardee Reservoir as part of an integrated system, and water releases are used to meet various demands for downstream users, including storage regulation for flood control and for the Mokelumne River Fish Hatchery, hydroelectric generation, and instream flow requirements for salmon (The Trust for Public Land 2009).

Fisheries and Aquatic Habitat

Five species of anadromous fish are present in the Mokelumne River below Camanche Dam, including fall-run Chinook salmon, steelhead, American shad[1], striped bass and pacific lamprey (USFWS 1995; M. Workman, USFWS, pers. comm. 2009). Fall-run Chinook salmon and steelhead are the primary management focus in the river (EBMUD 2008b).

Steelhead historically occurred in the Mokelumne River (USFWS 1998), but as recently as 2007, native steelhead were believed to be extinct, and were maintained in the river by hatchery plants (Marsh 2007). In the San Joaquin Basin, anadromy in *Oncoryhynchus mykiss* populations may be nonexistent or too low to detect while resident *O. mykiss* populations in the same rivers have remained strong (CDFW 2008). Because resident and anadromous *O. mykiss* juveniles can be difficult to differentiate, monitoring programs in these rivers typically report steelhead/rainbow trout captures as *O. mykiss*, rather than identifying the particular life history strategy of individual fish (CDFW 2008). Given the above considerations, in addition to the relatively recent, but extensive monitoring efforts that have been undertaken since implementation of the Joint Settlement Agreement[2] (1998), detailed findings regarding steelhead populations in the lower Mokelumne River are only beginning to emerge. Consequently, much of the information regarding anadromous salmonids habitat utilization in the Mokelumne River is based upon fall-run Chinook salmon.

Since the early 1900s, Chinook salmon in the lower Mokelumne River were adversely affected by poor water quality associated with winery and mine wastes, fish losses at unscreened diversions, and migration barriers due to dams (DFG 1991 in USFWS 1995). Runs up to 12,000 fish were recorded in the early 1940s (USFWS 1995). Spring-run Chinook salmon were probably present in the Mokelumne River prior to the construction of Pardee Dam in 1929. However, dams, poaching, and sedimentation caused by gold mining eliminated the spring-run Chinook salmon in the Mokelumne River (Reynolds *et al*. 1990 in USFWS 1995).

Wheaton *et al*. (2004) reports that "*the majority of salmonid spawning now takes place in a 14-km reach between Camanche Dam and Elliot Road (Merz and Setka, in press)*". The annual upstream fall-run Chinook salmon migration in the Mokelumne River begins in September, peaks in November and tapers off by early January (EBMUD 2009; (CDFW 1991 in USFWS 1995). Fall-run Chinook salmon spawning generally occurs in late October through January (EBMUD 2009). Myrick (1998 and 2000 in Reclamation 2008) found steelhead from the Mokelumne River preferred water temperatures between 62.5°F and 68°F. However, the

[1] Distribution is believed to be limited to reaches downstream of Woodbridge Dam (Michele Workman, USFWS, pers. comm. 2009).

[2] The Lower Mokelumne River Joint Settlement Agreement for the Lower Mokelumne River Project, FERC No. 2916, regarding flow and non-flow measures appropriate for the lower Mokelumne River was entered into by and between East Bay Municipal Utilities District, USFWS, and CDFW. The Agreement was intended to resolve: (1) pending FERC Proceeding No. 2916-004; and (2) pending Mokelumne River Water Rights Proceedings before the SWRCB.

condition of the aquatic habitat and the variation of conditions in the lower Mokelumne River have resulted in widely varying population levels of these species (USFWS 1995).

The major barrier to upstream migrating Chinook salmon and steelhead adults on the Mokelumne River is Woodbridge Dam (USFWS 1995). Woodbridge Dam, a flashboard dam constructed on the lower Mokelumne River in 1910, contained no fish ladder until 1925. Fish passage was dependent upon river flows and the length of the irrigation season. Upstream migration of adult Chinook salmon was generally possible only after the flashboards were removed at the end of the irrigation season (October). The fish ladder proved to be ineffective and was reconstructed in 1955. Subsequent analyses of passage conditions indicated that migration of adult Chinook salmon past the dam was potentially impaired by spills that attract fish away from the fish ladder (CDFW 1991 in USFWS 1995). CDFW identified a shallow portion of the Mokelumne River near Thornton as a migration barrier to adult Chinook salmon at flows less than 60 cfs (CDFW 1991 in USFWS 1995). Historically, inadequate attraction and migration flows (generally less than 50 cfs) below Woodbridge Dam during October and November resulted in poor adult returns to the Mokelumne River and the Mokelumne River Fish Facility (USFWS 1995). However, since completion of the Joint Settlement Agreement (1998), flows during the fall do not decrease below 350 cfs in any water year type. The failure of returning adults to detect Mokelumne River outflow also may be exacerbated by diversion of proportionately large volumes of Sacramento River water into the lower Mokelumne River via the Delta Cross Channel (DCC), and reverse flows in the lower San Joaquin River and south Delta channels.

As previously discussed, historic upstream migration of adult Chinook salmon in the Mokelumne River was often delayed due to high water temperatures below Woodbridge Dam, which could persist until early November, even during a normal water year (CDFW 1991 in USFWS 1995). Passage at natural riffles is not as much of a concern for steelhead as it is with Chinook salmon because steelhead are smaller and better swimmers and can better negotiate natural riffles and partial barriers (USFWS 1995). Poor water quality conditions below Camanche Reservoir had the potential to adversely affect Chinook salmon by inhibiting upstream migration of adult Chinook to spawning areas. Water quality problems in the Mokelumne River have been associated with heavy metal pollution from Penn Mine, drought conditions, and Pardee and Camanche Reservoir operations. Past fish kills at the Mokelumne River Fish Facility were attributed to Camanche Reservoir discharges containing toxic levels of copper and zinc, low dissolved oxygen levels, and high concentrations of hydrogen sulfide. These conditions were associated with low inflows from Pardee Reservoir; record low reservoir levels; and hypolimnetic mixing, which may have mobilized sediments during the late summer and fall turnover of the reservoir (CDFW 1991 in USFWS 1995).

Suitable water temperatures for Chinook salmon spawning in the Mokelumne River below Camanche Dam generally have not occurred until early November during a normal water year. Water quality standards have been recommended by CDFW, including water temperatures to protect aquatic resources, including adult Chinook salmon spawners (CDFW 1991 in USFWS 1995). Camanche Dam also prevented the natural recruitment of gravel from upstream sources to spawning areas below the dam. Net losses of spawning gravels and a general increase in the size of streambed materials have reduced the amount of suitable spawning area. In addition, armoring or compaction of spawning substrate has reduced spawning gravel quality (USFWS 1995). Suitable water temperatures for Chinook salmon incubation and emergence in the Mokelumne River below Camanche Dam generally have not occurred until early November during a normal water year. Potential stranding of juvenile salmonids as a result of flow fluctuations were evaluated in several reaches downstream of Camanche Dam based on predicted changes in wet surface area over a range of flows. The stranding potential increased at flows below 400 cfs (USFWS 1995).

As part of the Joint Settlement Agreement, water temperatures in the lower Mokelumne River were to be maintained to meet the life-history needs of aquatic organisms (e.g., fall-run Chinook salmon and steelhead). EBMUD opens the upper level outlet in Camanche Reservoir after lake turnover and closes the upper outlet when temperatures at Woodbridge Dam reach approximately 64°F to maintain the best possible release temperatures to meet the life-history needs of aquatic organisms, including steelhead. Using its best efforts, EBMUD also manages the hypolimnetic volume in Camanche Reservoir so that at the end of October, the volume has exceeded 28,000 acre-feet in every year except 2003. The Mokelumne River watershed received uncharacteristically high precipitation in April and May 2003 and high flood control releases were required which diminished the cold-water pool during 2003 to 16,700 acre-feet (EBMUD *et al*. 2008).

Dry year flows in the lower Mokelumne River below Woodbridge Dam during the spring period are inadequate to effectively convey juvenile salmonids downstream and through the Delta (USFWS 1995). Juvenile Chinook salmon in the Mokelumne River are allowed to migrate naturally to the ocean in wet, normal and above normal water year types, but are trapped at Woodbridge Dam and trucked to Rio Vista or other suitable locations in the Delta during dry or critically dry years. In general, peak adult returns to the Mokelumne River indicate favorable rearing and emigration conditions during preceding wet years. Nearly all Chinook salmon produced at the Mokelumne River Fish Facility are trucked as yearlings to release locations in the western Delta. Major diversions affecting juvenile Chinook salmon emigrants from the Mokelumne River are the Woodbridge Canal diversion and the south Delta SWP and CVP export facilities. The Woodbridge Canal diversion was screened in 1968 and operates from April to October, depending on irrigation demands. The Woodbridge Canal fish screen was identified as not meeting NMFS and CDFW fish screen velocity and design criteria (USFWS 1995). However, as part of the Lower Mokelumne River Restoration Program, one of the project's key elements is to improve the fish screens and the fish bypass system for anadromous salmonids at the Woodbridge Dam (CALFED 2000).

Adult steelhead are likely to encounter the DCC gates in both an open and closed configuration throughout their extended spawning migration. NMFS (2009a) suggests that elevated levels of net negative flow present a risk to emigrating fish that have entered the central Delta through Georgiana Slough or, when the DCC is open, the Mokelumne River system. Closure of the DCC gates from November 1 through May 20 may block or delay adult salmonids that enter the Mokelumne River system and enter through the downstream side of the DCC. However, it is anticipated that closure of the DCC gates during this period will reduce diversion of Sacramento River water into the Central Delta, thereby improving attraction flows for adults in the mainstem Sacramento River (NMFS 2009a).

Steelhead are reported to move out of the Mokelumne River during December and January. Steelhead smolts from the Mokelumne River system enter the Eastern Delta. The Mokelumne River fish can either follow the north or south forks of the Mokelumne River through the Central Delta before entering the San Joaquin River at RM 22. Some fish may enter the San Joaquin River farther upstream if they diverge from the South Fork of the Mokelumne River into Little Potato Slough. Smolts migrating naturally out of the Mokelumne River also are exposed to Delta flow patterns in the central and south Delta (USFWS 1995).

Anadromous salmonids are subject to loss as they cross the Delta during their downstream migration towards the ocean (NMFS 2009a), and steelhead from the Mokelumne River Basin must pass several points of potential entrainment into the south Delta prior to reaching the western Delta (NMFS 2009a). Reverse flows caused by CVP and SWP export pumping in the south Delta contribute to poor survival of juvenile Chinook salmon and steelhead that enter the central Delta from the Mokelumne River or from the Sacramento River via the DCC or Georgiana Slough. Mark-recapture studies indicate that juvenile Chinook salmon released in the lower Mokelumne River experience higher mortality than those released in the Sacramento River below the DCC under dry year conditions (USFWS 1987 in USFWS 1995). As shown by the Burau *et al*. (2007), Perry and Skalski (2008) and Vogel (2008a) studies, individual fish risk entrainment into the channels of Georgiana Slough under all conditions and into the Mokelumne River system when the DCC gates are open as they migrate downstream in the Sacramento River. Estimated average survival is only 33 percent with a range of approximately 10 percent to 80 percent survival (NMFS 2009a). Most of this loss is believed to be associated with predation, but may also include prolonged exposure to adverse water quality conditions represented by temperature or contaminants. Several years of salmonid survival studies utilizing both Coded Wire Tags (CWT) and acoustically tagged fish indicate that survival is low in the interior Delta waterways compared to the mainstem Sacramento River. Likewise, survival in the upper San Joaquin River is substantially lower than survival from Jersey Point to Chipps Island (VAMP studies), indicating that transiting the Delta interior is a risky undertaking for fish exiting from the San Joaquin River Basin or the east side tributaries (Mokelumne River Basin) (NMFS 2009a).

CDFW has determined that the river reaches between Camanche Dam and the confluence with the Delta are of considerable importance for maintenance and restoration of Chinook salmon and steelhead (CDFW 1991). Over the past few years, Mokelumne River studies have used an extensive acoustic receiver array system deployed in the river to track the movement, survival, and habitat use of hatchery origin steelhead smolts, hatchery steelhead kelts and multiple life stages (>160mm) of the wild river population of *O. mykiss (*Workman *et al*. 2008). EBMUD, CDFW and USFWS continue to collaboratively work to improve conditions for the lower Mokelumne River. Restoration objectives have focused on providing additional salmonid spawning gravel, improving intergravel water quality, and increasing floodplain connectivity and providing the energy needed to sustain river rehabilitation in the first 1 mile below Camanche Dam (EBMUD 2009). Spawning gravel augmentation, side channel reconnection, riparian and educational projects have been undertaken. Woodbridge Irrigation District has completed the rebuilding of the dam at Woodbridge with improved fish passage facilities and improved screening at the diversion (USFWS 2008).

Steelhead

Although steelhead historically had sustained annual runs up the Mokelumne River, no information exists on the size of these historic runs (USFWS 1995). The Mokelumne River Fish Hatchery was constructed in 1964 as mitigation for loss of spawning habitat between Camanche and Pardee Dam. The hatchery has received an average of about 500 Chinook salmon adults between 1967 and 1991 (USFWS 1995). The Mokelumne River Fish Hatchery has an annual production goal of 100,000 yearling fish, which are primarily from Feather River and American River stocks (Reclamation 2008). However, NMFS (1998; 1999) does not consider Mokelumne River Fish Installation stocks to be part of the Central Valley ESU. Mokelumne River rainbow trout (hatchery produced and naturally spawned) are genetically most similar to Mount Shasta Hatchery trout, but also show genetic similarity to the Northern California ESU (Nielsen 1997, as cited in NMFS 1997b).

More recently, monitoring has detected small, self-sustaining populations of steelhead (although influenced by the Mokelumne River Hatchery steelhead program) in the Mokelumne River. Since implementation of the Joint Settlement Agreement, East Bay Municipal Utilities District has monitored *O. mykiss* populations in the lower Mokelumne River using video monitoring as the Woodbridge Irrigation District Dam (WIDD) fish ladder, rotary screw traps in the lower Mokelumne River downstream of the WIDD, and conducted seasonal fish surveys from Camanche Dam downstream to WIDD (Table 1) (EBMUD *et al*. 2008). Steelhead redd surveys in the lower Mokelumne River are conducted between Camanche Dam and the Elliott Road Bridge (EBMUD *et al*. 2008).

Table 1. *O. mykiss* observed in the fisheries sampling conducted in the lower Mokelumne River from Camanche Dam downstream to Woodbridge Dam between 1998 and 2008

Year	Period	Community Surveys [1]		Rotary Screw Trap [2]		WID Fish Ladder [3]	
		Hatchery [4]	Wild [5]	Hatchery	Wild	Hatchery	Wild
1998/1999	Oct-Mar		347	620	22		555
1999	Apr-Sep		227	6	191		2
1999/2000	Oct-Mar		24	871	19		941
2000	Apr-Sep		205	31	148	8	3
2000/2001	Oct-Mar		274	487	77	3,067	89
2001	Apr-Sep		245	4	381	9	23
2001/2002	Oct-Mar		253	9	154	593	152
2002	Apr-Sep		213	1	50	357	400
2002/2003	Oct-Mar		196	82	78	1,017	117
2003	Apr-Sep		98	15	78	1,312	380
2003/2004	Oct-Mar		175	61	16	385	105
2004	Apr-Sep		131	9	43	749	439
2004/2005	Oct-Mar		410	28	7	265	70
2005	Apr-Sep		335	4	74	816	42
2005/2006	Oct-Mar		781	61	8	28	10
2006	Apr-Sep		189	6	51	108	22
2006/2007	Oct-Mar	2	324	75	15	337	16
2007	Apr-Sep	6	273	2	136	121	23
2007/2008	Oct-Mar		213	1	31	*	*

1 Includes seasonal electrofishing and seining (January - June)
2 Rotary screw trap(s) immediately below Woodbridge Irrigation District Dam (mid-December through July)
3 Includes video monitoring and trapping in old ladder
4 Fish of hatchery origin (adipose fin clip)
5 Fish of natural origin
* Monitoring system inoperable due to construction of fish screens at WID canal

Source: Reproduced from EBMUD *et al*. 2008.

American River Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to steelhead in the American River include the following:
- ❖ Nimbus and Folsom Dams (and smaller upstream dams) blocking access to historical spawning habitat;
- ❖ Warm water temperatures, particularly below dams, affecting juvenile rearing and outmigration and adult immigration and holding;
- ❖ Predation of juveniles;
- ❖ Loss of riparian habitat and instream cover affecting juvenile rearing and outmigration;
- ❖ Loss of floodplain habitat affecting juvenile rearing and outmigration;
- ❖ Loss of natural river morphology affecting juvenile rearing and outmigration;
- ❖ Competition for spawning habitat between natural- and hatchery-origin steelhead and the resultant effects on the genetic fitness of the natural population;
- ❖ Flow fluctuations affecting early life stages

Watershed Description

The American River drains a watershed of approximately 1,895 square miles (Reclamation 1996), and is a major tributary entering the Sacramento River and RM 60. The American River watershed drains about 1,900 square miles and ranges in elevation from 23 feet to more than 10,000 feet (SWRI 2001). The American River has historically provided over 125 miles of riverine habitat to anadromous and resident fishes.

Presently, use of the American River by anadromous salmonids is limited to the 23 miles of river below Nimbus Dam (i.e., the lower American River) (Figure 2).

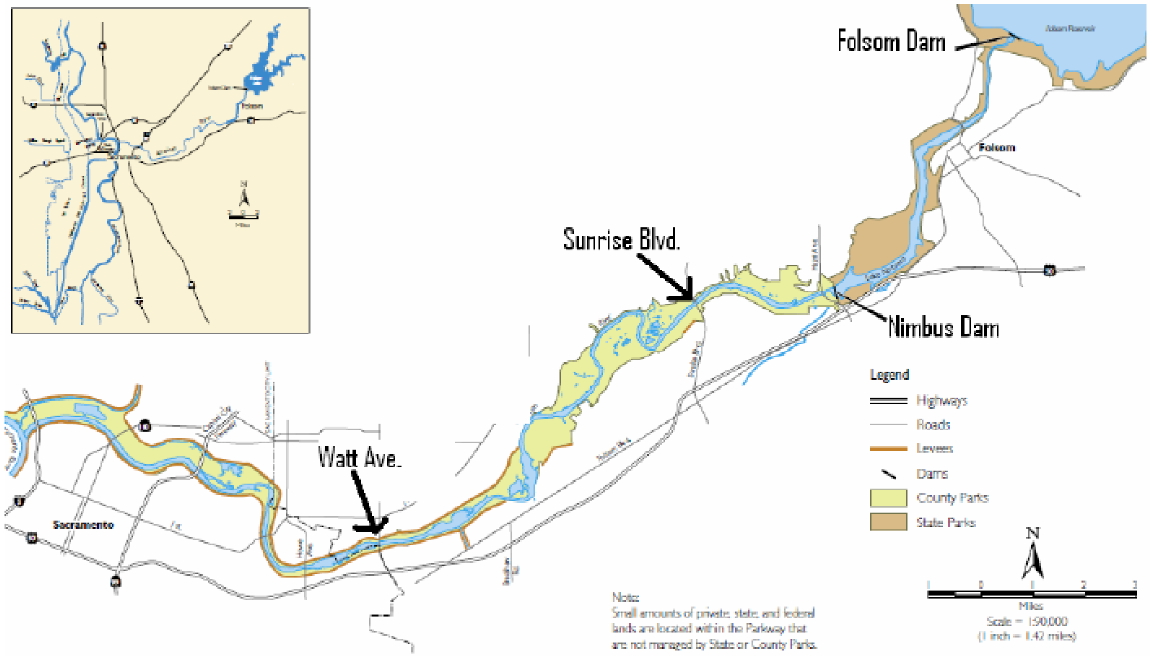

Figure 2. Map of lower American River. Modified from Water Forum (2005).

There is a general consensus in the available literature suggesting that habitat for steelhead in the American River below Nimbus Dam is impaired (Reclamation 2008; NMFS 2009a; Water Forum 2005; Water Forum 2005a; SWRI 2001; CDFW 1991, 2001). Of particular concern are warm water temperatures, flow fluctuations, and limited flow-dependent habitat (e.g., low flows during summer and fall limiting predator refuge habitat for juveniles). It has been suggested that the environmental factor probably most limiting to natural production of steelhead in the lower American River is high water temperatures during the summer and fall (Water Forum 2005; Reclamation 2008). Structural modifications may be needed to alleviate this limiting factor, including, but not limited to enhancing or replacing the shutter system at Folsom Dam, dredging and/or construction of temperature control curtains in Lake Natoma, and installation of a temperature control device at the El Dorado Irrigation District diversion.

Based on general observations of habitat complexity in terms of the distribution and availability of mesohabitat types (e.g., riffles, runs, and pools), with respect to geomorphology, it does not appear that the lower American River is in a highly degraded state, although a specific study addressing this issue is needed. One known concern regarding habitat complexity in the lower American River is that recruitment of large woody debris is limited, primarily because the debris is removed in order to provide safer conditions for rafting and other recreation activities.

The presence of Nimbus and Folsom dams have the most influence on the restoration potential of the American River watershed. Dams produce extensive ecological disruptions, including alteration of flow regimes, sedimentation, and nutrient fluxes, modification of stream-channel morphology, spatial decoupling of rivers and their associated floodplains, disruption of food webs, and fragmentation and loss of habitat (Ligon *et al*. 1995, Levin and Tolimieri 2001). All of these disruptions have occurred in the American River watershed due to the construction of Nimbus and Folsom dams.

Between Folsom Lake and the next upstream fish barrier, approximately 57 miles of riverine habitat exists in the North, Middle, and South forks combined. Within this 57 miles (and in more upstream habitats), evaluations of habitat quality with respect to anadromous salmonid life history requirements are needed. An indication that these riverine habitats above Folsom Dam may still be of sufficient quality to support anadromous salmonids is that populations of resident *O.mykiss* abundant enough to support recreational fisheries occur in all three forks, although the situation in the South Fork is complicated by the influence of stocking. The *O.mykiss* populations in the North and South Forks are entirely composed of wild fish.

Geology

As reported by SWRI (2001), from Folsom Dam to Fair Oaks, the American River floodplain is narrow. At Fair Oaks, the floodplain widens to about 1 to 5 miles, and the steep 125-foot high bluff of the Turlock Lake formation bounds the northern channel margin. Downstream, near Sacramento, the bluff height reduces to less than 10 feet and consists of the Riverbank Formation. The southern channel margin consists of a terrace of Recent-age alluvium that is lower than the northern bluff. The levees that have been constructed along both banks of the lower river are, therefore critical to flood control operations. The bed of the American River is primarily composed of gravel to cobble-sized material. However, gravel size can change seasonally and from year-to-year (SWRI 2001).

Hydrology

As reported by USFWS (1995), the American River accounts for approximately 15% of the total Sacramento River flow. Average annual precipitation over the watershed ranges from 23 inches on the valley floor to 58 inches at the river's headwaters. Snowmelt is the source of approximately 40% of the American River flow. Average historical unimpaired run-off at Folsom Dam, near the border between Sacramento and Placer counties, is 2.8 maf. The median historical unimpaired run-off is 2.5 maf, with a range of 0.3-6.4 maf. The American River has three major branches: the South Fork, the Middle Fork, and the North Fork. Today, 13 major reservoirs exist in the drainage with total storage capacity of 1.9 maf. Folsom Lake, the largest reservoir in the drainage, was constructed in 1956 and has a capacity of 974 taf. Folsom Dam, approximately 30 miles upstream from the mouth, is a major element of the Central Valley Project. The dam is operated by USBR as an integrated system with other Federal and State reservoirs to meet contractual water demands and instream flow and water quality requirements in the Delta (USFWS 1995).

Completion and operation of Folsom and Nimbus dams resulted in higher flows during fall, significantly lower flows during winter and spring, and significantly higher flows during summer.

Land Use

The following discussion on the historical land use in the American River watershed was directly taken from the *Impacts on Lower American River Salmonids and Recommendations Associated with Folsom Reservoir Operations to Meet Delta Water Quality Objectives and Demands* (Water Forum 2005a). Prior to 1849, the riparian vegetation along the river formed extensive, continuous forests in the floodplain, reaching widths of up to 4 miles. Settlement of the lower American River floodplain by non-indigenous peoples and the resulting modifications of the physical processes shaping the river and its floodplain have drastically altered the habitats along the river. Early settlers removed trees and converted riparian areas to agricultural fields. Hydraulic gold mining in the watershed caused deposits of 5-30 feet of sand, silt, and fine gravels on the riverbed of the lower American River. These deposits resulted in extensive sand and gravel bars in the lower river and an overall rising of the river channel and surrounding floodplain. This was later exacerbated by gravel extraction activities. As a result, the floodplain's water table has dropped, reducing the growth and regeneration of the riparian forest (Water Forum 2005a).

Additional habitat impacts resulted from the construction of Folsom and Nimbus Dams. These structures have blocked the main upstream sediment supply to the lower American River. This sediment deficit reduces the amount of material that can deposit into bars and floodplains in the lower reaches, resulting in less substrate for growth of cottonwoods and other riparian vegetation (Stromberg *et al*. 2007). Modification of river flows resulting from the operation of Folsom Dam and Reservoir has likely affected the potential for regeneration of cottonwood. Flows that had historically occurred during the seed dispersal period for cottonwood shifted from the late spring/early summer to late summer or no longer occur. Also, artificial flow fluctuations can cause the stranding of fish in ponds and depressions on the floodplain when high flows recede (Water Forum 2005a).

Since the 1970s, bank erosion, channel degradation and creation of riprap revetments have contributed to the decline of riparian vegetation along the river's edge, loss of soft bank and channel complexity, and reduced amounts of large woody debris in the river that are used by fish and other species. Currently, some of the large woody debris that does still accumulate in the river is removed to provide safer conditions for recreation activities such as swimming and rafting. In addition, there has been a decrease in overhanging bank vegetation called shaded riverine aquatic (SRA) habitat (Water Forum 2005a).

Urbanization throughout the greater Sacramento area has led to a replacement of agricultural land uses within the American River floodplain with urban land uses, and a corresponding increase in urban runoff (SWRI 2001). Based on data from 1992 through 1998 collected by the Ambient Monitoring Program, lower American River water quality exceeded State (California Toxics Rule) or Federal (EPA) criteria with respect to concentrations of four metals – lead, copper, zinc, and cadmium (SWRI 2001). High concentrations of these metals have adverse effects on fish. In particular, studies have demonstrated that fish fed diets contaminated with zinc exhibited reduced survival, growth, and increased incidence of disease (Farag *et al*. 1994, Bowen *et al*. 2006). It should be noted that zinc is easily bioaccumulated in stream invertebrates – an important food source for juvenile salmonids while rearing in freshwater systems (Bowen *et al*. 2006).

Fisheries and Aquatic Habitat

Including the mainstem, and north, middle, and south forks, historically over 125 miles of riverine habitat were available for anadromous salmonids in the American River watershed

(Yoshiyama *et al*. 1996). The construction of Nimbus Dam in 1955 blocked steelhead and spring-run Chinook salmon from all historic spawning habitat in the American River (Lindley *et al*. 2006). Hydrological and ecological changes associated with the construction of the dams contributed to the extirpation of summer steelhead and spring-run Chinook salmon, which were already greatly diminished by the effects of smaller dams (*e.g*., Old Folsom Dam and the North Fork Ditch Company Dam) and mining activities (Yoshiyama *et al*. 1996).

Development of the American River watershed has modified the seasonal flow and water temperature patterns in the lower American River. Operation of the Folsom-Nimbus project significantly altered downstream flow and water temperature regimes. In addition, operation of Sacramento Municipal Utility District's Upper American River Project (UARP) since 1962, as well as Placer County Water Agency's Middle Fork Project (MFP) since 1967, altered inflow patterns to Folsom Reservoir (SWRI 2001).

Seasonal water temperature regimes also have changed with development in the American River watershed, particularly with the construction and operation of Folsom and Nimbus Dams. Prior to the completion of Folsom and Nimbus Dams in 1955, maximum water temperatures during summer frequently reached temperatures as high as 75°F to 80°F in the lower American River (Gerstung 1971). Although summer water temperatures are cooler in the lower river after Folsom Dam was constructed as compared to the pre-dam conditions, prior to habitat elimination resulting from the dam, rearing fish had access to cooler habitats throughout the summer at higher elevations.

Water temperature management for anadromous salmonids is an issue of concern in the lower American River. For example, the occurrence of a bacterial-caused inflammation of the anal vent (commonly referred to as "rosy anus") of American River steelhead has been reported by CDFW to be associated with warm water temperatures. Sampling in the summer of 2004 showed that this vent inflammation was prevalent in steelhead throughout the river and the frequency of its occurrence increased as the duration of exposure to water temperatures over 65°F increased. At one site, the frequency of occurrence of the anal vent inflammation increased from about 10 percent in August, to about 42 percent in September, and finally up to about 66 percent in October (Water Forum 2005a). During the summer, mean daily water temperatures at Watt Avenue often exceed 68°F (NMFS 2009a).

Predators of juvenile steelhead in the lower American River include both native (*e.g*., pikeminnow) and non-native (*e.g*., striped bass) fish as well as avian species. Some striped bass reportedly reside in the lower American River year-round, although their abundance greatly increases in the spring and early summer as they migrate into the river at roughly the same time that steelhead are both emerging from spawning gravels as vulnerable fry and are migrating out of the river as smolts (SWRI 2001). Striped bass are opportunistic feeders, and almost any fish or invertebrate occupying the same habitat eventually appears in their diet (Moyle 2002). Empirical data examining the effect of striped bass predation on steelhead in the American River have not been collected, although one such study was recently conducted in the Delta (CDWR 2008). Results of this study concluded that steelhead of smolt size had a mortality rate within Clifton Court Forebay that ranged from 78 ± 4 percent to 82 ± 3 percent over the various replicates of the study. The primary source of mortality to these steelhead is believed to be predation by striped bass. Although Clifton Court Forebay and the lower American River are dramatically different systems, this study does demonstrate that striped bass are effective predators of relatively large-sized steelhead. Considering that striped bass are abundant in the lower American River during the spring and early summer (SWRI 2001), when much of the steelhead initial rearing and smolt emigration life stages are occurring, striped bass predation on juvenile steelhead is considered to be a very important stressor to this population.

Steelhead

Between 1944 and 1947, annual counts of summer-run steelhead passing through the Old Folsom Dam fish ladder during May, June, and July at Old Folsom Dam (RM 27) ranged from 400 to 1,246 fish (Gerstung 1971). After 1950, when the fish ladder at Old Folsom Dam was destroyed by flood flows, summer-run steelhead perished in the warm water in areas below Old Folsom Dam. By 1955, summer-run steelhead and spring-run Chinook salmon were completely extirpated and only remnant runs of fall- and winter-run steelhead and fall-run Chinook salmon persisted in the American River (Gerstung 1971).

Estimates of historic run sizes for fall- and winter-run steelhead in the American River were not identified in the available literature. However, all three (summer, fall, and winter) runs of steelhead were likely historically abundant in the American River considering: (1) the extent of available habitat; (2) the historic run size estimates of Chinook salmon before massive habitat degradation occurred; and (3) the reported historic run size estimates for summer-run steelhead in the 1940s which occurred even after extensive habitat degradation and elimination.

The following information on the current status of American River steelhead comes from the Biological Opinion on the Long-Term Central Valley Project and State Water Project Operations Criteria and Plan (NMFS 2009a) and references therein.

The Central Valley steelhead DPS includes naturally-spawned steelhead in the American River but excludes steelhead spawned and reared at Nimbus Fish Hatchery. The current population size of 300 to 400 in-river spawning steelhead (Hannon and Deason 2008) is much lower than estimates (*i.e.*, 12,274 -19,583) from the 1970s (Staley 1976), and is primarily composed of fish originating from Nimbus Hatchery. This means that the listed population (*i.e.*, naturally-produced fish) in the lower American River is at an abundance level lower than the estimates provided by Hannon and Deason (2008) and is likely on the order of tens.

In addition to small population size, other major factors influencing the status of naturally spawning steelhead in the American River include: (1) a 100 percent loss of historic spawning habitat resulting from the construction of Nimbus and Folsom Dams (Lindley *et al*. 2007), which has obvious and extreme implications for the spatial structure of the population; and (2) the operation of Nimbus Fish Hatchery, which has completely altered the diversity of the population.

Lindley *et al*. (2007) classifies the natural population of American River steelhead at a high risk of extinction because this population is reportedly mostly composed of steelhead originating from Nimbus Fish Hatchery. The small population size and complete loss of historic spawning habitat and genetic composition further support this classification.

Auburn Ravine/Coon Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Species that Historically Occurred in the Watershed

Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to steelhead in Auburn Ravine and Coon Creek include, but are not limited to the following:

- Passage impediments/barriers affecting adult immigration and spawning
- Flow conditions (i.e., low flows, flow fluctuations) associated with attraction and migratory cues into the Auburn Ravine and Coon Creek drainage affecting adult immigration and spawning
- Limited instream gravel supply and habitat availability affecting spawning
- Flow dependent habitat availability affecting juvenile rearing and outmigration
- Water temperature and water quality (e.g., agricultural and urban runoff) into the Auburn Ravine and Coon Creek drainage affecting juvenile rearing and outmigration
- Entrainment at individual diversions in the Auburn Ravine and Coon Creek drainages affecting juvenile rearing and outmigration
- Loss of natural morphology, riparian habitat and instream cover affecting juvenile rearing and outmigration
- Predation associated with non-site specific and structure-related habitats in the Auburn Ravine and Coon Creek drainage affecting juvenile rearing and outmigration

Watershed Description

Auburn Ravine originates north of the City of Auburn and flows 29 miles to its confluence with the East Side Canal, draining an area of approximately 79 square miles. The East Side Canal drains into the Cross Canal, which then drains into the Sacramento River just southeast (downstream) of the Feather River confluence. The elevation of the Auburn Ravine basin ranges from 1,600 to 30 feet above mean sea level (msl) (County of Placer 2002). Primary tributaries to Auburn Ravine include North, Dutch, and George's Ravines (County of Placer 2002).

The Coon Creek watershed originates in the foothills north and east of the City of Auburn, near Clipper Gap. The watershed east of SR 49 is primarily composed of two intermittent tributaries, Dry Creek and Orr Creek, which eventually merge approximately one mile west of SR 49 to form Coon Creek (County of Placer 2002). Primary tributaries to upper Coon Creek include Orr, Dry, and Rock Creeks, and Deadman Canyon. Doty Ravine is the primary tributary of Coon Creek. The Doty Ravine watershed originates in the Bald Hill area north of Newcastle and flows westerly for about 8.5 miles before leaving the upper watershed just east of McCourtney Road. Major tributaries to Doty Ravine include Sailor's Ravine and Caps Ravine (County of Placer 2002).

The limiting factor for steelhead in the Auburn Ravine system is suitable spawning habitat. Due to the current out of basin water imports and related flow regimes, these streams provide spawning and rearing habitats that would otherwise be limited or absent. Rainbow trout are known to spawn here, however, steelhead spawning has not been confirmed. If suitable spawning habitat were to be established, it is possible that there would be more active use of this creek by steelhead.

To facilitate Auburn Ravine water deliveries to users, there are approximately 10 small seasonal diversion dams installed throughout Auburn Ravine. Most of the dams are less than 10 feet high and pond water for diversion into agricultural areas. Larger dams also divert water into major canals. Installation of the seasonal dams during the spring and removal during the fall reportedly can affect the upstream migration of some fish species (e.g., steelhead and fall-run Chinook salmon) (Jones & Stokes Associates 1999).

As reported by SARSAS (2009), Placer Legacy and NID are currently in the process of retrofitting the Lincoln Gaging Station and Hemphill Dam for fish passage. These dams will be retrofitted by the end of Summer 2009. Fish will then be able to reach the base of NID's Gold Hill Diversion Dam. NID has identified retrofitting Gold Hill Dam to facilitate fish passage as a focus for NID once fish are able to reach the dam (SARSAS 2009).

Geology

As reported by North Fork Associates (2003), the area immediately around Auburn consists of Jurassic and Triassic metavolcanic rocks. The remainder of the upper foothills is composed of Mesozoic granitic rocks. Pliocene nonmarine sediments occur between the granitic rocks to the east and Highway 65 between Roseville and Lincoln. These sediments form the Mehrten Formation, which consists of a variety of cemented material and is well known for supporting vernal pools along the east side of the Central Valley. Eocene deposits of he Ione Formation form small pockets associated with the Mehrten Formation. West of Highway 65 is a large amount of Pliocene and Pleistocene nonmarine sediments, which tend to form coarse, well drained soils. Further to the west, more recent alluvial fan deposits form coarse to fine grained soils. Soils in the upper and lower foothills of western Placer County include Auburn, Sobrante, Andregg, Caperton, Sierra, Exchequer, and Inks. The upper foothill soils are shallow to moderately deep and are typically well drained. Therefore, much of the rainfall in this region enters streams either through direct runoff or groundwater discharges. The Exchequer-Inks soils occur over shallow volcanic rock. Inks soils are formed from consolidated or cemented sediments derived from volcanic rock, and is one of the primary Mehrten Formation soils. Valley soils include San Joaquin, Cometa, Fiddyment, Kasberg, Ramona, Kilga, Redding, and Corning Series. Several of these are Alfisols and have dense, subsurface clay layers that impede water percolation. Wetlands are often found on these soils because they tend to hold water, especially in depressions (North Fork Associates 2003).

Hydrology

As reported by County of Placer (2002), water management practices in Auburn Ravine, Coon Creek, and Doty Ravine are different than most small East Side foothill tributary streams. Because these watersheds are relatively small, very little of the stream flow is from natural runoff. Coon Creek's hydrology is similar to Auburn Ravine, except that nearly all irrigation water is diverted out of the channel just downstream of Highway 65 during the irrigation season. Water in the Coon Creek channel downstream of this diversion point is primarily groundwater inflows or agricultural return flows (County of Placer 2002).

Historically, Auburn Ravine flows were ephemeral (Sierra Business Council 2003). Flows gradually declined through the spring, summer, and early fall until the first seasonal storm events occurred. Compared to the historical flow regime, current management practices produce higher flows year-round and more consistent flows during the spring and summer months (Table 2). Most of the instream flow in Auburn Ravine is water imported from the Yuba River, Bear River, and American River watersheds through various means, to meet domestic and agricultural needs in western Placer County and southeastern Sutter County (Sierra Business Council 2003). Discharges from PG&E's Wise Powerhouse dominate instream flows during the irrigation season, which extends from April 15 through October 15. Winter flows are dominated by discharges from wastewater treatment facilities and natural runoff. Current water management practices in Auburn Ravine likely provide cold water habitat for salmonids during time periods which historically lacked cold water habitat (Sierra Business Council 2003).

Table 2. Estimated historic and existing streamflow regimes in Auburn Ravine (cfs)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Historic	70.6	50.9	32.3	20.1	2.4	0.2	0.1	0.0	0.0	4.1	11.7	38.2
Existing	117	120	132	66	88	82	114	99	43	30	39	84
Source: Jones & Stokes Associates 1999												

The relatively cool water discharged from the Wise Powerhouse originates from the Drum-Spaulding Project on the Yuba and Bear rivers. PCWA also discharges up to 50 cfs of water from the North Fork American River into Auburn Ravine during the irrigation season. NID, PCWA, and South Sutter Water District, and their customers, divert water from Auburn Ravine primarily for irrigation purposes. Water temperatures in Auburn Ravine during the irrigation season are heavily influenced by these discharges and diversions.

As reported by County of Placer (2002), the Placer County Wastewater Treatment Plant, discharges treated effluent into Rock Creek. Rock Creek joins Dry Creek about 50 yards downstream of the effluent outfall. Dry Creek continues to flow west to the confluence with Orr Creek, which flows from the northeast. Dry Creek and Orr Creek join together to form Coon Creek, which then flows generally westward to the Cross Canal before entering the Sacramento River. The upper half of the Coon Creek basin is characterized by a complex network of irrigation canals managed by NID to carry water imported from the Bear River (County of Placer 2002).

The maximum elevation of the Auburn Ravine watershed is approximately 1,000 feet above mean sea level (MSL). Therefore, precipitation in the watershed falls nearly exclusively as rainfall. The annual timing of rainfall is fairly consistent, with the majority of a water year's precipitation occurring between November and April. However, the amount of precipitation can vary greatly on an annual basis, and individual storm cells can deliver a large amount of rainfall in a relatively short period, even during drought periods (County of Placer 2002).

Winter flows vary widely between and among the Auburn Ravine and Coon Creek watersheds. Auburn Ravine's winter flow peaks can range from a few hundred cubic feet per second (cfs) to an estimated 100-year flow event exceeding 17,000 cfs. Coon Creek's peak flows can range from several hundred cfs in smaller events to more than 22,000 cfs in a hundred year event (County of Placer 2002). High flow events are not contained within the channel of Coon Creek and extensive overland flow occurs (County of Placer 2002).

The critical low flow period generally occurs in October when irrigation season ends and flows from imported sources cease or greatly diminish. Flows during this period (generally early October until winter rains are sufficient to generate additional natural stream flow) are often only a few cfs, resulting in a substantial decrease in aquatic habitat in the low gradient portions of the Auburn Ravine, Doty Ravine, and Coon Creek watersheds (County of Placer 2002).

Land Use

As reported by Placer of County (2002), portions of Auburn Ravine, Dutch Ravine, Doty Ravine, and Coon Creek were placer mined in the mid-to-late 1800s. This activity resulted in removal of riparian vegetation, excavation of soil, and redeposition of tailings. Large quantities of sediment, generated by hydraulic mining, were washed into stream channels and most of this sediment was deposited on the valley floor. Trees were also removed for firewood, construction materials, and to facilitate grazing and farming. In the western portion of the watersheds, the creeks have been largely confined to narrow channels and the riparian plant community reduced to a narrow band along the banks. In general, the eastern portion of the watersheds are in a more natural state.

Lower elevations, which were once dominated by marshlands, have been largely converted to irrigated agriculture. Stream channels have been converted to irrigation/flood canals, with some riparian vegetation within a generally open grassy levee system. Historic vernal pool grasslands have been largely replaced by farmland. Upstream, streams flow though non-native grassland (often grazed) and agricultural fields, with a thin margin of mixed native and non-native riparian species along the creeks. Grassland areas may include patches of valley oak woodland. Oak woodland and mixed oak woodland and scrub habitats become more predominant in the foothills, transitioning to heavier forested areas in the steeper portions of the watershed. These plant communities are affected significantly by the invasion of exotic plants, including a variety of non-native grasses and weedy species such as mustard, broom, and Himalayan blackberry. These species have largely replaced the native grass and forb habitats of the lower foothills (County of Placer 2002).

Auburn Ravine flows through the middle of the city of Auburn, where it is channelized and passes through a variety of culverts. The land adjacent to this portion of the watershed is highly urbanized. Immediately west of the City of Auburn, the character of the channel changes, adjacent land uses change, and water from various sources is discharged into to the channel (County of Placer 2002).

The primary ecological and land use concern in the Auburn Ravine and Coon Creek watersheds is the conversion of existing land uses from agriculture to urban and suburban development. Stream and riparian zone areas would face further ecological stress due to the conversion of adjacent upland habitats to urban and suburban development. Additionally, it is anticipated that water quality will decline with urbanization of the surrounding watersheds. Sustaining commercial agriculture, with its open space component, is a primary goal of habitat conservation, as planned urban development and uncontrolled annexation of agricultural lands continues (County of Placer 2002).

Urban development is least likely to occur along Coon Creek above Gladding Road due to large parcel sizes, current General Plan designations, a lack of urban services and environmental constraints. Auburn Ravine is experiencing the greatest pressures from urban encroachment with the expansion of housing tracts in the Lincoln area. Development could be a major constraint on fishery restoration as most land in the watershed is in private ownership and has no permanent protection (Bear River Watershed Group Website 2009).

Due to large parcel sizes, particularly along Coon Creek upstream of Gladding Road, blue oak woodlands are relatively intact and unfragmented, thus providing large patch sizes for terrestrial species. The Auburn Ravine's upper watershed is more fragmented due to the predominance of the rural resources land designation. The potential for subdivision development in the upper Coon Creek watershed is generally low under current General Plan designations and is unlikely to occur in the future because of a lack of urban services and environmental constraints. The dominant land use in the portion of the watersheds west of Lincoln is rice farming. This land use drives the current water management practices and the timing and flow volumes of water that is delivered during the spring, summer, and early fall (County of Placer 2002).

Fisheries and Aquatic Habitat

As reported by County of Placer (2002), Auburn Ravine provides a diversity of aquatic habitats, including shallow, fast-water riffles, glides, runs and pools. Near its headwaters in the City of Auburn, Auburn Ravine is highly restricted to its natural channel and passes through several culverts. From the western edge of the City of Auburn to west of Lozanos Road, Auburn Ravine is confined in a narrow canyon and has a steep gradient. Stream habitat units in this reach are primarily cascades and pool-riffle complexes, while the substrate consists of bedrock, sands, and cobbles. Just east of Gold Hill Road, the channel gradient in Auburn Ravine decreases to less than 2 percent and the stream habitat is dominated by pools, riffles, and runs, while the substrate is dominated by sands and gravels. Near the City of Lincoln, the stream gradient decreases to less than one percent and the stream habitat shifts from pool-riffle complexes with mixes of gravels and sands to dune-ripple complexes dominated by coarse sand. The lowermost seven miles of Auburn Ravine are confined within naturally erosion-resistant banks and man-made levees, and are dominated by dune-ripple complexes and a sandy substrate (County of Placer 2002).

Aquatic habitat surveys of Auburn Ravine, within and downstream of the City of Lincoln, indicate that a large percentage of the stream is dominated by sandy and silty substrates. Sandy and silty substrates also dominate the middle reaches of Coon Creek and portions of Doty Ravine. These substrate types are characterized by low instream productivity and low habitat diversity. The sources of these sediment inputs are not apparent, but the small grain size and continuously shifting nature of these substrate types contribute to what are considered low quality fish habitats. These substrate types eliminate, for all practical purposes, the potential for Chinook salmon and steelhead spawning in areas downstream of the Highway 65 Bridge in Lincoln (County of Placer 2002).

Without the water imported into these watersheds, most would be dry, or nearly so, for several months of the year. Due to the current water delivery schedules and flow volumes, there are riparian and aquatic habitats along tens of miles of stream channel length that would otherwise be absent. As a result, these streams may support aquatic species that would not otherwise have found suitable habitat in this region. At the same time, these enhanced flow regimes provide habitat for non-native species; for example, the regular flow regime may enhance conditions for Himalayan blackberry, a non-native species that crowds out native plants (County of Placer 2002).

Flows and water temperatures in Auburn Ravine are influenced by discharges from the Lincoln Wastewater Treatment and Reclamation Facility (WWTRF) and the Auburn Wastewater Treatment Plant (WWTP). These discharges likely are warmer than the receiving waters in Auburn Ravine. Another factor influencing Auburn Ravine water temperature is the amount of overhanging riparian vegetation. The lack of riparian buffers along the downstream reaches of Auburn Ravine likely contributes to elevated water temperatures.

To facilitate Auburn Ravine water deliveries to users, there are approximately 10 small seasonal diversion dams installed throughout Auburn Ravine. Most of the dams are less than 10 feet high and pond water for diversion into agricultural areas. Larger dams also divert water into major canals. Installation of the seasonal dams during the spring and removal during the fall reportedly can affect the upstream migration of some fish species (e.g., steelhead and fall-run Chinook salmon) (Jones & Stokes Associates 1999).

As reported by SARSAS (2009), Placer Legacy and NID are currently in the process of retrofitting the Lincoln Gaging Station and Hemphill Dam for fish passage. These dams will be retrofitted by the end of Summer 2009. Fish will then be able to reach the base of NID's Gold

Hill Diversion Dam. NID has identified retrofitting Gold Hill Dam to facilitate fish passage as a focus for NID once fish are able to reach the dam (SARSAS 2009).

Steelhead

Historically, low elevation streams such as Auburn Ravine likely were essentially dry during the summer and fall, at least in the foothill sections. Therefore, streams such as Auburn Ravine likely were not conducive to supporting significant or consistent steelhead populations. Local area residents have reported that steelhead routinely spawned near Auburn (Jones & Stokes Associates 1999).

Documented evidence of steelhead spawning (e.g., observations of steelhead actively spawning or confirmed steelhead redds) in Auburn Ravine has not been located, however, the presence of juvenile rainbow trout captured during electrofishing surveys and seining suggests that at least rainbow trout successfully spawn in Auburn Ravine (CDFW 2005, unpublished data).

Currently, information regarding steelhead presence and habitat utilization in Auburn Ravine is either limited or not readily available. Steelhead were not collected during the 1997 fish survey, although juvenile fishes were collected in upper reaches during the 1998 and 1999 surveys (Jones & Stokes Associates 1999). The 1998 survey reported that some of the captured juvenile fish exhibited the iridescent silvery sides typical of smolting salmonids (Jones & Stokes Associates 1999); however, it can be difficult to determine whether juvenile fish are anadromous or resident forms of the species. The juvenile fishes collected during the 1999 survey reportedly did not exhibit any obvious visual characteristics of emigration associated with the anadromous form (i.e., steelhead) (Jones & Stokes Associates 1999).

CDFW (2005, unpublished data) conducted two-pass electrofishing surveys on a total of seven reaches in Auburn Ravine during the fall/winter of 2004 and the spring of 2005. During the 2004 fall/winter survey, a total of 689 fish were collected in Auburn Ravine, 309 of which were identified as steelhead/rainbow trout. Of the 674 fish collected during the 2005 survey, 253 were identified as steelhead/rainbow trout. The CDFW survey results indicate that Auburn Ravine may constitute a probable steelhead spawning area given the presence of very small juveniles during spring. Auburn Ravine, both upstream and downstream of the tunnel outlet, may represent a year-round rearing area for juvenile steelhead, given the presence of both YOY and larger juveniles during November, December, and April.

Dry Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Species that Historically Occurred in the Watershed

Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to steelhead in Dry Creek include but are not limited to the following:

- Passage impediments/barriers in the Dry Creek watershed affecting adult immigration and holding
- Elevated water temperatures and water quality (agricultural and urban runoff) affecting adult immigration and holding, spawning and embryo incubation, juvenile rearing and outmigration
- Flow fluctuations affecting spawning
- Physical habitat alteration associated with limited supplies of instream gravel, habitat suitability and spawning habitat availability affecting adult spawning
- Flow dependent habitat availability affecting juvenile rearing and outmigration
- Loss of natural morphology, riparian habitat and instream cover affecting juvenile rearing and outmigration

Watershed Description

The following information on the Dry Creek watershed is summarized from the *Dry Creek Watershed Coordinated Resource Management Plan* (ECORP Consulting 2003).

Dry Creek originates in the Sierra Nevada Foothills, drains approximately 101 square miles, and is approximately 17.6 miles long (ECORP Consulting 2003) and is hydraulically connected to the Sacramento River *via* the Natomas East Main Drainage Canal. The Dry Creek watershed covers a range from just west of Auburn (Placer County) west to Steelhead Creek (north of Sacramento, Sacramento County), and south to Folsom (Sacramento County). The mainstem drainage system is composed of 1.3 miles of intermittent drainage, 20.3 miles of first-order perennial, and 21.6 miles of second-order perennial streams.

Elevations in the Dry Creek watershed ranges from approximately 1,200 feet above mean sea level (msl) down to approximately 30 feet above msl. Below Elverta Road, Dry Creek diverges into two channels (i.e., the Main Fork and the North Fork). The Main Fork lies to the south and contains flow year-round. The North Fork is several feet higher than the Main Fork and functions as an overflow channel (Foothill Associates 2003). Tributaries to Dry Creek include Secret Ravine, Miners Ravine, Strap Ravine, Antelope Creek, Clover Valley Creek, and Linda Creek.

Because of the extensive changes that have happened to Dry Creek's channel morphology, restoration of this creek has potential but will be tricky. Throughout the watershed, reaches have been straightened, floodplain area reduced, reaches dredged, and riparian vegetation removed, resulting in eroding banks, sediment deposition, lack of cover, lack of pools and riffles, lack of riparian vegetation, and barriers to fish passage. Additionally, placer mining in Secret, Strap, and Miners Ravines accelerated stream incision down to the bedrock in the upper reaches. However, Dry Creek does support a relatively healthy riparian corridor upstream of Folsom Road to the confluence with Miners and Secret ravines (ECORP Consulting 2003), and thus, the focus for restoration should be in those areas along that reach that can support stream cover and natural channel processes.

Geology

Soils within the Dry Creek watershed are variable, depending upon landscape position and underlying geology. Most soils are formed from either granitic or volcanic parent material, and often include a clay pan, hard pan, or other consolidated layer that impedes water permeability. Shallow soils and rock outcrops are fairly common at higher elevations. At lower elevations, soils are generally on flatter lands and underlain by a claypan or hardpan, have low permeabilities, finer texture (e.g., silts and clays), low soil strength, and high shrink-swell potential. These soils often require artificial drainage for development or agriculture. Additionally, areas of the watershed are underlain by Mehrten Formation that may present infiltration impediments and support vernal pool ecologies (ECORP Consulting 2003).

Hydrology

The headwaters of three major Dry Creek tributaries, Antelope Creek, Secret Ravine, and Miners Ravine, begin in the foothills of the Sierra Nevada mountain range at 900 to 1200 feet above mean sea level. Secret Ravine converges with Miners Ravine just upstream from Eureka Road in Roseville, CA. Antelope Creek enters Dry Creek just south of Atlantic Boulevard, also in Roseville. Linda Creek and Strap Ravine are lower gradient streams that begin near Granite Bay at a mean sea level elevation of 300 to 500 feet. Linda Creek is tributary to Cirby Creek. Cirby Creek then flows into Dry Creek just downstream of Royer Park in Roseville. The Dry Creek mainstem begins at the confluence of Secret Ravine and Miners Ravine and flows down to about 30 feet above mean sea level into Steelhead Creek (i.e., the Natomas East Main Drainage Canal) in Sacramento County (ECORP Consulting 2003).

Numerous canals, aqueducts, siphons, reservoirs, ponds, dams, pipelines, and other natural and non-natural water features significantly influence local hydrology within the Dry Creek watershed. Modification of the watershed's hydrology is compounded by modification of the instream configuration by channelization, levees, dredging, and reduced floodplain area. These modifications also result in altered stream flow where flow is faster in some areas (i.e., channelized conveyances), contributing to erosion and faster peak flow timing, but slower in other areas (i.e., behind dams and other impeding structures), contributing to flooding and sediment deposition.

Several historically intermittent drainages (e.g., Strap Ravine, upper portions of many tributaries) are currently perennial drainages due to nuisance flows (e.g., flows from artificial outfalls, irrigation runoff, and irrigation drainage). These flows may contribute to water quality degradation through associated pollutants and higher water temperatures.

A major facility discharging into the Dry Creek mainstem is the Roseville Wastewater Treatment Plant (Roseville WWTP). Discharges from the Roseville WWTP have minimal impacts to Dry Creek during wet months, however, they can compose a high proportion of flows during dry months (i.e., greater than 50% of total flow at the Vernon Street Bridge). As development continues to expand within this region, treated effluent discharges will likely increase. A new regional wastewater treatment plant is being built outside of the Dry Creek watershed by the City of Roseville. It is estimated that approximately 15,000 Roseville WTP customers will be transferred to the new facility.

From 1997 through 2008, the highest peak flow on Dry Creek at the Vernon Street Bridge was 7,950 cfs, occurring on Jan 22, 1997 (USGS Website 2009). From 2000 through 2008, annual daily mean flows at the Vernon Street Bridge ranged from 48.8 cfs in 2007 to 131.3 cfs in 2006 (USGS Website 2009).

The climate in which the Dry Creek watershed is located is considered a Mediterranean climate with a warm, dry season during April through October; and a wet, mild season from November through March. Annual precipitation is approximately 20 to 25 inches per year, with peak rainfall occurring during December through February. Summer stream flows are generally composed of flow from springs and urban runoff, and irrigation drainage and effluent from wastewater treatment systems.

Land Use

Various land uses in the Dry Creek Watershed over the past 150 years have resulted in direct and indirect impacts to channel morphology. Historical land uses include placer mining, quarry development, agricultural development, and urbanization. Dramatic levels of urbanization have occurred since the 1950s, particularly in the Roseville and Rocklin areas. Many roads traverse the stream valleys, modifying floodplain areas and channels where bridges and culverts have been installed for crossings. Streams have been channelized, moved or straightened to fit floodplain developments and riparian vegetation has been removed mechanically or by use of herbicides, resulting in bank instability and erosion (ECORP Consulting 2003).

Generally, the middle portion of the Dry Creek watershed has been subject to extreme development pressure by relatively recent growth, primarily within the cities of Roseville and

Rocklin. The upper and lower portions of the watershed are anticipated to experience similar growth in the coming years. Such development generally has been perceived to have exacerbated normal historical flooding conditions lower in the watershed, particularly in Sacramento County, by contributing greater and faster flood flows during storm events. In addition, water quality concerns have arisen, due to the perceived increase in sedimentation and potential contamination from non-point sources.

Within the Dry Creek Watershed, much of the native vegetation has been removed and either replaced with non-native species (e.g., landscaping, agriculture), developed, or left bare. The reduction in native vegetation has contributed to significant degradation of the watershed water resources. Reduction of riparian habitat and/or replacement with non-native species (e.g., ornamentals) occurs within all tributaries of the watershed. This has contributed to bank destabilization and erosion, higher water temperatures, and reduction in suitable habitat for aquatic life.

Historically, livestock traffic compaction and off-road recreational vehicle activities have contributed to bank destruction. In many areas, channels have been deepened, straightened, and/or re-located to accommodate roads, to create agricultural land, for sewage treatment ponds, to convey flows, and for other developments. This channelization and reconfiguration has resulted in reduced area for overbank flow and reduced channel meandering. Whether by erosive processes, historical placer mining or channel reconfiguration, these deepened channels have lowered the shallow groundwater table, particularly in the upper tributary reaches (ECORP Consulting 2003).

Fisheries and Aquatic Habitat

As discussed above, land use impacts have affected the form and function of stream channels throughout the Dry Creek Watershed, which in turn have impacted riparian and aquatic communities. Much of the focus of these impacts have been in the middle and lower reaches of the watershed, particularly Secret Ravine, Miners Ravine, and the mainstem of Dry Creek, due to their importance in sustaining salmonid populations and riparian habitat (ECORP Consulting 2003). Throughout the watershed, reaches have been straightened, floodplain area reduced, reaches dredged, and riparian vegetation removed, resulting in eroding banks, sediment deposition, lack of cover, lack of pools and riffles, lack of riparian vegetation, and barriers to fish passage. Additionally, placer mining in Secret, Strap, and Miners Ravines accelerated stream incision down to the bedrock in the upper reaches. However, Dry Creek does support a relatively healthy riparian corridor upstream of Folsom Road to the confluence with Miners and Secret ravines (ECORP Consulting 2003).

Below the confluence with Secret and Miners ravines, aquatic habitat is characterized by low gradient, slow moving water, dominated by sand/silt substrate. Water temperatures appear to be 5.6 ^{o}C (10 °F) warmer than upstream of the confluence. Available fish habitat is limited to undercut banks, overhanging vegetation, and some instream woody debris. Habitat is much more complex in Secret Ravine, with an abundance of pool habitat, large woody debris, and suitable spawning habitat.

Preliminary water temperature data collected by CDFW in 1999 and 2000 indicate that mean daily summer water temperatures above the confluence never reached 21.1 ^{o}C (70°F). This is in contrast to mean daily summer water temperatures below the confluence, which peaked at over 26.7 ^{o}C (80°F) in 1999. The Roseville WWTP has recorded mean daily water temperatures of greater than 31 ^{o}C in the mainstem of Dry Creek during the summer (period of record was 1998 through June 2003) (ECORP Consulting 2003).

Tributaries within the Dry Creek Watershed are known to support anadromous salmonids and other areas likely historically supported anadromous salmonids, but now either have passage barriers or severely degraded habitat. The mainstem of Dry Creek is not suitable fish habitat, but is considered to be a migratory corridor for anadromous salmonids. Linda Creek has two sites that might be suitable for spawning and rearing, however, most of the habitat is generally degraded with steep eroding banks and high summer water temperatures. Cirby Creek is heavily urbanized and likely no longer supports salmonids. Antelope Creek has two potential spawning areas, but these areas also are degraded. Rock dams and beaver dams act as barriers to fish passage in Antelope Creek, although a few fish have been found in this tributary. Miners Ravine still supports salmonids, however many reaches are heavily degraded. Secret Ravine also still supports salmonids and has the highest quality fisheries habitat in the Dry Creek watershed (ECORP Consulting 2003).

Given the increase in summer streamflows compared to historical conditions, the potential for improvement of existing juvenile steelhead rearing habitat exists, but primarily only within the uppermost portions of Dry Creek (i.e., Secret Ravine) (ECORP Consulting 2003). Several studies and projects have been implemented to improve fish passage and restore aquatic life habitat in Miners Ravine, Secret Ravine, and Cirby/Linda Creek. For example, riparian trees have been planted along Dry Creek by the City of Roseville in association with the Dry Creek Reforestation Project.

Steelhead

General information on the historical presence of anadromous salmonids in Dry Creek is available through many small-scale inventory surveys and anecdotal information. A review of this information suggests that suitable salmonid habitat is available at select sites (Sierra Business Council 2003), and that the system currently hosts a self-sustaining population of steelhead (Ayres *et al*. 2003; Sierra Business Council 2003). All spawning habitat and accounts of spawning anadromous salmonids have been reported to be located upstream of the Dry Creek WWTP.

The CDFW Native Anadromous Fish and Watershed Branch initiated a reconnaissance-level assessment of steelhead distribution and abundance, relative to stream habitat conditions, in 1998 and 1999. At that time, steelhead escapement to the upper Dry Creek watershed was estimated at a few hundred fish, with the most suitable spawning and rearing habitat in Secret Ravine and to a lesser extent, Miners Ravine. Monitoring of juvenile salmonid emigration also was conducted by CDFW during 1999 and 2000. During both years, juvenile steelhead (and Chinook salmon) were collected in rotary screw traps located immediately downstream of the confluence of Secret and Miners ravines (ECORP Consulting 2003).

During the fall/winter of 2004 and the spring of 2005, CDFW conducted two-pass electrofishing surveys on a total of seven reaches in Dry Creek, as well as in several reaches in Miners and Secret ravines. During the 2004 fall/winter survey, no steelhead/rainbow trout were captured in Dry Creek or Miners Ravine. However, 41 steelhead/rainbow trout were captured in Secret Ravine. During the 2005 spring survey, no steelhead/rainbow trout were identified in Dry Creek or Miners Ravine, but 95 steelhead/rainbow trout were captured in Secret Ravine (CDFW 2005, unpublished data). During the 2005 spring survey in Secret Ravine, five pit-tagged steelhead/rainbow trout were re-captured from the 2004 fall/winter survey. All of these fish were re-captured in the same reach of Secret Ravine as when they were originally captured and tagged during the 2004 fall/winter survey. Growth rates for these fish were quite variable, as shown in Table 3.

Table 3. Steelhead/rainbow trout growth in Secret Ravine

Length at Capture (mm)	Time to Re-capture (days)	Length at Re-capture (mm)	Growth (mm)
91	187	168	77
95	204	155	60
88	204	154	66
90	204	188	98
79	204	143	64

Source: CDFW 2005, unpublished data

Based on analysis of data from the 2004/2005 surveys conducted by CDFW, the findings are consistent with previous studies and anecdotal information suggesting that Dry Creek is utilized as a migratory corridor for anadromous salmonid passage upstream to spawning and rearing habitat in the upstream tributaries (Secret Ravine and Miners Ravine) (CDFW 1998). Catch data also is consistent with information presented in the Dry Creek Watershed Coordinated Resource Management Plan (ECORP Consulting 2003), which states that the mainstem of Dry Creek is not suitable anadromous salmonid habitat and is considered only as a migratory corridor to upstream areas containing suitable spawning and rearing habitat.

Feather River Watershed Profile

Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to Central Valley spring-run Chinook salmon and steelhead in the Feather River include, but are not limited to the following:

- ❖ Passage impediments/barriers at the Fish Barrier Dam and at the Oroville Dam affecting adult immigration and holding
- ❖ Flow conditions (i.e., low flows) associated with attraction and migratory cues into the Feather River affecting adult immigration and holding
- ❖ Water temperatures affecting adult immigration and holding, spawning, juvenile rearing and outmigration
- ❖ Passage impediments/barriers and hatchery effects related to redd superimposition, competition for habitat, hybridization/genetic integrity affecting spawning
- ❖ Physical habitat alteration associated with limited supplies of instream gravel, habitat suitability and spawning habitat availability affecting adult spawning
- ❖ Loss of natural river morphology, loss of riparian habitat and instream cover affecting juvenile rearing and outmigration
- ❖ Predation effects on juvenile rearing and outmigration

Watershed Description

The Feather River Watershed is located at the north end of the Sierra Nevada and encompasses an area of about 5,900 square miles (DWR 2007). The upper Feather River Watershed above Oroville Dam is approximately 3,600 square miles, and comprises approximately 68 percent of the Feather River Basin. Downstream of Oroville Dam, the watershed extends south and includes the drainage of the Yuba and Bear rivers (Figure 3). The Yuba River flows into the Feather River near the City of Marysville, 39 river miles downstream of the City of Oroville. The Bear River flows into the Feather River about 55 river miles downstream of the City of Oroville.

Approximately 67 miles downstream of the City of Oroville, the Feather River flows into the Sacramento River near the town of Verona (DWR 2007).

Geology

The watershed is bounded by the volcanic Cascade Range to the north, the Great Basin on the east, the Sacramento Valley on the west, and higher elevation portions of the Sierra Nevada on the south (DWR 2007). Downstream of Oroville Reservoir, the Feather River emerges from the Sierra Nevada and enters the Sacramento Valley. The Feather River below Thermalito Diversion Dam to Verona is mostly an alluvial stream flowing across its own sedimentary deposits of clay, silt, sand, and gravel. By far, historic hydraulic mining of Eocene gold-bearing gravel deposits caused the largest impact on the Feather River channel. Massive amounts of erosional debris, including cobbles, gravel, sand, silt, and clay, were washed into the river. Mining debris still profoundly affects the present-day Feather River. Both the human-modified cobble banks and clay rich slickens have increased bank stability. Between the cities of Oroville and Gridley, cobbles and coarse gravel dredge tailings constitute most of the banks, slowing the bank erosion process. Between Honcut Creek and the mouth of the Feather River, the meandering process has slowed, and the river is wide and shallow, with low sinuosity and a sand bed. Most of the reach is mapped as glides or long pools, with low mesohabitat variability. The lower Feather River meander belt (Figure 3) consists of recent alluvium and stream channel deposits. Of the two, the alluvium is older, but both consist of river deposits, including floodplain deposits, point bar deposits, channel fill, oxbow lake deposits, tributary delta deposits, and hydraulic mining debris. The deposits range in size from clay, silt, and sand to gravel, cobbles, and boulders. Coarse deposits predominate near the City of Oroville and fine deposits predominate from Gridley downstream to the mouth of the Feather River. Older alluvial deposits not directly linked to the present Feather River form terraces on both sides of the active stream channel. These deposits are typically higher in elevation, more resistant to erosion and define the boundaries of the active meander belt (DWR 2007).

The most common parent material for the soils downstream of Oroville Dam is river alluvium, with some soils derived from debris deposited during the hydraulic mining period. The predominant soil types or textures in the 100-year floodplain are characterized as fine sandy loam, loamy sand, and loam to silt loam. Minor soil types are clay, clay loam, sandy clay loam, sandy loam, silt loam, silty clay, sand and gravel, and river wash. Many of the soils are further divided by occurrence of flooding, such as occasionally flooded to frequently flooded. The soils range from shallow to very deep, with most being moderately deep to very deep. Floodplain soils are conducive to agriculture and many areas of riparian floodplain and fluvial terraces have been converted to irrigated crops and orchards (DWR 2007).

Hydrology

Climate in the region follows a Mediterranean pattern, with cool wet winters and hot dry summers. Air temperatures range from below zero to above 100 degrees Fahrenheit (ºF). Approximately 95 percent of the annual precipitation occurs during the winter months. Precipitation ranges from more than 90 inches at the orographic (i.e., mountain) crest near Bucks Lake, 33 inches at the City of Oroville, to less than 20 inches in the eastern headwaters.

Precipitation above 5,000 feet occurs primarily as snow, which regularly accumulates in excess of 5 to 10 feet during winter. There are infrequent summer thunderstorms, predominantly in the eastern third of the watershed. These storms can produce significant rainfall of short duration over a relatively small area (DWR 2007).

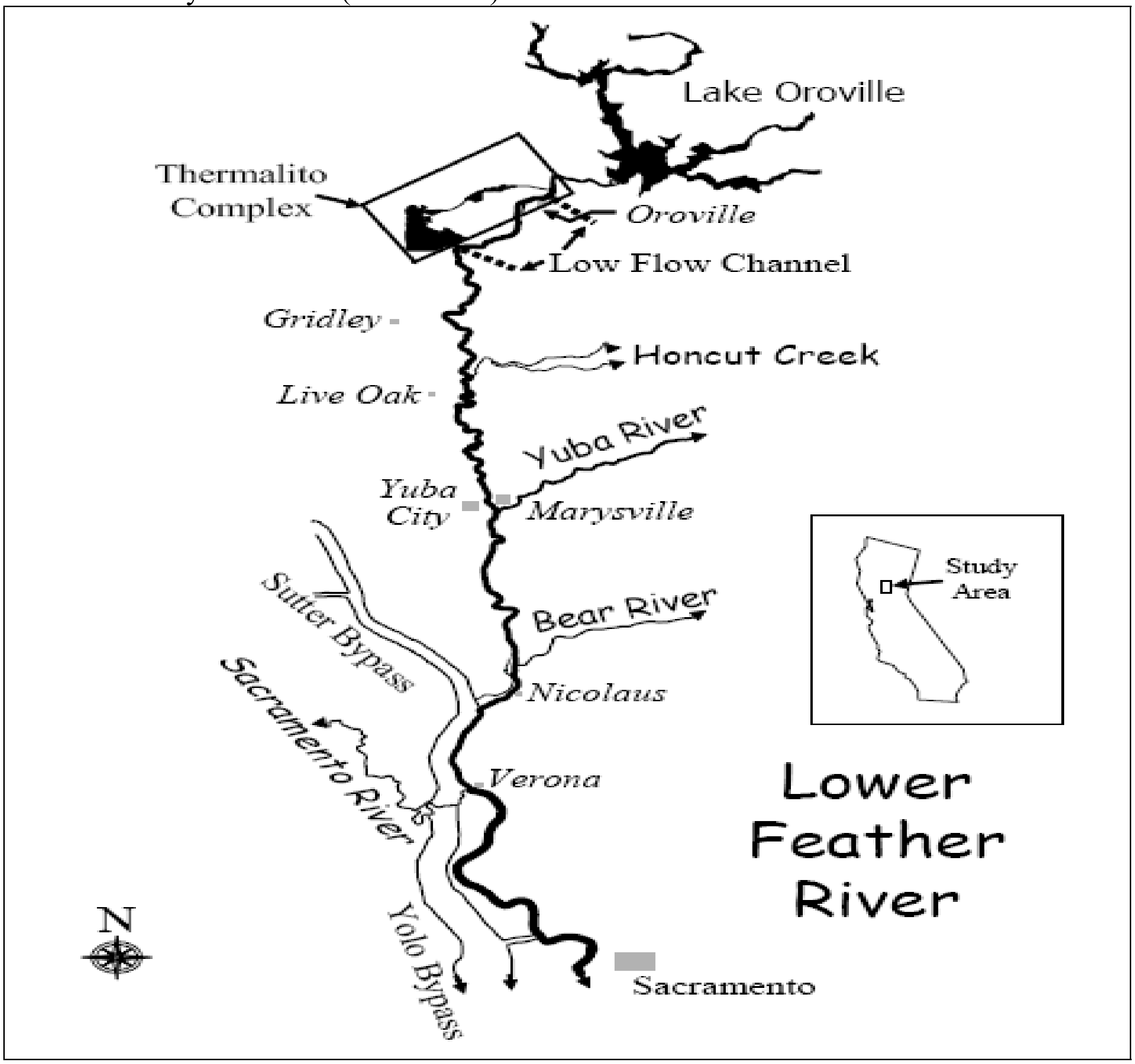

Figure 3. The Lower Feather River Source: DWR 2006

The Feather River is considered to be a major tributary to the Sacramento River and provides about 25 percent of the flow[3] in the Sacramento River (DWR 2007). The average annual yield of the upstream Feather River Basin at Oroville is about 4.2 million acre-feet (maf), with runoff generally occurring between January and June. Summer inflows into Oroville Reservoir are sustained at about 1,000 cfs by snowmelt and accretions from springs and groundwater in the upper watershed. Due to several diversions upstream, actual annual inflow into Oroville

[3] As measured at Oroville Dam.

Reservoir is about 4.0 maf. Annual flows are variable and depend upon precipitation. From 1979 to 1999, annual inflows ranged from a minimum of 1.7 maf to as high as 10 maf (DWR 2007).

Feather River flows are altered by hydroelectric, water storage, and diversion projects upstream of the Oroville Facilities[4], Oroville Reservoir operations, and by diversions from the Thermalito Afterbay to meet service area entitlements (DWR 2007). Upstream projects alter Feather River flows through operation of storage facilities and by diversions from the river and its tributaries. Water diversions to meet service area entitlements occur primarily during the irrigation months, April to October. Water also is required during all months of the year to meet State Water Project (SWP) water contractors' requests, with the highest requests typically occurring from June through August, and the lowest occurring during January. Water available for delivery varies depending on hydrologic conditions and operating requirements (DWR 2007).

Oroville Reservoir, operated by the California Department of Water Resources (DWR) and the keystone of the SWP, is the lowermost reservoir on the Feather River and the upstream limit for anadromous fish (USFWS 1995). With a storage capacity of more than 3.5 maf, Oroville Reservoir is located at the confluence of the West Branch and the North, Middle, and South Forks of the Feather River, upstream from the Yuba and Bear River tributaries at an elevation of 900 feet above msl (YCWA and Reclamation 2007). Water is released from Oroville Dam through a multilevel outlet to provide appropriate water temperatures for the operation of the Feather River Hatchery and to protect downstream fisheries. Approximately 5 miles downstream of Oroville Dam, water is diverted at the Thermalito Diversion Dam into the Thermalito Power Canal, thence to the Thermalito Forebay and another powerhouse, and finally into the Thermalito Afterbay. Water can be pumped from the Thermalito Diversion Pool back into Oroville Reservoir to generate peaking power. The Oroville-Thermalito complex (Figure 4), completed in 1968, provides water conservation, hydroelectric power, recreation, flood control, and fisheries benefits. The other major impoundment in the watershed is Lake Almanor, with a storage capacity of more than 1.1 maf. A number of other small- to moderate-sized impoundments, including Mountain Meadows Reservoir, Bucks Lake, Little Grass Valley Reservoir, Lake Davis, Frenchman Lake, Butt Valley Reservoir, Sly Creek Reservoir, and Antelope Lake, store an additional 450 taf or more (USFWS 1995).

[4] The Oroville Facilities were developed as part of the State Water Project (SWP), a water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. The Federal Power Act (FPA) license for the Oroville Facilities (issued by the FERC, on February 11, 1957) expired on January 31, 2007. The California Department of Water Resources (DWR) sought a new federal license to continue generating hydroelectric power while continuing to meet existing commitments and comply with regulations pertaining to water supply, flood control, the environment, and recreational opportunities. FERC issued an annual license to DWR for Project No. 2100 for a period effective February 1, 2007 through January 31, 2008, or until the issuance of a new license for the project or other disposition under the FPA, whichever came first. If issuance of a new license (or other disposition) did not take place on or before January 31, 2008, pursuant to 18 C.F.R. 16.18(c), an annual license under section 15(a)(1) of the FPA will be renewed automatically without further order or notice by FERC, unless FERC orders otherwise (FERC 2007).

Under an agreement with the CDFW, Feather River flows between the Thermalito Diversion Dam and the Thermalito Afterbay outlet are regulated at 600 cfs, except during flood events when flows have been as high as 150,000 cfs (DWR 1983). This section is often referred to as the "low-flow" river section. Water is released through a powerhouse, then through the Fish Barrier Dam to the Feather River Hatchery, and finally into the low-flow section of the Feather River. Thermalito Afterbay has a dual purpose as an afterbay for upstream peaking power releases to ensure constant river and irrigation canal flows, and as a warming basin for irrigation water being diverted to rice fields. Thus, water temperatures in the approximately 14 miles of salmon spawning area from the Thermalito Afterbay outlet to the mouth of Honcut Creek (referred to as the "high-flow" section) are always higher than those in the 8 miles of the low-flow section (USFWS 1995).

Land Use

Human activity over time has resulted in decreased vegetative cover from logging and grazing, channel clearing, levee construction and water diversions. These activities have contributed to the increased sediment load in the Feather River Watershed (Plumas County Flood Control and Water Conservation District 2004). Current land use patterns within the watershed are diverse, but the principal land use activities include recreation, agriculture, timber production, hydropower generation, and livestock grazing. About 4 percent (i.e., approximately 70 square miles) of all land in Butte County consists of urban uses (DWR 2007).

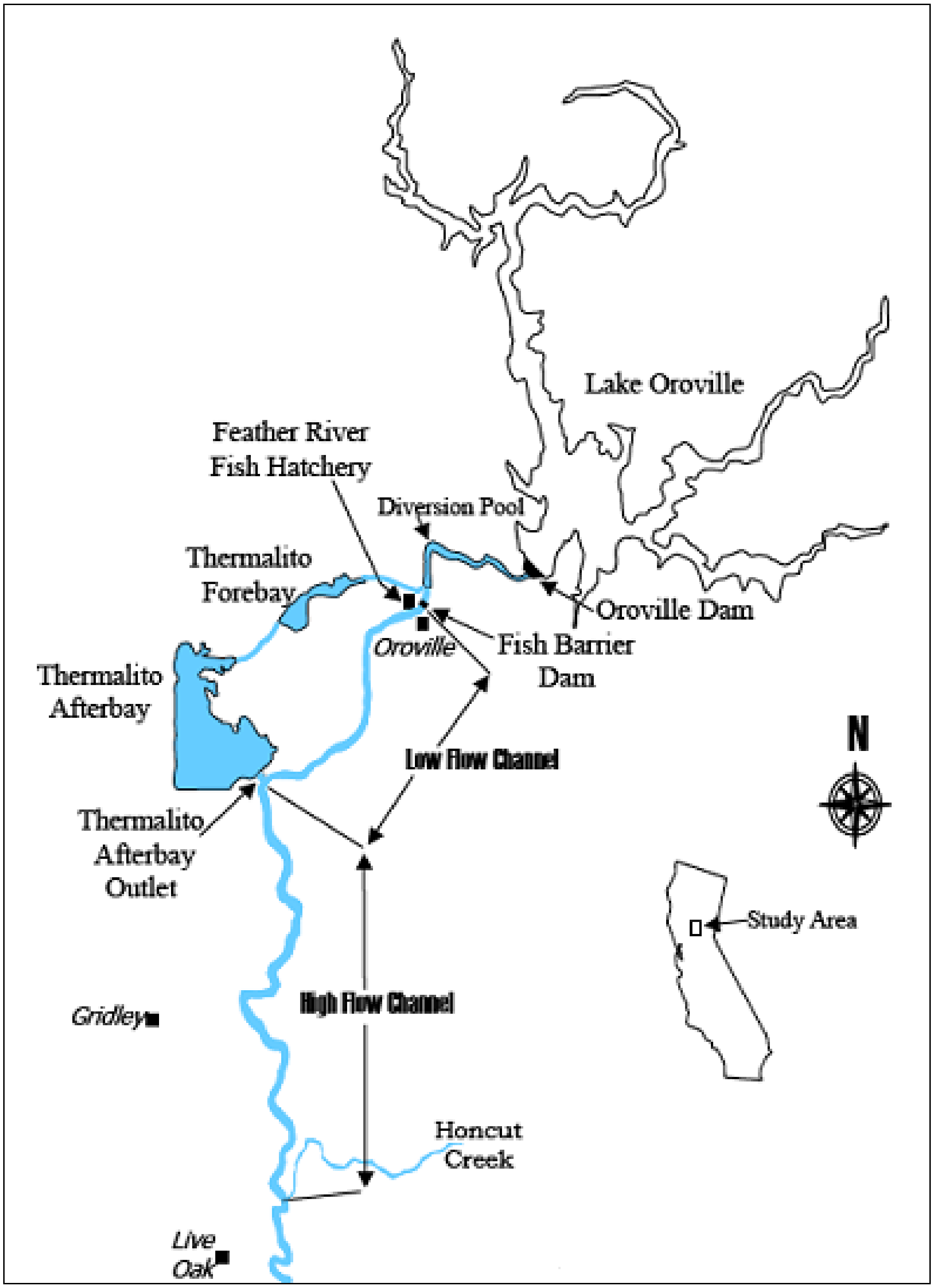

Figure 4. Oroville-Thermalito complex Source: Modified from DWR 2006

Fisheries and Aquatic Habitat

The Feather River Watershed is reported to have contained about 211 miles of historic anadromous fish habitat, and currently contains about 64 miles of habitat for Chinook salmon and steelhead (USFWS 2009). Spring-run historically ascended to the very highest elevation headwaters of the Feather River watershed prior to the construction of numerous hydroelectric power projects and diversions (Clark 1929). Spring-run Chinook salmon were reported to have occurred in the West Branch Feather up to Stirling City, and the North Fork past the present day site of Lake Almanor. In the Middle Fork, spring-run Chinook salmon were reported as far upstream as the natural barrier at Bald Rock, and potentially to Feather Falls located on the Fall River, a tributary to the Middle Fork (CDFW 1998). Spring-run may have ascended to the vicinity of Forbestown on the South Fork (Yoshiyama *et al.* (1996).

Based on broad-scale mesohabitat surveys, the major tributaries in the upper Feather River—the West Branch of the North Fork Feather River (West Branch), the North Fork Feather River (North Fork), the Middle Fork Feather River (Middle Fork), and the South Fork Feather River (South Fork)—generally provide suitable habitat for all life stages of Chinook salmon and steelhead (DWR 2005). For both Chinook salmon and steelhead, spawning and embryo incubation is the life stage for which the smallest amount of suitable habitat is available in the upper Feather River. The greatest amount of suitable habitat is available for the following life stages: (1) Chinook salmon juvenile rearing and downstream movement; (2) steelhead adult immigration and holding; (3) steelhead fry and fingerling rearing and downstream movement; and (4) steelhead smolt emigration. Overall, the North Fork appears to be the most suitable for occupancy of anadromous salmonids, while the South Fork appears to be the least suitable (DWR 2005). Water temperatures, at the locations for which water temperature data were available, approached or exceeded potentially stressful levels generally from May through October (DWR 2005). However, water temperature data loggers were generally located at low elevations near the tributary/reservoir boundary, which is the location within tributaries that is typically believed to experience the highest water temperatures (DWR 2005). In general, the upper Feather River appears to be suitable for migratory Chinook salmon and steelhead based on available mesohabitat data, water temperature profiles, and the current distribution of resident rainbow trout populations (DWR 2005). However, if these upper tributaries become accessible to anadromous salmonids in the future, additional data is required to definitively determine the suitability of habitat in the upper Feather River (DWR 2005).

The lower Feather River commences at the Low Flow Channel (LFC), which extends eight miles from the Fish Barrier Dam (RM 67) to the Thermalito Afterbay Outlet (RM 59) (Figure 5). As described above, flows in this reach of the river are generally regulated at 600 cfs (DWR 1983). Average monthly water temperatures typically range from about 47°F in winter to about 65°F in summer. The majority of the LFC flows through a single channel contained by stabilized levees. Side-channel or secondary channel habitat is extremely limited, occurring primarily in the Steep Riffle and Eye Riffle areas between RM 60 and 61. The channel banks and streambed consist of armored cobble as a result of periodic flood flows and the absence of gravel recruitment. However, there are nine major riffles with suitable spawning size gravel, and approximately 75 percent of the Chinook salmon spawning takes place in this upper reach (Sommer *et al*. 2001). Releases are made from the coldwater pool in Oroville Reservoir and this cold water generally provides suitable water temperatures for spawning in the LFC (DWR 2001).

The lower reach extends 15 miles from the Thermalito Afterbay Outlet (RM 59) to Honcut Creek (RM 44) (Figure 5). Releases from the outlet vary according to operational requirements. In a normal year, total flow in the lower reach ranges from 1,750 cfs in fall to 5,000-8,000 cfs in spring. Water temperature in winter is similar to the Low Flow Channel but increases to 74°F in summer. Higher flows dramatically increase the channel width in this reach. Numerous mid-channel bars and islands braid the river channel, creating side-channel and backwater habitat. The channel is not as heavily armored and long sections of riverbanks are actively eroding. In comparison to the LFC, there is a greater amount of available spawning areas, which are isolated by longer and deeper pools (DWR 2001).

For currently occupied habitats below Oroville Dam, it is unlikely that habitats can be restored to pre-dam conditions, but many of the processes and conditions that are necessary to support a population of CV spring-run Chinook and CV steelhead can be improved and sustained with extensive long-term human intervention, including improvements to water temperature management, habitat availability, spatial distribution and separation of spring- and fall-run Chinook salmon as part of hatchery management. Implementation of the Settlement Agreement for the Oroville FERC license is expected to help address these factors and improve the habitat in the lower Feather River.

CV spring-run Chinook salmon and CV steelhead are produced by the Feather River Hatchery, but also spawn in the river downstream from the Fish Barrier Dam approximately 8 miles to the Thermalito Afterbay Outlet. The majority of the spawning occurs in the upper three miles of river downstream from the Feather River Hatchery. CWT information from these hatchery returns indicates substantial introgression has occurred between fall-run and spring-run Chinook salmon populations within the Feather River system due to hatchery practices which have compromised the genetic integrity of spring-run Chinook salmon. Lindley *et al.* (2007) characterized CV spring-run Chinook salmon and CV steelhead populations in the Feather River as data deficient. However, the existing spring-run Chinook population in the Feather River, including the hatchery fish, may be the only remaining representatives of this important ESU component and that the Feather River hatchery spring-run Chinook stock may play an important role in the recovery of spring-run Chinook in the Feather River Basin.

This is primarily based on the presence of hatchery supported populations that are known to reproduce naturally in the Low Flow Channel between river mile 59 and 67. The Settlement Agreement for Licensing of the Oroville Facilities (March 2006) includes the Lower Feather River Habitat Improvement Plan, which requires the development and implementation of numerous programs and projects that will improve the ecological condition of the Lower Feather River, in a manner that is expected to improve the quality and quantity of CV spring-run Chinook salmon and CV steelhead habitat for the next 50 years. Most significantly, the Settlement Agreement includes measures to improve the short- and long-term genetic management of the Feather River Hatchery, measures to physically separate and isolate CV spring-run Chinook salmon from CV fall-run Chinook salmon, and measures that will increase the spatial availability of spawning habitat for CV steelhead.

Spring-run Chinook Salmon

NMFS (2009a) reports that four independent populations of spring-run Chinook salmon historically occurred in the upper tributaries (*i.e.*, North, Middle and South forks, and the West Branch) of the Feather River Watershed, but they are now extinct. However, a hatchery population currently occurs in the lower Feather River below Oroville Dam (see below).

A naturally-spawning dependent population of spring-run Chinook salmon currently is restricted to accessible reaches of the lower Feather River (CDFW 1998). Approximately two-thirds of the natural Chinook salmon spawning in the Feather River occurs between the Fish Barrier Dam and the Thermalito Afterbay Outlet (RM 67 to 59), and one-third of the spawning occurs between the Thermalito Afterbay Outlet and Honcut Creek (RM 59 to 44) (DWR 2007).

Chinook spawning typically occurs from September through December. Spring-run Chinook salmon spawning may occur a few weeks earlier than fall-run spawning, but currently there is no clear distinction between the two, because of the disruption of spatial segregation by Oroville Dam. Thus, the spawning and embryo incubation life stage of spring-run Chinook salmon in the Feather River generally occurs during the same months (i.e., September through February) as fall-run Chinook salmon spawning and embryo incubation (Moyle 2002). Because of hatchery overproduction and the inability to physically separate spring-run and fall-run Chinook salmon adults, significant redd superimposition occurs in the lower Feather River and this concurrent spawning has led to hybridization between the spring- and fall-run Chinook salmon in the Feather River.

Most juvenile Chinook salmon emigrate from the lower Feather River within a few months of emergence, and 95 percent of the juvenile Chinook have typically emigrated from the Oroville Facilities project area by the end of May (DWR 2007). However, spring-run Chinook salmon juveniles reportedly can rear in their natal streams for up to 15 months (Moyle 2002). Adult Chinook salmon exhibiting the typical life history of the spring-run are found holding at the Thermalito Afterbay Outlet and the Fish Barrier Dam as early as April (DWR 2007).

Over the past several decades, Chinook salmon are reported to be the most numerous fish species in the lower Feather River, and between 30,000 and 170,000 Chinook salmon spawn in the lower Feather River annually (DWR 2007). Significant numbers of spring-run Chinook salmon, as identified by run timing, return to the Feather River Fish Hatchery (FRFH). Between 1967 and 2008, the highest annual hatchery spring-run Chinook salmon escapement was 8,662, occurring in 2003 (CDFW 2009). From 1986 to 2007, the average number of spring-run returning to the FRFH was 3,992, compared to an average of 12,888 spring-run returning to the entire Sacramento River Basin. More recently, FRFH spring-run Chinook salmon escapement from 2005 through 2008 was 1,774, 2,061, 2,674, and 1,418, respectively (CDFW 2009). Coded Wire Tag (CWT) information from hatchery returns indicates substantial introgression has occurred between spring-run and fall-run populations within the Feather River system due to hatchery practices. Because Chinook salmon have not always been temporally separated in the hatchery, spring- and fall-run Chinook salmon have been spawned together, thus compromising the genetic integrity of the spring-run and early fall-run stocks. The number of naturally spawning spring-run in the Feather River has been estimated only periodically since the 1960s, with estimates ranging from 2 fish in 1978 to 2,908 in 1964. However, the genetic integrity of this population is questionable because of the significant temporal and spatial overlap between spawning populations of spring-run and fall-run Chinook salmon (Good *et al*. 2005). Spring-run Chinook salmon escapement estimates for the Feather River Hatchery are available from 1962 through 2011 (Table 4).

Table 4. Adult spring-run Chinook salmon population estimates for the Feather River Hatchery from 1963 to 2011. Estimates are not available for all years.

Year	Adult Estimate	Year	Adult Estimate	Year	Adult Estimate
1963	600	**1980**	669	**1997**	3653
1964	2908	**1981**	1000	**1998**	6746
1965	738	**1982**	2000	**1999**	3731
1966	297	**1983**	1702	**2000**	3657
1967	146	**1984**	1562	**2001**	4135
1968	208	**1985**	1632	**2002**	4189
1969	348	**1986**	1433	**2003**	8662
1970	235	**1987**	1213	**2004**	4212
1971	481	**1988**	6833	**2005**	1774
1972	256	**1989**	5078	**2006**	2061
1973	205	**1990**	1893	**2007**	2674
1974	198	**1991**	4303	**2008**	1418
1975	691	**1992**	1497	**2009**	989
1976	699	**1993**	4672	**2010**	1661
1977	185	**1994**	3641	**2011**	1900
1978	204	**1995**	5414		
1979	250	**1996**	6381		

Sources: CDFW Grandtab; personal communications with CDFW and USFWS biologists.

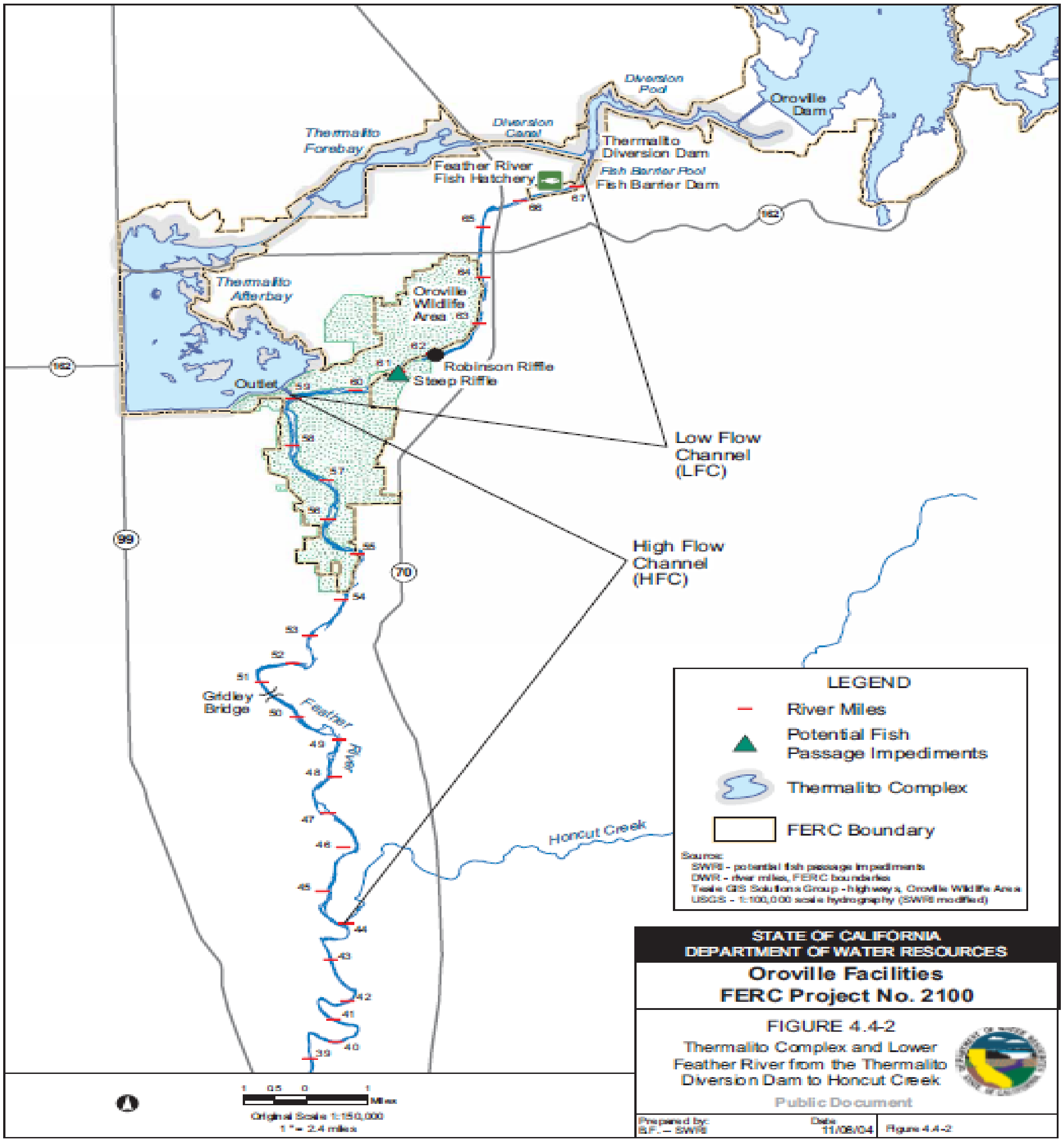

Figure 5. Thermalito complex and lower Feather River from Thermalito Diversion Dam to Honcut Creek Source: DWR 2007

Steelhead

NMFS (2009a) reports that existing wild steelhead stocks in the Central Valley are mostly confined to the upper Sacramento River and its tributaries (e.g., Antelope, Deer, and Mill creeks and the Yuba River). However, some wild steelhead are produced in the Feather River (McEwan and Jackson 1996).

Most of the natural steelhead spawning in the Feather River occurs in the LFC, particularly in the upper reaches near Hatchery Ditch, a side channel located between RM 66 and RM 67 (DWR

2007). Adult steelhead typically ascend the Feather River from September through April (Busby *et al*. 1996; Cavallo 2004 pers. comm.; McEwan 2001; Moyle 2002); spawning occurs during the winter and early spring. The majority of the steelhead spawning and embryo incubation life stage in the Feather River generally lasts from December through May (Busby *et al.* 1996; Cavallo 2004 pers. comm.; McEwan 2001; Moyle 2002). The residence time of adult steelhead in the Feather River after spawning and the extent of adult steelhead post-spawning mortality is currently unknown. It appears that most of the natural steelhead spawning in the Feather River occurs in the LFC, particularly in the upper reaches near Hatchery Ditch. Limited steelhead spawning also occurs below the Thermalito Afterbay Outlet (DWR 2007). After emerging from the gravel, a moderate percentage of the fry appear to emigrate (DWR 2007). The remainder of the population rears in the river for at least six months to two years (McEwan 2001; Moyle 2002), then reportedly emigrate from January through June (Cavallo 2004 pers. comm.,). Studies have confirmed that juvenile rearing (and probably adult spawning) is most concentrated in small secondary channels within the LFC. The smaller substrate size and greater amount of cover (compared to the main river channel) likely make these side channels more suitable for juvenile steelhead rearing. Currently, this type of habitat comprises less than 1 percent of the available habitat in the LFC (DWR 2001 in DWR 2007).

Since 2001, DWR has conducted redd dewatering and juvenile salmonid stranding surveys to assess the impact of water operations on the population of juvenile salmonids in the lower Feather River. Objectives of this long-term study are to determine the number of redds dewatered by reductions in flow; identify potential ponding areas; determine the relative abundance of stranded salmonids; and determine the biological significance of redd dewatering and juvenile stranding (DWR 2006).

Between January 6 and April 3, 2003, a total of 13 weekly redd surveys were conducted and 108 steelhead and 75 redds were observed during this sampling period (DWR 2005). Redd construction likely began sometime in late December, peaked in late January, and was essentially complete by the end of March. During January, February, and March, steelhead constructed, at minimum, 45, 26, and 4 redds, respectively. The surveys revealed that nearly half (48 percent) of all redds were constructed in the uppermost reach of the lower Feather River (between RM 66 and RM 67), between the Table Mountain Bicycle Bridge and Lower Auditorium Riffle. This section of river maintained 36 redds per mile, more than 10 times more than any other reach surveyed. Hatchery Ditch alone had 26 redds constructed within it, 5 times more redds than were constructed in any other location (DWR 2005). Attempts were not made to estimate the number of adult steelhead spawning (DWR 2005). Difficulties associated with identifying all steelhead redds indicated only the minimum number of spawning steelhead for the 2002–2003 spawning period. Assuming one female per redd and a male-to-female ratio of 1.2:1, the minimum number of males and females expected to have spawned was 88 and 75, respectively, for a total of 163 steelhead (DWR 2005). Physical characteristics of constructed redds in both the High Flow Channel and LFC appeared suitable for successful spawning and egg incubation. High flows in the High Flow Channel during three weeks in February may have reduced spawning in the High Flow Channel or forced steelhead to spawn near the river margin. There was no evidence that any redds were dewatered after the flow reduction. It is unknown whether a flow of 8,000 cfs (experienced on February 20, 21, and 22) would scour recently constructed redds in the High Flow Channel (DWR 2005).

Steelhead returns to the Feather River Fish Hatchery have decreased substantially in recent years with only 679, 312, and 86 fish returning in 2008, 2009 and 2010, respectively (Figure 6) (NMFS 2011). Because almost all of the returning fish are of hatchery origin and stocking levels have remained fairly constant over the years, the data suggest that adverse freshwater and/or ocean survival conditions have caused or at least contribute to these declining hatchery returns. The Central Valley experienced three consecutive years of drought (2007-2009) which would likely have impacted parr and smolt growth and survival and poor ocean conditions are known to have occurred in at least 2005 and 2006 which impacted Chinook populations in the Central Valley and may well have also impacted steelhead populations.

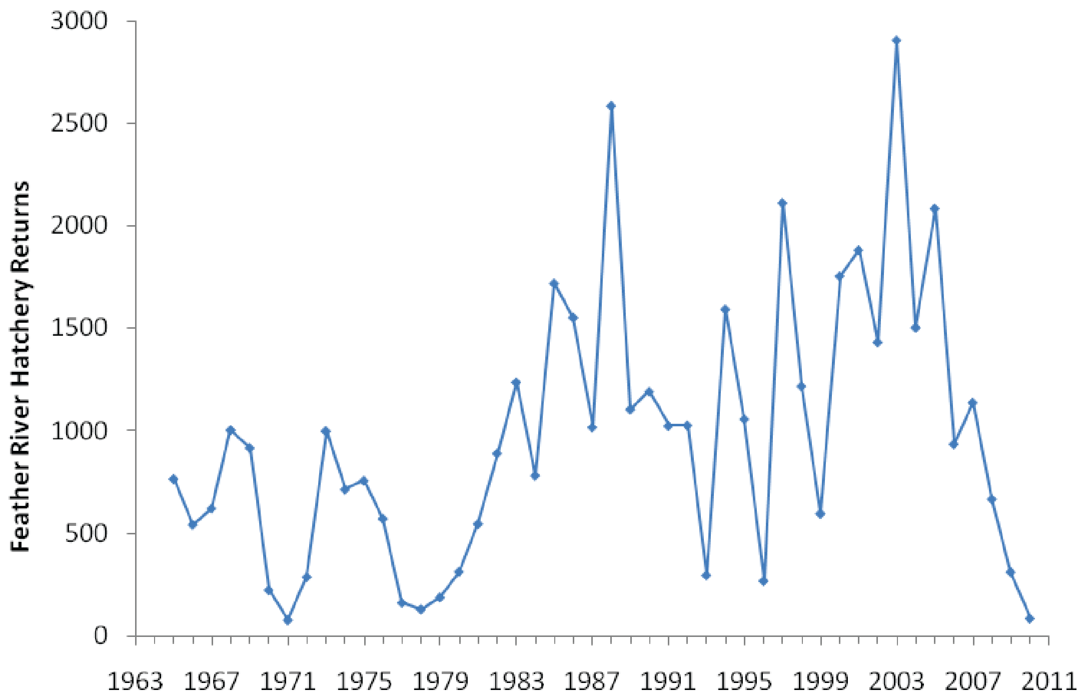

Figure 6. Steelhead Returns to Feather River Fish Hatchery 1965-2010 Source: NMFS 2011

Bear River Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley steelhead

Diversity Group

Northern Sierra Nevada Diversity Group

Key Stressors

Key stressors to Central Valley steelhead in the Bear River include, but are not limited to the following:

- Loss of natural river morphology, riparian habitat, floodplain habitat and instream cover affecting juvenile rearing and outmigration
- Flow conditions (i.e., low flows and flow fluctuations) associated with attraction and migratory cues in the Bear River affecting adult immigration and holding, spawning, embryo incubation, juvenile rearing and outmigration
- Water temperature affecting adult immigration and holding, embryo incubation
- Physical habitat alternation associated with limited supplies of instream gravel, and suitability of available habitat affecting adult spawning
- Water quality affecting embryo incubation, juvenile rearing and outmigration
- Flow dependent habitat availability affecting juvenile rearing and outmigration
- Entrainment at individual diversions affecting juvenile rearing and outmigration

Watershed Description

As reported by the Bear River Watershed Group Website (2009), the Bear River rises on the west side of the Sierra Nevada just below Lake Spaulding at an elevation of 5,500 feet. From there it flows southwest about 65 miles to its confluence with the Feather River at RM 12 of the Feather River, draining portions of Nevada, Placer, Sutter and Yuba counties. The 292 square mile Bear River watershed includes over 990 miles of streams, creeks, and rivers, and reaches 20 miles across at its greatest width. It can be divided into three major reaches, the upper Bear River, middle Bear River and lower Bear River (Bear River Watershed Group Website 2009).

The Upper Bear River extends from its headwaters above Bear Valley to Rollins Lake at approximately 3,300 feet elevation. The middle Bear River extends from Rollins Dam about 15 miles downstream at 2,100 foot elevation; then another 10 miles to Lake Combie at 1,600 foot elevation; then another 17 miles to New Camp Far West Reservoir at the 300 foot elevation. The lower Bear River extends from New Camp Far West Reservoir 16 miles to its confluence with the Feather River at 23 foot elevation (Bear River Watershed Group Website 2009).

The upstream limit of anadromous fish access in the Bear River is the South Sutter Irrigation District's diversion dam, approximately 15 miles above the confluence with the lower Feather River (USFWS 1995).

The lower Bear River continues to support remnant and/or “stray” wild and/or hatchery-sustained salmon, and in the past it supported both steelhead and sturgeon as well (Bear River Watershed Group Website 2009). Inadequate streamflow in the Bear River prevents the establishment of a self-sustaining steelhead population (JSA 2004).

Geology

The Bear River is an example of an “underfit” stream—a stream whose channel was formed by a larger flow than presently existed (Johnson 2002). The deep V-shaped canyon of the Bear River reflects the work of a much larger river at some point in the past. Researchers have studied glacial stratigraphy of the Bear River, and the features indicate that at least two and probably three glacial advances occupied both the South Yuba and Bear valleys (Johnson 2002). These advances are believed to have ground through a narrow ridge separating the South Fork of the Yuba River from the Bear River, just downstream of what is now Lake Spaulding. Water from the upper watershed of the Bear River then began to flow into the Yuba River drainage (James 1995). Outwash deposits extend downstream from Bear Valley and grade into coarse channel lag gravel and boulders upstream of the Drum Powerhouse (NID 2008). This capture reflects a structural advantage to the Yuba River drainage, such as a lower base level and softer material that is less resistant to erosion (Johnson 2002). The Bear River contains surface basin deposits, which are composed of stream channel and floodplain deposits, and dredger tailings. These deposits consist of highly permeable boulders, gravels, cobbles and sands (Onsoy *et al*. 2005). The Bear River contains an estimated 125 million cubic meters (160 million cubic yards) of mining sediment, which, in combination with restricting levees, has caused the lower Bear River to change from wide and shallow to deeply incised (Sierra Club Website 2007). In addition, mercury imported from the Coastal Ranges is found in sediments within the historic gold mining areas downstream of Spaulding Reservoir on both the Yuba and Bear rivers (May *et al*. 2000).

Hydrology

The main tributaries of the Bear River include Steephollow and Greenhorn creeks above Rollins Lake, and Wolf and Little Wolf creeks between Lake Combie and Camp Far West Reservoir (Bear River Watershed Group Website 2009). Rock Creek drains into Camp Far West Reservoir. Dry Creek runs through the Spenceville Wildlife Area and into the Bear River below Wheatland. Yankee Slough, from the south, and Best Slough, from the north, enter the Bear just below the confluence with Dry Creek (Bear River Watershed Group Website 2009).

The largest impoundment in the Bear River watershed, Camp Far West Reservoir, is operated by the South Sutter Water District and has a storage capacity of 104 thousand acre-feet (taf). Other small impoundments in the watershed include Rollins Lake and Lake Combie, which store an additional 70 taf or more (USFWS 1995).

The Bear River watershed is one of the most heavily managed watersheds in California for water conveyance. By the late 1800's, hydraulic mining had largely given way to inter-basin water and hydropower development which served agricultural water supply and power generation needs throughout the western foothills region and beyond. By the turn of the 20th century, much of the region's contemporary water infrastructure was in place. Flows are currently largely controlled by the Nevada Irrigation System and PG&E (Bear River Watershed Group Website 2009).

In the 1960's, when growth in the foothills area increased, some of the original water and hydropower infrastructure was replaced or expanded while several new dams, powerhouses, and conveyance works were added. Throughout this period, the Bear River became the region's hydraulic workhorse, conveying water for consumption and energy generation from the upper Yuba, upper American, and its own headwaters and tributaries into the middle and lower Bear, the lower American, and the associated foothill creek-ravine region (Bear River Watershed Group Website 2009). The drainage pattern of the middle and lower reaches of the Bear River is illustrated in Figure 7.

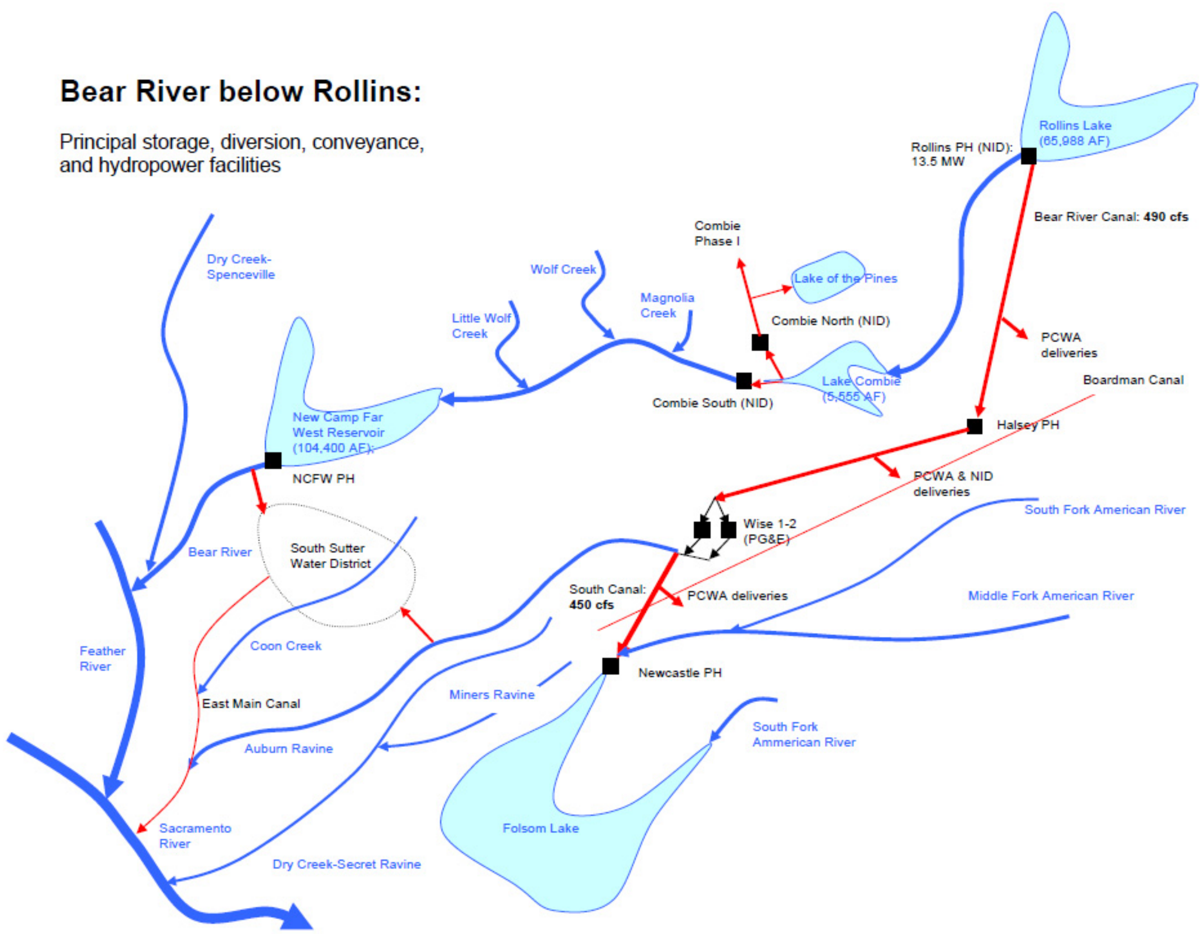

Figure 7. Schematic of the Middle and Lower Reaches of the Bear River
Source: Bear River Watershed Group Website 2009

Land Use

Much of the lower Bear River is under private ownership. While the condition of riparian habitat has not been investigated, it is likely that some riparian habitat has been degraded due to agricultural encroachment into the riparian zone. The upper Bear River includes approximately eight miles of relatively undeveloped river from its spring-fed headwaters above Bear Valley to Rollins Lake (Bear River Watershed Group Website 2009).

The Bear River was far more heavily impacted by hydrologic mining than the Yuba or American rivers and, unlike the Yuba or American rivers, contains a large volume of mining sediment stored in its main channel which is subjected to continual erosion. As mentioned above, it is estimated that 125 million cubic meters (160 million cubic yards) of mining sediment is stored in the lower Bear River. The high volume of mining sediment, in combination with restricting levees, has caused the lower Bear River to change from wide and shallow to deeply incised (Sierra Club Website 2007).

Fisheries and Aquatic Habitat

The upstream limit of anadromous fish access in the Bear River is the South Sutter Irrigation District's diversion dam, approximately 15 miles above the confluence with the lower Feather River (USFWS 1995).

The lower Bear River continues to support remnant and/or “stray” wild and/or hatchery-sustained salmon, and in the past it supported both steelhead and sturgeon as well (Bear River Watershed Group Website 2009). Inadequate streamflow in the Bear River prevents the establishment of a self-sustaining steelhead population (JSA 2004). Minimum releases below Rollins Lake (10 cfs) and Lake Combie (5 cfs) from approximately June to November result in warm water temperatures that are suitable only for bass or other warm water species (Bear River Watershed Group Website 2009). However, during periods of high flows, steelhead are known to utilize the river for limited spawning (JSA 2004). Because environmental conditions do not support a self-sustaining population of steelhead in the Bear River, those steelhead that do spawn during high flow years have likely originated from the Feather River Fish Hatchery. The present system of diversions results in abnormal flow fluctuations, in contrast to historical natural seasonal flow variations.

In addition to inadequate flows, due to the past accumulation of mining sediments and the presence of overly-constrictive levees, the lower reach has become narrow and incised and will likely require physical remediation as part of any flow-related restoration effort, in addition to eradication of invasive plant species such as Giant arundo (Bear River Watershed Group Website 2009). Downstream gravel recruitment has been limited for many years and also would have to be actively supplemented to provide suitable habitat conditions for anadramous fish. In addition, New Camp Far West Reservoir is both shallow and warm and may not be able to provide releases or through-flows when needed (i.e., during late summer and early fall) at water temperatures that are suitable to salmonids downstream; the result will depend upon the

particular reservoir storage and mixing, as well as the volume, timing, source, and temperature of any upstream flow improvements (Bear River Watershed Group Website 2009).
Continued high levels of mercury in present day river sediments indicate that the majority of the estimated 2.5 million pounds of the heavy metal that were lost in the Bear River Watershed during 32 years of hydraulic mining are still present, trapped in the 1.5 billion cubic yards of sediment stripped from hillsides (Bear River Watershed Group Website 2009).

Steelhead

As discussed above, the Bear River does not support a self-sustaining population of steelhead; steelhead that do spawn in the Bear River, during favorable environmental conditions, likely originated from the Feather River Fish Hatchery.

Yuba River Watershed Profile

Listed Species Present in the Watershed

Central Valley Spring-run Chinook Salmon (ESU)
Central Valley Steelhead (DPS)

Listed Species that Historically Occurred in the Watershed

Central Valley Spring-run Chinook Salmon (ESU)
Central Valley Steelhead (DPS)

Diversity Group

Northern Sierra Nevada Diversity Group

Background

The Yuba River supports a persistent population of steelhead and historically supported the largest, naturally-reproducing population of steelhead in the Central Valley (CDFW 1996). Adult Chinook salmon expressing the phenotypic timing of adult immigration associated with spring-run Chinook salmon also persist and spawn in the lower Yuba River below the U.S. Army Corps of Engineers' (Corps) Englebright Dam (Lindley *et al.* 2007). The lower Yuba River is among the last Central Valley floor tributaries supporting populations of naturally-spawning spring-run Chinook salmon and steelhead. There is no hatchery located on the lower Yuba River, although substantial straying of Feather River Hatchery spring- and fall-run Chinook salmon into the Yuba River does occur (Corps 2012, Kormos *et al*. 2012).

Analysis of VAKI Riverwatcher data (Corps 2012) and of coded-wire tag recovery data from Chinook salmon (Kormos *et al*. 2012) indicates that hatchery influence in the Yuba River can be high, particularly when the proportion of Yuba River flow to Feather River flow is high (Corps 2012). Corps (2012) reported that the contribution of hatchery-origin spring-run Chinook salmon to the annual total number of spring-run Chinook salmon returning to the Yuba River ranged from 2.9% in 2008 to 63.0% in 2010. Kormos *et al*. (2012) reported that 71% of Chinook salmon returning to the Yuba River were of hatchery origin. One option being discussed to minimize the impacts of hatchery Chinook salmon (and wild fall-run Chinook salmon) on wild spring-run Chinook salmon in the Yuba river is to utilize a barrier to exclude hatchery Chinook salmon (and wild fall-run Chinook salmon) from wild spring-run Chinook salmon spawning areas.

In recent years, major factors (directly flow-related) influencing the status of naturally-spawning spring-run Chinook salmon and steelhead in the Yuba River include: (1) restricted flow-dependent habitat availability; (2) limited habitat complexity and diversity; (3) elevated water temperatures; and (4) flow fluctuations (YCWA *et al.* 2007; CALFED and YCWA 2005).

In 2003, the SWRCB issued RD-1644 which prescribed minimum instream flow requirements for the lower Yuba River. However, RD-1644 was the subject of legal challenges from both the YCWA and environmental interests. To resolve this controversy, the litigants - YCWA, the South Yuba River Citizens League, Trout Unlimited, the Bay Institute and Friends of the River - along with CDFW, USFWS, NMFS, DWR and Reclamation, developed the comprehensive flow proposal contained in the Fisheries Agreement component of the Proposed Lower Yuba River Accord (Yuba Accord). The Yuba Accord (through the Fisheries Agreement) proposed new instream flow requirements in the lower Yuba River to substantially increase protection for the fisheries resources.

Parties to the Yuba Accord that also are parties to litigation related to RD-1644 were granted a stay in the California Superior Court so that the parties and other participants in the Yuba Accord process could complete environmental documentation and review of the Yuba Accord. After two one-year pilot programs in 2006 and 2007, on March 18, 2008, the SWRCB approved the consensus-based, comprehensive Yuba Accord to protect and enhance 24 miles of aquatic habitat in the lower Yuba River extending from Englebright Dam downstream to the river's confluence with the Feather River near Marysville. The Yuba Accord will be in effect at least until 2016. In addition, the SWRCB ordered that studies be conducted to further evaluate flow fluctuations and potential effects on redd dewatering and juvenile isolation and fry stranding. These studies continue to be conducted. Since the issuance of the SWRCB Yuba Accord Decision, a full-flow bypass structure has been installed on the Narrows II hydropower facility which will essentially eliminate the potential for flow fluctuations to occur in the lower Yuba River associated with maintenance and operation of the Narrows II facility.

Implementation of the flow schedules specified in the Fisheries Agreement of the Yuba Accord is expected to address the flow-related major stressors including flow-dependent habitat availability, flow-related habitat complexity and diversity, and water temperatures. In fact, water temperature evaluations conducted for the Yuba Accord EIR/EIS indicate that Yuba River water temperatures generally would remain suitable for all life stages of spring-run Chinook salmon and steelhead. In general, water temperatures would remain below 58 °F year-round (including summer months) at Smartville, below 60 °F year-round at Daguerre Point Dam and, at Marysville, below 60 °F from October through May, and below 65 °F from June through September (YCWA *et al.* 2007).

Major factors (not directly flow-related) influencing the status of naturally-spawning spring-run Chinook salmon and steelhead in the Yuba River include: (1) blockage of historic spawning habitat resulting from the construction of the Corps' Englebright Dam in 1941, which has implications for the spatial structure of the populations; (2) impaired adult upstream passage at Daguerre Point Dam; (3) high hatchery influence; (4) unsuitable spawning substrate in the uppermost area (i.e., Englebright Dam to the Narrows) of the lower Yuba River; (5) limited riparian habitats, riverine aquatic habitats for salmonid rearing, and natural river function and morphology; and (6) impaired juvenile downstream passage at Daguerre Point Dam (CALFED and YCWA 2005).

NMFS has prioritized the upper Yuba River (upstream of Englebright Dam) as a primary area to re-establish viable populations of spring-run Chinook salmon and steelhead for four main reasons. First, spring-run Chinook salmon and steelhead historically occurred there (Lindley *et al*. 2004, Yoshiyama *et al*. 1996) and studies suggest that multiple areas in the upper river would currently still support those species (DWR 2007; Stillwater Sciences 2012). Second, evidence suggests that significant amounts of summer holding habitat in the upper Yuba River are expected to remain thermally suitable for spring-run Chinook salmon throughout the 21st century even if the climate warms by as much as 5°C (Lindley *et al*. 2007). That expectation of thermally suitable habitat in the upper Yuba River watershed in the face of climate change is based on a simple analysis of air temperatures and did not account for the presence of New Bullard's Bar Reservoir, a deep, steep-sloped reservoir with ample coldwater pool reserves that could be used to provide suitable flows and water temperatures in the upper watershed downstream of the reservoir in perpetuity. The coldwater pool in New Bullards Bar Reservoir has never been depleted, even during the most extreme critically dry year on record (1977) (YCWA 2010). Third, there is considerable distance between the Yuba River watershed and the cluster of watersheds in the diversity group that currently support wild spring-run Chinook salmon. This spatial isolation is important because if one or more spring-run Chinook salmon populations were established in the upper Yuba River watershed, those populations would not be at risk if there was a volcanic eruption at Mt. Lassen, a volcano that the USGS views as highly dangerous. In contrast, all three extant independent populations (Mill, Deer, and Butte creeks) of spring-run Chinook salmon are in basins whose headwaters occur within the debris and pyroclastic flow radii of Mt. Lassen. Even wildfires, which are of much smaller scale than large volcanic eruptions, pose a significant threat to the spring-run Chinook salmon ESU in its current configuration. A fire large enough to burn the headwaters of Mill, Deer and Butte creeks simultaneously, has roughly a 10% chance of occurring somewhere in the Central Valley each year (Lindley *et al*. 2007). Lastly, the Yuba River watershed has an ample supply of water to support spring-run Chinook salmon and steelhead with one of the highest annual discharges (~2,300,000 acre-feet/year) in the Central Valley (Lindley *et al*. 2004).

In February 2010, the Yuba Salmon Forum was initiated by NMFS as a means for multiple stakeholders, including hydropower operators, local, State, and Federal agencies, and conservation organizations, to explore voluntary options for addressing the complex hydropower, water management, and natural resource management issues in the Yuba watershed. There are three hydroelectric projects licensed by the Federal Energy Regulatory Commission (FERC) in the upper Yuba watershed: (1) Nevada Irrigation District's Yuba-Bear Hydroelectric Project (FERC Project No. 2266), which controls water releases into the Middle Yuba River; (2) Pacific Gas and Electric Company's Drum-Spaulding Project (FERC No. 2310), which controls water releases into the South Yuba River; and (3) Yuba County Water Agency's Yuba River Development Project (FERC No. 2246), which controls releases into the North Yuba River downstream of New Bullard's Bar Dam. Each of these companies is currently engaged in regulatory proceedings with FERC to obtain a new license to operate their projects, and each relicensing proceeding has the potential to impact spring-run Chinook salmon and steelhead reintroduction efforts in the Yuba River Basin. The specific purpose of the Yuba Salmon Forum is to seek to implement actions to establish viable salmonid populations in the Yuba River watershed, while also considering other beneficial uses of water resources and habitat values in neighboring watersheds. The Yuba Salmon Forum is not the only collaborative effort looking at options to reintroduce salmon and steelhead into the upper Yuba River watershed.

In November 2010, a diverse group of local, State and Federal agencies and conservation organizations began exploring options to voluntarily reintroduce salmon and steelhead into the North Yuba River, upstream of New Bullards Bar Dam. This North Yuba Reintroduction Initiative would include a fish passage program around the Army Corps of Engineers' Englebright Dam on the lower Yuba River and Yuba County Water Agency's New Bullard's Bar Dam, farther upstream, which would allow fish to access as much as 45 miles of additional historic habitat.

The potential to improve both adult upstream and juvenile downstream passage at Daguerre Point Dam has been the subject of previous studies, including: (1) Daguerre Point Dam Fish Passage Improvement Project Alternative Concepts Evaluation (DWR and Corps 2003); (2) Daguerre Point Dam Fish Passage Improvement Project 2002 Fisheries Studies – Analysis of Potential Benefits to Salmon and Steelhead from Improved Fish Passage at Daguerre Point Dam (DWR and Corps 2003a); and (3) Daguerre Point Dam Fish Passage Improvement 2002 Water Resources Studies (DWR and Corps 2003b). In November 2007 NMFS issued a biological opinion (NMFS 2007) on the operation of Corps facilities on the Yuba River, including Daguerre Point Dam and Englebright Dam. A new biological opinion on the Corps' operations of these facilities was issued in 2012; as of April 2013, the Corps is in the process of re-initiating ESA consultation.

Programs to improve spawning substrate conditions in the lower Yuba River from Englebright Dam to the Narrows have recently been undertaken. With the assistance of the University of California, Davis, the Corps completed a pilot gravel injection project on November 30, 2007 which involved placing 500 tons of gravel approximately 200 yards downstream of Englebright Dam. Additionally, the Corps began injecting gravel into the reach of the Yuba River below Englebright Dam, just downstream of the PG&E's Narrows I power plant, on November 20, 2010. Due to high river flows, the injection was suspended from December 20, 2010 to January 4, 2011, and then was resumed and the injection of 5,000 tons of gravel was completed on January 13, 2011. As part of the gravel injection project, the Corps is implementing a monitoring program to track gravel movement and document the occurrence of salmonid redds in the newly injected gravel. The 2012 Biological Opinion on the Corps operations of Englebright and Daguerre Point Dams requires the Corps to implement a gravel augmentation program, which includes adding 15,000 short tons of graded and washed gravel and cobble into the Englebright Dam Reach annually (NMFS 2012).

The Fisheries Agreement of the Yuba Accord established a River Management Fund. A portion of the River Management Fund is dedicated to a restoration projects account, which includes addressing restoration actions such as riparian habitat establishment and instream aquatic habitat improvement. Such considerations are subject to the recommendation and approval of the Yuba Accord River Management Team, and are expected to be addressed within the next few years.

Implementing the Yuba River actions described in Chapter 5 of this recovery plan is expected to result in viable populations of spring-run Chinook salmon and steelhead, which would directly contribute to meeting the recovery criteria for those species. In the long-term, the Yuba River has high potential for maintaining suitable anadromous salmonid habitat, despite the expected long-term climate warming. Under the expected climate warming scenario of about 5 °C by the year 2100, substantial salmonid habitat would be lost in the Central Valley, with the Yuba River being one of the only Central Valley tributaries with significant amounts of habitat remaining (Lindley *et al.* 2007).

Key Stressors

Key stressors to Central Valley spring-run Chinook salmon and steelhead in the Yuba River watershed include, but are not limited to the following:

- Passage barrier at Englebright Dam blocking access to all historic spawning habitat, and blocking gravel and wood recruitment to the lower river
- High hatchery influence
- Loss of riparian habitat, instream cover, and floodplain habitat affecting juvenile rearing and outmigration
- Passage impediment at Daguerre Point Dam affecting adult immigration, and juvenile outmigration
- Predation of juveniles
- Unsuitable spawning substrate conditions in the reach extending from Englebright Dam to the Narrows

Additional stressors are presented in Appendix A of the Recovery Plan.

Watershed Description

The Yuba River Watershed drains 1,339 square miles of the western slope of the Sierra Nevada and includes portions of Sierra, Placer, Yuba, and Nevada counties (YCWA *et al.* 2007). The watershed is comprised of the North, Middle and South Forks of the Yuba River. There also are several other small- to medium-sized impoundments in the watershed, including Lake Spaulding, Bowman Lake, Jackson Meadows Reservoir, Englebright Reservoir, Lake Fordyce, and Scotts Flat Reservoir. The North Fork of the Yuba River flows into New Bullards Bar Reservoir and is joined by the Middle Fork about 5 miles downstream from the 645-foot New Bullards Bar Dam. The South Yuba begins with runoff near Donner Pass high in the Sierra Nevada, and its source is Lake Angela at 7,190 feet. The South Yuba River extends for 64 miles before joining the other two forks at Englebright Dam and Reservoir to form the main stem of the lower Yuba River (SYRCL 2009). The main stem of the lower Yuba River is a tributary of the Feather River, which drains into the Sacramento River. The lower Yuba River consists of the approximately 24-mile stretch of river extending from Englebright Dam, the first impassible fish barrier along the river, downstream to the confluence with the Feather River near Marysville, California.

Geology

The Yuba River watershed rises from an elevation of about 88 feet msl at its mouth to about 8,590 feet msl at its headwaters, and is bordered by the basins of the Feather River to the north, the Truckee River to the east, and the Bear River and American River to the south (SYRCL 2009). Above 6,000 feet, ponderosa pine, sugar pine, Douglas fir, white fir, and incense cedar are abundant. Precipitation in the watershed can range from 50 to 70 inches annually (SYRCL 2009). The upper Yuba River tributaries (North Yuba, Middle Yuba, and South Yuba rivers) are steep, mountain drainages that flow through narrow, deeply incised canyons alternating between bedrock and alluvial reaches. Alluvial reaches store considerable volumes of sediment in the channel bed, active bars, and infrequent well-vegetated floodplains and terraces (Curtis *et al.* 2005). Bedrock reaches have minimal channel storage, although patchy alluvium may be found in deep pools or behind bedrock constrictions or large boulders (Curtis *et al.* 2006). A stratum of serpentine traverses the Yuba River Watershed in a direction generally parallel with the crest of the Sierras. This stratum is generally softer and more easily eroded than adjoining strata (Department of Agriculture 1901).

Large volumes of sediment, derived from past upstream hydraulic-mining activities, are currently stored in several upland tributaries that flow into the Middle Yuba and South Yuba rivers. A significant part of the Yuba River sediment load is deposited in New Bullards Bar Reservoir (Brown and Thorpe 1947; Dendy and Champion 1978), in Englebright Reservoir (Childs *et al.* 2003; Snyder *et al.* 2004; Snyder *et al.* 2004a), and behind Log Cabin Dam and Our House Dam (YCWA 1989).

Hydrology

New Bullards Bar Reservoir, located on the North Yuba River, is operated by the Yuba County Water Agency (YCWA) and is the principal storage facility of YCWA's Yuba River Development Project (Yuba Project). The reservoir has a total storage capacity of 966 TAF with a minimum pool of 234 TAF (as required by YCWA's FERC license), thus leaving 732 TAF of capacity that can be regulated. A portion of this regulated capacity, 170 TAF, normally must be held empty from September through April for flood control (YCWA *et al.* 2007).

Englebright Dam and Reservoir were constructed in 1941 to capture sediment produced by upstream hydraulic mining activities, and are located downstream of New Bullards Bar Dam at the confluence of the Middle and South Yuba rivers. With a storage capacity of approximately 70 TAF, Englebright Dam and Reservoir essentially serves as a re-regulating afterbay for New Bullards Bar Reservoir and fluctuates on a frequent basis. Most of the water from Englebright Dam is released through the Narrows I and II powerhouses for hydroelectric power generation (USFWS 1995). The 0.2-mile reach of river between the dam and the two powerhouses typically does not contain much water except when the reservoir is spilling. Deer Creek flows into the Yuba River at approximately RM 22.7. The 0.7-mile reach of river downstream of the Narrows I and II powerhouses to the mouth of Deer Creek is characterized by steep rock walls, long deep pools, and short rapids. Below this area, the river cuts through 1.3 miles of sheer rock gorge called the Narrows, where the river forms a large, deep, boulder-strewn pool (USFWS 1995). YCWA and PG&E coordinate the operations of Narrows I and II for hydropower efficiency and to maintain relatively constant flows in the lower Yuba River. The Narrows I Powerhouse typically is used for low-flow reservoir releases, or to supplement the Narrows II Powerhouse capacity during high flow reservoir releases. Because of the recreational and power generation needs, the storage level within the reservoir seldom drops below 50 TAF (YCWA *et al.* 2007).

The river canyon opens into a wide floodplain at the downstream end of the Narrows where large quantities of hydraulic mining debris have been deposited during past gold mining operations. This 18.5-mile section is typified as open valley plain. Dry Creek flows into the Yuba River at RM 13.6, approximately two miles upstream of Daguerre Point Dam (YCWA *et al.* 2007). Daguerre Point Dam, located 12.5 miles downstream from Englebright Dam, is the major diversion point on the lower river. The open valley plain continues 7.8 miles below Daguerre Point Dam to beyond the downstream terminus of the Yuba Goldfields. This section is composed primarily of alternating pools, runs, and riffles with a gravel and cobble substrate. The remaining 3.5 miles of the lower Yuba River extending to the confluence with the Feather River is bordered by levees and is subject to backwater influence of the Feather River (USFWS 1995).

Operations of New Bullards Bar Reservoir can be described in terms of: (1) water management operations (i.e., baseflow operations), (2) storm runoff operations, and (3) flood control operations. Baseflow operations describe normal reservoir operations when system flows are controlled through storage regulation. These operations occur outside periods of flood control operations, spilling, bypassing uncontrolled flows into Englebright Reservoir, or outside periods of high unregulated inflows from tributary streams downstream from Englebright Dam. Storm runoff operations occur during the storm season, typically between October and May. Storm runoff operations target Englebright Reservoir operations, because it is the downstream control point for releasing water into the lower Yuba River. Storm runoff operations guidelines for Englebright Reservoir specify target storage levels and release rates. During flood control operations, the seasonal flood pool specified in the Corps flood operation manual for New Bullards Bar Reservoir is kept evacuated for flood protection, and to avoid unnecessary flood control releases. Reservoir releases may be required to maintain flood control space between September 15 and June 1 (YCWA *et al.* 2007).

Instream flow requirements are specified for the lower Yuba River at the Smartville Gage (RM 23.6), located approximately 2,000 feet downstream from Englebright Dam, and at the Marysville Gage (RM 6.2). The annual unimpaired flow at the Smartville Gage on the lower Yuba River has ranged from a high of 4.93 MAF in 1982 to a low of 0.37 MAF in 1977, with an average of about 2.37 MAF per year (1901 to 2005).[5] In general, runoff is nearly equally divided between runoff from rainfall during October through March and runoff from snowmelt during April through September. Below the Smartville Gage, accretions, local inflow, and runoff contribute, on average, approximately 200 TAF per year to the lower Yuba River.

[5] The forecasted seasonal unimpaired flow at Smartville is estimated each year by DWR and reported monthly in Bulletin 120, *Water Conditions in California*. The unimpaired flow at Smartville controls YCWA contractual delivery obligations to senior water right holders on the lower Yuba River, and is used to calculate the Yuba River Index (YRI), defined in RD-1644, and the North Yuba Index (NYI), defined in the Yuba Accord (YCWA *et al.* 2007).

Land Use

The upper basins of the Middle Yuba and South Yuba rivers have been extensively developed for hydroelectric power generation and consumptive uses by Nevada Irrigation District (NID) and PG&E. Total storage capacity of about 307 TAF on the Middle Yuba and South Yuba rivers and associated diversion facilities enable both NID and PG&E to export an average of approximately 410 TAF per year from the Yuba River Basin to the Bear River and American River basins. In addition, the South Feather Water and Power Agency exports an average of about 70 TAF per year from Slate Creek (a tributary to the North Yuba River) to the Feather River Basin. The operations in these upper basins can significantly reduce the water supply available to the lower Yuba River, particularly during dry and critical water years (YCWA *et al.* 2007).

The Corps and YCWA both own storage facilities in the Yuba Region. Englebright Dam and Daguerre Point Dam were originally constructed by the California Debris Commission, a unit of the Corps, for debris control and now are operated and maintained by the Corps. Englebright Reservoir is used extensively for recreation. The Yuba River Development Project, constructed and operated by YCWA, is a multiple-use project that provides flood control, power generation, irrigation, recreation, and protection and enhancement of fish and wildlife. It includes New Bullards Bar Dam and Reservoir, New Colgate Powerhouse, and Narrows II Powerhouse. Englebright Dam and Reservoir and Daguerre Point Dam are not part of the Yuba River Development Project. However, Englebright Dam and Reservoir are used to regulate power peaking releases from the New Colgate Powerhouse, and Daguerre Point Dam is used by YCWA to divert water to its Member Units. Water projects operated by PG&E, NID, and South Feather River Water and Power Agency export up to approximately 530 TAF of water per year into adjacent basins. Once exported, this water is not available to the lower Yuba River.

Fisheries and Aquatic Habitat

The lower Yuba River consists of the approximately 24-mile stretch of river extending from Englebright Dam, the first impassible fish barrier along the river, downstream to the confluence with the Feather River near Marysville. The vast amounts of hydraulic mining debris deposited in the lower Yuba River's channel and floodplain a century ago, and the lack of gravel recruitment caused by the construction of Englebright Dam, continue to have a dominant influence on the geomorphic character and processes of the lower Yuba River. High winter flows continue to cause extensive channel migration and erosion of bars and dredger tailings throughout much of the lower Yuba River because of the large quantities of unconsolidated cobbles and gravels, the lack of extensive riparian forests, and confinement of much of the active river corridor by dredger tailings (CALFED and YCWA 2005).

Daguerre Point Dam was constructed to create a retention basin for hydraulic mining debris transported downstream from upper reaches of the Yuba River watershed. Because mercury was used as an amalgam for the extraction of gold in the mining process, the sediments stored in the pool formed by the dam may contain elevated concentrations of mercury in its elemental and methylated forms (CALFED and YCWA 2005). The Central Valley Regional Water Quality

Control Board (CVRWQCB) detected elevated levels of mercury in the Yuba River in 1986 (CALFED and YCWA 2005). Ongoing research by the University of California, Davis, has confirmed the upper reach of the Yuba River above Englebright Reservoir as among those with the highest levels of bioavailable mercury, as measured with instream bioindicator organisms. A survey conducted in 1997 by the USGS National Water Quality Assessment Program confirmed that elevated concentrations of bioavailable mercury were still present in the sediments of the upper and lower Yuba River (Corps 2000).

Shaded riverine aquatic (SRA) habitat generally occurs in the lower Yuba River as scattered, short strips of low-growing woody species (e.g., *Salix sp*.) adjacent to the shoreline (CALFED and YCWA 2005). The most extensive and continuous segments of SRA habitat occur along bars where recent channel migrations or avulsions have cut new channels through relatively large, dense stands of riparian vegetation (Beak 1989). Due to a lack of riparian vegetation throughout much of the lower stream, instream woody material also is limited in the lower Yuba River (CALFED and YCWA 2005).

CALFED and YCWA (2005) used previously developed delineations and descriptions for the various reaches in the lower Yuba River. The Narrows Reach of the lower Yuba River is steep and consists of a series of rapids and deep pools confined by a bedrock canyon, and is dominated by deep pool habitat (CALFED and YCWA 2005). Habitats classified as moderate gradient riffles are found only in this reach of the lower Yuba River (CALFED and YCWA 2005). Salmonid spawning gravels are scarce in the Narrows Reach due to the truncation of gravel recruitment resulting from the construction of Englebright Dam and the high-energy hydraulic nature of this reach. Furthermore, the quantity and quality of salmonid spawning substrate in this reach has been significantly reduced by the deposition of large, consolidated rock fragments (i.e. "shotrock") in the vicinity of Englebright Dam. Although montane hardwoods occupy much of the Narrows Reach, the steep-walled canyons preclude immediate riparian growth, thereby limiting the potential for positively affecting the instream aquatic habitat (CALFED and YCWA 2005).

With the exception of moderate gradient riffles, the proportion of mesohabitat compositions of the Garcia Gravel Pit Reach and Daguerre Point Dam Reach are more evenly distributed than in the Narrows Reach, with run and glide habitats comprising the largest proportion of habitat types (CALFED and YCWA 2005). The Simpson Lane Reach is dominated by deep pools and has lower proportions of the remaining habitat types. Spawning gravels are abundant and generally of high quality throughout both the Garcia Gravel Pit and Daguerre Point Dam reaches (YCWA *et al.* 2000). Spawning gravels have been supplied to the river largely from local sources including deposition of hydraulic mining debris in the riverbed between the mid-1800s and 1941 (Beak 1989) and gravel recruitment from Deer Creek. The quality of gravels in the Garcia Gravel Pit and Daguerre Point Dam reaches is considered excellent for Chinook salmon spawning (CDFW 1991). The occurrence of fine interstitial sediments increases in the downstream portions of the Simpson Lane Reach, rendering the habitat less suitable for salmonid spawning (CDFW 1991). In the vicinity of Daguerre Point Dam, the Yuba River is largely devoid of sufficient riparian vegetation to provide suitable juvenile salmonid rearing habitat conditions (CALFED and YCWA 2005).

The Yuba Goldfields area, comprised of approximately 11,000 acres of land adjoining the Yuba River near Daguerre Point Dam, is the result of intensive gold dredging in the late 1800s and early 1900s when up to 27 gold dredges along the river and floodplain worked the area at one time (Smith 1990). One large gold dredge continues to work the area (CALFED and YCWA 2005). A dewatering channel, dug to lower the water level in the Yuba Goldfield area south and west of Daguerre Point Dam, collects subsurface and surface flows and empties them into the Yuba River approximately one mile downstream of the Yuba Goldfields (CALFED and YCWA 2005). The Yuba Goldfields section near Daguerre Point Dam is largely devoid of any streamside vegetation. Land use in the Simpson Lane Reach is comprised primarily of agricultural activities (e.g., orchards, grasslands, rice cultivation) and provides little shading to this portion of the lower Yuba River. In addition, Simpson Lane Reach is bordered by levees and is subject to backwater influence of the Feather River, further restricting the establishment of riparian vegetation in this area (CALFED and YCWA 2005).

Spring-run Chinook Salmon

Historical accounts of the spring-run Chinook salmon population in the Yuba River prior to the impacts associated with gold mining, dam construction, and water diversions, indicate that large numbers of spring-run Chinook salmon were taken by miners and Native Americans as far upstream as Downieville on the North Yuba River, and that during the construction of the original Bullards Bar Dam (1921 - 1924), the number of salmon that congregated and died below the dam was so large, the salmon had to be burned (Yoshiyama *et al.* 1996). Due to their presence high in the watershed, Yoshiyama concluded that these fish were spring-run Chinook salmon (NMFS 2007).

Prior to 2001, when CDFW conducted a study to quantify the number of adult spring-run Chinook salmon immigrating into the Yuba River by trapping fish in the fish ladder at Daguerre Point Dam, there was almost no specific information on the run timing and size of the population in the Yuba River. In the 2001 CDFW study, which involved limited sampling of fish ascending the north ladder, a total of 108 adult Chinook salmon were estimated to have passed the dam between March 1, 2001, and July 31, 2001 (CDFW 2002).

Infrared-imaging technology has been used to monitor fish passage at Daguerre Point Dam in the lower Yuba River since 2003 using VAKI Riverwatcher systems. VAKI Riverwatcher systems are located at both the north and south ladder of Daguerre Point Dam to record and identify the timing and magnitude of passage for Chinook salmon at Daguerre Point Dam during most temporal periods, however system failures predominantly caused by low-voltage disconnections, system maintenance or unknown malfunctions reduced the ability of the equipment to document ladder use during some months. As a result, prior to conducting any temporal modalities analysis for the 7 annual time series of Chinook salmon VAKI daily counts, an estimation procedure of the annual daily count series of each ladder was applied to account for days when the VAKI Riverwatcher systems were not fully operational (Corps 2012). The procedural methodology for this estimation procedure is detailed in Appendix B to Corps (2012).

Corps (2012) indicate that the time series of Chinook salmon moving daily upstream of Daguerre Point Dam for the 2004 to the 2010 biological years (March 1 through February 28) were inspected to identify modes that could be useful in the separation of spring-run Chinook salmon counts from those of fall-run Chinook salmon. Corps (2012) reports that although the combined annual time series displayed considerably daily variability, at least two main groups of fish were identified. One group, presumably spring-run Chinook salmon, is present primarily during May, June and early July, and the other group, presumably fall-run Chinook salmon, is present from mid-August through January.

Corps (2012) reports that for the period (2004-2010) during which VAKI Riverwatcher data are available, the annual number of spring-run Chinook salmon estimated to have passed upstream of Daguerre Point Dam ranged from 285 in 2007 to 2,998 in 2005, with an average of 1,279. For the past four years, the abundance of in-river spawning spring-run Chinook salmon has steadily increased. For the last three consecutive years, an estimated total of 4,130 spring-run Chinook salmon have passed upstream of Daguerre Point Dam, with an average of 1,377 fish per year. As previously described by NMFS (2011), populations with a low risk of extinction (less than 5% chance of extinction in 100 years) are those with a minimum total escapement of 2,500 spawners in 3 consecutive years (mean of 833 fish per year).

Corps (2012) also indicates that the abundance of spring-run Chinook salmon in the lower Yuba River has exhibited a very slight increase over the seven years examined, although the trend is not statistically significant. Nonetheless, the relationship indicates that the population over this time period is at least stable, and did not exhibit a declining trend.

The detection of adipose fin clips on some of these fish indicates that they were hatchery strays, most likely from the Feather River Fish Hatchery. Corps (2012) estimated the annual number of non-hatchery origin spring-run Chinook salmon to have passed upstream of Daguerre Point Dam during the 2004-2010 period ranged from 246 in 2007 to 2,339 in 2005, with an annual average of 866 fish. For the last three consecutive years, an estimated total of 2,080 non-hatchery origin spring-run Chinook salmon have passed upstream of Daguerre Point Dam, with an average of 693 fish per year. Corps (2012) demonstrates a slightly decreasing trend in the abundance of spring-run Chinook salmon of non-hatchery origin in the lower Yuba River over the 7 years examined, although not statistically significant. Corps (2012) also reports a slightly increasing trend in the abundance of spring-run Chinook salmon of hatchery origin in the lower Yuba River over the 7 years examined, although not statistically significant. Table 1 summarizes the results of the separation of the annual VAKI counts of Chinook salmon passing upstream of Daguerre Point Dam into spring-run Chinook salmon, and into spring-run Chinook salmon of hatchery origin for 2004 through 2010. The lowest contribution of spring-run Chinook salmon of hatchery origin to the annual total number of lower Yuba River spring-run Chinook salmon occurred in 2008 (2.9%). The highest contribution of hatchery fish occurred in 2010 (63.0%).

Table 5. Separation of annual VAKI Riverwatcher counts identified as Chinook salmon passing upstream of Daguerre Point Dam into spring-run Chinook salmon, and into spring-run Chinook salmon of hatchery origin (adipose clipped fish) for 2004 through 2010. Percentages indicate the annual percent contributions of spring-run Chinook salmon counts to Chinook salmon, and the annual percent contributions of spring-run Chinook salmon of hatchery origin to spring-run of both hatchery and natural origin.

Year	Chinook Salmon Passing Upstream DPD (Vaki RiverWatcher)				
	Chinook Salmon	Spring-run Chinook Salmon[1]			
		Hatchery + Natural Origin		Hatchery Origin[2]	
	(No. Fish)	(No. Fish)	(%)	(No. Fish)	(%)
2004	5,927	738	(12.5 %)	75	(10.2 %)
2005	11,374	2,998	(26.4 %)	659	(22.0 %)
2006	5,203	803	(15.4 %)	67	(8.3 %)
2007	1,394	285	(20.4 %)	39	(13.7 %)
2008	2,533	521	(20.6 %)	15	(2.9 %)
2009	5,378	723	(13.4 %)	217	(30.0 %)
2010	6,469	2,886	(44.6 %)	1,818	(63.0 %)

[1] For each biological year (March 1 - February 28), all daily Chinook salmon Vaki counts occurring before an annually variable demarcation date were classified as spring-run Chinook salmon counts.

[2] For each biological year, all daily Ad-clipped Chinook salmon Vaki counts occurring before an annually variable demarcation date, multiplied by the average of the production expansion factors corresponding to the CWTs of spring-run Chinook salmon released by the hatcheries and were recovered as carcasses during the annual Yuba River escapement surveys, were classified as spring-run Chinook salmon of hatchery origin.

Source: Corps 2012

In the lower Yuba River, spring-run Chinook salmon adult immigration and holding primarily extends from March through October (YCWA *et al.* 2007). Spring-run Chinook salmon are reported to hold over during the summer in the deep pools and cool water downstream of the Narrows I and Narrows II powerhouses, or further downstream in the Narrows Reach (CDFW 1991; SWRCB 2003), where water depths can exceed 40 feet (YCWA *et al.* 2007). Congregations of adult Chinook salmon (approximately 30 to 100 fish) have been observed in the outlet pool at the base of the Narrows II Powerhouse, generally during late August or September when the powerhouse is shut down for maintenance. During this time period the pool becomes clear enough to see the fish (Michael Tucker, NMFS, pers. obs., September, 2003; Steve Onken, YCWA, pers. comm., April, 2004). While it is impossible to visually distinguish spring-run from fall-run Chinook salmon in this situation, the fact that these fish are congregated this far up the river at this time of year indicates that some of them are likely to be spring-run Chinook salmon (NMFS 2007).

The spring-run Chinook salmon spawning period extends from September through November, while the embryo incubation life stage generally extends from September to March (YCWA *et al.* 2007). Redd surveys conducted by CDFW during late August and September have detected spawning activities beginning during the first or second week of September. They have not detected a bimodal distribution of spawning activities (i.e., a distinct spring-run spawning period followed by a distinct fall-run Chinook salmon spawning period) but instead have detected a slow build-up of spawning activities starting in early September and transitioning into the main fall-run spawning period. The earliest spawning generally occurs in the upper reaches of the highest quality spawning habitat (i.e., below the Narrows pool) and progressively moves downstream throughout the spawning season (NMFS 2007).

Some spring-run Chinook salmon juveniles emigrate as YOY, while others rear in the lower Yuba River year-round. In general, juvenile Chinook salmon have been observed throughout the lower Yuba River, but with higher abundances above Daguerre Point Dam. This may be due to larger numbers of spawners, greater amounts of more complex, high-quality cover, and lower densities of predators such as striped bass and American shad, which reportedly are restricted to areas below Daguerre Point Dam (YCWA *et al.* 2007).

The spring-run Chinook salmon smolt emigration period is believed to extend from November through June, although based on CDFW's run-specific determinations, the vast majority (approximately 94 percent) of spring-run Chinook salmon were captured as post-emergent fry during November and December, with a relatively small percentage (nearly 6 percent) of individuals remaining in the lower Yuba River and captured as YOY from January through March. Only 0.6 percent of the juvenile Chinook salmon identified as spring-run were captured during April, 0.1 percent during May, and none were captured during June (YCWA *et al.* 2007).

Steelhead

CDFW estimated a steelhead spawning population of only about 200 fish annually prior to 1969. Prior to construction of Englebright Dam, CDFW fisheries biologists stated that they observed large numbers of steelhead spawning in the uppermost reaches of the Yuba River and its tributaries (CDFW 1998; Yoshiyama *et al.* 1996). During the 1970s, CDFW annually stocked hatchery steelhead from Coleman National Fish Hatchery into the lower Yuba River, and by 1975 CDFW estimated a run size of about 2,000 fish (CDFW 1991). CDFW stopped stocking steelhead into the lower Yuba River in 1979, and currently manages the river to protect natural steelhead through strict "catch-and release" fishing regulations (NMFS 2007).

Ongoing monitoring of the adult steelhead population in the lower Yuba River has been conducted since 2003 with VAKI Riverwatcher systems at Daguerre Point Dam. For the assessment of steelhead in the lower Yuba River, Corps (2012) examined silhouettes and corresponding photographs for species identification and categorization using methodology similar to that for spring-run Chinook salmon. However, by contrast to the identification of Chinook salmon which may be conducted with a single attribute, the identification of steelhead becomes more problematic with the absence of a defining silhouette or a clear digital photograph (Corps 2012). The methodology to estimate the annual number of steelhead passing upstream of Daguerre Point Dam is provided in Corps (2012).

For the period between 2003 to 2011 Corps (2012) reportedly used the daily counts of adult steelhead passing upstream at Daguerre Point Dam to represent the abundance of steelhead, with the understanding that the resultant estimates were minimal numbers, and in most of the survey years considerably underestimate the potential number of steelhead because the annual estimates: (1) do not include periods of VAKI Riverwatcher system non-operation; and (2) do not consider the fact that not all steelhead migrate past Daguerre Point Dam, and some spawn in the lower Yuba River below Daguerre Point Dam. Corps (2012) states that although the VAKI Riverwatcher systems have been in place since June of 2003, reliable estimates of the number of adult steelhead passing upstream at Daguerre Point Dam are essentially restricted to the last year of available data (2010/2011). VAKI Riverwater data are presently available through February 2011, which represents only a portion of the annual upstream migration. Nonetheless, from August through February of 2010/2011, an estimated 446 adult steelhead passed upstream of Daguerre Point Dam.

Steelhead adult immigration and holding in the lower Yuba River extends from August through March (Corps 2012; YCWA *et al.* 2007). Spawning generally extends from January through April, primarily occurring in reaches upstream of Daguerre Point Dam (CALFED and YCWA 2005; CDFW 1991a; Corps 2012; YCWA *et al*. 2007). The embryo incubation life stage generally extends from January through May (CALFED and YCWA 2005; SWRI 2002). Juvenile steelhead are believed to rear in the lower Yuba River year-round. The steelhead smolt emigration period is believed to extend from October through May (CALFED and YCWA 2005; SWRI 2002; YCWA *et al.* 2007).

The primary rearing habitat for juvenile steelhead/rainbow trout is upstream of Daguerre Point Dam. Juvenile trout (age 0 and 1+) abundances were substantially higher upstream of Daguerre Point Dam, with decreasing abundance downstream of Daguerre Point Dam. Large juveniles and resident trout up to 18 inches long also have been commonly observed in the lower Yuba River upstream and downstream of Daguerre Point Dam (SWRI *et al.* 2000).

Butte Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to spring-run Chinook salmon and steelhead in Butte Creek include, but are not limited to the following:

- Water temperatures affecting adult immigration and holding and embryo incubation
- Passage impediments/barriers affecting adult immigration and holding
- Predation of juveniles in the Butte Sink and Sutter Bypass
- Flow fluctuations and turbidity affecting spawning and embryo incubation
- Summer instream recreation activities stressing holding adults
- Loss of natural river morphology, riparian habitat and instream cover affecting juvenile rearing and outmigration
- Lack of certainty regarding a long-term flow agreement with irrigation districts (T. Parker, USFWS, pers. comm. 2009)
- Upper watershed condition and fire risk

Watershed Description

The following information on the Butte Creek watershed is generally summarized from the *Butte Creek Watershed Project: Existing Conditions Report* (Butte Creek Watershed Conservancy 1999).

Butte Creek originates in the Jonesville Basin, Lassen National Forest, on the western slope of the Sierra Nevada Mountains, and drains about 800 square miles in the northeast portion of Butte County. The Butte Creek Watershed encompasses approximately 510,000 acres and lies predominantly in Butte County with smaller portions in Tehama, Glenn, Colusa and Sutter Counties. Butte Creek enters the Sacramento Valley southeast of Chico and meanders in a southwesterly direction to the initial point of entry into the Sacramento River at Butte Slough. Butte Creek also enters the Sacramento River through the Sutter Bypass and Sacramento Slough.

In addition to Butte Creek and its tributaries, the watershed includes a series of dams, diversions and canals mostly located in the valley portion of the watershed and in the middle and lower canyon portions of Butte Creek. The Sutter Bypass section of Butte Creek begins downstream of the Butte Slough Outfall. Butte Creek (named Butte Slough in this section) splits into two channels, known as the East and West Borrow Canals, as it enters the Sutter Bypass near Highway 20. Generally, Butte Creek enters the Sacramento River via Sacramento Slough immediately upstream of the mouth of the Feather River near Verona.

Butte Creek historically supported a self-sustaining population of spring-run Chinook salmon despite being at somewhat low elevation (all spawning occurs below 300 m) and having rather warm summer water temperatures (exceeding 20_C in 2002 in the uppermost and coolest reach) (Lindley *et al*. 2004). In recent years, inflows to Butte Creek from the upper West Branch Feather River deliver cold water that help support CV spring-run Chinook salmon. The cold water import from the West Branch Feather River helps spring-run Chinook salmon to oversummer, spawn and successfully occupy Butte Creek.

The success of numerous restoration efforts that have been undertaken on Butte Creek are illustrated by the abundance of CV spring-run Chinook salmon that have been observed since 1998. Once impaired by numerous dams with poor fish passage facilities, no dedicated fish flows, and unscreened diversions, Butte Creek now provides state-of-the-art fish ladders and screens, and dedicated instream flows. Water temperatures continue to pose threats to holding adult spring-run Chinook salmon and may limit habitat availability for steelhead.

Because the Butte Creek spring-run fish population is now considered persistent and viable, the watershed is considered a conservation stronghold for all life stages of spring-run Chinook salmon. Butte Creek is one of the most productive spring-run Chinook salmon streams in the Sacramento Valley (DWR 2005), and is one of only three streams (in addition to Deer and Mill creeks) that harbor a genetically distinct, sustaining population of spring-run Chinook salmon (CDFW 1998, as cited in CDFW 2008). Therefore, the viability of the Central Valley spring-run Chinook salmon ESU is reliant upon sustaining the Butte Creek spring-run Chinook salmon population. Lindley *et al*., (2007) characterized the Butte Creek population as being at a low risk of extinction due to the abundance of the population, positive production trends, and a very low hatchery influence. Recent years have seen a sharp reduction in adult abundance, but the population still remains strong and should still be considered at moderate to low risk of extinction.

In addition, due to the low elevation habitat available to spring-run Chinook salmon in Butte Creek, climate change and potentially warmer water temperatures in the future may become a key threat to their recovery. If summer water temperatures warm even by one or two degrees (°C), it is unlikely that Butte Creek spring-run Chinook salmon would persist (Williams 2006). With a rise in air temperatures of 2 °C, the 25°C isotherm might just rise to the upper limit of the historical distribution of spring-run Chinook salmon in Butte Creek (Lindley *et al*. 2007). These threats currently are being evaluated and will be addressed over the next five years through the issuance of a new FERC license of the operation of the DeSabla-Centerville Hydroelectric project. Water temperature improvements are expected to reduce maximum water temperatures by as much as 1 to 2 degrees Celsius and reduce the frequency of heat events that trigger adult mortality.

The status of steelhead in Butte Creek is unknown. Although water temperatures are adequate to support summer rearing, and *O. mykiss* are present in high densities through the reach between lower Centerville Diversion Dam and the Centerville Powerhouse, high quality spawning and rearing habitat is essentially limited to only about 5 miles of stream. Further monitoring of steelhead in the system, as well as, studying the habitat use and needs of steelhead for Butte Creek is needed to develop a recovery strategy for this Creek. However, given that spring-run Chinook salmon are productive in Butte Creek, the potential to support a viable steelhead population appears to moderate at the least.

Geology

The following information on geology in the Butte Creek watershed was taken from or summarized from the *Butte Creek Watershed Project: Existing Conditions Report* (Butte Creek Watershed Conservancy 1999).

The geology of the headwaters area in the Butte Meadows Basin is composed of volcanic rocks, associated with the Pliocene volcano Mt. Yana. The area contains andesitic rocks, basaltic rocks, and pyroclastic formations (Tuscan Formation).

As Butte Creek leaves the Butte Meadows area, it begins to incise into the Pre-Cretaceous metavolcanic and (older) Paleozoic marine sedimentary and metasedimentary geologic structures, known as the Sierra Nevada Basement Series or Basement Complex. These rocks underlie the volcanic structures that dominate the drainage basin. This formation is composed of massive greenstones, tuffaceous schists, dark schistose metasedimentary and metavolcanic rocks of the “Calaveras Formation”, slates, dark phyllite, quartzite, serpentine, and greywacke. It is in this area that the interface between the Tuscan (mudflow) Formation and the underlying Basement Series geology, in part containing the "Tertiary Auriferous gravels", begins to become exposed. The Tertiary Auriferous gravels are ancient, gold-bearing (auriferous) stream deposits, with their deposition occurring in the Tertiary period of the geologic time scale. Cape Horn, a geologic feature that dominates the canyon landscape, is visible 3/4 of a mile downstream of the Inskip Creek confluence. This outcropping of more resistant metavolcanic material has forced Butte Creek to flow around the rock outcrop, while the Butte Creek Canal, some 180 feet above the creek, enters a tunnel through the rock itself.

The middle section of the Butte Creek canyon downstream of the confluence with Clear Creek, is an area of extensive faulting of the Basement Series, where mining activity and settlement concentrated during the Gold Rush. There are many mines in the area, identified on USGS 7.5' quadrangles (Dix, Royal Drift, Black Diamond, etc.). The natural topography of the inner gorge of Butte Creek Canyon in the area around the Forks of Butte (the confluence with the West Branch of Butte Creek) has been modified by the mining of the stream and terrace gravel in the area of the confluence itself. Tailing piles and old sluice channels are scattered along the banks. The interface between the Tuscan and Basement Series rocks was exploited extensively on the Platte Ravine, off the West Branch of Butte Creek, accounting for headcuts and some hardrock tunneling in this area. Although many of the cutbanks in the area now have 100+ year old trees growing out of them, the landscape is still visibly altered.

The predominant geologic unit in the watershed, the Tuscan Formation, covers all other geologic formations in the mid-section of the watershed and effectively "caps" the landscape. Its estimated 300 cubic miles of material are spread out over a range of 2,000 square miles, covering an area from Oroville to Red Bluff. This formation was created by a mudflow deposit of late Pliocene age and is composed of angular to surrounded volcanic and metamorphic fragments, up to 3 meters in diameter, in a matrix of gray-tan volcanic mudstone. Downstream of the Centerville Diversion Dam, Butte Creek is entrenched in the metamorphic and igneous rocks that comprise the Basement complex of the Sierra Nevada. The sides of the creek show signs of past mining, with tailings piles and tunnels through bedrock banks.

The geologic character of Butte Creek changes markedly about 1.25 miles upstream of Helltown Bridge. At this location the Sierran Basement geology is covered by the Chico Formation (a unit of Cretaceous age associated with the inland seas of the Sacramento Valley). The Chico Formation is composed of fossiliferous marine sandstone. Gravel bars begin to form on the insides of meander bends, and the banks are covered with vegetation as roots more easily penetrate the softer sandstone. Due to a large landslide sometime within the last 11,000 years, the creek is forced up against the west side of the canyon just downstream of Helltown Bridge, cutting deeply into the Chico Formation, leaving well-exposed tan sandstone cliffs. Directly below this landslide area begins a unit known as the Modesto Formation, composed of gravel, sand, silt and clay derived from the Tuscan and Chico Formations. The Modesto Formation is perched atop the Chico Formation along Butte Creek, and is prevalent along the canyon bottom, leading to the Sacramento Valley. Although mining debris are visible further upstream, the Modesto Formation area reveals the first obvious signs of dredge tailings. These tailings, consisting of cobble-sized and larger rocks, sit in piles where they were left after being sluiced through by gold miners. The tailings continue down the canyon along Butte Creek.

Hydrology

The following information on hydrology in the Butte Creek watershed was taken from or summarized from the *Butte Creek Watershed Project: Existing Conditions Report* (Butte Creek Watershed Conservancy 1999).

The hydrology of Butte Creek has been extensively modified and developed. It contains multiple hydropower diversions and imports water from other watersheds. Figure 8 displays the main hydrologic features (e.g., streams, diversions, powerhouses) within the Butte Creek watershed. There are three main sections of Butte Creek (upper, middle and lower).

Upper Butte Creek (i.e., Butte Meadows)

After Butte Creek flows through the Butte Meadows Basin, it transitions through the steep Butte Creek Canyon some 25 miles to the point where it enters the valley floor near Chico. In this section Butte Creek flows in a north-northeast to south-southwest direction, and is characterized by numerous small tributaries and springs, and deep, shaded pools interspersed throughout the upper section of the canyon above Centerville with flora dominated by pine and fir. The creek averages a drop of over 100 feet per mile in this section. The canyon section below Centerville has a shallower gradient and a riparian canopy of alder, oak, sycamore and willow. PG&E owns and operates two hydroelectric power generation dams (Butte Creek Head Dam and Centerville Head Dam) in the canyon.

Middle Butte Creek (i.e., Butte Canyon)

After Butte Creek leaves the canyon near Chico, it flows through a portion of the Sacramento Valley known as the Butte Creek Valley Section that extends to the Butte Slough Outfall, where Butte Creek first enters the Sacramento River. Four dams and numerous diversions in the valley section remove water to irrigate rice fields and orchards. The upstream-most diversion, Parrott-Phelan, diverts water year-round, but most diversions operate during April through September. Dams also impound and divert water for wildlife and agricultural uses in the lower portion of the section (Butte Sink). These dams include: Sanborn Slough, White Mallard Dam, East-West Diversion weir, and weirs number 1 through 5.

Lower Butte Creek (i.e., Butte Valley)

The Sutter Bypass section of Butte Creek, also known as Butte Basin, extends downstream of the Butte Slough Outfall for approximately 40 miles. Butte Creek (named Butte Slough in this section) splits into two channels, known as the East and West borrow pits, as it enters the Sutter Bypass near Highway 20.
The tributaries that enter each of the three Butte Creek reaches (*i.e*., Butte Meadows, Butte Creek Canyon and Butte Creek Valley Section) are listed in an upstream-downstream order in Table 4.

Land Use

As described in the *Butte Creek Watershed Project: Existing Conditions Report* (Butte Creek Watershed Conservancy 1999), the diversity in the terrain encompassed by the Butte Creek Watershed has resulted in very diverse landownership and land uses. The land use map displayed in Figure 9 identifies the general land uses present in the Butte Creek Watershed as of 1997. The map displays broad land use designations and presents numerous generalizations; consequently, it should be only used in a broad or regional context. The areas assigned to each of the 13 land use categories in Figure 9 are quantified in terms of acreage and percent of the total watershed area in Table 2. Most of the lands in the Butte Creek watershed were allocated to grazing and agricultural use (64%), with the remaining lands almost equally split between commercial, industrial and residential use (13.1%) and forest related uses (13%). It is likely that in the recent 10 years these percentages may have changed somewhat due to the increase in residential development at the expense of grazing and agricultural use.

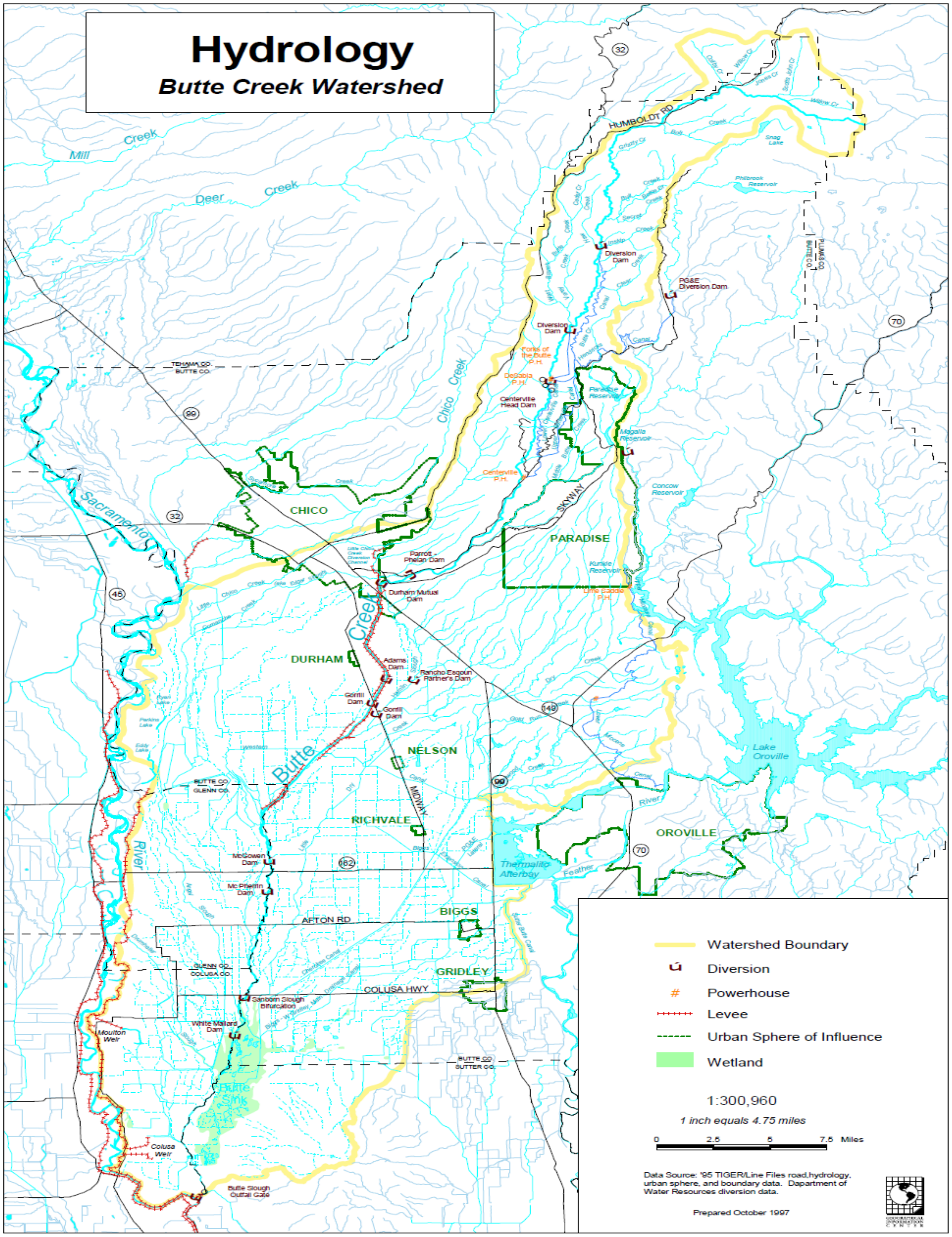

Figure 8. Hydrologic Features within the Butte Creek Watershed
Source: Butte Creek Watershed Conservancy 1999

Table 6. Butte Creek Tributaries

Watershed Section	Tributaries to Butte Creek	
	Butte Creek Left Bank	Butte Creek Right Bank
Butte Meadows	Unnamed Creek Unnamed Creek Bolt Creek Grizzly Creek	Willow Creek Scotts John Creek Jones Creek (joined by another Willow Creek) Colby Creek
Butte Canyon	Three unnamed creeks Bull Creek (joined by Bottle Creek and Secret Creek) Unnamed Creek Inskip Creek Two unnamed creeks Clear Creek (joined by Kanaka Creek) Numerous unnamed small, spring-fed creeks Four unnamed small creeks Little Butte Creek (joined by Middle Butte Creek)	Haw Creek Numerous unnamed small, spring-fed creeks West Branch Butte Creek (joined by Cedar Creek and later Varey Creek) Three unnamed small creeks
Butte Valley	Hamlin Slough Biggs-West Gridley Main Drain joined to Cherokee Canal (result of consolidating Cottonwood Creek, Clear Creek, Gold Run Creek and Dry Creek)	Little Butte Creek Angel Slough Drumheller Slough

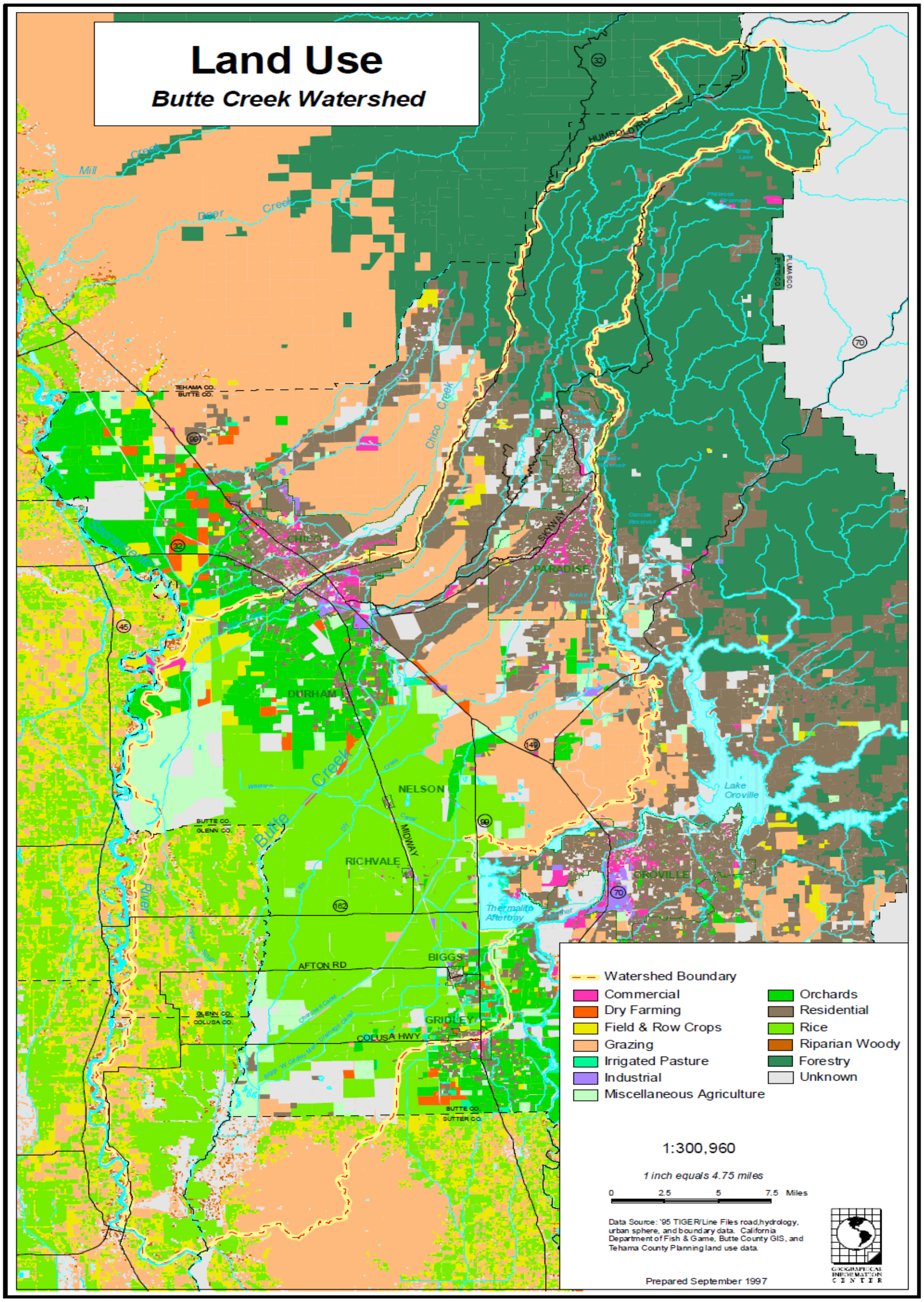

Figure 9. Land uses in the Butte Creek watershed

Source: Butte Creek Watershed Conservancy 1999. Created by the Geographic Information Center at CSU, Chico, with data provided by Butte, Tehama, Sutter, Glenn and Colusa Counties, and CDFW.

Table 7. Land use acreage in the Butte Creek watershed

Land Use Category	Acres	Percent of Butte Creek Watershed
Residential	62,362.3	12.0
Commercial	3,518.5	0.7
Industrial	1,690.0	0.3
Dry Farming	2,580.7	0.5
Field & Row Crops	24,168.0	4.7
Grazing	84,871.4	16.4
Irrigated Pasture	1,666.6	0.3
Orchards	31,254.7	6.0
Rice	158,915.7	30.7
Miscellaneous Agriculture	27,893.6	5.4
Riparian Forest	2,033.6	0.4
Upland Forest	65,708.4	12.7
Roads, rivers and creeks	51,125.3	9.9
Unknown	59.2	0.01
Total watershed acreage	517,848	100

Source: Butte Creek Watershed Conservancy 1999

Fisheries and Aquatic Habitat

Butte Creek is unique among the remaining spring-run Chinook salmon independent populations in that all of the holding and spawning area for spring-run Chinook salmon is below 285 m (931 ft) elevation, by contrast to Deer and Mill creeks where spring-run Chinook salmon hold and spawn in areas above that elevation (CDFW 2008). Due to the lower elevation habitat, Butte Creek exhibits water temperatures above the ideal temperatures for holding and spawning Chinook salmon (Ward *et al*. 2003, as cited in CDFW 2008). According to CDFW (2008), minimum instream flow levels need to be established in Butte Creek in order to assure the continued viability of fisheries resources. The extensive temperature modeling above the DeSabla Centerville dam has helped managers mitigate for this lack of cold water downstream. The cold water can be released when need because the managers now know where that colder water is in the thermocline.

Salmonids currently have access to approximately 53 miles of Butte Creek (DWR 2005). The upstream limit of migration is considered to be Quartz Bowl Falls, a 15 foot tall waterfall located at an elevation of approximately 900 feet. Fish passage through Butte Creek is affected by about 22 major structures and an estimated 60 to 80 minor structures (DWR 2005). Salmon have been observed upstream from Quartz Bowl Falls and below the Centerville Head Dam on three occasions in the past 25 years, when spring flows were in excess of 2,000 cfs (e.g., during 1998 and 2003) (DWR 2005).

Extensive habitat evaluations have been conducted throughout Butte Creek have identified and quantified habitat upstream from the Quartz Bowl that is be suitable for CV spring-run Chinook salmon production (Holtgrieve and Holtgrieve 1995). For many years, this habitat was thought to be blocked by Centerville Diversion Dam, but recent evaluations by DFG have concluded that natural, historic passage to these areas was not likely due to the presence numerous waterfalls and high gradient reaches that start approximately one mile upstream from Centerville Diversion Dam (CDFW 1998, NMFS 2006).

Since the early 1990s, restoration actions in Butte Creek have focused on improving instream flow during the critical spring immigration period, thereby increasing the likelihood that fish will succeed in reaching the upstream holding and spawning areas, even in dry years. Currently, the minimum flow deemed necessary to allow for spring-run Chinook salmon upstream passage is estimated at 80 cfs (CALFED 2006).

PG&E's minimum instream flow requirement at the Lower Centerville Diversion Dam is 40 cfs from June 1 to September 14. Average monthly flows from June through September (1998-2002) were between 46 cfs and 49 cfs. During the onset of the spring-run Chinook salmon spawning period in mid-September of 2004, PG&E, in consultation with CDFW and NMFS, increased flows to 60 cfs (PG&E 2005). Flows in Butte Creek begin to increase during the steelhead spawning period from November through April. Because there are no large storage facilities on Butte Creek, flow regimes during the winter months when agriculture diversions are not occurring tend to mimic the historic hydrology of the watershed.

Based on an analysis of the percentage of available spring-run Chinook salmon spawning habitat, CDFW (2008) recently recommended new minimum instream flows for Butte Creek from Centerville Head Dam downstream to Parrot-Phelan Diversion Dam, related to the FERC relicensing of the DeSabla-Centerville hydropower project. CDFW's analysis of spring-run Chinook salmon spawning habitat was conducted using a 2-dimensional hydraulic and habitat model (USFWS 2003, as cited in CDFW 2008), an analysis of historical regulated flow data, including inter-basin water transfer from the West Branch of the Feather River to Butte Creek data (CDFW 2008b, as cited in CDFW 2008), and water quality (e.g., temperature) benefits (CDFW 2008b, as cited in CDFW 2008). Spawning habitat was identified as a limiting-factor for spring-run Chinook salmon in Butte Creek based on a considerable amount of redd superimposition observed during data collection efforts by the USFWS (USFWS 2003; USDOI 2008, as cited in CDFW 2008). CDFW (2008) suggest that their minimum instream flow recommendations for Butte Creek would allow for greater dispersal of spring-run Chinook salmon redds and reductions in redd superimposition. CDFW's (2008) recommended minimum flows in Butte Creek for each month of the year for normal and dry water year types are presented below (Table 8).

Table 8. CDFW's recommended minimum instream flows (cfs)

Month	Normal	Dry
Oct	100	75
Nov	100	75
Dec	100	75
Jan	100	75
Feb	100	75
Mar 1-14	100	75
Mar 15-31	80	75
Apr	80	75
May	80	65
Jun	40	40
Jul	40	40
Aug	40	40
Sep	100	75

In addition to efforts to implement new minimum instream flow requirements, significant restoration efforts have been conducted in Butte Creek to remove passage barriers, rehabilitate fish passage structures, screen unscreened diversions, and improve riparian habitat conditions.

The State Water Resources Control Board is in the process of identifying new regulatory minimum instream flow requirements for Butte Creek.

Spring-run Chinook Salmon

From 2005 through 2008, Butte Creek spring-run Chinook salmon escapement was 10,625, 4,579, 4,943 and 3,935, respectively (CDFW 2009). Between 1960 and 2008, the highest annual spring-run Chinook salmon escapement was 20,259, occurring in 1998 (Table 9).

Table 9. Adult Spring-run Chinook salmon population estimates for Butte Creek from 1960 to 2012

Year	Adult Estimate	Year	Adult Estimate	Year	Adult Estimate
1960	8700	**1978**	128	**1996**	1413
1961	3082	**1979**	10	**1997**	635
1962	1750	**1980**	226	**1998**	20259
1963	6100	**1981**	250	**1999**	3679
1964	600	**1982**	534	**2000**	4118
1965	1000	**1983**	50	**2001**	9605
1966	80	**1984**	23	**2002**	8785
1967	180	**1985**	254	**2003**	4398
1968	280	**1986**	1371	**2004**	7390
1969	830	**1987**	14	**2005**	10625
1970	285	**1988**	1290	**2006**	4579
1971	470	**1989**	1300	**2007**	4943
1972	150	**1990**	250	**2008**	3935
1973	300	**1991**		**2009**	2059
1974	150	**1992**	730	**2010**	1160
1975	650	**1993**	650	**2011**	2130
1976	46	**1994**	474	**2012**	8665
1977	100	**1995**	7500		

Sources: CDFW Grandtab; personal communications with DFG and FWS biologists.

Water temperatures between the Parrot-Phelan Diversion Dam and the Centerville Head Dam in Butte Creek frequently exceed the reported optimum temperatures for spring-run Chinook spawning. Water temperatures frequently exceed 59ºF from July through September. During 2002 and 2003 elevated water temperatures, in conjunction with a large number of adult spring-run Chinook salmon returns, resulted in an outbreak of Columnaris (*Flavobacterium columnare*). 1,699 pre-spawning mortalities were observed from June 26, 2002 to September 19, 2002 from the Parrot-Phelan Diversion to the Centerville Head Dam. During 2003, an estimated 17,294 adult spring-run Chinook salmon migrated to Butte Creek, of which an estimated 11,231 died prior to spawning (Ward *et al.* 2003).

Juvenile Chinook salmon rear in the Butte Creek Canyon downstream of Centerville Head Dam for up to one year. Although summer flows of 40 cfs generally keep water temperature below 68°F throughout most of the reach (Kimmerer and Carpenter, 1989), water temperature often exceeds 76°F in the canyon between Butte Creek Head Dam and Centerville Head Dam in July and August. Moreover, water temperatures could be of concern during the late spring, particularly in the lower reaches of Butte Creek.

Studies in Butte Creek (Ward *et al*. 2003) found the majority of spring-run migrants to be fry moving downstream primarily during December, January, and February, and that these movements appeared to be influenced by flow. Small numbers of spring-run juveniles remain in Butte Creek above the Parrot-Phelan Diversion Dam prior to emigrating in the spring (Ward *et al.* 2004).

Steelhead

As reported by the Butte Creek Watershed Conservancy (1999), steelhead have been reported in Butte Creek principally through reports by CDFW wardens of angler catches. However, no estimate of steelhead abundance in Butte Creek is known to be available (Butte Creek Watershed Conservancy 1999; FERC 2008).

Adult steelhead ascend Butte Creek during the late fall and winter. Steelhead spawning occurs in tributaries such as Dry Creek and in the mainstem of Butte Creek above Parrott-Phelan diversion during winter and spring (generally December through April). As reported by the Butte Creek Watershed Conservancy (1999), the spawning area for steelhead in Butte Creek extends from the Centerville Head Dam downstream to the vicinity of the Western Canal Siphon crossing. Steelhead generally spawn upstream of the Parrott-Phelan diversion. Spawning gravel in the reach of the creek from the Centerville Head Dam downstream to the vicinity of Helltown is extremely limited, with the major gravel beds existing below the Centerville Powerhouse (Butte Creek Watershed Conservancy 1999). The Sutter Bypass is reportedly used by juvenile steelhead as rearing habitat (Butte Creek Watershed Conservancy 1999).

Big Chico Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to spring-run Chinook salmon and steelhead in Big Chico Creek include, but are not limited to the following:

- ❖ Physical passage impediments and flow-based barriers at Iron Canyon, City of Chico Swimming Holes and associated dams affecting adult immigration and holding
- ❖ Water temperatures affecting adult immigration and holding, spawning and embryo incubation
- ❖ Habitat suitability and spawning habitat availability affecting adult spawning
- ❖ Loss of floodplain habitat and natural river morphology affecting juvenile rearing and outmigration
- ❖ Passage impediments related to the reverse flows caused by M&T pumps affecting juvenile outmigration

Watershed Description

Big Chico Creek Watershed (Figure 10) is located within Butte and Tehama Counties, encompassing an area of approximately 72 square miles (USFWS 1995). The headwaters of Big Chico Creek originate from the southwest slope of Colby Mountain at an elevation of approximately 5,400 feet. Big Chico Creek is approximately 45 miles in length and enters the Sacramento River west of the City of Chico (USFWS 1995). The watershed also encompasses three smaller drainages to the north including Sycamore, Mud, and Rock creeks (USFWS 1995; USFWS 2007).

A small dependent population of spring-run Chinook salmon continues to occur in Big Chico Creek, but relies on extant independent populations for its continued survival. The run size is under 500 returning adults annually and is considered a remnant population. Steelhead do occur in Big Chico Creek along with resident trout. The numbers of steelhead have not been estimated, however, they are believed to use the foothill zone to spawn except in low water years they spawn in the lower river.

Big Chico Creek is a small watershed with substantial urban impacts in the lower watershed. Big Chico Creek contains marginally suitable habitat for salmon that most likely was opportunistically used in the past by salmon and steelhead (Yoshiyama *et al*. 1996). The middle and upper watershed areas however, are not urbanized and much effort by local groups and land owners has been made to secure conservation easements along this portion of the river corridor. These easements protect the riparian zone from the impacts of development long term. To keep this small population of spring-run and steelhead persistent in this watershed, there are several restoration actions that could help the watershed: 1) improve fish passage through Iron Canyon 2) improve habitat function in the lower habitat through riparian and off channel improvements.

One of the limiting factors for the dependent population of spring-run Chinook salmon is fish passage through Iron Canyon which lies approximately 7 miles from the town of Chico. This ladder provides access for spring-run salmon into the upper watershed where cooler water is found in the late summer. The ladder connects Big Chico Creek through a section of the valley that was impacted by a previous earthquake. There are plans to improve this fish ladder, which would be an important restoration activity for this watershed to assist the current population to remain viable.

Geology

The Great Valley geomorphic province lies to the west and the Sierra Nevada geomorphic province lies to the east and south. Rocks from the Cascade Range and Great Valley provinces are exposed along Big Chico Creek, and include Upper Cretaceous marine sedimentary rocks of the Chico Formation, Miocene volcanic rocks of the Lovejoy Basalt, and Pliocene volcanic and sedimentary rocks of the Tuscan Formation (USFWS 2006). In response to tectonic uplift and tilting, Big Chico Creek eroded through the Tuscan Formation and exposed the older Lovejoy Basalt. Continued downcutting through the very hard and resistant basalt resulted in the formation of a steep-sided, narrow canyon, primarily oriented along two primary joint sets within the basalt (USFWS 2006). Where the creek has cut entirely through the basalt into the softer Chico Formation, the steep canyon walls have been prone to instability due to undercutting and the loss of support (Guyton and DeCourten 1978 in USFWS 2006). Upstream of Higgin's Hole (RM 23), the Big Chico Creek stream channel has cut through metamorphic rock, creating a narrow canyon with big boulders, bedrock potholes, and spectacular waterfalls (USFWS 1995).

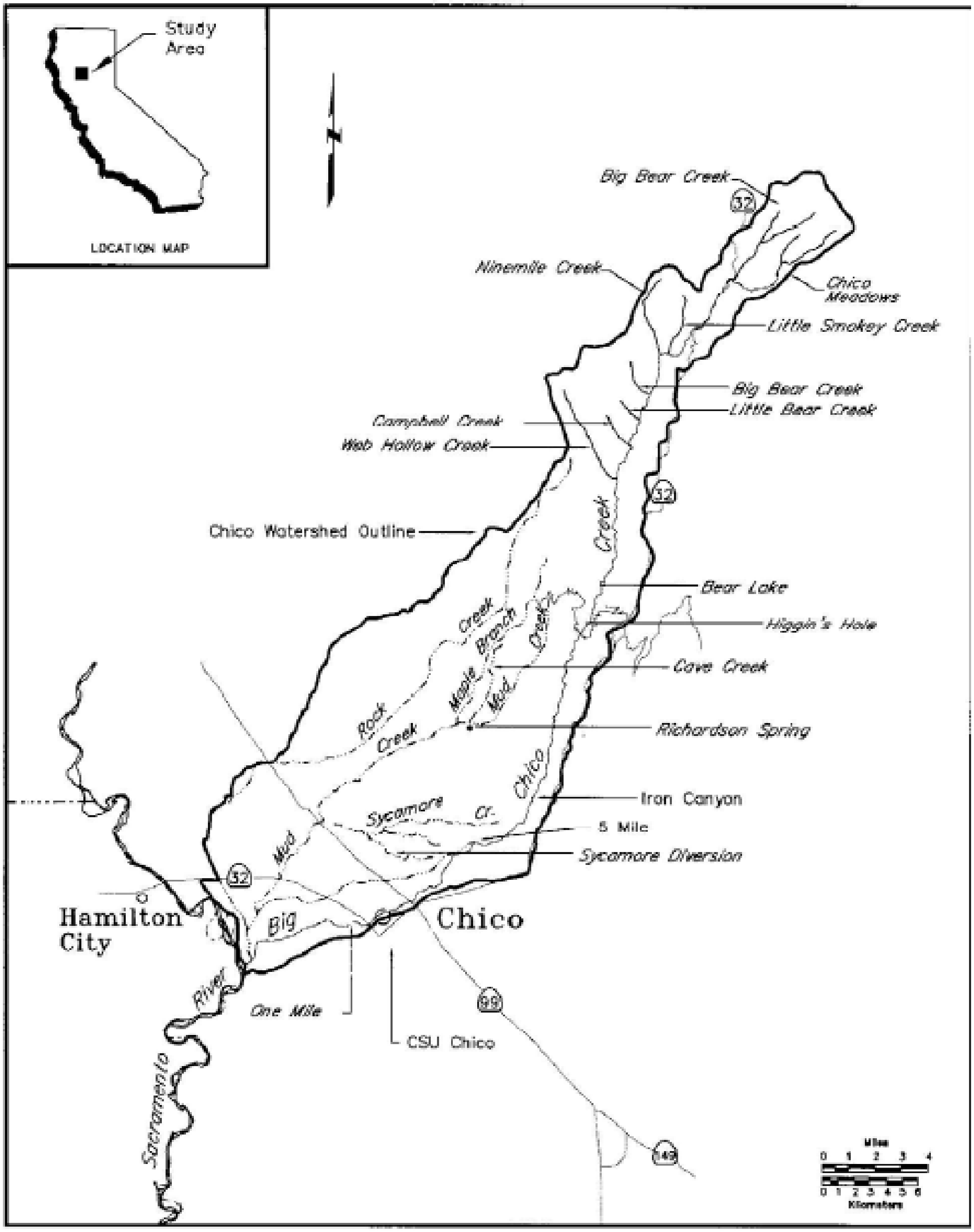

Figure 10. The Big Chico Creek Watershed Source: CDFW 2001**.**

Hydrology

The main channel of Big Chico Creek begins in Chico Meadows, fed by a number of springs that originate from Colby Mountain, and flows 45 miles to its confluence with the Sacramento River

(CDFW 2001). Big Chico Creek can be divided into three zones: (1) the upper zone extends from the headwaters and Higgin's Hole; (2) the middle zone extends from Higgin's Hole to Iron Canyon; and (3) the lower zone extends from Iron Canyon to the Sacramento River (Maslin 1997). The unimpaired average annual yield is approximately 54,000 acre-feet (USFWS 1995). Above Five-Mile Diversion, base flows in Big Chico Creek during the summer (i.e., June-October) typically range from 20 to 25 cfs. However, most of this base flow is lost to infiltration in the region of the creek's outwash fan (i.e., roughly the city of Chico), therefore, by late summer of most years surface flow does not extend downstream of Rose Avenue (USFWS 1995).

Mud Creek and Rock Creek join Big Chico Creek about 0.75 miles before it enters the Sacramento River. These two tributaries differ from Big Chico Creek, in that: (1) these two creeks receive precipitation primarily as rain, rather than snow; and (2) their channel structure is shorter and dendritic, draining from the surface of the tilted Tuscan formation at relatively lower elevations than most of the Big Chico Creek drainage. Accordingly, they are seasonal (flowing from about November to June in the Central Valley portion of their channels) and warm up more rapidly during the spring (USFWS 1995).

Flowing 26 miles before entering Big Chico Creek, Mud Creek is a spring-fed stream that is one of the primary tributaries in the Big Chico Creek Watershed. Richardson Springs (Figure 10) serves as a barrier to upstream fish migration in Mud Creek (BCCECR in CDFW 2001). An outflow weir at Lindo Channel diverts excess flows through a diversion channel to Sycamore Creek, where it then flows into Mud Creek (Maslin, Analysis of the Sycamore in CDFW 2001).

Land Use

Most of Big Chico Creek is bordered by private land with smaller holdings by the United States Forest Service and the Bureau of Land Management (USFWS 1995). Big Chico Creek flows through Bidwell Park (the third largest municipal park in the United States), downtown Chico, and the California State University campus (USFWS 1995). The headwaters of Mud and Rock creeks are in privately held forest land; foothill reaches are mostly pastured brush land or woodland; and Central Valley reaches traverse agricultural land. Both Mud and Rock creeks have minor agricultural diversions (USFWS 1995). In addition, Mud Creek is impounded for domestic water supply at Richardson Springs. The Sycamore Diversion passes floodwater from Big Chico Creek to Mud Creek (USFWS 1995).

Fisheries and Aquatic Habitat

The lowermost 24 miles of Big Chico Creek are identified as providing both historic and current aquatic habitat for anadromous salmonids (USFWS 2008). It has been reported that Big Chico Creek is important for providing aquatic habitat for adult spring-run Chinook salmon holding and spawning, while Mud, Rock and Sycamore creeks have been shown to be important non-natal rearing areas for salmonids (Big Chico Creek Watershed Alliance 1997).

Unless otherwise specified, the following information on fisheries and aquatic habitat in Big Chico Creek comes directly from the Big Chico Creek Watershed Existing Conditions Report (Big Chico Creek Watershed Alliance 2000).

In the lower reach of Big Chico Creek (known as Iron Canyon) that is located approximately 13 miles upstream of the confluence with the Sacramento River (DWR 2002), the valley narrows abruptly and the stream gradient increases. At its upper end, the basalt near the area from Bear Hole to Brown's Hole in Bidwell Park is undercut and large boulders have tumbled into the creek bed, possibly by a rock slide that occurred as a result of the 1906 San Francisco earthquake (DFG 1958 in USFWS 2006). During periods of normal creek flow, this debris field of boulders acted as an impassable barrier to upstream movement of fish and represented the most downstream barrier to fish passage. In 1958, CDFW constructed a fish ladder to provide pools of water for the fish to traverse the blocked area and reach the cooler pools to hold over the summer for fall spawning (DFG 1958 in USFWS 2006; Big Chico Creek Watershed Alliance 2008). The ladder was comprised of seventeen weirs, which reportedly were constructed to bypass a 14-foot-high waterfall created by the debris field (USFWS 2006). Since the original construction, the limited fish passage that does occur beyond the Iron Canyon Fish Ladder is believed to occur during higher flows (USFWS 2006). Over time, the fish ladder has fallen into disrepair. The Big Chico Creek Watershed Alliance (2008) has been working together with the resource agencies to fund construction of a rehabilitated fish ladder. In 2007, the final designs and specifications for rehabilitation of the structure were completed. If funding is secured, it is anticipated that the project would be constructed in the summer/ fall of 2010 (Big Chico Creek Watershed Alliance 2008).

Upstream of Iron Canyon and approximately four miles downstream of Web Hollow Creek (Figure 10), the canyon narrows and consists of large boulders, bedrock potholes, and waterfalls. Near Higgin’s Hole (RM 23), there is a considerable waterfall that is believed to be the uppermost barrier to anadromous fish passage (CDFW 2001). In very unusual years when migration corresponds exactly with high flow, salmon or steelhead may pass through this canyon to the waterfall at Bear Lake, but there is only one record of salmon being sighted at Bear Lake (Big Chico Creek Watershed Alliance 2000).

In Mud Creek, the main fish passage barrier is the 69-foot waterfall at Richardson Springs, which stops all upstream movement of fish, at the upstream extent of the valley zone. The Mud Creek foothill zone is extremely short, only extending from the top of the waterfall 1.1-mile to another series of falls. In Rock Creek, the upstream end of the valley zone for many years has been the diversion dam about 0.3 miles upstream of the Anderson Fork confluence.

Additional fish passage barriers in the Big Chico Creek watershed (depending on flow conditions) include the Lindo Channel Weir, a diversion dam at stream mile 18 in Rock Creek, a diversion dam between Ponderosa Way and Higgin’s Hole, and various undersized culverts. Higgin's Hole is the upstream limit for spring-run Chinook salmon and steelhead, approximately 0.5 to 1 mile above the crossing of Ponderosa Way (Yoshiyama *et al.* 1996). The size of the waterfalls and the scenic nature of the upstream canyon preclude construction of fishways (USFWS 1995).

Historically the foothill zone of Big Chico Creek was dominated by migratory fish including spring-run Chinook salmon and steelhead. However, there are no accurate records of historical fish populations in the watershed. Anecdotal accounts suggest existence of former populations of steelhead and spring-run Chinook salmon in both Mud and Rock creeks. However, it is unlikely that either creek could sustain its own salmon or steelhead population indefinitely; historical populations were likely lost in each series of drought years and then re-established by strays from Big Chico Creek. Although no formal counts have ever been conducted, it is likely that only a few adult salmonids stray into Mud and Rock Creeks under present conditions.

During the winter and early spring, juvenile Chinook salmon of all races move from the Sacramento River where they were spawned into tributaries for rearing (Maslin *et al.* 1997). Some move upstream substantial distances (e.g., to Hicks Lane in Mud Creek; to Highway 99 in Rock Creek), although they are more numerous closer to the Sacramento River confluence. Maslin *et al.* (1998) estimated that approximately 50,000 juvenile Chinook salmon from the Sacramento River reared in Mud and Rock creeks, including an estimated 10,000 winter-run Chinook salmon. Juvenile Chinook salmon rearing in the tributaries reportedly grow faster and are in better condition than those remaining in the Sacramento River, and smolt and emigrate earlier than they would in the mainstem Sacramento River (Maslin *et al.* 1997; 1998). However, some tributary-rearing juveniles get trapped by receding water, particularly in low water years (Maslin *et al*. 1998).

Spring-Run Chinook Salmon

A dependent population of spring-run Chinook salmon continues to occur in Big Chico Creek, relying on strays from extant independent populations for its continued survival. CDFW (2007) also reports that the creek currently exhibits only a remnant non-sustaining population of spring-run Chinook salmon and, thus, Big Chico Creek is not currently used as a population trend indicator.

As reported by the Big Chico Creek Watershed Alliance (2000), Big Chico Creek spring-run Chinook salmon spend the summer in deep pools from Iron Canyon to Higgin's Hole and spawn in adjacent riffles when temperatures drop during early Fall. Relatively high water temperatures limit the ability of holding spring-run Chinook salmon to tolerate additional stressors such as harassment by swimmers, particularly during drought years when water temperatures tend to be higher and salmon are over-summering in pools downstream of the Iron Canyon ladder. Due to elevated water temperatures in the area where adults are forced to spawn, their offspring develop rapidly; nearly all juveniles emigrate by the following spring (unlike Deer and Mill Creeks where many juveniles emigrate during the wet season more than a year after being spawned) (Big Chico Creek Watershed Alliance 2000).

The average annual run-size of Big Chico Creek spring-run Chinook salmon is believed to have been less than 500 fish during the 1950s and 1960s, but is now considered to be only a remnant population (CDFW 1993 as cited Yoshiyama *et al*. 1996). GrandTab data for Big Chico Creek spring-run Chinook salmon is available for some of the years between 1960 and 2008[6]. Between 1962 and 1969, escapement was 200, 500, 100, 50, 50, 150, 175, and 200, respectively (CDFW 2009). Between 1993 and 2008, escapement was 38, 2, 200, 2, 2, 369, 27, 27, 39, 0, 81, 0, 37, 299, 0, 0, respectively (CDFW 2009). For years not mentioned, escapement data either was not available or was intermittently available. During 2006, the most recent year that spawning fish were observed, about 83 percent (248) of estimated adults that returned to spawn in Big Chico Creek were found above the Iron Canyon Fish Ladder (USFWS 2007). In this diversity group, spring-run Chinook salmon populations seem to persist in Antelope and Big Chico creeks, albeit at an annual population size in the tens or hundreds of fish, with no returning spawners in some years (NMFS 2009a). Spring-run Chinook salmon escapement estimates for Big Chico Creek are available from 1962 through 2011 (Table 10).

Table 10. Adult spring-run Chinook salmon population estimates for Big Chico Creek from 1962 to 2011. Estimates are not available for all years.

Year	Adult Estimate	Year	Adult Estimate	Year	Adult Estimate
1962	200	**1979**		**1996**	2
1963	500	**1980**		**1997**	2
1964	100	**1981**		**1998**	369
1965	50	**1982**		**1999**	27
1966	50	**1983**		**2000**	27
1967	150	**1984**	0	**2001**	39
1968	175	**1985**	0	**2002**	0
1969	200	**1986**		**2003**	81
1970		**1987**		**2004**	0
1971	0	**1988**		**2005**	37
1972		**1989**		**2006**	299
1973	50	**1990**		**2007**	0
1974	100	**1991**		**2008**	0
1975		**1992**		**2009**	6
1976		**1993**	38	**2010**	2
1977	100	**1994**	2	**2011**	124
1978		**1995**	200		

Sources: CDFW Grandtab; personal communications with DFG and FWS biologists.

[6] *Data availability for Big Chico Creek during this period has been dependent on funding availability and other considerations (T. Parker, USFWS, pers. comm. 2009).*

Steelhead

Existing wild steelhead stocks in the Central Valley are mostly confined to the upper Sacramento River and its tributaries (e.g., Antelope, Deer, and Mill creeks and the Yuba River) (NMFS 2009a). However, populations also may exist in Big Chico and Butte creeks (McEwan and Jackson 1996).

As reported by the Big Chico Creek Watershed Alliance (2000), adult steelhead usually spawn in the foothill zone of the Big Chico Creek Watershed, but during low-flow years they may spawn in the valley zone. Historically, steelhead were probably predominant when the habitat was more suitable for anadromous salmonids. The decline of steelhead has permitted their replacement by resident rainbow trout. Studies have not been conducted to determine whether the rainbow trout are migratory (i.e., steelhead) or resident fish. Additionally, there have been no reported occurrences or estimates of steelhead spawning in Big Chico Creek (Big Chico Creek Watershed Alliance 2000).

Deer Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to spring-run Chinook salmon and steelhead in Deer Creek include, but are not limited to the following:

- Agricultural diversion dams impeding or blocking passage of immigrating adults
- Elevated water temperatures affecting adult immigration and holding
- Low flows affecting juvenile outmigration, and attraction and migratory cues of immigrating adults
- Possible catastrophic event (e.g., fire or volcanic activity)
- Loss of genetic and life history diversity from steelhead hybridization with out-of-basin rainbow trout that are planted into reaches of Deer Creek upstream from the Upper Deer Creek Falls.

Watershed Description

As reported by DWR (2009), Deer Creek is an eastside tributary to the Sacramento River that flows in a southwesterly direction for approximately 60 miles and drains 134 square miles. Deer Creek originates near the summit of Butt Mountain at an elevation of approximately 7,320 feet. It initially flows through meadows and dense forests and then descends rapidly through a steep rock canyon into the Sacramento Valley. Upon emerging from the canyon, the creek flows 11 miles across the Sacramento Valley floor, entering the Sacramento River at approximately 1 mile west of the town of Vina at an elevation of approximately 180 feet (DWR 2009).

Deer Creek, along with Mill Creek and Butte Creek, is recognized as supporting one of three remaining self-sustaining CV spring-run Chinook populations. Habitat used for holding and spawning is located at high elevations and habitat is considered to be high quality (CDFW 1998). The high elevation habitats in Deer Creek are isolated from fall-run Chinook salmon by low summer and fall flows and high water temperatures that prevent geographic co-occurrence and maintains genetic and phenotypic diversity of the population. The NMFS TRT did not conclude as to whether Mill and Deer creeks are independent of one another, although they did conclude that spring-run Chinook salmon in these streams are currently independent from other spring-run Chinook salmon populations and represent a significant lineage within Central Valley Chinook ESU.

When considering watersheds in the Central Valley that contribute current viable populations for Spring-run chinook, Deer Creek is considered a conservation stronghold for the ESU. Lindley *et al.* (2007) classified the Deer Creek spring-run Chinook salmon population as having a low risk of extinction. Over the past three years poor ocean conditions combined with drought, and other stressors have affected the abundance of the Deer Creek population and the extinction risk may be trending toward moderate to high. With the implementation of key recovery actions, the watershed has a high potential for sustaining a population at a low risk of extinction (Lindley *et al*. 2007)) for the following reasons: (1) Deer Creek contains a sufficient amount holding and spawning habitat to support a population with an effective size greater than 500 adults or a census population near 2,500 (see Table 4-1 of the Recovery Plan), based on our review of historic and recent abundance; (2) hatchery influence is low and expected to decrease over time, (3) the number and magnitude of recovery actions needed within the Deer Creek watershed are limited and localized.

Deer Creek also supports all life history stages of steelhead, although not is much is known about the long term viability of steelhead in the ESU. The carrying capacity of steelhead in Deer Creek is not known, the watershed historically supported strong populations that likely persisted at low levels of extinction prior to water development on the valley floor. Deer Creek has a high potential to support a viable, self-sustaining steelhead population because of the extensive (25 miles) or suitable spawning and rearing habitat, the existing occurrence of *O. mykiss* throughout Deer Creek at high densities (up to several thousand rearing fish per mile (Mike Berry, CDFW, pers. com., 2005)), and the limited number and localized nature of watershed-specific recovery actions.

The anadromous fish habitats in Deer Creek (along with Mill, Antelope, Battle and Butte Creeks) are probably the best remaining habitat above the Central valley for anadromous salmonids, and serve as important anchors for their recovery. It is also worth noting that aquatic resources in the Deer Creek watershed have regional significance for a number of reasons. There are diversion structures in the valley section of Deer Creek, however, as opposed to 90% of the rivers draining into the Sacramento Basin, there are no major water impoundments along the Deer Creek corridor. Unlike many other rivers in the Central Valley which find relief in the Sacramento River because their channels have been blocked by dams and diversions, anadromous fish have been able to maintain passage, and native fish communities have survived in the free flowing sections. Deer Creek is also considered essential to the recovery and perpetuation of the wild stocks of winter-run steelhead in the Central Valley (Reynolds et. al. 1993; McEwan and Jackson 1996) in part because of its current habitat conditions.

In Deer Creek the primary focus for spring-run Chinook salmon restoration is on improving flow conditions for upstream migrating adults so they can access important holding and spawning habitat (Mills and Ward 1996) and for outmigration fry. To this end, water exchange programs are underway or in development with cooperating irrigation districts. The programs are intended to develop and operate wells to offset bypass flows needed for spring-run Chinook salmon and to implement water use efficiency measures to reduce irrigation water demand.

How will Deer Creek help to buffer the negative effects of climate change for salmonids in the Central Valley?

Under the expected climate warming of around 5°C, substantial salmonid habitat would be lost in the Central Valley, with significant amounts of habitat remaining primarily in the Feather and Yuba rivers, and remnants of habitat in the upper Sacramento, McCloud, and Pit rivers, Battle and Mill creeks, and the Stanislaus River (Lindley *et al*. 2007). Under the less likely but still possible scenario of an 8°C warming, spring-run Chinook salmon habitat would be found only in the upper-most reaches of the north fork Feather River, Battle Creek, and Mill Creek (Lindley *et al*. 2007).

In addition, while warming may pose as a key threat to spring-run Chinook salmon in Deer Creek, suitable water temperature conditions should persist longer in Deer Creek (and Mill Creek), where fish can reach higher altitudes (Williams 2006). Some existing or potential habitat should also remain for some time below various dams that currently release cool water through the summer (Williams 2006).

Geology

Deer Creek is located within the southernmost extension of the Cascade Range. As reported in Armentrout *et al*. (1998), the Tuscan formation of the Pliocene age, comprised primarily of mudflows, dominates the geology. This formation dips gently and thins toward the southwestern portions of the watersheds. Geologic diversity is supplied by several influences. These include andesitic plugs that intrude the Tuscan formation along two linear trends, relatively minor exposures of marine sedimentary rocks, and at lower elevations, quaternary sediments of the Sacramento Valley. Glacial processes shaped some of the higher elevation landforms.

Soils generated from these parent materials are generally productive; erosion rates range from low to moderate on the andesitic soils to high to very high on the rhyolitic soils. Mass wasting is evident in the Deer Creek watershed, dominated by debris flows in colluvium-filled hillslope hollows. Failures are episodic and triggered by extreme precipitation events. Surface erosion, especially on the rhyolitic soils, is the other major source of sediment (Armentrout *et al*. 1998).

The soils of the Deer Creek watershed are derived from volcanic breccia, including basalt, andesite, dacite and rhyolite. Dominant soils in the Deer Creek watershed are of the Lyonsville and Jiggs association, Cohasset series, McCarthy series and the Windy series. The Lyonsville soils are generally found along ridges, are moderately deep and well-drained. The Jiggs soils are derived from volcanic flow of rhyolite and are somewhat excessively drained. The Lyonsville and Jiggs soils are mapped together because they both have erosive properties due to their rhyolitic component. The Cohasset soils are derived from weathered andesite and breccia. They are generally found on slopes of canyons in mountainous areas, and are moderately deep, moderately coarse textured, and have a granular structure. The Windy soils are well-drained soils derived from basic volcanic rocks, andesite and basaltic rocks from volcanic flows, and in some places are cemented together with tuffaceous material. These soils are found in mountainous areas (Armentrout *et al*. 1998).

Hydrology

As reported in Armentrout *et al*. (1998), precipitation varies from 25 to nearly 80 inches per year, over the range in elevation (approximately 180 to 7320 feet msl) in the Deer Creek watershed. Deer Creek produces on average 228,700 acre ft of water per year. Peak flows from the watershed are dominated by rain-on-snow events.

The majority of annual flow events occur in December, January and February when snow could be expected to be present in the transient snow zone (above about 3,000 feet in elevation). Earlier peaks (September through November) are most likely rain events with little snow influence. Later peaks (mid-March through May) indicate snowmelt generated peaks. The recorded maximum flow on Deer Creek was 23,800 cfs on December 10, 1937 (Armentrout *et al*. 1998).

There are three diversion dams and four diversion ditches on the 10 miles of stream between the canyon mouth of Deer Creek and the Sacramento River. During low flow periods, the existing water rights are sufficient to dewater the stream. Late spring and early summer diversions have resulted in flows low enough to block access for late-migrating adults (Armentrout *et al*. 1998).

Land Use

As reported by Armentrout *et al*. (1998), the Deer Creek watershed is relatively long and narrow, with moderate to steep slopes. Extended low gradient channel types are uncommon on the mainstem, restricted to Deer Creek Meadows and reaches in the Valley floor. Steep slopes adjacent to the main channel historically served as barriers to human activity, and recent land use allocations have protected these areas such that the main stem is essentially undisturbed. However, the presence of Highway 32 along portions of Deer Creek is a notable exception. In addition, timber harvest and grazing have impacted many of Deer Creek's tributary streams. These impacts have resulted in increased sedimentation to the Deer Creek watershed. The Lassen National Forest, through their Land and Resource Management Plan (USFS 1992), is decommissioning roads throughout the forest that are no longer in use. One of the primary reasons for this decommissioning is to reduce sediment load to anadromous watersheds such as Deer and Mill creeks.

Currently, approximately half of the forest lands in the region are in private ownership, providing support to local economies. Historically, range management was a major land use in the watershed. In the upper watershed, the number of animals grazing has declined substantially over the past hundred years, but ranching still provides limited employment. Pressure has increased on ranchers and growers to convert their lands to residential development (Armentrout *et al*. 1998).

Recreational activities in the watershed have steadily increased over the past decades with the increased population in the region. Lassen National Park and Forest Service Campgrounds in the Deer Creek watershed are sites of concentrated use. State Highway 32 provides easy access to stretches of Deer Creek, and is a major site of recreational fishing (Armentrout *et al*. 1998).

Fisheries and Aquatic Habitat

Deer Creek contains approximately 40 miles of anadromous fish habitat, with approximately 25 miles of adult spawning and holding habitat, most of which is on public lands managed by the Lassen National Forest. Unlike most tributary streams of the Sacramento and San Joaquin rivers that now have major water storage facilities that inundate or block miles of historical anadromous spawning habitat, headwater stream habitat in Deer Creek is still available for utilization by anadromous fish (Armentrout *et al*. 1998). Deer Creek provides approximately 42 miles of anadromous habitat extending from the confluence with the Sacramento River upstream to Upper Deer Creek Falls. Like the anadromous reaches of Mill Creek, the habitat is utilized and/or available to fulfill one or more riverine life history requirements for both spring-run Chinook salmon and winter-run steelhead.

Until 1943, when a ladder was built to provide access to habitat upstream of the falls, Lower Falls (at a reported height of 16 feet) was the upstream limit to migration (Cramer and Hammack 1952). Construction of the ladder effectively provided access to an additional five miles of habitat which is now an important area for adult holding and spawning. In the early 1950's, a fish ladder was also built at Upper Falls, although upstream habitat was not considered suitable for spring-run Chinook salmon (Armentrout *et al*. 1998). The ladder currently remains closed for a variety of reasons during the adult spring-run Chinook salmon upstream migration period. In some years, anadromous fish have been observed above Upper Falls, but habitat appears to be utilized only on rare occasions when a few hardy fish are capable of surmounting the falls under suitable conditions (Armentrout *et al*. 1998).

Evaluations of Central Valley anadromous fishery resources (Reynolds et. al. 1993; McEwan and Jackson 1996; Harvey-Arrison 2008) have consistently identified insufficient instream flows, and elevated water temperatures particularly during the adult spring-run Chinook salmon upstream migration and holding period (May-September) as factors limiting anadromous fish production in the Deer Creek watershed. Recognition of these limitations has led to the establishment of the Deer Creek Watershed Conservancy, and development of cooperative programs between local, state and federal agencies, water users, and landowners to implement water exchange and other programs to sustain spring-run Chinook salmon and steelhead in Deer Creek.

Relatively few restoration actions are needed to restore watershed and ecosystem function for the purpose of supporting the freshwater life history stages of CV spring-run Chinook salmon and CV steelhead in Deer Creek. With the exception of impaired stream flows and fish passage conditions on the valley floor below agricultural diversions, habitat in the upper watershed in good condition. Those actions that are required are localized in nature and when fully implemented have a high likelihood of restoring good fish passage conditions. In particular, long-term fish passage improvements should be addressed by installing state-of-the-art passage facilities at the Cone-Kimball, Stanford Vina, and Deer Creek Irrigation District dams, and existing dam structures should be replaced with inflatable bladder dams that can be installed during the irrigation season and lowered during periods of high stream flow and bedload transport. In the upper watershed Federal land management practices are guided by a long-term anadromous fish conservation strategy. Private timberland management plans lack a comprehensive anadromous habitat protection strategy.

Spring-run Chinook Salmon

Estimates of spring-run Chinook salmon abundance in Deer Creek are available since 1963 (CDFW Grandtab 2011) (Table 11). During the years 1992-2008, spring-run Chinook salmon counts in Deer Creek ranged from 140 to 2,759 salmon. From 2005 through 2008, Deer Creek spring-run Chinook salmon escapement was 2,239, 2,432, 644, and 140, respectively (CDFW 2009). Between 1940 and 1964, an average of 2,200 spring-run Chinook salmon was counted annually using fish ladder counts and carcass surveys. These historical surveys were often expansions of partial weir counts and incomplete carcass surveys and are not comparable to current survey efforts (Harvey-Arrison 2008).

Table 11. **Adult spring-run Chinook salmon population estimates for Deer Creek from 1963 to 2012.** Estimates are not available for all years.

Year	Adult Estimate	Year	Adult Estimate	Year	Adult Estimate
1963	2302	**1981**		**1999**	1591
1964	2874	**1982**	1500	**2000**	637
1965		**1983**	500	**2001**	1622
1966		**1984**		**2002**	2185
1967		**1985**	301	**2003**	2759
1968		**1986**	543	**2004**	804
1969		**1987**	200	**2005**	2239
1970	2000	**1988**	371	**2006**	2432
1971	1500	**1989**	84	**2007**	644
1972	400	**1990**	496	**2008**	140
1973	2000	**1991**	479	**2009**	213
1974	3500	**1992**	209	**2010**	262
1975	8500	**1993**	259	**2011**	271
1976		**1994**	485	**2012**	655
1977	340	**1995**	1295		
1978	1200	**1996**	614		
1979		**1997**	466		
1980	1500	**1998**	1879		

Sources: CDFW Grandtab 2011; personal communications with DFG and FWS biologists.

Spring-run Chinook salmon have been documented migrating upstream on Deer Creek from March through early July. Because data is limited, adult immigration timing and immigration peaks are not well known. In 1944 the peak period of adult immigration was during April, and from 1945-1948 the peak period was during May (Cramer and Hammack 1952). According to Cramer and Hammack (1952), the end of adult spring-run Chinook salmon counts made in Deer Creek (from 1940 through 1948) were always brought about by the lack of sufficient water below irrigation diversions for salmon to ascend readily, in addition to the onset of lethal water temperatures (Armentrout *et al*. 1998). From available data compiled for Deer Creek and Mill Creek (Fisher 1994), the peak spring-run migration appears to occur earlier in Deer Creek than in Mill Creek (Armentrout *et al*. 1998).

More recent data regarding the abundance of adult spring-run Chinook salmon is available from snorkel surveys to count holding adults. In late July 2007, a total of 644 adult spring-run Chinook salmon was observed (Harvey-Arrison (2008) (Table 12). Twenty-four miles of stream were surveyed from the Upper Deer Creek Falls downstream to within 2 miles of Dillon Cove (Figure 11). This encompasses the known holding habitat of adult spring-run Chinook salmon in Deer Creek (Harvey-Arrison 2008). Only 1% of the spring-run Chinook salmon population held between Upper Falls and Lower Falls in 2007 (Table 13). Normally, up to 28 % of the population holds in this reach. In 2006, only 3% held upstream of Lower Falls. Attraction flows in the Lower Falls fish ladder has been declining in recent years. The stream channel upstream of the ladder is slowly degrading, reducing the amount of flow being diverted into the ladder. In addition, the supporting wall of the lowermost weir was lost in the 1997 flood, further decreasing the attraction flow for fish. A long-term solution is being explored to improve performance of the ladder by providing more flow through the ladder (Harvey-Arrison 2008).

The Lassen National Forest conducted spring-run Chinook salmon redd surveys in Deer Creek in October 2007. A total of 403 complete redds, 21 practice redds, 18 carcasses and 87 live fish on redds was observed (Harvey-Arrison 2008) (Table 12). As with Mill Creek, this spawner survey is a one-time pass, scheduled after the peak of spawning activity. The redd-to-holding fish ratio in 2007 was 1.6, or one redd for every 1.6 fish counted in the snorkel survey. Ratios of redds to holding spring-run Chinook salmon in Deer Creek for the past 11 years have ranged from 1.1 to 2.5, with an average of 2 fish per redd (Harvey-Arrison 2008).

Table 12. Adult spring-run Chinook salmon holding and redd counts in Deer Creek for 2007

Section	Holding Survey		Spawning Survey	
	# of salmon	% of total	# of redds	% of total
Upper Falls to Potato Patch	7	1	3	1
Potato Patch to Hwy 32	3	<1	0	0
Hwy 32 to Lower Falls	1	<1	0	0
Lower Falls to A-Line	137	22	42	10
A-Line to Wilson Cove	26	4	75	19
Wilson Cove to Polk Springs	66	10	88	22
Polk Springs to Murphy Trail	224	35	63	16
Murphy Trail to Ponderosa Way	53	8	123	30
Ponderosa Way to Trail 2E17	127 [1/]	20	9	2
Trail 2E17 to Dillon Cove			ns	
Totals	**644**	100%	**403**	100%

Source: Harvey-Arrison 2008

As reported by Harvey-Arrison (2008), base flow within spring-run Chinook salmon holding and spawning habitat (measured at the DCV gage) during 2007 ranged from 255 cfs in early May to 74 cfs by the time of spawning. The average base flow during the same time periods for the previous 115 years of record are 395 cfs and 96 cfs, respectively (Harvey-Arrison 2008).

Water temperatures in Deer Creek are recorded at six locations at elevations ranging from 1,500 ft to 3,200 ft. Two recorders failed in 2007, representing thermal conditions at 1,700 ft. elevation and 2,000 ft. elevation. Water temperatures exceeded 2006 values at all locations recorded (Table 13). Water temperatures exceeded optimal values for spring-run Chinook salmon holding at all locations and may have reduced spawning success in 2007. Water temperatures were below tolerance limits for successful spawning after September 2 upstream of A-Line Bridge. At the lowest elevation of spring-run Chinook spawning in Deer Creek, water temperatures were suitable for successful spawning after September 19 (Harvey-Arrison 2008).

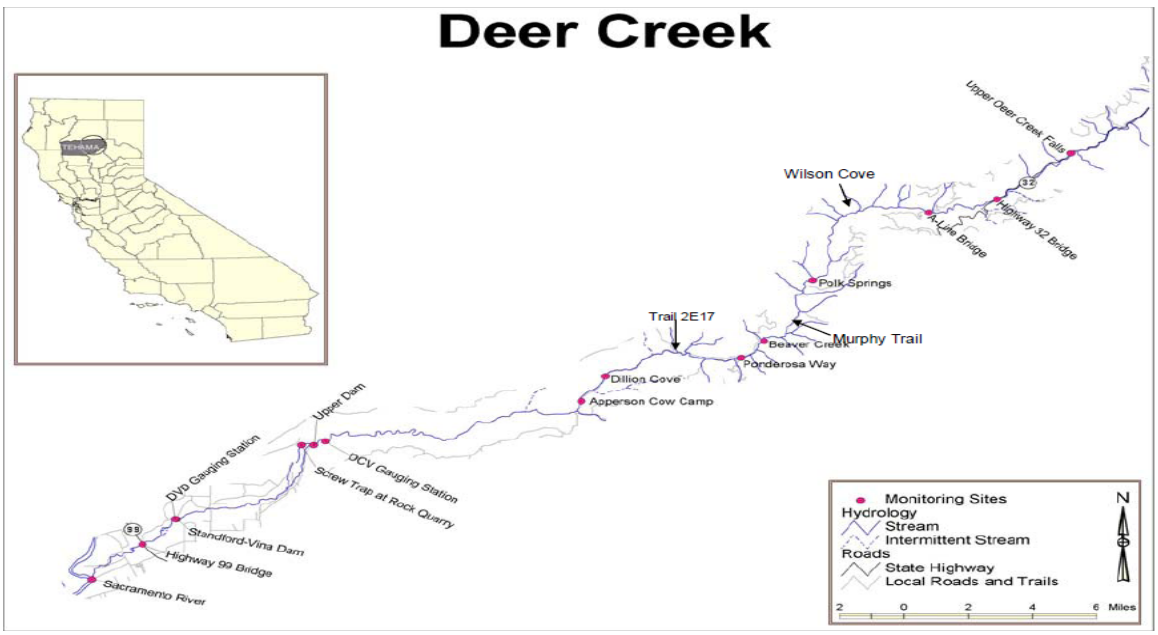

Figure 11. Spring-run Chinook salmon holding and spawning habitat in Deer Creek
Source: Harvey-Arrison 2008

Table 13. Water temperature exceedence and spring-run Chinook salmon distribution in Deer Creek, May through September, 2006 and 2007

Location	Elevation (ft)	% Holding/ % Spawning Salmon 2007	Number of Days Mean Daily Temperature Exceeds:					
			≥59.0°F normal egg viability		≥63.5°F reduced egg viability		≥68.0°F partial mortality	
			2006	2007	2006	2007	2006	2007
At Upper Falls	3600	1 / 1	5	10	0	0	0	0
To A-Line	3000	22 / 10	28	62	0	8	0	0
To Wilson Cove	2700	4 / 19	43	84	3	13	0	0
To Murphy Trail	2000	45 / 38	na	na	na	na	na	na
To Ponderosa Way	1700	8 / 30	90	na	28	na	3	na
To Trail 2E17	1500	20 / 2	99	119	43	86	4	17

Source: Harvey-Arrison 2008

During 2007, bi-monthly Chinook salmon rearing surveys were conducted in Deer Creek. Two locations were sampled (A-line Bridge and Ponderosa Way, Figure 11). Data from the rearing surveys were used to compare relative growth and occurrence of rearing spring-run Chinook salmon juveniles with fall-run and spring-run Chinook salmon juveniles captured downstream at the rotary screw trap (RST) location (Harvey-Arrison 2008a).

Studies in Butte Creek (Ward *et al.* 2003) found the majority of spring-run migrants to be fry moving downstream primarily from December through February associated with flow events, with small numbers of juveniles remaining to rear and migrate as yearlings later in the spring. Juvenile spring-run Chinook salmon emigration patterns in Deer Creek are similar to patterns observed in Butte Creek, with the exception that Deer Creek juveniles typically exhibit a later young-of-the-year migration and an earlier yearling migration (Lindley *et al.* 2004).

The RST, located approximately 9 miles upstream of Deer Creek's confluence with the Sacramento River, was operated from mid-December 2007 through late-March 2008. However, a combination of low flows, shallow water and a damaged live car reduced sampling efficiencies during this period. During this limited sampling period, 23 broodyear (BY) 2006 yearling spring-run Chinook salmon were captured, ranging in size from 66 mm fork length up to 101 mm fork length. A total of 1,197 BY 2007 young-of-year (YOY) Chinook salmon were captured during February and March, ranging in size from 32 mm to 52 mm fork length (Harvey-Arrison 2008a).

According to Lindley *et al.*, (2004) the best available information suggests that Mill and Deer creek spring-run Chinook salmon populations were never very large historically. Hanson *et al.*, (1940) estimated that Mill Creek could support about 3000 and Deer Creek about 7500 spring-run Chinook salmon spawners. Large numbers of spring-run Chinook salmon once migrated past Mill and Deer creeks on their way to upper Sacramento tributaries, and Mill and Deer creeks may have received significant numbers of strays, causing their dynamics to be linked to that of the up-river tributary populations. The NMFS TRT did not conclude as to whether Mill and Deer creeks are independent of one another, although they did conclude that spring-run Chinook salmon in these streams are currently independent from other spring-run Chinook salmon populations and represent a significant lineage within Central Valley Chinook ESU.

Steelhead

Steelhead begin migration into Deer Creek during the late-fall and winter, primarily when flows increase from storms. Ladder counts at Clough Dam, on Mill Creek, between 1953 and 1963, show that adult steelhead migrate upstream from September through June (Van Woert 1964). Harvey (1995) observed two distinct migration peaks in Van Woert=s (1964) data. The largest peak occurred from late-October to mid-November, and accounted for 30 percent of the run. A smaller peak occurred in the first 2 weeks of February, and accounted for 11 percent of the run. Because Deer Creek is in the same geographic region as Mill Creek, and runoff patterns are similar, historic steelhead migration timing was probably likely to be similar. Chinook salmon emigration studies on Deer and Mill Creeks have incidentally captured emigrating steelhead in rotary screw traps. Steelhead generally are captured from November through June, with most fish captured from December through March.

The three diversion dams on the 10 miles of stream between the canyon mouth of Deer Creek and the Sacramento River can provide passage impediments to adult steelhead during low flow periods. All of the diversion structures have CDFW designed and operated fish ladders and screens (Deer Creek Conservancy Website 2007).

The Upper Falls fish ladder is functioning during the time steelhead would be migrating upstream (Deer Creek Conservancy Website 2007). As previously discussed, the ladder is closed during the time when spring-run Chinook salmon would be migrating upstream because very little holding habitat exists above this point.

Steelhead habitat in the upper watershed is considered to be excellent with an abundance of spawning gravel (DWR 2005; USFWS 1999).

Water temperatures throughout the Deer Creek watershed are suitable for juvenile steelhead rearing except for the summer months when temperatures in the lower watershed become too high to support juvenile steelhead rearing. Cold water refugia are likely available during the summer months in the upper watershed.

The explicit time period when juvenile steelhead emigrate from Deer Creek has not been documented. However, it is likely that it occurs from October through May as seasonal flows increase. The extent to which flow fluctuations from water diversions in Deer Creek may cause juvenile stranding is currently unknown.

As described above, during 2007-2008 RST monitoring was conducted sporadically between mid-December and late-March. The Deer Creek RST was in operation a total of 32 days. A total of 18 outmigrating steelhead was captured in the Deer Creek RST between December and March, ranging in size from 58 mmfl to 282 mm (fork length) (Harvey-Arrison 2008a).

With the exception of some limited data on juvenile outmigration (mentioned above), little is known about the winter-run steelhead in Deer Creek and the distribution and abundance of their habitat. Considering steelhead life-history requirements, however, their range within the system is likely to include the range described for spring-run Chinook salmon, and may actually extend beyond this range (i.e., into potentially suitable upstream habitat or tributaries). Because steelhead are, on average, smaller in size than Chinook salmon and can utilize smaller substrate for spawning, potential habitat exists for them beyond the known range of Chinook salmon.

Mill Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to Central Valley spring-run Chinook salmon and steelhead in Mill Creek include, but are not limited to the following:

- Elevated water temperatures affecting adult immigration and holding
- Low flows affecting attraction and migratory cues of immigrating adults
- Possible catastrophic events (e.g., fire or volcanic activity)

Watershed Description

Mill Creek is an eastside tributary to the Sacramento River that flows in a southwesterly direction for approximately 60 miles and drains 134 square miles (DWR 2009). The creek originates near a thermal spring area in Lassen Volcanic National Park (LVNP) at an elevation of approximately 8,200 feet. It initially flows through meadows and dense forests and then descends rapidly through a steep rock canyon into the Sacramento Valley. Upon emerging from the canyon, the creek flows 8 miles across the Sacramento Valley floor, entering the Sacramento River about 1 mile north of the town of Tehama, near Los Molinos, at an elevation of approximately 200 feet (DWR 2009).

Relatively few restoration actions are needed to restore watershed and ecosystem function for the purpose of supporting the freshwater life history stages of CV spring-run Chinook salmon and CV steelhead in Mill Creek. With the exception of impaired stream flows and fish passage conditions on the valley floor below agricultural diversions, habitat in the upper watershed is in good condition. Those actions that are required are localized in nature and when fully implemented have a high likelihood of restoring or maintaining good fish passage conditions. A water exchange agreement already is in place between the CDFW and water users on Mill Creek. Although the agreement improves fish passage conditions for CV spring-run Chinook salmon, a comprehensive hydraulic fish passage evaluation and monitoring plan has not been developed to assess the effectiveness of the agreement. Long-term verification of the flows, and an evaluation of existing dams for fish passage suitability are needed to ensure passage is provided at a wide range of stream flows and water year types. In the upper watershed Federal land management practices are guided by a long-term anadromous fish conservation strategy. Private timberland management plans lack a comprehensive anadromous habitat protection strategy.

Mill Creek, along with Deer Creek and Butte Creek, is recognized as supporting one of three remaining self-sustaining CV spring-run Chinook populations. Habitat used for holding and spawning is located at high elevations and is considered to be high quality (CDFW 1998). The high elevation habitats in Mill Creek are isolated from fall-run Chinook salmon by low summer and fall flows. High water temperatures prevent geographic co-occurrence and is the thermal gradient that maintains genetic and phenotypic diversity of the populations. The NMFS TRT did not conclude as to whether Mill and Deer creeks are independent of one another, although they did conclude that spring-run Chinook salmon in these streams are currently independent from other spring-run Chinook salmon populations and represent a significant lineage within Central Valley Chinook ESU.

When considering watersheds in the Central Valley that contribute current viable populations for spring-run Chinook salmon, Mill Creek is considered a conservation stronghold for the ESU. Lindley *et al.* (2007) classified the Mill Creek spring-run Chinook salmon population as having a moderate risk of extinction. Over the past three years, the abundance of the Mill Creek population has been in steep decline, and the extinction risk may be trending toward moderate to high. With the implementation of key recovery actions, the watershed has a high potential for sustaining a population at a low risk of extinction (Lindley *et al*. 2007) for the following reasons: (1) Mill Creek contains a sufficient amount of holding and spawning habitat to support a population with an effective size greater than 500 adults or a census population greater than 2,500; (2) hatchery influence is low and expected to decrease over time, (3) the number and magnitude of recovery actions needed within the Mill Creek watershed are limited and localized.

Mill Creek also supports all life history stages of steelhead, although not is much is known about the long term viability of steelhead in the DPS. Mill Creek has a high potential for supporting a viable, self-sustaining steelhead population because of the extensive (25 miles) or suitable spawning and rearing habitat.

The anadromous fish habitats in Mill Creek (along with Deer, Antelope, Battle and Butte Creeks) are probably the best remaining habitat above the Central valley for anadromous salmonids, and serve as important anchors for their recovery. It is also worth noting that aquatic resources in the Mill Creek watershed have regional significance for a number of reasons. There are diversion structures in the valley section of Mill Creek, however, as opposed to 90% of the rivers draining into the Sacramento Basin, there are no major water impoundments along the Mill Creek corridor. Unlike many other rivers in the Central Valley which find relief in the Sacramento River because their channels have been blocked by dams and diversions, anadromous fish have been able to maintain passage, and native fish communities have survived in the free flowing sections. Deer Creek is also considered essential to the recovery and perpetuation of the wild stocks of winter-run steelhead in the Central Valley (Reynolds et. al. 1993; McEwan and Jackson 1996) in part because of its current habitat conditions.

In Mill Creek the primary focus for spring-run Chinook salmon restoration is on maintaining flow conditions for upstream migrating adults so they can access important holding and spawning habitat (Mills and Ward 1996) and for outmigration fry. To this end, water exchange programs are underway or in development with cooperating irrigation districts. The programs are intended to develop and operate wells to offset bypass flows needed for spring-run Chinook salmon and to implement water use efficiency measures to reduce irrigation water demand.

How will Mill Creek help to buffer the negative effects of climate change for salmonids in the Central Valley?

Under the expected climate warming of around 5°C, substantial salmonid habitat would be lost in the Central Valley, with significant amounts of habitat remaining primarily in the Feather and Yuba rivers, and remnants of habitat in the upper Sacramento, McCloud, and Pit rivers, Battle and Mill creeks, and the Stanislaus River (Lindley *et al*. 2007). Under the less likely but still possible scenario of an 8°C warming, spring-run Chinook salmon habitat would be found only in the upper-most reaches of the north fork Feather River, Battle Creek, and Mill Creek (Lindley *et al*. 2007).

Geology

Mill Creek is located within the southernmost extension of the Cascade Range. As reported by Armentrout *et al*. (1998), the Tuscan formation of the Pliocene age, comprised primarily of mudflows, dominates the geology. This formation dips gently and thins toward the southwestern portions of the watersheds. Overlaying the Tuscan formation are flows of rhyolite, which form the Mill and Lost Creek Plateaus. Geologic diversity is supplied by several influences. These include andesitic plugs that intrude the Tuscan formation along two linear trends, relatively minor exposures of marine sedimentary rocks, and at lower elevations, quaternary sediments of the Sacramento Valley. Glacial processes shaped some of the higher elevation landforms.

Soils generated from these parent materials are generally productive; erosion rates range from low to moderate on the andesitic soils to high to very high on the rhyolitic soils. Mass wasting is evident in the Mill Creek watershed, dominated by debris flows in colluvium-filled hillslope hollows. Failures are episodic and triggered by extreme precipitation events. Surface erosion, especially on the rhyolitic soils, is the other major source of sediment. Erosion from recent volcanic deposits in and near LVNP within the headwaters of Mill Creek contributes turbidity to Mill Creek nearly year round (Armentrout *et al*. 1998).

The headwaters of Mill Creek are cutting through an ancient andesitic stratocone (layered andesitic lavas and pyroclastic deposits that were erupted at 600-400 ka). The hydrothermal system associated with this ancient volcano has altered the more permeable pyroclastic rocks in the center of it to mostly clay. This has enhanced erosion locally and is a significant contributor to the fine-grained sediment load of Mill Creek.

The soils in the Mill Creek Watershed range in parent material from volcanic breccia, including basalt, andesite, and rhyolite, to metamorphic rock. Dominant soils in the Mill Creek watershed are Toomes soils and Supan soils (Armentrout *et al*. 1998). The Toomes series is a well drained, shallow to very shallow, extremely rocky soil. The erosion hazard is moderate to severe, depending on the slope. Much of the watershed is composed of colluvial land which is characterized by steep slopes and is highly erosive due to loose rock and soil material. Therefore catastrophic events such as large rain events, stand reducing fires, and volcanic activity could lead to mass wasting events that could potentially devastate the fishery. So, management actions to address these threats, such as good fire plans need to be in place to avert this risk to the population.

Hydrology

The range in elevation in the Mill Creek watershed influences precipitation which varies from 25 to nearly 80 inches. Mill Creek produces on average 215,000 acre ft (or 2.56 ft/acre) of water per year. Peak flows from the watershed are dominated by rain-on-snow events.

The majority of annual flow events occur in December, January and February when snow could be expected to be present in the transient snow zone (above about 3,000 feet in elevation). Earlier peaks (e.g., September, October and November) are most likely rain events with little snow influence. Later peaks (mid-March through May) indicate snowmelt generated peaks. The recorded maximum flow on Mill Creek occurred on December 11, 1937. This storm was far above the gauge height (maximum at that time of 14,000 cfs), and was first calculated by USGS at 23,000 cfs, but later revised to 36,400 cfs.

Morgan and Growler Hot Springs are located along Mill and Canyon Creeks just north of Highway 36. The last additional geothermal input into Mill Creek occurs just north of the town of Mill Creek. These springs have a seasonal and diurnal variation but contribute about 10-15 % to the stream flow (Armentrout *et al*. 1998). Arsenic is added to Mill Creek by the Morgan/Growler hydrothermal system but the clay from the altered volcanics act as a stabilizing influence and adsorbs 70% of the arsenic by the time the stream reaches Highway 36 (Armentrout *et al*. 1998).

There are three diversion dams on Mill Creek. Two are operated by LMMWC and one is operated by the Clough and Owens ranches. During low flow periods the existing water rights are sufficient to dewater the stream. Late spring and early summer diversions have resulted in flows low enough to block access for late-migrating adult salmonids. Low flows may also prevent downstream migrating smolts from reaching the Sacramento River (McEwan and Jackson 1996).

Land Use

As reported by Armentrout *et al*. (1998), extended low gradient channel types are uncommon on the Mill Creek mainstem, and are restricted to upper Mill Creek and reaches in the Valley floor. Steep slopes adjacent to the main channel historically served as barriers to human activity, and recent land use allocations have protected these areas such that the mainstem is essentially undisturbed. However, timber harvest and grazing have impacted many of Mill Creek's tributary streams.

Approximately half of the forest lands in the region are in private ownership, providing support to local economies. Historically, range management was a major land use in the watershed. In the upper watershed, the number of animals grazing has declined substantially over the past hundred years, but ranching still provides limited employment. Pressure has increased on ranchers and growers to convert their lands to residential development (Armentrout *et al*. 1998).

The Lassen National Forest, through their Land and Resource Management Plan (USFS 1992), is decommissioning roads throughout the forest that are no longer in use. One of the primary reasons for this decommissioning is to reduce sediment load to anadromous watersheds such as Mill and Deer creeks.

Recreational activities in the watershed have steadily increased over the past decades with the increased population in the region. Lassen National Park and Forest Service Campgrounds in the Mill Creek watershed are sites of concentrated use.

Fisheries and Aquatic Habitat

As reported by Armentrout *et al*. (1998), Mill Creek (in addition to Antelope and Deer Creeks) still support the majority of their original native aquatic species assemblages. The three watersheds have been rated as having high "biotic integrity" (defined as "the ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region") (Moyle and Randall 1996 as cited in Armentrout *et al*. 1998).

Unlike most tributary streams of the Sacramento and San Joaquin rivers that now have major water storage facilities that inundate or block miles of historical anadromous spawning habitat, headwater stream habitat in Mill Creek is still available for utilization by anadromous fish. Within the boundary of the Lassen National Forest, an estimated total of 43 miles of anadromous fish habitat is present in Mill Creek. From its origin in Lassen Valley National Park (LVNP) to its confluence with the Sacramento River, Mill Creek is approximately 58 miles long. Nearly all of the mainstem aquatic habitat is utilized and/or available to spring-run Chinook salmon and winter-run steelhead for one or more life history requirements (Armentrout *et al*. 1998).

Evaluations of Central Valley anadromous fishery resources (Reynolds et. al. 1993; McEwan and Jackson 1996; Harvey-Arrison 2008) have consistently identified insufficient instream flows as one factor limiting anadromous fish production in the Mill Creek watershed. This has led to progressive cooperative programs between agencies and water users including the irrigation district, landowners, the local Conservancy, DWR and CDFW in the Mill Creek watershed to develop and operate wells, or to obtain water rights (lease or purchase) to offset bypass flows needed for spring-run Chinook salmon and steelhead.

Elevated water temperatures during the adult spring-run Chinook salmon upstream migration and holding period (May-September) also have been identified as a limiting factor, particularly at elevations $\leq$ 2,100 feet msl.

Spring-run Chinook Salmon

The spring-run salmon population currently represents a good example of a viable population of fish in the Central Valley. The factors that contribute to this persistent viable spring-run population are cold water inputs from the upper watershed, relatively intact riparian habitat, and unimpeded corridor. Although the watershed lies in the Lassen National Forest, where cutting has occurred, many of the road systems have been decommissioned, so sedimentation rates, with the exception of high flood events or areas that have been burned, should be considered to be at the historic baseline. Therefore, the spring-run populations are experiencing conditions still close to ideal for their evolutionary life history trajectory.

In terms of population abundance, much good data has been collected**.** As reported by Harvey-Arrison (2008), Mill Creek spring-run Chinook salmon populations have been monitored since the late 1940's (Table 14). Various counting methods have been employed, including carcass and redd counts, electronic counters and fish traps. The natural turbidity of Mill Creek makes annual counts by direct observation impractical. The most consistent data available is a trapping station at the Clough dam that operated from 1954 thru 1963 (Van Woert 1964, as cited in Harvey-Arrison 2008). During this 10 year period, spring-run Chinook salmon counts ranged from 1,203 to 3,485. Since the removal of Clough dam in 1997, redd counts have been used to estimate returning spring-run Chinook salmon. Spring-run Chinook salmon escapement estimates for Mill Creek are available from 1960 through 2012 (Table 14).

Table 14. Adult spring-run Chinook salmon population estimates for Mill Creek from 1960 to 2012. Estimates are not available for all years.

Year	Adult Estimate	Year	Adult Estimate	Year	Adult Estimate
1960	2368	**1978**	925	**1996**	253
1961	1245	**1979**		**1997**	202
1962	1692	**1980**	500	**1998**	424
1963	1315	**1981**		**1999**	560
1964	1539	**1982**	700	**2000**	544
1965		**1983**		**2001**	1100
1966		**1984**	191	**2002**	1594
1967		**1985**	121	**2003**	1426
1968		**1986**	291	**2004**	998
1969		**1987**	90	**2005**	1150
1970	1500	**1988**	572	**2006**	1002
1971	1000	**1989**	563	**2007**	920
1972	500	**1990**	844	**2008**	362
1973	1700	**1991**	319	**2009**	220
1974	1500	**1992**	237	**2010**	482
1975	3500	**1993**	61	**2011**	366
1976		**1994**	723	**2012**	542
1977	460	**1995**	320		

Sources: CDFW Grandtab; personal communications with DFG and FWS biologists.

Based on observations of spring-run Chinook salmon adults holding and/or spawning, the known range of salmon habitat extends a distance of approximately 48 miles from near the Little Mill Creek confluence (C. Harvey 1996, personal communications, as cited in Armentrout *et al*. 1998) upstream to within 1/2 mile of the LVNP boundary (personal observation of adult holding, as cited in Armentrout *et al*. 1998). Although adults have been reported spawning in "Middle Creek" (Armentrout *et al*. 1998), a small tributary located approximately 2 miles downstream of the park boundary, suitable spawning habitat on the mainstem of Mill Creek extends to near Morgan Hot Springs (approximately three miles downstream of LVNP).

Mill Creek spring-run Chinook salmon redd survey results from 2007 are provided in Table 15 (Harvey-Arrison 2008). Forty-one miles of spring-run Chinook salmon spawning habitat were surveyed beginning upstream of the Highway 36 Bridge downstream to the Steel Tower Transmission Lines (Figure 12). Reaches with the highest number of redds observed include Canyon Camp to Sooner Place, and Sooner Place to McCarthy.

Table 15. Mill Creek spring-run Chinook salmon spawning distribution in 2007

Survey Reach	# of Redds Counted	% of Total
Above Hwy 36	3	1
Hwy 36 to Little Hole-in-Ground	17	4
Little Hole-in-Ground to Hole-in-Ground	14	3
Hole-in-Ground to Ishi Trailhead	18	4
Ishi Trailhead to Big Bend	11	2
Big Bend to Canyon Camp	29	6
Canyon Camp to Sooner	70	15
Sooner Place to McCarthy	78	17
McCarthy to Savercool	38	8
Savercool to Black Rock	35	8
Black Rock to Ranch House	65	14
Ranch House to Avery	23	5
Avery to Pape	51	11
Pape to Buckhorn	8	2
Buckhorn to Transmission Lines [1]	ns [1]	
Total Redds	460	100%
Population Estimate (redds x 2)	920	

[1] Helicopter Survey not made in 2007

Source: Harvey-Arrison 2008

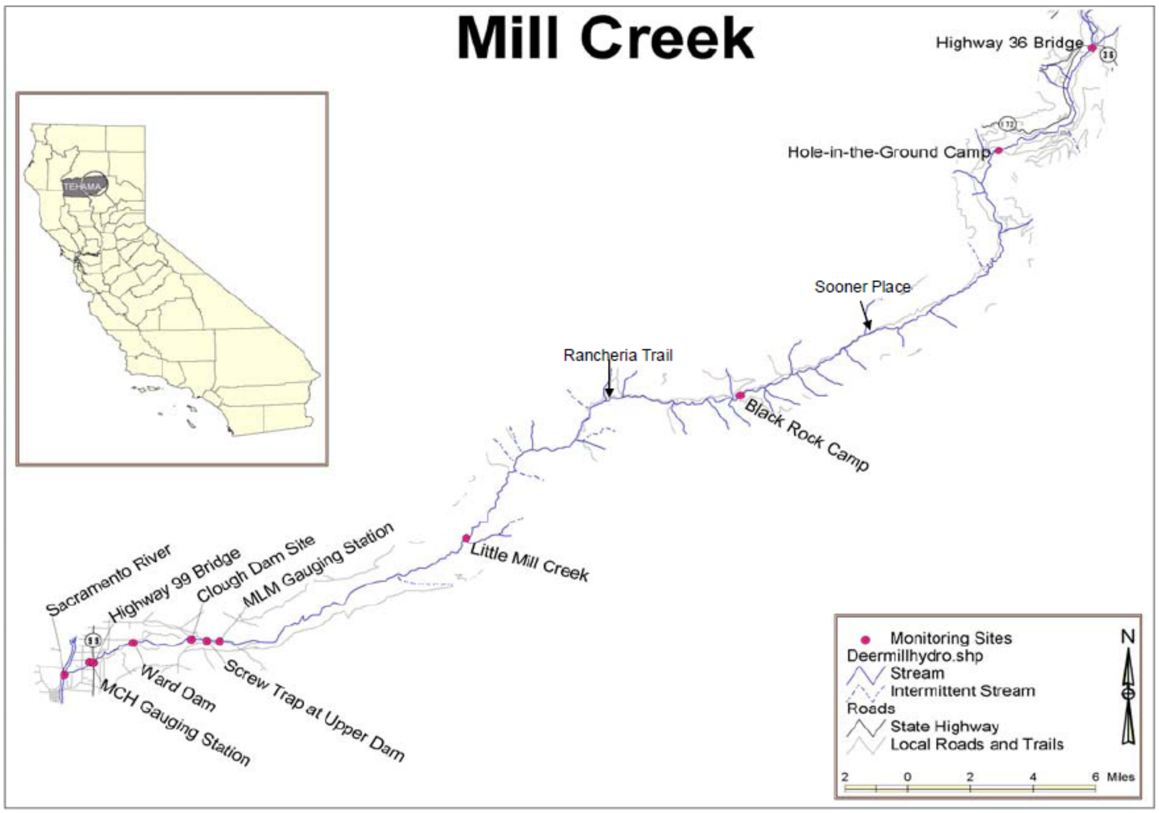

Figure 12. Map of spring-run Chinook salmon holding and spawning habitat in Mill Creek
Source: Harvey-Arrison 2008

Water temperature recorders are located in six locations in spring-run Chinook salmon holding and spawning areas in Mill Creek, ranging from 4800 ft. elevation to 1000 ft. elevation. Table 14 shows the number of days at each elevation that water temperatures exceeded upper tolerance limits for normal egg development and adult salmon survival for both 2007 and 2006. These exceedence periods have an effect on the population in terms of growth and survival, particularly in the egg and incubation stages. Mill Creek water temperatures were higher in 2007 than 2006.

In 2007, exceedence of optimal water temperatures occurred at elevations below 2800 ft. In 2006, water temperatures remained at levels supporting normal egg viability above 2100 ft elevation (Harvey-Arrison 2008).

Table 16. Water temperature exceedence and spring-run Chinook salmon spawning distribution in Mill Creek, May through September, 2006 and 2007

Location	Elevation (ft)	% Spawning Salmon 2007	Number of Days Mean Daily Temperature Exceeds: ≥59.0°F normal egg viability		≥63.5°F reduced egg viability		≥68.0°F partial mortality	
			2006	2007	2006	2007	2006	2007
To Brokenshire	4800	1	0	na	0	na	0	na
To Hole-in-Ground	4200	7	0	14	0	0	0	0
To Sooner Place	2800	27	5	19	0	0	0	0
To Black Rock	2100	33	26	91	3	13	0	0
To Rancheria Trail	1600	16	77	160	13	57	0	10
To Little Mill	1000	2	91	124	45	99	5	42

Source: Harvey-Arrison 2008

Studies in Butte Creek (Ward *et al.* 2003) found the majority of spring-run migrants to be fry moving downstream primarily from December through February associated with *flow events*, with small numbers of juveniles remaining to rear and migrate as yearlings later in the spring. Juvenile spring-run Chinook salmon emigration patterns in Mill Creek are similar to patterns observed in Butte Creek, with the exception that Mill Creek juveniles typically exhibit a later young-of-the-year migration and an earlier yearling migration (Lindley *et al.* 2004).

Steelhead

Steelhead begin migration into Mill Creek during the late-fall and winter, primarily when flows increase from storms. Ladder counts at Clough Dam, on Mill Creek, between 1953 and 1963, show that adult steelhead migrate upstream from September through June (Van Woert 1964). Harvey (1995) observed two distinct migration peaks in Van Woert=s (1964) data. The largest peak occurred from late-October to mid-November, and accounted for 30 percent of the run. A smaller peak occurred in the first 2 weeks of February, and accounted for 11 percent of the run. Based on observations using a video weir in Mill Creek from March 6 through June 18, 2007, peak upstream and downstream steelhead passage occurred from May 8-10, 2007 (Killam and Johnson 2008). This may represent the presence of two runs of steelhead in Mill Creek, with one run exiting the system while another run is entering the system during May (Killam and Johnson 2008).

Chinook salmon emigration studies on Deer and Mill Creeks have incidentally captured emigrating steelhead in rotary screw traps. Steelhead generally are captured from November through June, with most fish captured from December through March. Harvey-Arrison (2008a), reported that during the 2007-2008 juvenile steelhead outmigration monitoring period, 297 steelhead were captured in the Mill Creek RST from mid-October 2007 through early June 2008.

Steelhead counts in Mill Creek are available from 1953 to 1963, 1980, 1993, and 1994, for adult fish that passed Clough Dam. From 1953 to 1963, between 417 and 2,269 steelhead, with an annual average of 911 steelhead were counted at Clough Dam (Van Woert 1964). In 1980, 280 steelhead were counted, and in the 1993 to 1994 migration season, 34 steelhead were estimated. Moore (2001) used snorkel and foot surveys in January, March, and April to count adult steelhead and steelhead redds in Mill Creek. These surveys observed 15 adult steelhead and 31 redds in about 3 to 4 percent of the accessible anadromous habitat in Mill Creek. The observations do not represent a population estimate because the entire amount of habitat was not surveyed, and surveys may have missed the peak spawning period.

Antelope Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to Central Valley spring-run Chinook salmon and steelhead in Antelope Creek include, but are not limited to the following:

- ❖ Agricultural diversion dams impeding or blocking adult immigration
- ❖ Water diversions entraining juveniles
- ❖ Low flow conditions affecting immigrating adults
- ❖ Poorly defined migration channels downstream from canyon mouth
- ❖ Noxious weeds invading downstream areas affecting juvenile rearing and outmigration
- ❖ Possible catastrophic event (e.g., fire or volcanic activity)

Watershed Description

Antelope Creek originates in the Lassen National Forest in Tehama County at an elevation of about 6,800 feet. The creek flows southwest from the foothills of the Cascade Range and enters the Sacramento River at RM 235, 9 miles southeast of the town of Red Bluff. The Antelope Creek drainage encompasses approximately 123 square miles (USFWS 1995).

Relatively few restoration actions are needed to restore watershed and ecosystem function for the purpose of supporting the freshwater life history stages of CV spring-run Chinook salmon and CV steelhead in Antelope Creek. With the exception of impaired stream flows and fish passage conditions on the valley floor below agricultural diversions, habitat in the upper watershed in good condition. Those actions that are required are localized in nature and when fully implemented have a high likelihood of restoring good fish passage conditions. Antelope Creek is diverted into several channels below the Edward Diversion Dam and a single migration channel and fish passage flows need to be established to ensure that adult salmon and steelhead have unimpeded access to upstream spawning habitat and juveniles have unimpaired downstream migration. Fish screens with suitable bypass flows also need to be installed at the Edward Dam. In the upper watershed Federal land management practices are guided by a long-term anadromous fish conservation strategy. Private timberland management plans lack a comprehensive anadromous habitat protection strategy.

Antelope Creek is believed to support a natural population of spring-run Chinook salmon as well as steelhead. CDFW (1998) states that the Antelope Creek spring-run population is not persistent, and the Central Valley Technical Recovery Team considers the Antelope Creek population to be dependant upon the populations in Deer, Mill and Butte creeks (70 FR 37160 (June 28, 2005)). In addition, the upper reaches of Antelope Creek are still fairly undeveloped and contain good habitat for Chinook salmon and steelhead trout. Antelope Creek has the potential to produce a sustainable population of 2,000 spring-run Chinook salmon, although inadequate flows due to two low head diversion dams prevent runs from realizing this potential (Rectenwald 1998).

In Antelope Creek, the primary focus for anadromous salmonid restoration is on improving flow conditions and fish passage for upstream migrating adults so they can access important holding and spawning habitat, and for outmigrating fry.

Geology

Antelope Creek is located within the southernmost extension of the Cascade Range. The Tuscan formation of the Pliocene age, comprised primarily of mudflows, dominates the geology (Armentrout *et al*. 1998). This formation dips gently and thins toward the southwestern portions of the watershed. Geologic diversity is supplied by several influences. These include andesitic plugs that intrude the Tuscan formation along two linear trends, relatively minor exposures of marine sedimentary rocks, and at lower elevations, quaternary sediments of the Sacramento Valley. Glacial processes shaped some of the higher elevation landforms.

Soils generated from these parent materials are generally productive; erosion rates range from low to moderate on the andesitic soils to high to very high on the rhyolitic soils. Mass wasting is evident in the Antelope Creek watershed, dominated by debris flows in colluvium-filled hillslope hollows. Failures are episodic and triggered by extreme precipitation events. Surface erosion, especially on the rhyolitic soils, is the other major source of sediment. However, Antelope Creek has less rhyolitic soils than nearby watersheds including Deer Creek and Mill Creek and thus, has lower surface erosion rates and less mass wasting than these other watersheds (Armentrout *et al*. 1998).

Hydrology

The Antelope Creek watershed produces on average 110,800 acre ft (1.41 ft/acre) of water per year. The majority of annual flow events occur during December through February when snow could be expected to be present in the transient snow zone (i.e., above about 3,000 feet in elevation). Earlier peaks (September through November) are most likely rain events with little snow influence. Later peaks (mid-March through May) indicate snowmelt-generated peaks.

In wettest years, average flows in winter months range from 200 to 1,200 cfs. In the driest years, flows in winter average 50 cfs. In all but the wettest years, summer and early fall flows average from 20 to 50 cfs. The natural flow pattern is altered by diversions in the lower creek from spring through fall. Flows are typically diverted from April 1 through October 31 (County of Butte Website 2007).

There are two diversions on Antelope Creek, both located at the canyon mouth. One is operated by the Edwards Ranch, which has a water right of 50 cfs, and the other is operated by the Los Molinos Mutual Water Company (LMMWC), which has a water right of 70 cfs (USFWS 1995, CDFW 1998). Unimpaired natural flows are often less than the combined water rights of the two diverters, resulting in a total dewatering of Antelope Creek (92 cfs from 1940 to 1980) during critical migration periods (USFWS 1995). Although diversions typically occur between April 1 and October 31, in 2009 Edwards Ranch diverted water during January (P. Bratcher, CDFW, pers. comm. 2009). The stream can potentially be dewatered when both diversions operate. Late spring and early summer diversions have resulted in stream flows low enough to block access for late-migrating adult salmonids. In addition, flow from Antelope Creek can move through a different channel (i.e., New Creek), further impacting instream flow in Antelope Creek (P. Bratcher, CDFW, pers. comm. 2009).

Land Use

The middle and upper portions of Antelope Creek are narrow, with moderate to steep slopes (Armentrout *et al*. 1998). Extended low gradient channel types are uncommon on the mainstem, restricted to McClure Place, Paynes Place, and reaches in the Valley floor. Steep slopes adjacent to the main channel historically served as barriers to human activity, and recent land use allocations have protected these areas such that the mainstem is essentially undisturbed. Timber harvest and grazing have impacted many of Antelope Creek's tributary streams (Armentrout *et al*. 1998).

Approximately half of the forest lands in the region are in private ownership, providing support to local economies. Historically, range management was a major land use in the watershed. In the upper watershed, the number of animals grazing has declined substantially over the past hundred years, but ranching still provides limited employment. Pressure has increased on ranchers and growers to convert their lands to residential development (Armentrout *et al*. 1998).

Recreational activities in the watershed have steadily increased over the past decades with the increase in the human population in the region. Sites of concentrated recreational use in the Antelope Creek watershed include Lassen National Park, Forest Service campgrounds, and the Tehama Wildlife Area. The Tehama Wildlife Area is located approximately one hour east of Red Bluff, California, and contains 46,862 acres of oak woodland, grassland and chaparral. Recreational activities in the Tehama Wildlife Area include hunting, camping, fishing, and wildlife viewing (CDFW Website 2009).

Fisheries and Aquatic Habitat

Antelope Creek provides approximately 30 miles of anadromous fish habitat from its confluence with the Sacramento River upstream and 2 and 3 miles of habitat on the North and South Forks of Antelope Creek, respectively, above their confluence (Armentrout *et al*. 1998). CDFW habitat surveys and water temperature monitoring have identified limited, but adequate adult holding and spawning habitat for CV spring-run Chinook salmon, most of which is located in the Mainstem of Antelope Creek, near the confluence with the North and South Fork. Antelope Creek fish habitat is relatively unaltered above the valley floor but lack of adequate migratory attraction flows into the Sacramento River to this habitat prevents optimum use by anadromous fish (DWR 2009).

Two water diversions exist at the canyon mouth of Antelope Creek. Flow in Antelope Creek is typically diverted April 1 through October 31. In 1976 two fish screens were installed on the LMMWC diversion dam. Fish screens were design to keep salmon and steelhead from being lost in the diversions (Rectenwald 1998). A fish ladder at Edwards Irrigation Dam was constructed in 2007 and is reported to be adequate for fish passage. Currently, Paynes Crossing (Middle Slab) is a passage impediment during springs when there is low flow (Brenda Olson, USFWS, personal communication).

The lower reach of the stream is usually dry when both diversions are operating. Such flows affect migrating adult steelhead at the end and beginning of the run and smolts that are migrating in the spring. Also, adult spring-run are unable to enter the stream during the irrigation and diversion season (Rectenwald 1998). In 2007 and 2008, rescues of spring Chinook salmon juveniles and steelhead have been necessary due to an early irrigation season (Brenda Olson, USFWS, personal communication).

Anadromous salmonid habitat in the Antelope Creek watershed occurs at elevations of 1600 feet and below, resulting in an increased susceptibility to warmer water temperatures and potentially less optimal conditions for anadromous salmonids, compared to some of the other Northern Sierra Nevada watersheds (i.e., Mill and Deer creeks) (P. Bratcher, CDFW, pers. comm. 2009).

Spring-run Chinook Salmon

Historically, Antelope Creek supported “a few hundred” adult fish (Hallock 1956; Van Woert 1959). Hayes and Lingquist (1966) estimated the run to be about 500 fish annually. From 2005 through 2008, Antelope Creek spring-run Chinook salmon escapement was estimated at 82, 102, 26 and 2 fish, respectively (Table 15) (CDFW 2009). Between 1993 and 2008, the highest annual spring-run Chinook salmon escapement was 154, occurring in 1998 (CDFW 2009).

The range of spring-run Chinook salmon in the Antelope Creek watershed extends from upstream of Judd Creek on the North Fork, to Buck’s Flat on the South Fork, downstream to approximately Facht Place on the mainstem (Harvey-Arrison 2008). Approximately 16 miles of suitable holding and spawning habitat is available to spring-run Chinook salmon (Harvey-Arrison 2008).

Antelope Creek was snorkel surveyed to count holding adult spring-run Chinook salmon in July 2007 (Harvey-Arrison 2008). A total of 26 adult Chinook salmon were observed. Sixteen miles of stream were surveyed including the North Fork from 0.8 miles upstream of Judd Creek's confluence to the South Fork confluence, the South Fork from the South Antelope Gun Club to the North Fork confluence, and the mainstem from the North and South Fork confluence to Facht Place (Table 17 and Figure 13).

One spawning survey was completed in October 2007, covering the same reaches as the holding survey, except it omitted the North Fork upstream of Judd creek and the mainstem downstream of Canyon Mouth. A total of 10 redds, 0 carcasses and 3 live salmon was observed (Table 18 and Figure 13) (Harvey-Arrison 2008).

Table 17. Adult spring-run Chinook salmon population estimates for Antelope Creek from 1983 to 2011. Estimates are not available for all years.

Year	Adult Estimate	Year	Adult Estimate	Year	Adult Estimate
1983	59	**1993**	3	**2003**	46
1984		**1994**	0	**2004**	3
1985		**1995**	7	**2005**	82
1986		**1996**	1	**2006**	102
1987		**1997**	0	**2007**	26
1988		**1998**	154	**2008**	2
1989		**1999**	40	**2009**	0
1990		**2000**	9	**2010**	17
1991		**2001**	8	**2011**	6
1992	0	**2002**	46		

Sources: CDFW Grandtab; personal communications with DFG and FWS biologists.

Table 18. Adult spring-run Chinook salmon holding and redd counts in Antelope Creek for 2007

Section	Holding Salmon		Spawning Salmon	
	# of salmon	% of total	# of redds	% of total
North Fork	0	0	2	20
South Fork	0	0	0	
Main Stem to Paynes	2	8	0	
Paynes to Canyon Mouth	22	84	8	80
Canyon Mouth to Facht Place	2	8	ns	
Totals	**26**	100%	**10**	100%

[1] ns = no survey

Source: Harvey-Arrison 2008

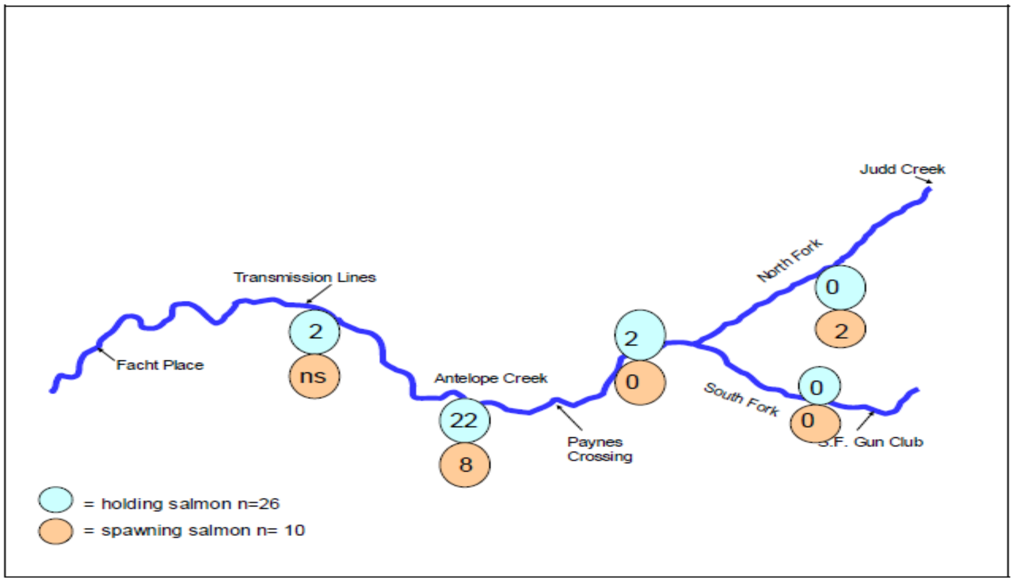

Figure 13. Map of Spring-run Chinook salmon holding and spawning distribution in Antelope Creek for 2007 Source: Harvey-Arrison 2008

Steelhead

Steelhead begin migration into Antelope Creek during the late-fall and winter, primarily when flows increase from storms. Ladder counts at Clough Dam, on Mill Creek, between 1953 and 1963, show that adult steelhead migrate upstream from September through June (Van Woert 1964). Harvey (1995) observed two distinct migration peaks in Van Woert=s (1964) data. The largest peak occurred from late-October to mid-November, and accounted for 30 percent of the run. A smaller peak occurred in the first 2 weeks of February, and accounted for 11 percent of the run. Because Antelope Creek is in the same geographic region as Mill Creek, and runoff patterns are similar, historic steelhead migration timing was probably likely to be similar.

Little is known about the winter-run steelhead in Antelope Creek, including their population status and annual run size, or their distribution in the creek and utilization of habitat. Although steelhead have been observed in Antelope Creek, records of population estimates have not been noted (Rectenwald 1998), and adult counts are limited. Moore (2001) used snorkel and foot surveys from March through May to count adult steelhead and steelhead redds in Antelope Creek. These surveys observed a total of 47 steelhead and 52 redds in about 53 percent of the accessible anadromous habitat in Antelope Creek. These numbers do not represent a population estimate because the entire amount of habitat was not surveyed, and surveys may have missed the peak spawning period. In 2007/2008, DFG installed a video camera and observed 140 adult CV steelhead moving through the newly constructed fish ladder at the Edwards Diversion.

Considering steelhead life-history requirements, however, their range within the system is likely to include the range described for spring-run chinook salmon, and may actually extend beyond this range. Because steelhead are, on the average, smaller in size than salmon and can utilize smaller substrate for spawning, habitat potentially exists for them beyond the known range of salmon (Armentrout *et al*. 1998).

BASALT AND POROUS LAVA DIVERSITY GROUP

Battle Creek Watershed Profile

Listed Species with Current Populations in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Sacramento River winter-run Chinook salmon (ESU) - *Oncorhynchus tshawytscha*
Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Basalt and Porous Lava

Key Stressors

Key stressors to Central Valley spring-run Chinook salmon and steelhead in Battle Creek include, but are not limited to the following:

- Passage impediments/barriers by hydropower dams affecting immigrating adults
- Hatchery effects (competition) on juvenile rearing and outmigration
- Flow conditions (e.g., low flows) and associated high water temperatures affecting immigrating, holding and spawning adults, as well as rearing and outmigrating juveniles
- Entrainment of rearing and outmigrating juveniles at hydropower and hatchery diversions

Watershed Description

Battle Creek enters the Sacramento River (at river mile 273) approximately five miles southeast of the Shasta County town of Cottonwood. It flows into the Sacramento Valley from the east, draining a watershed of approximately 360 square miles (DWR 2009). The watershed includes the southern slopes of the Latour Buttes, the western slope of Mt. Lassen, and mountains south of Mineral, California (Ward and Moberg 2004). Nearly 350 miles of streams in the Battle Creek watershed drain land at elevations as high as 10,400 feet and cascade steeply down through basalt canyons and foothills to the confluence with the Sacramento River (Ward and Moberg 2004).

Battle Creek is comprised of three main branches - the North Fork (approx. 29.5 miles in length from headwaters to confluence), the South Fork (approximately 28 miles in length from headwaters to confluence), and the mainstem valley reach (approximately 15.2 miles from the confluence of the North and South forks to the Sacramento River), in addition to numerous tributaries (Kier Associates 1999).

Battle Creek has had persistent spawning populations of spring-run Chinook salmon and steelhead in the reaches currently accessible on the mainstem, North Fork and South Fork in recent years, although the populations have been relatively small. Until recently, the Battle Creek Watershed has five dams blocking upstream migration of salmonids to much of the suitable and historic habitat; however, there is a major restoration project underway, the Battle Creek Salmon and Steelhead Restoration Project (Restoration Project), which started in the summer of 2009 and is scheduled for completion by the end of 2015. The Restoration Project, once complete, will open up 21 miles of currently blocked historical habitat, and will restore and enhance a total of nearly 50 miles of habitat. The Restoration Project provides increased instream flows and an adaptive management program to evaluate the effectiveness of these flows.

Early fisheries investigators claimed that Battle Creek was the most important salmon-producing tributary to the Sacramento River when its ecosystem had its original form and function before settlement in the 1850's (Rutter 1904; CDFW 1993c *as cited in* Kier Associates 1999). It is anticipated that the Battle Creek watershed, once restored, will be a conservation stronghold for spring-run and winter-run salmon and steelhead (Battle Creek AMP). Battle Creek provides the only remaining currently accessible habitat (post Restoration Project) in the Sacramento River watershed, other than the Sacramento River, that is thought to be suitable for populations of winter-run Chinook salmon. Also, Battle Creek offers the best opportunity for restoration of wild steelhead populations in the upper Sacramento River (McEwan and Jackson 1996). Battle Creek has been identified as having high potential for successful fisheries restoration, because of its relatively high and consistent flow of cold water (Newton *et al*. 2008). It has the highest base flow (i.e., dry-season flow) of any tributary to the Sacramento River between the Feather River and Keswick Dam (Ward and Kier 1999, as cited in Newton *et al*. 2008). As these cold water inputs and good flows still exist, this system, if restored, will allow access by fish to these key areas upstream where cold water is more available.

Implementation of key recovery actions (completing the Restoration Project) could improve population viability by reducing the risk of extinction to low, based on achieving an effective population size of greater than 500 spawning adults, or a census population size of greater than 2500, as described by Lindley *et al*. (2007) as criteria for assessing the level of extinction risk for Pacific salmonids.

Factors that increase the potential for these species to see increased populations or reintroduction success in this watershed, are: (1) historically, Battle Creek was a uniquely important salmon-producing watershed due to the large numbers and composition of Chinook salmon that were produced there (Kier Associates 1999); (2) McEwan and Jackson stated (1996) that Battle Creek offers the best opportunity for restoration of wild steelhead populations in the upper Sacramento River; (3) presence of a cold, spring-fed stream system that has exceptionally high flows during the dry season.; and (4) a memorandum of agreement between CDFW, USFWS and NMFS has been undertaken as a component to success for population viability to occur. Battle Creek is therefore, a great candidate to lead to a strong contribution toward population viability for spring-run and winter-run Chinook salmon and for steelhead.

How will Battle Creek help to buffer the negative effects of climate change for salmonids in the Central Valley?

Under the expected climate warming of around 5°C, substantial salmonid habitat would be lost in the Central Valley, with significant amounts of habitat remaining primarily in the Feather and Yuba rivers, and remnants of habitat in the upper Sacramento, McCloud, and Pit rivers, Battle and Mill creeks, and the Stanislaus River (Lindley *et al*. 2007). Under the less likely but still possible scenario of an 8°C warming, spring-run Chinook salmon habitat would be found only in the upper-most reaches of the north fork Feather River, Battle Creek, and Mill Creek (Lindley *et al*. 2007).

Battle Creek offers important cold water inputs for spring-run and steelhead populations, that could prove to provide some of the Central Valley's best protection against extinction for these species as climate change effects take place.

Geology

The geology of Battle Creek is unique among the tributaries to the upper Sacramento River downstream of Shasta Dam, but quite similar to tributaries upstream of Shasta Dam (Kier Associates 1999) (Figure 14).

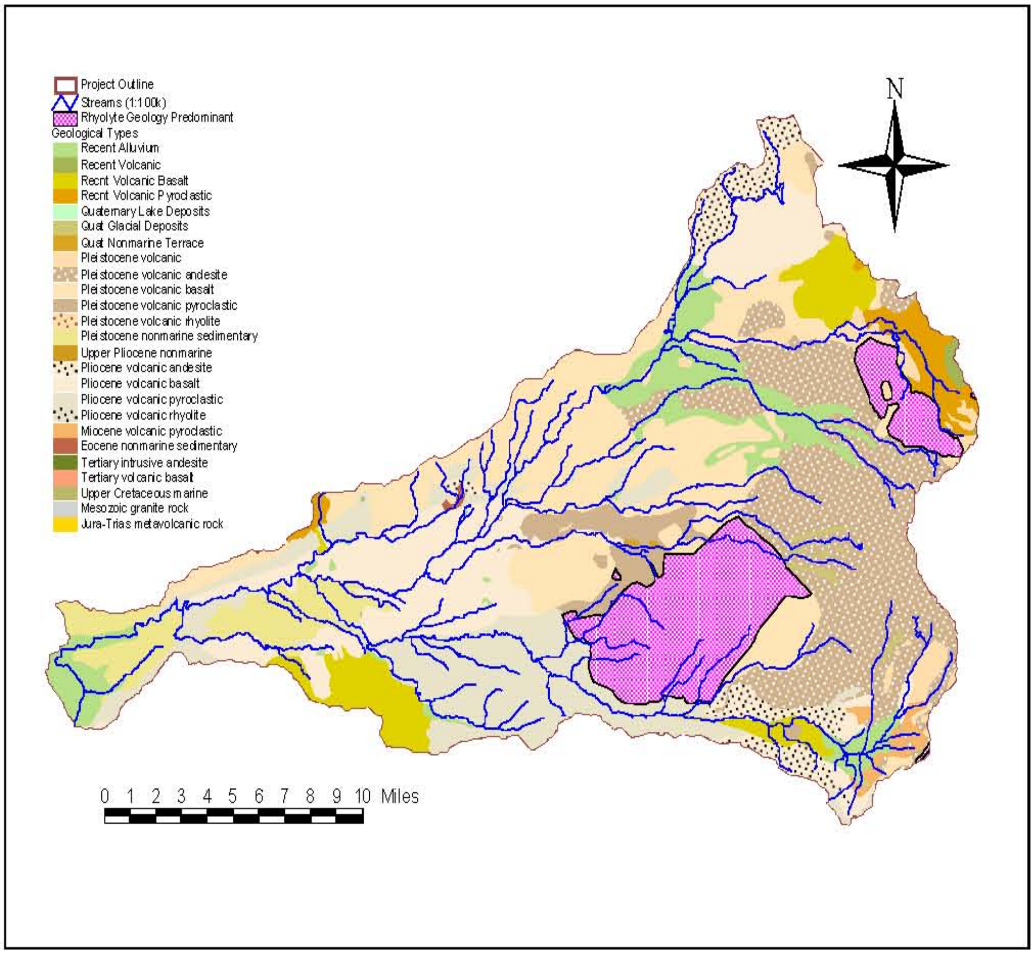

Figure 14. Battle Creek geologic types and location of rhyolitic soils (purple)
Source: Ward and Moberg 2004

Hydrology

Battle Creek has the largest base flow during the low flow season of any of the tributaries to the Sacramento River between the Feather River and Keswick Dam on the Sacramento River (Kier and Associates 1999). The spring-fed nature of Battle Creek ensures than an average September flow of 255 cfs reaches the Sacramento River (USGS 1995 as cited in Kier Associates 1999). Battle Creek and its tributaries drain the volcanic slopes of Mt. Lassen located at the top and center of the watershed (NPS circa 1998 as cited in Kier Associates 1999). The large snowfields on this 10,000 foot peak maintain stream flow until late in the summer (Kier Associates 1999). The volcanic formations and ancient stream channels buried by lava flows store a portion of the wet season runoff and convey it to the streams in the dry season via numerous cold springs (USGS 1956; NPS circa 1998; CDM n.d.; California Mines and Geology Redding Area Geologic Map; Koll Buer, DWR, Red Bluff, California, pers. comm. as cited in Kier Associates 1999).

There are two agricultural diversions in the valley reach of Battle Creek, including the Orwick Diversion (50 cfs) and the Gover Diversion (approximately 50 cfs) which are both considered to be pre-1914 water rights and enable year-round diversions. In addition, the diversions for Coleman National Fish Hatchery (CNFH) are located in the valley reach, and the amount of diversion varies seasonally (Kier Associates 1999). Irrespective of these diversions, Battle Creek remains hydraulically connected year-round, including the dry season and low flow conditions, to the Sacramento River (Kier Associates 1999). During the wet-season, the valley reach of Battle Creek has a natural unimpaired stream flow pattern (Kier Associates 1999).

Above the valley reach, Battle Creek has been extensively developed to produce hydroelectric power using a continuous series of small "run of the river" diversions (Kier Associates 1999). The structures that divert water for hydroelectric power production in the North Fork of Battle Creek include three diversion dams: (1) Wildcat Dam; (2) Eagle Canyon Dam; and (3) North Battle Creek Feeder Dam. These three dams are located downstream of natural barriers to upstream fish migration. The South Fork of Battle Creek also has three hydroelectric diversion dams downstream of natural barriers: (1) Coleman Dam; (2) Inskip Dam; and (3) South Diversion Dam.

Land Use

Land use in Battle Creek ranges from rural residential development to undeveloped wilderness areas of Lassen National Park, and is predominated by industrial timber harvesting, livestock ranch lands, grape growing, and other agricultural development (Ward and Moberg 2004). Private land adjacent to the anadromous reaches of Battle Creek is managed by relatively few landowners for agriculture and cattle grazing (Ward and Moberg 2004).

Timber harvest occurs on both publicly managed lands and privately owned lands. Sierra Pacific Industries is a major landowner in the Battle Creek watershed. Lassen National Forest also manages land for timber harvest in the upper elevation portions of the watershed. Long-term sediment monitoring studies have been conducted by the USFS and timber companies (Ward and Moberg 2004). Fine sediment in the upper watershed shows a higher percentage of fines compared to other nearby streams (e.g., Deer, Mill and Antelope creeks) (Ward and Moberg 2004). Significant timber harvest during 2005-2009 contributed high amounts of fine sediment (M. Woodhouse, pers. comm., 2009.).

Current controversy includes the active lawsuit between concerned citizens and a proposed timber harvest plan for 900 acres near Manton, California. In 2007 this clearcutting plan for over 90% of the proposed project area was approved by the state; a subsequent lawsuit was filed and the controversy is yet to be resolved (January 15, 2008 Tehama County Superior Court, State of California) (T. Parker, USFWS, pers. comm. 2009).

Fisheries and Aquatic Habitat

Historically all four runs of Chinook salmon, including winter-run, spring-run, fall-run, and late-fall-run, occurred in Battle Creek (Yoshiyama *et al*. 1996; Yoshiyama *et al*. 1998). No reliable records exist that documented the number of winter-run Chinook salmon entering Battle Creek (Kier Associates 1999). Systematic counts were not made during the high-flow winter months when adult winter-run Chinook salmon migrate upstream (Kier Associates 1999).

The Coleman National Fish Hatchery (CNFH) was established in 1942 to mitigate the loss of natural salmon to historic spawning areas. The hatchery production goal included 250,000 winter-run Chinook salmon annually (USFWS 2008). In 1998, the winter-run propagation program was relocated from CNFH to the Livingston Stone Fish Hatchery on the Sacramento River. Winter-run Chinook salmon still have access to Battle Creek upstream of the Coleman National Fish Hatchery (CNFH) weir from a fish ladder that is opened during the peak of the winter-run Chinook migration period (Ward and Kier 1999). However, if a winter-run Chinook salmon population exists in Battle Creek, its population size is unknown, likely very small, and is potentially mainly or entirely composed of strays from the mainstem Sacramento River.

As reported by Newton *et al*. (2008), since the early 1900's, a hydroelectric power generating system of dams, canals, and powerhouses, now owned by Pacific Gas and Electric Company (PG&E), has operated in the Battle Creek watershed in Shasta and Tehama Counties, California. The hydropower system has had severe impacts upon anadromous salmonids and their habitat (Ward and Kier 1999, as cited in Newton *et al*. 2008). The Central Valley Project Improvement Act's Anadromous Fisheries Restoration Program outlined several actions necessary to restore Battle Creek, including the following: "to increase flows past PG&E's hydropower diversions in two phases, to provide adequate holding, spawning, and rearing habitat for anadromous salmonids (USFWS 2001a, as cited in Newton *et al*. 2008)." CALFED, PG&E, and other contributors funded the Battle Creek Salmon and Steelhead Restoration Project (Restoration Project). The Restoration Project will provide large increases in minimum instream flows in Battle Creek, remove five dams, and construct fish ladders and fish screens at three other dams (Newton *et al*. 2008).

As reported by Newton *et al*. (2008), PG&E is required under its current FERC license to provide minimum instream flows of 3 cfs downstream of diversions on North Fork Battle Creek (North Fork) and 5 cfs downstream of diversions on South Fork Battle Creek (South Fork). Beginning in 1995, the CVPIA Water Acquisition Program (1995 to 2000) and ERP (2001 to present) contracted with PG&E to increase minimum instream flows in the lower reaches of the North Fork and South Fork (Newton *et al*. 2008). In general, flows are increased to 30 cfs (plus or minus 5 cfs) below Eagle Canyon Dam on the North Fork and below Coleman Diversion Dam on the South Fork (Newton *et al*. 2008). Increased flows were not provided on the South Fork in 2001 and most of 2002, due in part to lack of funds (Newton *et al*. 2008). Based on an agreement in 2003, flows can be redistributed between the forks to improve overall conditions for salmonids, based on water temperatures and the distribution of live Chinook salmon and redds (Newton *et al*. 2008).

As reported by Newton *et al*. (2008), the ERP-funded Interim Flow Project will continue until the Restoration Project construction begins (currently scheduled for 2009). The intent of the Interim Flow Project is to provide immediate habitat improvement in the lower reaches of Battle Creek to sustain current natural salmonid populations while implementation of the more comprehensive Restoration Project moves forward (Newton *et al*. 2008).

Central Valley Spring-Run Chinook

At the start of CNFH operations, a failed spring-run propagation effort collected 227, 1,181, 468, and 2,450 spring-run from Battle Creek in the years from 1943 to 1946, respectively, indicating that a large population was present in the creek (Kier Associates 1999). From 1946 to 1956, Battle Creek spring-run Chinook salmon numbered approximately 2,000 fish in most years (Yoshiyama *et al*. 1996). Escapement data for Battle Creek spring-run Chinook salmon is unavailable from 1960 to 1994 and 1997 to 1998. However, in 1995 and 1996, estimated adult spring-run Chinook salmon escapement was 66 and 34 fish, respectively (USFWS 1996; Croci and Hamelberg 1998). From 1999 through 2008, Battle Creek spring-run Chinook salmon escapement was estimated to be 70, 40, 100, 144, 100, 70, 80, 154, 291, and 101, respectively (CDFW 2009).

As reported by Newton *et al*. (2008), linear regression techniques indicate that the spring-run Chinook salmon population in Battle Creek increased by about 13 fish per year, on average, from 1995 to 2007. This suggests that environmental conditions in Battle Creek have been suitable to maintain and lead to a modest increase in the population; interim flows, provided by PG&E, CVPIA, and CALFED since 1995 have likely been a primary contributing factor to this increase (Newton *et al*. 2008).

Table 19 displays total escapement estimates in Battle Creek of all four runs of Chinook salmon and rainbow trout/steelhead passing upstream of Coleman National Fish Hatchery (CNFH) barrier weir. Total estimated escapement includes Chinook salmon and steelhead passed during the CNFH broodstock collection and spawning program prior to March and fish passed through the barrier weir fish ladder between March 1 and August 31 (period of ladder operation was shorter in some years). Maximum potential spring-run Chinook salmon estimates include all unclipped salmon passing during the ladder operation period. Estimated spring-run Chinook salmon escapement is a reduced estimate based on apportioning some Chinook salmon to the winter, fall, and late-fall runs (Newton *et al*. 2008).

The pre-restoration *upper* limits of spring-run Chinook salmon in the Battle Creek watershed are Eagle Canyon Dam on the North Fork and Coleman Diversion Dam on the South fork (e.g., Newton *et al*. 2007, 2008).

As reported by Newton *et al*. (2007), during 2006 the upstream-most observation of a Chinook salmon on the North Fork was a carcass observed at RM 5.06. During 2007 the upstream-most observation of a Chinook salmon on the North Fork was a carcass observed at RM 4.65 (Newton *et al*. 2008). During both 2006 and 2007, the upstream-most observation of a live Chinook salmon on the South Fork was immediately below Coleman Diversion Dam, which blocks fish passage (Newton *et al*. 2007, 2008).

In 2006, the upstream-most Chinook salmon redd observed on the North Fork was located at about RM 4.6. The upstream-most redd observed on the South Fork was located at about RM 2.5, immediately downstream of Coleman Diversion Dam. In 2007 the upstream-most Chinook salmon redd observed on the North Fork was located at approximately RM 3.8. The upstream-most redd on the South Fork was located at about RM 2.1, downstream of Coleman Diversion Dam (Newton *et al*. 2008).

Table 19. Multi-year summary of total estimated escapement in Battle Creek of all for runs of Chinook salmon and rainbow trout/steelhead passing upstream of Coleman National Fish Hatcher (CNFH) barrier weir.

Year	Winter Chinook	Spring Chinook		Fall Chinook	Late-fall Chinook	Rainbow trout / steelhead	
		Maximum	Estimate			Clipped	Unclipped
1995		66				161[a]	
1996		35				317[a]	
1997		107				344[a]	
1998		178				469[a]	
1999		73				1263[a]	
2000		78				1520[a]	
2001	0+	111	100	9 to 14	98 to 102	1382	225
2002	3	222	144	42	249	1442	593
2003	0	221	100	130	61	772	534
2004	0	90	70	20	42	329	304
2005	0	73	67	6	23	0	344
2006	1	221	154	66	50	1	438
2007	0	291			N/A[b]	3	346
2008	0	105			N/A[b]	1	279
2009	0	194			N/A[b]	20	331
2010*	0	174[c]			N/A[b]	18	392
2011*	1	159 [c]			N/A[b]	78	250
2012*	0	799[c]			N/A[b]		310

[a] Clip status was not used to differentiate hatchery- and natural-origin adult steelhead until 2001 because Coleman National Fish Hatchery did not begin marking all of their production until brood year 1998.

[b]Genetic samples have not been analyzed to determine the total estimate of Late-fall Chinook

[c]Number includes all unclipped spring-run Chinook salmon passed during ladder and video operation as well as approximately 130 clipped spring-run Chinook salmon from the Feather River hatchery.

Source: Newton and Stafford 2011; *personal communication with Matt Brown (USFWS)

Central Valley Steelhead

Escapement estimates of Battle Creek clipped and unclipped rainbow trout/steelhead passing upstream through the CNFH barrier weir fish ladder between March and August from 1995 through 2012 are presented in Table 17 (Newton and Stafford 2011; pers. comm. Matt Brown). Clip status was not used to differentiate hatchery- and natural-origin adult steelhead until 2001 because CNFH did not begin marking all of their production until brood year 1998. Battle Creek is one of the few Central Valley streams where quantification of the abundance of steelhead/rainbow trout is actually provided. The basis of the estimation of the annual run size is the number of adults passing the CNFH barrier weir. The total number of steelhead entering Battle Creek based upon these estimates increased every year from 1995 through 2002 (Newton *et al*. 2008). Starting in 2005 Coleman NFH longer passed clipped steelhead above the weir during the egg collection season, or during manual passage above the barrier weir.

Null *et al.* (2013) found between 36% and 48% of kelts released from Coleman NFH in 2005 and 2006 survived to spawn the following spring, which is in sharp contrast to what Hallock reported for Coleman NFH in the 1971 season, where only 1.1% of returning adults were fish that had been tagged the previous year.

Cow Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Basalt and Porous Lava

Key Stressors

Key stressors to steelhead in the Cow Creek Watershed include but are not limited to the following:

- ❖ Passage impediments/barriers affecting adult immigration and holding and spawning
- ❖ Flow conditions (i.e., low flows) associated with attraction and migratory cues into Cow Creek affecting adult immigration
- ❖ Passage impediments/barriers in the Cow Creek Watershed and resultant effects associated with redd superimposition, competition for habitat, hybridization/genetic integrity affecting adult spawning
- ❖ Elevated water temperatures and poor water quality affecting adult immigration and holding, spawning, embryo incubation, and juvenile rearing and outmigration
- ❖ Changes in flow conditions (low flows) in Cow Creek affecting juvenile rearing and outmigration
- ❖ Flow dependent habitat availability affecting juvenile rearing and outmigration
- ❖ Entrainment at individual unscreened permanent and temporary water diversions affecting juvenile rearing and outmigration
- ❖ Loss of natural river morphology, riparian habitat and instream cover, and floodplain habitat affecting juvenile rearing and outmigration
- ❖ Predation affecting juvenile rearing and outmigration
- ❖ Hatchery effects associated with trout stocking in upper Cow Creek affecting the genetic integrity of steelhead

Watershed Description

The Cow Creek watershed encompasses approximately 425 square miles and has an average annual discharge of more than 500 thousand acre-feet (USFWS 1995). Cow Creek flows southwest from the base and foothills of Mt. Lassen and enters the Sacramento River at RM 280

(USFWS 1995, USFWS 2000). Most of the Cow Creek tributaries originate at 5,000 to 7,000 feet in elevation, and have steep gradients in their upper reaches. The landscape in the higher elevations consists predominately of mixed conifer forest of ponderosa pine, Douglas-fir, incense cedar, and California black oak (USFWS 1995). The oak-digger pine association is predominant in the lower foothills, while the valley floor is dominated by oak grassland and pasture (USFWS 1995).

As reported in the Cow Creek Watershed Assessment (SHN 2001), Cow Creek has been identified by DFG and USFWS as a candidate for restoration of anadromous fisheries. The Working Paper on Restoration Needs, compiled by the Anadromous Fish Restoration Program Core Group in 1995, identified Cow Creek and its tributaries as in "relatively good condition" regarding salmon and steelhead spawning habitat (WSRCD and Cow Creek Management Group 2001). During several DFG fish surveys in 2002 and 2003 primarily Terri Moore (DFG unpublished data) noted that there are sections throughout the watershed that appear to have suitable water temperatures year-round (primarily in the upper reaches of Old Cow and South Cow creeks). Overall, the habitat appeared to be suitable for spawning adult and rearing juvenile steelhead trout, with no definite barriers to anadromy. Moore further noted that there is no obvious reason for the absence of adult steelhead in the upper reaches of South Cow Creek. Yet, many sections of the watershed do not have suitable habitat, insufficient flows (*e.g.* irrigation and hydropower diversions – over 20 unscreened diversion in the watershed), resulting in water temperatures in holding pools that become too warm for spring-run Chinook salmon by midsummer (California Agriculture 2006). In addition, water temperatures and flows for rearing steelhead are less suitable than other nearby watersheds. Extensive restoration is needed in the Cow Creek Watershed for a population to persist. There have been an increase in focus on restoration in the system, particularly addressing passage and entrainment issues, as well as the large hydropower project has filed decommission plans, which will return flows to their natural state, as well as remove passage impediments and entrainment concerns for these areas.

Geology

As reported by USFWS (2000), Cow Creek and its tributaries carve into diverse layers of geologic features. The eastern high of the Cow Creek watershed elevation reaches are the result of relatively recent volcanic activity, with the last eruption series occurring from 1915-1917 (Alt and Hyndman 1975 *as cited in* USFWS 2000). Encrusted lava rocks along with loose volcanic debris were deposited over more ancient (Cretaceous) marine sandstone and shale formations (USFWS 2000). Over time the Cow Creek tributaries have sliced through the blanket of volcanic deposits and eroded into the underlying sandstone and shale producing extensive alluvial deposits (Alt and Hyndman *as cited in* USFWS 2000). Gradient-transition points (i.e., head-cuts or knick-points) are evident in all five of the main tributaries at approximately 1000 feet elevation, forming notable waterfalls. These erosional deposits are the source of rich, well-draining soils that support lush forests and agricultural development (USFWS 2000).

Hydrology

The Cow Creek watershed is a dendritic system and can be divided into five main tributary subbasins, including Little Cow Creek, Oak Run Creek, Clover Creek, Old Cow Creek and South

Cow Creek (USFWS 2000) (**Table 20**). The following subbasin descriptions come from USFWS (2000).

Table 20. Summary data for tributaries of the Cow Creek basin

Stream Name	Basin Area (square miles)	Stream Length
Little Cow Creek	148	36
Oak Run Creek	42	23.5
Clover Creek	54	27.5
Old Cow Creek	80	32.9
South Cow Creek	78	28.5
Main Stem Cow Creek	29	15
Total to Sacramento River	**430**	**47.8**

Source: USFWS 2000

Little Cow Creek

Also known as North Cow Creek, this subbasin drains 148 square miles. The headwaters (Cedar Creek, North Fork, and Mill Creek) originate at an elevation of roughly 5900 feet on the west slopes of Tolladay Peak, Snow Mountain and Clover Mountain. Little Cow Creek flows for 36 miles southwesterly, and then southerly prior to joining the Cow Creek mainstem at Hwy 44.

Oak Run Creek

Oak Run Creek is the smallest of the five main tributaries, draining 42 square miles. Oak Run Creek originates at an elevation of approximately 3200 feet. Oak Run Creek flows 23.5 miles southwesterly to its confluence with the Cow Creek mainstem in Palo Cedro.

Clover Creek

Clover Creek drains 54 square miles and originates at approximately 5500 feet on the south slope of Clover Mountain. Clover creek flows 27.5 miles from its headwaters to its confluence with the mainstem of Cow Creek.

Old Cow Creek

Old Cow Creek drains 80 square miles and originates at an elevation of 6500 feet in the Latour Demonstration State Forest. Old Cow Creek flows 32 miles and joins with Hunt Creek, Glendenning Creek, Canyon Creek and Coal Gulch prior to entering South Cow Creek three miles east of Millville.

South Cow Creek

South Cow Creek drains a 78 square mile basin and originates at an elevation of 5800 feet in the Latour Demonstration State Forest. South Cow Creek flows 28.5 miles to its confluence with Old Cow Creek near Hwy 44. Its larger tributaries include Atkins Creek, Beal Creek, Hamp Creek, and Mill Creek.

Land Use

Settlers were initially drawn to the Cow Creek watershed for its agricultural potential, due to its fertile floodplains (USACE 1971). Irrigation in the Cow Creek basin began soon after its settlement and continues today with a complex series of diversions and lift-pumps in all of the main tributaries. Diversions and pumps carry water to fields, pasturelands and residences in the upper and lower elevation areas. The lowland area primarily supports livestock ranches. Private and public timberlands dominate the eastern upland parts of the basin (above 2000 ft). Mining activity was limited to the northern portion of the basin along Little Cow Creek, where the Afterthought Mine near Ingot (Hwy 299) was a source for gold and copper ore from 1862 to 1952 (Albers and Robertson 1961 *as cited in* USFWS 2000). Hydro-power plants were established on Old Cow Creek (Kilarc Reservoir and Powerplant) and South Cow Creek (Olsen Diversion) in the early 1900s to provide electricity for copper smelting, businesses and residents (Allen 1979 *as cited in* USFWS 2000). PG&E is in the process of decommissioning the Kilarc-Cow Creek hydroelectric project (FERC 606). There are also multiple small individual hydropower setups throughout the watershed, including on Clover Creek (P. Bratcher, pers. comm., 2009).

Fisheries and Aquatic Habitat

As reported by USFWS (1995), primary limiting factors for anadromous salmonids include low fall and summer flows, caused in part by irrigation diversions. Irrigation diversions also affect steelhead by delaying or blocking adult immigration and entraining juveniles. Loss of habitat and water diversions in the Cow Creek watershed is largely due to activities associated with livestock production (USFWS 1995).

As reported by USFWS (1995), agricultural diversions in the Cow Creek watershed are unscreened, and ditches are unlined and poorly maintained. Habitat surveys conducted by DFG in 1992 identified several permanent and temporary irrigation diversions in the various tributary streams, including 13 diversions in South Cow Creek, 10 diversions on Old Cow Creek, one on Clover Creek, and two on North Cow Creek (USFWS 1995). No surveys were conducted on Oak Run Creek. Steelhead are directly affected by water diversions because they impede upstream migration of adults and entrain downstream migrating juveniles. Agricultural diversions and Pacific Gas and Electric Company's hydropower diversions on South Cow Creek also reduce summer flows important for juvenile steelhead rearing (USFWS 1995).

As reported by USFWS (1995), livestock grazing has reduced riparian vegetation and eroded streambanks in the various tributary streams and in the mainstem Cow Creek, degrading the quality of spawning gravel in Cow Creek. Habitat surveys conducted by DFG in 1992 identified stream sections within the various tributaries where excessive erosion has occurred. Fencing these stream sections to protect the riparian corridor has been recommended for approximately 42,600 feet of stream on South Cow Creek, 45,600 feet on Old Cow Creek, 39,120 feet on Clover Creek, and 19,500 feet on North Cow Creek (Harvey pers. comm., as cited in USFWS 1995). Population growth in the towns of Palo Cedro, Bella Vista, Oak Run, and Millville is resulting in increased demand for domestic water and is affecting riparian habitat within the Cow Creek watershed (Reynolds *et al*. 1993, as cited in USFWS 1995).

According to data collected during 2002 and 2003, water temperatures appear to be suitable for salmonids year-round in the upper reaches of Old Cow and South Cow creeks. Stressful and lethal water temperatures were observed in the lower reaches, but may not affect steelhead adult immigration or emigrating steelhead smolts because water temperatures are relatively cool between October and June (Moore 2003).

Steelhead

As reported in the Cow Creek Watershed Assessment (SHN 2001), steelhead populations have not been estimated in Cow Creek. No specific studies have been conducted on Cow Creek to estimate the size of the steelhead spawning run, although CDFW estimated that Cow Creek supported annual spawning runs of 500 steelhead (SHN 2001). Adult steelhead have been observed in North Cow, Old Cow and South Cow creeks; however, it is unknown what percentage of the steelhead run utilizes the other tributaries (SHN 2001). Most steelhead spawning in South Cow Creek probably occurs above South Cow Creek diversion. The best spawning habitat occurs in the 5-mile reach of stream extending from about 1.5 miles below South Cow Creek Diversion Dam to 3.5 miles above the diversion dam (Healy 1997, as cited in

SHN 2001). Additional spawning habitat occurs upstream of this reach, but it is much less abundant. Sightings of adult steelhead have been made at the South Cow Creek Campground (approximately 8.5 miles upstream of the South Cow Creek Diversion Dam) and in Atkins Creek, located just upstream from the campground (SHN 2001).

During February – April of 2002 snorkel surveys were conducted in South Cow Creek, but no steelhead adults, carcasses or redds were identified (Moore 2003). During February – April of 2003, snorkel surveys and one walking survey in South Cow Creek, and one snorkel survey in Old Cow Creek were conducted to identify steelhead adults, carcasses and redds. Seven adult steelhead and two possible redds were identified in South Cow Creek (Moore 2003).

Upper Sacramento River Watershed Profile

Listed Species Present in the Watershed

Central Valley winter-run Chinook salmon
Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley winter-run Chinook salmon
Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Basalt and Porous Lava Diversity Group

Key Stressors

Key stressors to winter-run Chinook salmon in the upper Sacramento River include, but are not limited to the following:

- Passage impediments/barriers affecting adult immigration and holding and spawning (Keswick and Shasta Dams)
- Flow conditions affecting embryo incubation
- Predation of juveniles due to Glen Colusa Irrigation District (GCID) Dam, Red Bluff Diversion Dam (RBDD) and other structures
- Short-term inwater construction affecting embryo incubation
- Water quality affecting embryo incubation
- Water temperatures affecting spawning and embryo incubation
- Loss of natural morphologic function affecting juvenile rearing and outmigration
- Habitat suitability affecting spawning

Watershed Description

The upper Sacramento River watershed includes sub-basins above Shasta Dam and (Little Sacramento River, McCloud, and Pit Rivers) and areas below the Shasta and Keswick Dams downstream to the vicinity of Red Bluff. The areas above Shasta Reservoir include nearly 5,000 square miles of steep mountainous terrain, mid to high gradient stream channels, forested by mixed conifers at high elevations and oak woodlands, scattered pines and brush at lower elevations. Watershed condition, geology, hydrology, land ownership and land use are diverse. The Little, or Upper, Sacramento is a spring-fed river draining Mt. Shasta. The Little Sacramento River is a moderate-size basin (2370 km2) and well-isolated from the McCloud River (Lindley *et al*., 2004). The Little Sacramento River historically supported winter-run

Chinook salmon, as well as spring-run Chinook salmon (Yoshiyama *et al*., 1996). In their report to the California Fish and Wildlife Commission (DFG 1998), concerning the status of spring-run Chinook salmon in the Central Valley, DFG states there are no precise estimates of spring run abundance upstream of the present day site of Shasta Dam, this was the principle spawning area of the Sacramento River basin, and the numbers of fish must have been high. Lindley *et al.*, (2007) concluded that the Little Sacramento was large enough and well-isolated enough to have supported an independent population of spring-run Chinook salmon. Access to the Little Sacramento is presently blocked by Keswick and Shasta dams.

The McCloud River is spring-fed tributary to the Lower Pit River and drains Mt. Shasta, and was swift, cold and tumultuous before hydropower development (Moyle *et al*., 1982). The McCloud River supported winter-run and spring-run Chinook salmon and steelhead. The area above 500 m elevation is isolated from other areas historically used by spring-run Chinook salmon. Lindley *et al*. (2007) concluded that the McCloud River was large enough and well-isolated enough to have supported an independent population of spring-run Chinook salmon. Access to this watershed is now blocked by Keswick and Shasta dams.

The upper Pit River, Fall River and Hat Creek are documented to have contained spring-run Chinook salmon (Yoshiyama *et al*., 1996). The middle and upper Pit is relatively low gradient, meandering across a flat valley floor, and is warm and turbid (Moyle *et al*., 1982). Large falls block access shortly above the confluence of the Fall River (Yoshiyama *et al*., 1996). The Fall River arises from springs at the edge of a lava field, and subsequently has a fairly large discharge of clear water. Hat Creek is similar to the Fall River. The whole region is above 500 m, and Hat Creek and the Fall River are within 50 km of each other. Based on the similarity and proximity of Hat Creek and the Fall River, and the fairly short lengths of accessible habitat within the tributaries, Lindley *et al.* (2004) decided that this area probably was occupied by a single population that had significant substructure. Access to this watershed is presently blocked by Keswick and Shasta dams on the Sacramento River, and numerous other hydroelectric facilities throughout much of its length. Unlike the Little Sacramento and McCloud Rivers, the Pit River is significantly impaired by hydro development and much of the historic habitat is either inundated by reservoirs or dewatered.

The Sacramento River reach below Keswick Dam is the most urbanized and industrialized of the four Sacramento River reaches, while also supporting agriculture. It has three water control structures (i.e., Anderson-Cottonwood Irrigation District[ACID] dam, RBDD dam operated with gates out year round after 2012, and GCID dams). This dams are operated for mainly agricultural diversions from April through October. The broad alluvial portion of the reach between Redding and Balls Ferry has the potential to support significant tracts of riparian forest. Along much of this reach, however, riparian forests are confined to narrow corridors at the base of canyon walls (SRCAF 2003).

How will the Upper Sacramento River help to buffer the negative effects of climate change for salmonids in the Central Valley?

Under the expected climate warming of around 5°C, substantial salmonid habitat would be lost in the Central Valley, with significant amounts of habitat remaining primarily in the Feather and

Yuba rivers, and remnants of habitat in the upper Sacramento, McCloud, and Pit rivers, Battle and Mill creeks, and the Stanislaus River (Lindley *et al*. 2007). Under the less likely but still possible scenario of an 8°C warming, spring-run Chinook salmon habitat would be found only in the upper-most reaches of the north fork Feather River, Battle Creek, and Mill Creek (Lindley *et al*. 2007).

The upper Sacramento River most likely will offer important cold water inputs for and steelhead populations, that could prove to provide some of the Central Valley's protection against extinction for these species as climate change effects take place.

Geology

The upper Sacramento River watershed geology above Shasta Reservoir is dominated by the Cascade Range Geomorphic Province to the west and the Modoc Plateau Geomorphic Province to the East. The Cascade region contains some of the highest peaks in California, and includes several active volcanic formations. The Modoc region is dominated high elevation plateaus with basalt geology.

As reported by SRCAF (2003), the geologic characteristics of the upper Sacramento River reach vary greatly. From Keswick Dam to Redding the river flows through volcanic and sedimentary formations. The canyon is relatively narrow in this area with little floodplain and a correspondingly narrow riparian corridor. From Redding to the Cow Creek confluence there are limited areas where the river has meandered over a broader floodplain of alluvium derived from the Klamath Mountains and the Coast Ranges. From the Cow Creek confluence to near Red Bluff the river is almost entirely controlled by the Tuscan Formation (DWR 1981, as cited in SRCAF 2003). Here the channel is often narrow and deep, between high canyon walls. Table Mountain, a 2-mile long volcanic plateau adjacent to the river, and steep-sloped Iron Canyon (RM 250-253) are both examples of Tuscan Formation outcrops. At Red Bluff the river flows out onto the broad alluvial floodplain of the Sacramento Valley (SRCAF 2003).

As reported by SRCAF (2003), the bed material and floodplain deposits of this portion of the Sacramento River consist generally of well-rounded material composed of various metamorphic, sedimentary, and igneous rocks. The size of this material ranges from clay fines to boulders (DWR 1981, as cited in SRCAF 2003). Since the closure of Shasta Dam in December 1943, the transport of sediment from reaches upstream of the dam has ceased, resulting in an armored channel surface below the dam as the river has transported sediments out of the area (DWR 1981, as cited in SRCAF 2003).

Other factors influencing the sediment supply in this reach include: (1) the urbanization of the Redding-Anderson area, resulting in reduced bank erosion due to the installation of bank protection and levees; and (2) large quantities of sand and gravel being mined at locations in and adjacent to the Sacramento River and its tributaries (DWR 1981, as cited in SRCAF 2003).

Hydrology

As reported by USFWS (1995), the Sacramento River is the largest river system in California, yielding 35% of the state's water supply. The median historical unimpaired run-off above Red

Bluff is 7.2 million acre-feet (maf), with a range of 3.3-16.2 maf (USFWS 1995). Most of the Sacramento River flow is controlled by the USBR Shasta Dam, which stores up to 4.5 maf of water (USFWS 1995). As reported by SRCAF (2003), the Keswick-Red Bluff Reach is highly influenced by the altered hydrology resulting from the operation of the Central Valley Project (CVP). The operation of the CVP in this reach includes Shasta and Keswick Dams on the mainstem of the Sacramento River, as well as the diversion of Trinity River and Clear Creek water through Whisketown Reservoir to Keswick Reservoir via the Spring Creek tunnel (SRCAF 2003).

As reported by SRCAF (2003), CVP operations reduce flood peaks during the winter and spring and increase discharge during the summer and autumn. For example, without the CVP, a 100-year flood is calculated to be about 336,000 cubic feet per second (cfs) at Bend Bridge (SRCAF 2003). Under the controlled operation of the CVP, however, this is reduced to 202,000 cfs (SRCAF 2003). A smaller 2-year flood is reduced from 110,000 cfs to 70,800 cfs (TNC 1996, as cited in SRCAF 2003). During July, August, and September, the mean monthly flows of the Sacramento River at Keswick since 1963 are nearly 400 percent higher than the mean monthly flows prior to 1943 (DWR 1981, as cited in SRCAF 2003). The effect of these changes to hydrology is most obvious directly below the dams. The principal west side tributaries to the Sacramento River in the Keswick-Red Bluff Reach include Clear, Cottonwood, and Dibble Creeks. These creeks flow from the valley floor and parts of the Klamath Mountains to the Sacramento River. Main east side tributaries include Churn, Stillwater, Cow, Bear, Ash, Battle, and Paynes Creeks. Battle and Paynes Creeks originate in the Cascade Mountains east of Redding and flow through confined canyons before joining the Sacramento River (SRCAF 2003).

Land Use

Land ownership in the upper sub-basins above Shasta Reservoir is up to 50 percent public (USFS and USBLM) and land use is dominated by timber management, hydroelectric energy production, grazing, and agriculture. Historic land use included extensive mineral management.

As reported by SRCAF (2003), the Keswick-Red Bluff Reach has a variety of land uses—urban, residential, industrial, and agricultural. About 35 percent of the area is in agriculture, and about 12 percent is urban, residential, or industrial. Predominant agricultural crops include walnuts, mixed pasture and prunes. Industrial land uses within this reach include lumber mills and gravel removal operations. Residential and commercial land uses in the cities of Redding, Anderson, and Red Bluff are common as well. In addition, this reach has the most recreational facilities on the Sacramento River (SRCAF 2003). Historically, the river between Redding and Anderson supported several gravel mining operations (SRCAF 2003).

Fisheries and Aquatic Habitat

The distribution of Sacramento River winter-run spawning and rearing historically is limited to the upper Sacramento River and its tributaries, where spring-fed streams provided cold water throughout the summer, allowing for spawning, egg incubation, and rearing during the mid-summer period (Slater 1963, Yoshiyama *et al.* 1998). CV spring-run Chinook salmon and CV steelhead also occurred in these tributaries. The headwaters of the McCloud, Pit, and Little Sacramento Rivers, and Hat and Battle Creeks, historically provided clean, loose gravel; cold, well-oxygenated water; and optimal stream flow in riffle habitats for spawning and incubation. These areas also provided the cold, productive waters necessary for egg and fry development and survival, and juvenile rearing over the summer. Approximately, 299 miles of tributary spawning habitat in the upper Sacramento River is now inaccessible to winter-run (NMFS 2009a). Yoshiyama *et al.* (2001) estimated that in 1938, the Upper Sacramento had a "potential spawning capacity" of 14,303 redds. Most components of the winter-run life history (*e.g.*, spawning, incubation, freshwater rearing) have been compromised by the habitat blockage in the upper Sacramento River.

CDFW (1998) reports that Clark (1929) characterized CV spring-run Chinook salmon habitat above Shasta Dam as ideal. Yoshiyama (1996) concluded that CV spring-run Chinook salmon would have had access to habitat in the Little Sacramento River as far upstream as the vicinity of Box Canyon Dam, near Mount Shasta. Spring-run Chinook salmon also could have ascended as high as Lower Falls, on the McCloud River but probably stopped near Big Spring (Wales 1939 as reported in CDFW 1998); and ascended the Pit River to the Fall River (Yoshiyama 1996), Hat and Kosk Creek, and the lower one mile of Burney Creek (CDFW 1998). Much of the historic spawning habitat in the Little Sacramento and McCloud Rivers is still present above Shasta Reservoir without significant reductions in amount or connectivity. The Pit River has an extensive hydroelectric footprint, and much of the historic habitat is currently impounded, dewatered or otherwise affected by the presence and operation of facilities.

The ACID Dam (RM 298.5) was constructed in 1917 about three river miles downstream of the current Keswick Dam. Originally the ACID Dam was a barrier to upstream fish migration until 1927 when a poorly designed fish ladder was installed (NMFS 1997). The ACID Dam is only installed during the irrigation season which typically runs from early April to October, or early November. As mentioned above, the fish ladder providing passage around the dam was poorly designed and although winter-run Chinook salmon were able to negotiate the ladder, it did present a partial impediment to upstream migration. However, a new fish ladder installed in 2001 appears to be operating effectively (CDFW 2004). The high volume releases from the ACID's canal downstream of the dam may create false attraction flows for migrating adult salmon where they could be stranded (NMFS 1997). Also, flow fluctuations necessary to install the dam may dewater salmon redds.

The proportion of the winter-run Chinook salmon spawning above ACID has increased since the ladder improvements in 2001.An average of 62% spawn between Keswick Dam and ACID Dam (CDFW 20012 unpublished aerial redd counts). Data on the temporal distribution of winter-run Chinook salmon upstream migration suggest that in wet years about 50 percent of the run has passed the RBDD by March, and in dry years, migration is typically earlier, with about 72 percent of the run having passed the RBDD by March (CUWA and SWC 2004).

The RBDD at RM 243 has 11 gates which are raised or lowered to control the level of Lake Red Bluff, enabling gravity diversion into the Tehama Colusa Canal (TCC). Permanent fish ladders are located on each abutment of the dam, however, the ladders are inefficient in allowing upstream migration of adult salmonids (NMFS 1997). Winter-run Chinook salmon, spring-run

Chinook salmon, and CV steelhead experienced delays during spawning runs due inefficient ladders at RBDD. Juvenile Chinook salmon and steelhead were also subject to predation as they passed downstream through Lake Red Bluff and the gates. Since 1993 NMFS had required gates out for winter-run Chinook salmon upstream passage for longer and longer periods from May through September. In 2012 the gates were left open year round to meet NMFS' Biological Opinion on the Long-term Operations of the CVP and SWP (2009). The gates out operation was accommodated with construction of a new pumping plant and fish screen to divert water for irrigation, with an initial capacity of 2,180 cfs (Tehama-Colusa Canal Authority 2008).

During recent years the majority of winter-run Chinook salmon (*i.e.*, > 50 percent since 2007) spawn in the area from Keswick Dam downstream to the ACID Dam (approximately 5 miles). Keswick Dam re-regulates flows from Shasta Dam and mixes it with water diverted from the Trinity River through the Spring Creek tunnel to control water temperatures below ACID pursuant to actions in the NMFS (2009a) biological opinion.

Sacramento River winter-run Chinook salmon

The upper Sacramento River contains the only existing habitat for Sacramento River winter-run Chinook salmon. As reported by NMFS (2009a), historical winter-run population estimates, which included males and females, were as high as over 230,000 adults in 1969, but declined to under 200 fish in the 1990s (Good *et al.* 2005). A rapid decline occurred from 1969 to 1979 after completion of the RBDD. Over the next 20 years, the population eventually reached a low point of only 186 adults in 1994. At that point, winter-run Chinook salmon were at a high risk of extinction, as defined by Lindley *et al*. (2007). However, several conservation actions, including a very successful captive broodstock program (i.e., Livingston Stone National Fish Hatchery (LSNFH)), construction of a temperature control device (TCD) on Shasta Dam, maintaining the RBDD gates up for much of the year, and restrictions in ocean harvest, have likely prevented the extinction of wild winter-run Chinook salmon.

In recent years, the carcass survey population estimates of winter-run Chinook salmon included a high of 17,205 (Table 17) in 2006, followed by a precipitous decline in 2007 that continued in 2008, when less than 3,000 adult fish returned to the upper Sacramento River. The total escapement estimate for winter-run Chinook salmon in 2012 is 2,581 (CDFW 2013).

Table 21 also provides data on the cohort replacement rate (CRR), which is similar to the SRR recommended by Anderson *et al*. (2009), that is, the ratio of the number of recruits returning to the spawning habitat divided by the number of spawners producing those recruits. As discussed, above, the majority of winter-run spawners are 3 years old. Therefore, NMFS calculated the CRR using the spawning population of a given year, divided by the spawning population 3 years prior.

A conservation program at LSNFH located at the base of Keswick Dam annually supplements the in-river production by releasing on average 180,000 winter-run smolts into the upper Sacramento River. The LSNFH operates under strict guidelines for propagation that includes genetic testing of each pair of adults and spawning less than 25 percent of the hatchery returns.

This program and the captive broodstock program (phased out in 2007) were instrumental in stabilizing the winter-run Chinook population following very low returns in the 1990s.

Table 21. Winter-run population estimates from RBDD counts (1986 to 2001) and carcass counts (2001 to 2008), and corresponding cohort replacement rates for the years since 1986

Year	Population Estimate[a]	5-Year Moving Average of Population Estimate	Cohort Replacement Rate[b]	5-Year Moving Average of Cohort Replacement Rate	NMFS-Calculated Juvenile Production Estimate (JPE)[c]
1986	2,596	-	-	-	
1987	2,186	-	-	-	
1988	2,885	-	-	-	
1989	696	-	0.27	-	
1990	433	1,759	0.20	-	
1991	211	1,282	0.07	-	40,100
1992	1,240	1,092	1.78	-	273,100
1993	387	593	0.90	0.64	90,500
1994	186	491	0.88	0.77	74,500
1995	1,297	664	1.05	0.94	338,107
1996	1,337	889	3.45	1.61	165,069
1997	880	817	4.73	2.20	138,316
1998	3,002	1,340	2.31	2.48	454,792
1999	3,288	1,961	2.46	2.80	289,724
2000	1,352	1,972	1.54	2.90	370,221
2001	8,224	3,349	2.74	2.76	1,864,802
2002	7,441	4,661	2.26	2.22	2,136,747
2003	8,218	5,705	6.08	3.02	1,896,649
2004	7,701	6,587	0.94	2.71	881,719
2005	15,730	9,463	2.11	2.83	3,556,995
2006	17,205	11,259	2.09	2.70	3,890,534
2007	2,488	10,268	0.32	2.31	1,100,067
2008	2,850[d]	9,195	0.18	1.13	1,152,043[e]
median	**2,488**	**1,961**	**1.54**	**2.31**	**370,221**

a Population estimates were based on RBDD counts until 2001. Starting in 2001, population estimates were based on carcass surveys.

b The majority of winter-run spawners are 3 years old. Therefore, NMFS calculated the CRR using the spawning population of a given year, divided by the spawning population 3 years prior.

c JPE estimates were derived from NMFS calculations utilizing RBDD winter-run counts through 2001, and carcass counts thereafter for deriving adult escapement numbers. Only estimated to RBDD, does not include survival to the Delta.

d CDFW (2009)

e NMFS (2009b) preliminary estimate to Reclamation

Sources: CDFW 2004, CDFW 2007, CDFW 2009, NMFS 2009b

Lindley *et al.* (2007) determined that the winter-run Chinook salmon population, which is confined to spawning below Keswick Dam, is at a moderate extinction risk according to population viability analysis (PVA), and at a low risk according to other criteria (*i.e.*, population size, population decline, and the risk of wide ranging catastrophe). However, concerns of genetic introgression with hatchery populations are increasing. Hatchery-origin winter-run from LSNFH have made up more than 5 percent of the natural spawning run in recent years and in 2005, it exceeded 18 percent of the natural run. If this proportion of hatchery origin fish from the LSNFH exceeds 15 percent in 2006-2007, Lindley *et al*. (2007) recommends reclassifying the winter-run population extinction risk as moderate, rather than low, based on the impacts of the hatchery fish over multiple generations of spawners. In addition, data used for Lindley *et al*. (2007) did not include the significant decline in adult escapement numbers in 2007 and 2008, and thus, does not reflect the current status of the population size or the recent population decline. Furthermore, the drought conditions in 2007, 2008 and 2009 in the Central Valley were not incorporated into the analysis of the winter-run population status in Lindley *et al*. (2007) as a potential catastrophic event.

In consideration of the almost 7-fold decrease in population in 2007, coupled with the dry water year type in 2007, followed by the critically dry water year type in 2008 (which could be qualified as a high-risk catastrophe) and likely a similar forecast for 2009, NMFS concludes that winter-run Chinook salmon are at high risk of extinction based on population size (NMFS 2009a).

CV spring-run Chinook Salmon

The status of the spring-run population within the mainstem Sacramento River above RBDD appears to have declined from a high of 25,000 in the 1970s to the current low of less than 800 counted at RBDD (Figure 15). Significant hybridization with fall-run has made identification of a spring-run in the mainstem very difficult to determine, and there is speculation as to whether a true spring-run still exists below Keswick Dam. This shift may have been an artifact of the manner in which spring-run were identified at RBDD. Fewer spring-run are counted today at RBDD because an arbitrary date, September 1, was used to determine spring-run and gates are now open year round for winter-run passage (NMFS 2009a). It is unknown if spring-run still spawn in the Sacramento River mainstem, but the physical habitat conditions below Keswick Dam is capable of supporting spring-run, although in some years high water temperatures can result in substantial levels of egg mortality. Current redd surveys have observed 20-40 salmon redds in September, from Keswick Dam downstream to the Red Bluff Diversion Dam. This is typically when spring-run spawn, however, there is no peak that can be separated out from fall-run spawning, so these redds also could be early spawning fall-run. Additionally, even though habitat conditions may be suitable for spring-run occupancy, spring-run Chinook salmon depend on spatial segregation and geographic isolation from fall-run Chinook salmon to maintain genetic diversity. With the onset of fall-run Chinook salmon spawning occurring in the same time and place as potential spring-run Chinook salmon spawning it is likely to have caused extensive introgression between the populations (CDFW 1998).

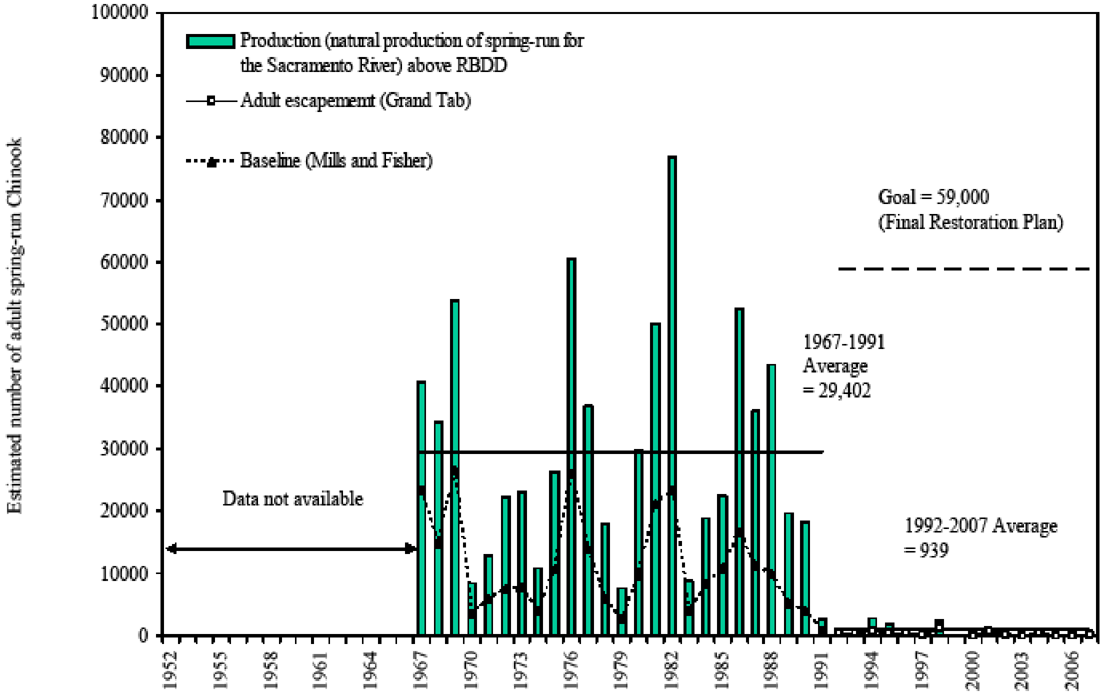

Figure 15. Estimated yearly spring-run escapement and natural production above RBDD
Source: Hanson 2008

CV steelhead

Estimates of CV steelhead abundance in the mainstem Sacramento River typically use the RBDD counts for historical trend data. Since 1991, the RBDD gates have been opened after September 15, making estimates of CV steelhead pass RBDD unreliable. Based on counts at RBDD, adult migration into the upper Sacramento River can occur from July through May, but peaks in September, with spawning occurring from December through May (Hallock 1998). Since the RBDD gates started operation in 1967, the CV steelhead abundance in the upper Sacramento River has declined from 20,000 to less than 1,200 (Figure 16). CV steelhead passage above RBDD after 1991 can be estimated based on the average of the 3 largest tributaries (*i.e.*, Battle Creek, Clear Creek and Cottonwood Creek). The average of these tributaries for the last 14 years (1992 through 2005) is 1,282 adults, which represents a continuous decline from the 1967 through 1991 average RBDD count of 6,574 (Figure 16). The decline in CV steelhead abundance is similar to winter-run and spring-run declines.

Actual estimates of CV steelhead spawning in the mainstem Sacramento River below Keswick Dam have never been made due to high flows and poor visibility during the winter time. Aerial redd surveys conducted for winter-run have observed resident *O. mykiss* spawning in May and late-falls spawning in January. Since resident trout redds are smaller than steelhead redds and late-fall salmon spawn at the same time as steelhead, it would seem likely that CV steelhead redds could be observed. A CV steelhead monitoring plan is being developed by CDFW with a goal of determining abundance in the Sacramento River (Jim Hopelain per.com 2008).

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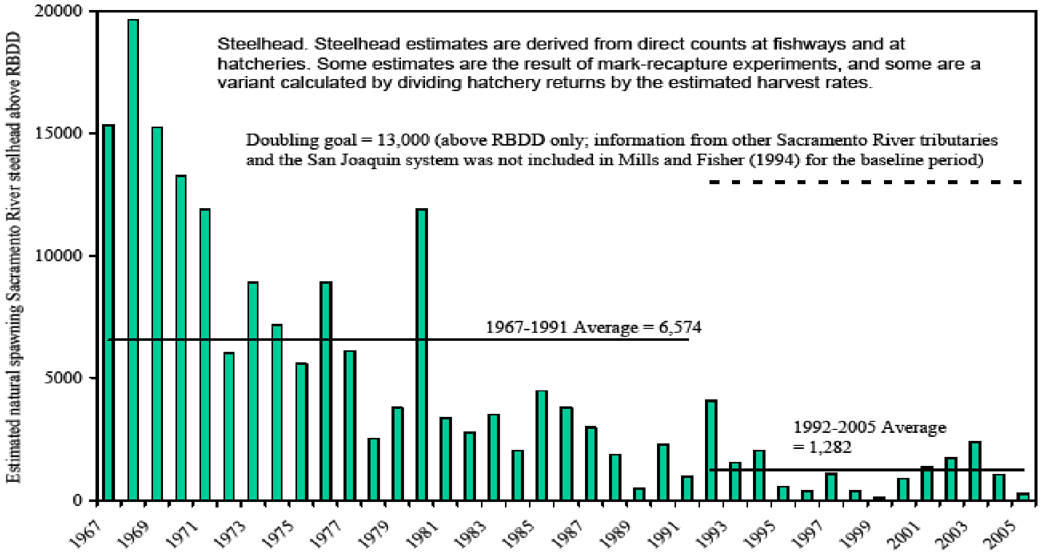

Figure 38. Estimated yearly number of natural spawning of steelhead on the Sacramento River, upstream of the RBDD (Mills and Fisher, 1994). Data for 1992-2005 is from CDFG, Red Bluff.

Figure 16. Estimated yearly number of natural spawning CV steelhead on the Sacramento River upstream of the RBDD 1967-2005. Data from 1992 to 2005 is based on tributary counts from CDFW, Red Bluff Source: Hanson 2008

Small Tributaries to the Upper Sacramento River[7]
(including Salt, Sulphur, Olney, Churn, Stillwater, Inks, and Paynes Creeks)

Listed Species Currently and Historically Occurring in these Creeks

Central Valley Steelhead

Key Threats and Stressors

Key threats and stressors (i.e., identified as "Very High") to Central Valley steelhead in the Upper Sacramento River Tributaries include, but are not limited to the following:

- Passage impediments/barriers in the upper Sacramento River tributaries
- Physical habitat alternation associated with limited supplies of instream gravel affecting adult spawning
- Water temperature and water quality effects on adult immigration and holding, and on juvenile rearing and outmigration
- Flow conditions (i.e., low flows) affecting attraction and migratory cues for adult immigration and holding, and flow dependent habitat availability affecting juvenile rearing and outmigration
- Entrainment at individual diversions affecting juvenile rearing and outmigration
- Predation effects on juvenile rearing and outmigration
- Loss of riparian habitat and instream cover affecting juvenile rearing and outmigration

Additional stressors for both species are presented in Appendix A.

General Description

Along the Sacramento River are many small, often ephemeral, tributaries that are not used to any significant extent by spawning anadromous salmonids (Figure 17). Maslin and McKinney (1994) have shown that these tributaries may be used as rearing habitat by juvenile salmonids. Only a few of the potential tributaries have been investigated, but those that have been examined contained juvenile Chinook salmon. In some cases, the juveniles had gone as far as 14 miles upstream from the river. Most of these tributaries also have resident rainbow trout populations in upstream perennial reaches. For many, there also are anecdotal accounts of historical steelhead runs (USFWS 1995).

[7] For this appendix, the Upper Sacramento River section starts at Keswick Dam and ends at the Red Bluff Diversion Dam site.

USFWS (1995) identified several small Sacramento River tributaries in which juvenile salmon had been reported, and the characteristics of these known rearing streams were compared to those of streams for which no information was available. Table 22 presents a list of small Sacramento River tributaries thought to not support, or to be of minimal utilization, for salmonid spawning (USFWS 1995) and divides them into the following categories:

- Tributaries known to support juvenile rearing
- Tributaries that are of similar in morphometry and location to known rearing streams and, thus, presumed to support juvenile rearing
- Tributaries that have steep gradients near the river or that enter the river upstream from any spawning habitat and, therefore, are presumed to have low potential to support juvenile rearing

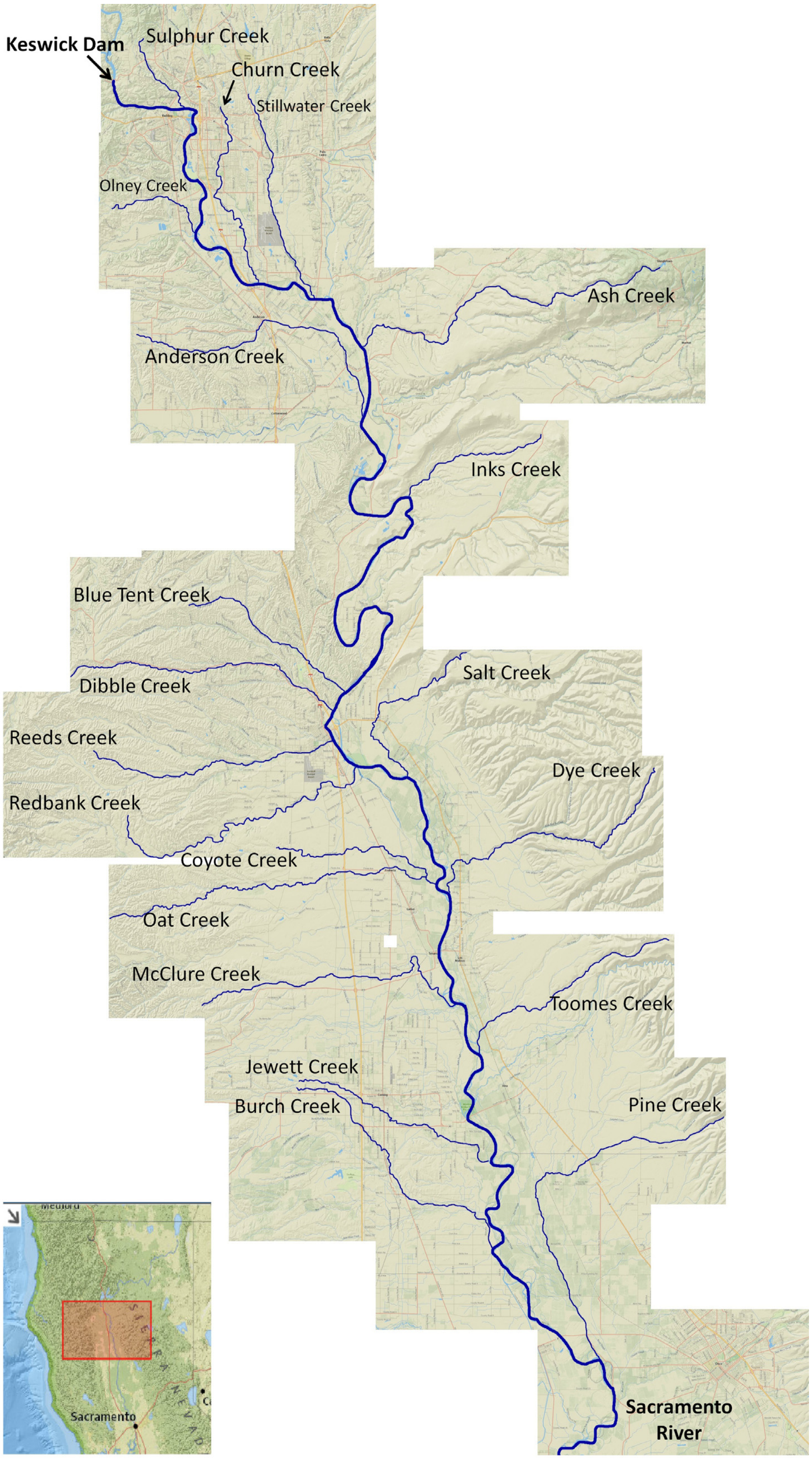

Figure 17. Upper Sacramento River Tributaries

Table 22. Upper Sacramento River Tributaries that May Provide Juvenile Rearing Habitat for Salmonids

Name	USGS Quad	Tributary Proximity to the Sacramento River
Tributaries Known to Support Juvenile Salmonid Rearing		
Pine	Ord Ferry	East
Toomes	Vina	East
Dye	Los Molinos	East
Oat	Los Molinos	West
Coyote	Gerber	West
Reeds	Red Bluff East	West
Brewery	Red Bluff East	West
Blue Tent	Red Bluff East	West
Dibble	Red Bluff East	West
Inks	Bend	East
Anderson	Ball's Ferry	West
Olney	Enterprise	West
Tributaries Presumed to Support Juvenile Salmonid Rearing		
Burch	Foster Island	West
Jewett	Vina	West
McClure	Vina	West
Red Bank	Red Bluff East	West
Salt	Red Bluff East	East
Ash	Ball's Ferry	East
Stillwater	Ball's Ferry	East
Churn	Cottonwood	East
Sulfur	Redding*	East
Tributaries with Low Potential to Support Juvenile Salmonid Rearing		
Seven Mile	Red Bluff East	East
Frasier	Bend	West
Spring	Bend	West
Clover	Cottonwood	East
Middle	Redding[a]	West
Salt	Redding[a]	West
Jenny	Redding[a]	West
Rock	Redding[a]	West
[a] Indicates 15-minute topographical quadrangle map		

Source: Modified from USFWS 1995

Fisheries and Aquatic Habitat

In addition to the diverse aquatic habitat provided by major and perennial tributaries to the Sacramento River, intermittent tributaries, floodplains and seasonal sloughs provide important non-natal seasonal rearing habitat for anadromous salmonids and seasonal breeding and rearing habitat for native and non-native resident fish species (Tehama County 2008). Rearing conditions in the tributaries are reported exist from approximately December through March. By April, conditions may be less favorable as water temperatures rise to intolerable levels, and piscivorous fish enter the tributaries to spawn. Juvenile Chinook salmon entering the tributaries early in the year, such as winter- and spring-run, probably derive the most benefit from tributary rearing (Maslin *et al*. 1995).

Intermittent tributaries in Tehama County where anadromous salmonid non-natal rearing has been observed include Toomes, Dye, Oat, Coyote, Reeds, Blue Tent, Dibble, Inks, Red Bank and Reeds Creek (Maslin *et al*. 1997; Maslin *et al*. 1998; and Maslin *et al*. 1999). However, there is no recent quantitative data on the extent to which salmon and steelhead use these intermittent streams (Tehama County 2008).

Many other small streams that feed larger tributaries may be found to be important for salmonid rearing. Because many of these small streams may have characteristics and habitat constraints similar to those listed in Table 1, they are not discussed in detail. In addition to its many tributaries, the Sacramento River has many sloughs (partially abandoned river or creek channels). The dynamics of the river change sloughs too rapidly for topographic maps to be useful in locating or describing them. Therefore, they can be addressed only generally. Sloughs that are open to the river, particularly if they have any flow from seepage, small tributaries, or agricultural drainage, have potential to provide rearing habitat. These sloughs have characteristics and habitat needs similar to the tributaries (USFWS 1995). Additional information regarding aquatic habitats for anadromous salmonids in the upper Sacramento River tributaries is summarized below for the north westside tributaries, Salt Creek (near Keswick), Sulphur Creek, Olney Creek, Churn and Stillwater Creeks, Inks Creek, and Paynes Creek .

North Westside Tributaries - Small streams draining the west side of the Sacramento Valley in the Redding-Anderson municipal area include Olney, Anderson, Salt (near Keswick Dam, not Red Bluff), and Middle creeks. These creeks do not have natural flow during the dry season. During the wet season, however, they have relatively large flows compared to the small size of the watersheds. The high flash-flood potential of the streamflow regime is attributable to the intensity of rainstorms at the north end of the valley and is further amplified by urbanization of the watershed. These tributaries enter the Sacramento River downstream of Shasta Reservoir.

The watersheds of these streams drain parts of the Coast Ranges and Klamath Mountains. The soils in these mountains are moderately to severely erodible in contrast to the soils of the eastside Sierra Nevada watersheds. Also in contrast with the eastside tributaries, the geology of the west side of the valley is not as conducive to the large groundwater springs that provide cold, sustained flows in the dry season (UFWS 1995).

Salt Creek Watershed – The Salt Creek watershed encompasses an area of about 2,800 acres and contains about 3 miles of tributary streams (Western Shasta RCD 2005). Salt Creek is an alluvial channel with some bedrock along its length, and flows from southwest to northeast, originating in the gently rolling terrain. The channel transports fine to medium coarse sediment with maximum sizes reaching one foot. The channel is somewhat confined in the lower one-half of its length (Highway 299 to Sacramento River) and has broader floodplain areas above Highway 299 with significant sediment depositional areas. The channel appears to be in relatively good condition from its confluence to its headwaters, and there is minimal channel modification, consisting mostly of road crossings (Western Shasta RCD 2005). Salt Creek is reportedly one of the last remaining relatively undeveloped watersheds in the rapidly growing Redding area (Shasta Resources Council 2005).

Salt Creek enters the west side of the Sacramento River approximately a half mile below Keswick Dam. Because Salt Creek is still relatively undeveloped and of good water quality, flows entering the Sacramento River just below Keswick Dam aid in dilution of contaminants entering from Iron Mountain Mine (Shasta Resources Council 2005). Resident rainbow trout, steelhead and fall-run Chinook salmon are known to use lower Salt Creek for spawning and juvenile rearing (CDFG 2004). Since 1997, Reclamation has injected over 96,000 tons of spawning gravel in the Sacramento River at the mouth of Salt Creek. In 2001, CALFED agencies funded activities to improve two fish ladders and a fish screen at the ACID diversion dam located in the Sacramento River downstream of Salt Creek. These spawning gravels and fish passage improvement were implemented to encourage spawning by natural runs of Chinook salmon, particularly winter-run Chinook salmon and steelhead in the Sacramento River between the ACID and Keswick dams (CDFG 2004).

Sulphur Creek Watershed – The Sulphur Creek watershed encompasses almost 3,000 acres, and has about 7 miles of intermittent stream and 2 miles of ephemeral stream, all located within a protected greenway. One of these intermittent streams, Sulphur Creek, is an urban stream that drains about 4.42 square miles in Shasta County and the City of Redding (SWAG 2004). Extensive mining, road building and railroad construction within the watershed resulted in the deterioration of fisheries and wildlife habitat, alteration of the natural hydrology, and stream channel degradation (SWAG 2004). The Sulphur Creek hydrograph has been dramatically altered by historic and current land-use practices. The long and narrow shape of the watershed leads to naturally-occurring high peak flows with a relatively short time of concentration (CALFED ERP 1998). These hydrograph conditions are compounded and exacerbated by the level of urbanization within the watershed. The channel in the lower reach of Sulphur Creek was filled with large deposits of boulders and cobbles, and there is evidence that later gravel mining further concentrated large sediment deposits in the channel. Additionally, when the stream was diverted through dredger mine tailings in the 1940's, it self-adjusted to the increased bedload transport by straightening and steeping itself (CALFED ERP 1998). The resulting abnormally high bedload in this reach has caused aggradation, which in turn has caused lateral migration of the stream causing extreme bank erosion, loss of riparian vegetation, and an increase in the width-to-depth ratio (SWAG 2004).

Sulphur Creek, especially the lower reach, is believed to provide winter spawning and rearing habitat for native anadromous fish (SWAG 2004).

Olney Creek Watershed – The Olney Creek watershed encompasses an area of about 9,400 acres and contains about 8 miles of tributary streams. Flows during the dry months vary based on precipitation patterns, and the larger tributaries, such as Rock and Olney creeks, receive groundwater seepage throughout the summer months. This seepage may include normal groundwater discharge and seepage from the ACID canal (Western Shasta RCD 2005). Olney Creek flows from west to east through relatively undeveloped areas east of Highway 273 and through moderately developed areas between Highway 273 and the Sacramento River. The two-year peak flood flow in Olney Creek is estimated to be 1,939 cubic feet per second (cfs). The

100-year peak flood flow is estimated to be 4,318 cfs. The lower reach consists of flat gradient, meandering alluvial channel while the upper reaches are mostly confined with significant reaches of continuous bedrock. The channel transports fine to coarse sediment, with maximum sizes reaching three feet or greater. The upper reaches of Olney Creek appear to be in fair condition. Water quality samples taken from Olney Creek between September 2001 and July 2002 indicate that pH values ranged between 7.26 and 8.09. Dissolved oxygen was measured during 2002 and was detected from 8.8 to 9.1 mg/l. While some development has occurred, including construction of small dams and water diversions, the channel is relatively stable in that there are no significant erosion or depositional areas. The lower reach, however, has undergone some modification in the form of channelization, road crossings, and bank stabilization. As a result, the channel exhibits typical morphology for this stream type, with some available floodplain areas, pools and riffles, and riparian vegetation along stream banks (Western Shasta RCD 2005).

Western Shasta RCD has recently completed a fish passage barrier removal project for tributaries on the west side of Redding, including Olney Creek. Although CDFG does not believe that Olney Creek is suitable for fall-run Chinook salmon, it is believed that it would increase significant spawning area for resident (Sacramento River) rainbow trout (CDFG 2007). The removal of this structure would broaden the time window and the geographic range for upstream and downstream migration of *O. mykiss*.

Stillwater-Churn Creek Watershed – The Stillwater-Churn Creek watershed encompasses about 78,000 acres and is located in Shasta County east/northeast of Redding, California (SWRCB 2008). The area is bordered on the east by the Cow Creek watershed, west and southwest by the Sacramento River, and on the north by the Upper Sacramento River watershed. Stillwater, Churn and Clover creeks are the primary tributaries to the Sacramento River (SWRCB 2008). Precipitation occurs mostly during the winter and spring months as rain and averages 33.3 inches annually. The area exhibits a Mediterranean climate consisting of summers that are hot and dry, and winters that tend to be cool, rainy, and overcast. Temperatures average 62.0°F and range from an average of 55.3°F in the winter to 98.3°F in the summer. Extended periods of air temperatures exceeding 100° F during the day are not uncommon. Elevation ranges from 500 to 1,600 feet above sea level, and the topography of the watershed ranges from being nearly flat at the confluences with the Sacramento River, undulating in the foothills, and being of steep mountainous terrain at the headwaters of Stillwater and Churn Creeks (SWRCB 2008).

Stillwater, Churn, and Clover Creeks are intermittent streams that provide seasonally available habitat to fish and other aquatic organisms. Portions of Stillwater and Churn Creeks are designated as critical habitat for steelhead (*Oncorhynchus mykiss*) and spring-run Chinook (*O. tshawytscha*). However, salmonids have been observed in upstream portions that are not currently designated Critical Habitat (SWRCB 2008). There is no documentation of spawning spring-run Chinook salmon (Western Shasta RCD 2008). Steelhead may use the system as well, though most *O. mykiss* are likely the more common resident Sacramento River rainbow trout (Western Shasta Resource Conservation District 2008). Churn Creek may be a gravel-poor system and, while the creek remains un-dammed, it in many ways illustrates similar geomorphic responses that are frequently observed following impoundment, including: (1) winnowing of finer gravels from riffles; (2) channel incision; (3) long pools with steep banks and reduced complexity, (4) heavily vegetated riffles; (5) gravel bars entombed by vegetation (GMA 2006, Western Shasta RCD 2008 and SWRCB 2008). Urbanization (with commensurate alterations to the hydrologic regime and reduction in available sediment supply) is believed to be the primary driver for the modifications in physical processes resulting in these and other conditions (Western Shasta RCD 2008). These features make it challenging for Chinook salmon to find areas with adequate gravel for spawning and habitat for rearing juveniles.

Inks Creek Watershed – Inks Creek in an intermittent stream that enters the Sacramento River at RM 265. The watershed contains a Tuscan-Inks soil association found on old terraces east of the Sacramento River, which is comprised of soils that are cobbly and can be shallow to moderately deep. The Tuscan soils typically have a cemented hardpan, and the Inks soils consist of cobbly loam and a clay loam over a cemented substratum (Tehama County 2008). The Inks Creek watershed contains public lands managed by the Bureau of Land Management.

Inks Creek is reported to contain potential and current non-natal rearing habitat for juvenile Chinook salmon (Tehama Country RCD 2008). In 1989, CDFG surveyed about 3.5 miles of Inks Creek from the mouth to the confluence with the south fork. Ten salmon carcasses, four live fish, and three redds were observed. However, a population estimate was not made (CDFG 1989).

Paynes Creek Watershed – Originating in a series of small lava springs about 6 miles west of the town of Mineral, California, Paynes Creek flows into the Sacramento Valley from the east, and drains a watershed of approximately 93 square miles (USFWS 1995). Paynes Creek enters the Sacramento River at RM 253, which is about 5 miles north of the town of Red Bluff, California. Although there are no significant dams located on the stream, flows in Paynes Creek have been significantly affected by the recent drought conditions, as well as by 16 seasonal diversions for irrigation and stock watering. The lowermost irrigation diversion, about 2 miles upstream from the mouth, is the largest, with a capacity of approximately 8 cfs. This diversion provides water to irrigate the agricultural water rights holders who live in the Bend District, and BLM's Paynes Creek wetlands. CDFG owns and operates a fish screen on this diversion (USFWS 1995).

Paynes Creek is reported to support fall-run Chinook salmon when water conditions are adequate (USFWS 1995). Low flow and inadequate spawning gravel have been identified as significant factors limiting salmon production in Paynes Creek. In 1988, CDFG built five spawning riffles using 1,000 tons of spawning gravel. Because of low flows attributable principally to the recent drought, however, the reconstructed riffles have been sparsely used (USFWS 1995).

NORTHWESTERN CALIFORNIA DIVERSITY GROUP

Putah Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley steelhead

Diversity Group

Northwestern California

Key Stressors

Key stressors to Central Valley steelhead in Putah Creek include, but are not limited to the following:

- Passage impediments/barriers by Solano Dam and Montecello dams affecting immigration and holding
- Low flow conditions and flow fluctuations affecting adult immigration and holding, juvenile rearing and outmigration, and embryo incubation
- Physical habitat alteration (i.e., limited instream gravel supply) affecting spawning
- Loss of floodplain habitat, natural river morphology, and riparian habitat and instream cover affecting juveniles

Watershed Description

The watershed of Putah Creek begins in the Coast Ranges at Cobb Mountain in Lake County at an elevation of 4,700 feet, and flows down to the Central Valley where it empties into the Yolo Bypass near sea level (Lower Putah Creek Coordinating Committee 2005). Putah Creek is the southernmost major drainage entering the Sacramento Valley from the west. The Putah Creek watershed is defined by two subbasins, the lower and upper Putah Creek watersheds (Lower Putah Creek Coordinating Committee 2005).

Lower Putah Creek is located in the southwestern corner of the Sacramento Valley and flows 26 miles across the valley floor from the Putah Diversion Dam to the Toe Drain in the Yolo Bypass. Putah Diversion Dam is a reregulating reservoir below Monticello Dam. The upper Putah Creek subbasin is defined by the portion of the watershed located upstream of Monticello Dam, which forms Lake Berryessa. Lake Berryessa captures runoff from 90 percent of the watershed. The upper watershed occupies about 600 square miles within the Coast Ranges (Lower Putah Creek Coordinating Committee 2005).

Geology

Four major rock units characterize the Coast Ranges, including areas in which the Putah Creek watershed has formed: (1) the Franciscan formation; (2) the Great Valley sequence; a relatively thin (1 mile or more thick) layer of black igneous rock and unusual green serpentinite (between the Franciscan and Great Valley units) that is believed to have originated in the Earth's mantle from beneath the continental crust; and (4) a fossil-filled sandstone and mudstone layer that is younger than the other formations and lays over the top of them (Lower Putah Creek Coordinating Committee 2005). The upper Putah Creek watershed area is formed within the steep mountain slopes formed by sandstone and shale, local areas of serpentine, and areas of volcanic rocks. As Putah Creek emerges from the mountains it enters the Central Valley, which was formed by the filling of an inland sea with thousands of feet of marine deposits, and with alluvial deposits from the Coast Ranges and the Sierra Nevada (Lower Putah Creek Coordinating Committee 2005).

Over the geologic timescale, high-flow events in Putah Creek have transported large quantities of erosive sandstone and other parent material from the mountains to the valley floor (Lower Putah Creek Coordinating Committee 2005). These high-flow events would deposit large-sized alluvium near the base of the mountains, forming the Putah Creek fan, and finer sediments were transported farther east onto the valley floor, providing the basis for the formation of productive agricultural soils that exist today (Lower Putah Creek Coordinating Committee 2005).

Hydrology

Hydrologic conditions in Putah Creek have been significantly modified since the construction of Monticello Dam and other Solano Project facilities (Putah Diversion Dam and Putah South Canal). Prior to the completion of Monticello Dam and other Solano Project facilities, runoff events were large and escaped the confinement of the stream banks, and caused extensive flooding along the creek (Lower Putah Creek Coordinating Committee 2005). Following the construction of the Solano Project facilities, Putah Creek's hydrologic regime became highly regulated (Lower Putah Creek Coordinating Committee 2005).

The seasonal instream flow and release patterns from Monticello Dam have become regulated through the May 2000 Putah Creek Accord (Accord) (Solano County Superior Court 2000). The Accord is intended to balance the competing uses for water and create as natural of a flow regime as feasible from the Putah Diversion Dam to the connection at the East Toe Drain in the Yolo Bypass. The focus of the Accord is on the protection and enhancement of native resident and anadromous fish populations and maintenance of riparian vegetation. Four functional flow requirements are set forth in the Accord pertaining to juvenile rearing flows, spawning flows for native resident fishes, supplemental flows for anadromous fishes, and drought-year flows. Table 18 shows the basic required flow regimes specified by the Accord as prescribed for "normal" and "drought" conditions (Lower Putah Creek Coordinating Committee 2005).

Land Use

The lower Putah Creek watershed is comprised of public and private lands. Private lands within and adjacent to the riparian corridor account for 78% of the creek and creek-side parcels, while 21.2% of the parcels within and adjacent to the creek are designated as public lands (Lower Putah Creek Coordinating Committee 2005). Land use consists of agriculture, idle farmland, and urban uses (i.e., residential, commercial, and industrial).

Fisheries and Aquatic Habitat

Prior to the mid-1800s, Putah Creek flowed out of the mountains spreading to the Sacramento Valley and deposited a delta-like sheath of silts, sands, and cobbles by major flood events (Lower Putah Creek Coordinating Committee 2005). With each major flood event, the sediment deposition elevated the creek bed, resulting in Putah Creek changing its course, leaving levee-like strips of gravel flanking the channel (Lower Putah Creek Coordinating Committee 2005). These natural levees were overtopped as the creek sought new configurations (Lower Putah Creek Coordinating Committee 2005).

During the Euro-American settlement, riparian vegetation was removed along the creek to accommodate agricultural practices (Shapovalov 1946 *as cited in* Lower Putah Creek Coordinating Committee 2005). Riparian vegetation removal narrowed the riparian corridor and resulted in elevated water temperatures (Lower Putah Creek Coordinating Committee 2005). Flood control modifications reduced flow velocities and increased the ratio of still to flowing water by widening the channel and eliminating floodplains within incised channels (Marovich, R., pers. comm. 2003 *as cited in* Lower Putah Creek Coordinating Committee 2005). The combination of these alterations increased habitat for introduced warmwater species (e.g., common carp, small mouth bass, etc.) (Lower Putah Creek Coordinating Committee 2005). The Solano Projects altered the flow regime, and further altered physical channel characteristics (e.g, channel structure, sediment transport, etc) and biological characteristics (e.g., species diversity, trophic structure, etc.) (Lower Putah Creek Coordinating Committee 2005).

Table 23. Summary of flows at or near Putah Diversion Dam before and after construction of the Solano Project, and the Putah Creek Accord release schedule

Variable	Flow (cfs)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pre-Project (1934–1956) [1]												
Max	3,957	6,468	3,506	2,729	452	156	64	32	21	45	807	5,110
Med	794	1,075	736	281	125	42	7	5	6	6	37	296
Min	45	67	151	50	17	7	2	0	2	1	3	9
Post Project (1971–1981, 1985–1990) [1]												
Max	1,239	2,239	3,403	2,020	51	43	43	34	36	20	50	85
Med	38	41	33	46	43	43	43	34	20	20	25	25
Min	25	18	26	45	33	33	33	26	16	15	26	25
Putah Creek Accord Release Schedule [2]												
Normal Year – PDD [3,4,5]	25	16	26	46	43	43	43	34	20	20	25	25
Normal Year – I-80 [3, 4, 5]	15	15	25	30	20	15	15	10	5	5	10	10
Drought Year – PDD [6]	25	16	26	46	33	33	33	26	15	15	25	25
Drought Year – I-80 [6]	2	2	2	2	2	2	2	2	2	2	2	2

1 Adapted from USFWS 1993; years post-project data selected to reflect periods similar to available pre-project conditions.
2 Solano County Superior Court 2000 and Moyle, pers. comm., 2002. Note: specific pulse flow requirements not shown.
3 Normal year rearing flows. Normal year exists when Lake Berryessa storage exceeds 750,000 acre-feet on April 1. Values are shown as daily average flow requirements. Continuous flow must be maintained from the I-80 bridge to the Yolo Bypass.
4 Spawning flows modify the normal year rearing flows, as follows: a) 3-day pulse release at PDD sometime between February 15 and March 31 every year, with minimum of 150 cfs, then 100 cfs, then 80 cfs, each for 24 hours, and following the pulse; b) 30 days of releases sufficient to maintain 50 cfs at I-80 bridge, then ramped down over 7 days to match the normal year rearing requirements.
5 Supplemental flows modify the normal year rearing flows, as follows: a) 5-day pulse is required sometime between November 15 and December 15 (timed following removal of flash boards at Los Rios dam) to maintain at least 50 cfs average daily flow at confluence with East Toe Drain, and following the pulse; b) a minimum of 19 cfs is required at I-80 bridge until March 31; and c) 5 cfs flow at East Toe Drain is required from November 1 to December 15 and from April 1 to May 31.
6 Drought year exists when Lake Berryessa storage is less than 750,000 acre-feet on April 1. Values reported in same format as for normal year flow requirements. Continuous flow is not required at Yolo Bypass.

Source: Lower Putah Creek Coordinating Committee 2005.

Steelhead

Anadromous steelhead are considered to have historically spawned in the upper tributaries flowing into Putah Creek above the Berryessa Valley (now Lake Berryessa). Steelhead were sometimes reported to occur downstream of the Putah Diversion Dam, but the reports are unconfirmed (Moyle and Crain 2003). O.mykiss continue to spawn in the tributaries to Lake Berryessa (Moyle, pers. comm., 2003, as cited in Lower Putah Creek Coordinating Committee 2005).

Stony Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Northwestern California

Key Stressors

Key stressors to Central Valley steelhead in Stony Creek include, but are not limited to the following:

- Passage impediments/barriers by Black Butte and North Diversion dams affecting immigrating adults
- Water temperature and/or water quality changes in Stony Creek affecting adult immigration and holding, juvenile rearing and outmigration, and embryo incubation

Watershed Description

Originating in the Coast Ranges (USFWS 1995), Stony Creek is the second-largest west-side tributary to the Sacramento River and drains approximately 740 square miles along California's Coastal Range in Tehama, Glenn, Colusa, and Lake Counties. The Stony Creek watershed has three reservoirs (Black Butte, Stony Gorge, and East Park), which have a combined storage capacity of more than 260 thousand-acre-feet (taf) (GCRCD 2009). Typically, the watershed is discussed as two separate sections, the Upper Stony Creek Watershed and the Lower Stony Creek Watershed, with Black Butte Dam and its associated ridgeline forming the boundary (H.T. Harvey and Associates 2007a). The upper watershed encompasses approximately 473,915 acres including the Grindstone Creek, Briscoe Creek, Upper and Middle Stony Creek watersheds, while the lower watershed is approximately 24,497 acres in size (H.T. Harvey and Associates 2007a).

Existing conditions in Stony Creek preclude the annual production of spring-run Chinook salmon and steelhead (H.T. Harvey and Associates 2007a). Excessively low flows and warm water temperatures in Stony Creek during all life stages prevents the successful production of spring-run Chinook salmon and steelhead (H.T. Harvey and Associates 2007a). Any efforts to improve habitat conditions for anadromous salmonids in Stony Creek should consider the potential effects of climate change, which may prohibit successful production of coldwater fish in this low elevation watershed.

Geology

Upper Stony Creek

The Upper Stony Creek Watershed overlies mechanically weak volcanic, metamorphic and metasedimentary rocks of the Franciscan Complex (Swanson and Kondolf 1991 *as cited in* H.T. Harvey and Associates 2007a). The west side of the north-south trending linear valley marks the contact between the Franciscan Complex and younger sedimentary marine sandstones and conglomerates of the Great Valley Sequence, tertiary volcanic rocks, and alluvial deposits of Pleistocene and Holocene age (H.T. Harvey and Associates 2007a). The older non-marine alluvial deposits consist of consolidated inter-bedded gravel, sandstones, and siltstones (H.T. Harvey and Associates 2007a).

Lower Stony Creek

The majority of the Lower Stony Creek Watershed is comprised of alluvial fan deposits of the Pleistocene and Holocene epochs (H.T. Harvey and Associates 2007a). Releases from Black Butte Dam enter lower Stony Creek near the apex of the Stony Creek alluvial fan, and lower Stony Creek flows entirely through these Pleistocene and Holocene Stony Creek alluvial fan deposits, until near Mills Orchard, where the fan deposits become interbedded with finer-grained Sacramento River floodplain deposits (H.T. Harvey and Associates 2007a).

The alluvial fan surface's broad, concave-upward topography typically drains rainfall-derived runoff away from, not into the lower Stony Creek channel. The alluvial fan surface does not contribute flow to the channel so it is not technically within the watershed (H.T. Harvey and Associates 2007a). The Lower Stony Creek Watershed area is therefore a narrow band, which includes the currently active channel area and formerly active channel and floodplain terraces inset within the broader inactive fan deposits (H.T. Harvey and Associates 2007a).

Hydrology

Upper Stony Creek Watershed

Streamflows in the Upper Stony Creek Watershed are regulated by East Park and Stony Gorge reservoirs before flowing into Black Butte Lake. The main tributary streams drain eastward from their headwaters into a broad north-south trending valley through which Stony Creek flows northerly for about 30 miles to its confluence with Grindstone Creek, then flows northeasterly for about 10 miles to Black Butte Lake (Swanson and Kondolf 1991 *as cited in* H.T. Harvey and Associates 2007a).

East Park and Stony Gorge reservoirs impound water for irrigation and have no flood control capacity. These reservoirs likely attenuate flood peaks from the upper watershed to some degree, but their primary effect on the hydrology of the system is increasing summer base flows downstream. These reservoirs do not significantly reduce the sediment yield from the upper basin because they do not intercept sediment from tributaries with the greatest sediment yield, notably Grindstone Greek (H.T. Harvey and Associates 2007a).

Lower Stony Creek Watershed

Flows from Lower Stony Creek Watershed are controlled by releases made from Black Butte Lake for flood control and irrigation, and irrigation diversions. Black Butte Lake is operated from April to October for irrigation by the U.S. Bureau of Reclamation, while the U.S. Army Corps of Engineers (USACE) operates the reservoir from November to March for flood control purposes (H.T. Harvey and Associates 2007a).

Since the construction of Black Butte Dam in 1963 the frequency and extent of flooding along lower Stony Creek has been significantly reduced (H.T. Harvey and Associates 2007a). However, there are now higher and more variable summer and early fall flows, attributed to irrigation releases. Flows are often sustained through late fall. In 2007, H.T. Harvey and Associates (2007b) conducted a detailed analysis of hydrologic changes due to Black Butte Dam. Their analysis showed that the dam reduced the duration of flows larger than 15,000 cfs by an average of about 1 day per year since 1963, while the duration of flows between 14,000 and 15,000 cfs has increased by an average of 0.62 days per year (H.T. Harvey and Associates 2007b).

Land Use

Upper Stony Creek Watershed

The majority of the Upper Stony Creek Watershed is publicly owned (i.e., Mendocino National Forest) (H.T. Harvey and Associates 2007a). The landscape of the Upper Stony Creek Watershed reflects the inhabitation and management of several cultures and eras, including Native American residence and Euro-American settlement (USDA 1995 *as cited in* H.T. Harvey and Associates 2007a). Mining, timber harvesting, agriculture and grazing, water management, and recreational land use practices can be observed in the Upper Stony Creek Watershed.

Lower Stony Creek Watershed

Compared to the Upper Stony Creek Watershed, the Lower Stony Creek Watershed is smaller in area. By contrast, approximately 96% of the land within the lower watershed is privately owned. Land uses include agriculture, grazing, gravel mining and rural residences (USBR 1998 *as cited in* H.T. Harvey and Associates 2007a). Some public land, associated with diversion canals and other types of infrastructure also exists within the lower watershed (H.T. Harvey and Associates 2007a).

Fisheries and Aquatic Habitat

The upper limit of anadromous fish access in Stony Creek is Black Butte Dam. The existing opportunistic use by salmonids of Stony Creek is currently limited both spatially and temporally, due to unsuitable water temperatures and flows. Only fall-run Chinook salmon have life history requirements nearly compatible with the existing conditions of lower Stony Creek. Improvements to water temperature and flows sufficient to support annual production of fall-run Chinook salmon also would enhance periodic rearing of non-natal Chinook salmon and steelhead trout (H.T. Harvey and Associates 2007a).

Stony Creek does not currently support a sustained annual cycle of anadromous salmonid production. When connected with the Sacramento River, Lower Stony Creek provides non-natal rearing habitat for steelhead and all four runs of Chinook salmon (H.T. Harvey and Associates 2007a).

Steelhead

Data on the relative abundance of fishes in lower Stony Creek comes from trapping and netting by the U. S. Bureau of Reclamation from 2001-2004 (Corwin and Grant 2004). From a total catch of 64,962 fish, two were juvenile steelhead (H.T. Harvey and Associates 2007a). As reported by H.T. Harvey and Associates (2007a), 53 stranded juvenile steelhead were rescued from Lower Stony Creek in March 1997.

While natal rearing by salmonids in Stony Creek occurs during some years, many juvenile steelhead (and Chinook salmon) from Lower Stony Creek are believed to primarily represent non-natal rearing by juveniles spawned elsewhere in the Sacramento River system. Maslin and McKinney (1994) collected fall-run Chinook salmon, spring-run Chinook salmon and steelhead juveniles in the lower three miles of Stony Creek. Corwin and Grant (2004) linked capture of steelhead (and spring- run Chinook salmon) in Lower Stony Creek to specific hatchery releases upstream in the Sacramento River or at Coleman National Fish Hatchery (H.T. Harvey and Associates 2007a).

Thomes Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon (Dependant, not historically abundant) - *Oncorhynchus tshawytscha*
Central Valley steelhead

Diversity Group

Northwestern California

Key Stressors

Key stressors to Central Valley spring-run Chinook salmon and steelhead in the Thomes Creek watershed as identified in the Recovery Plan, include but are not limited to the following:

- Passage impediments/barriers by agricultural diversion dams, braiding and natural channel gradients affecting adult immigration and holding
- Water temperature changes affecting adult immigration and holding, spawning, and embryo incubation
- Agricultural diversions limiting instream flows

Watershed Description

As reported by TCRCD (2006), Thomes Creek originates in the western portion of the Tehama West Watershed and flows eastward for approximately 70 miles before entering the Sacramento River four miles north of the town of Corning, California. The Thomes Creek Watershed extends from the Yolla Bolly-Middle Eel Wilderness Area, south to Anthony Peak.

Numerous seasonally created agricultural diversions in Thomes Creek reduce instream flows, impede fish passage, and entrain small fish. Most of these diversions are unscreened. Restoration actions for anadromous salmonids in Thomes Creek should be directed at minimizing the adverse effects of agricultural diversions and improving fish passage to the upper watershed. Much of Thomes Creek can be characterized as boulder filled canyons, which likely present challenging conditions for spring-run Chinook salmon and steelhead on their upstream migration to holding and spawning habitats in the headwaters.

Geology

The Tehama West Watershed encompasses an area of diverse geologic features critical to Tehama County's agricultural and mining industries (TCRCD 2006). The Thomes Creek watershed includes portions of the eastern Coast Range and western Great Valley Geologic Provinces (TCRCD 2006). The Coast Range Province is characterized by northwest-trending mountain ranges composed of thick Mesozoic and Cenozoic strata, commonly characterized by zones of extensive shearing and the presence of ophiolite/serpentinite mélanges (TCRCD 2006). The Great Valley Province is a sedimentary basin, characterized by a thick deposit of moderately deformed Jurassic and Cretaceous marine sedimentary layers that consist of detrital materials derived from uplifted basement rocks of the Klamath Mountain and Coast Range Provinces (TCRCD 2006). Great Valley rocks consist primarily of mudstone, shale, and sandstone (TCRCD 2006). These units yield an abundance of suspended sediment but relatively little gravel to the watershed (TCRCD 2006). An analysis by the USGS showed that the annual suspended sediment yield of Thomes Creek is nearly three times higher than other streams of comparable size (TCRCD 2006). Thomes Creek continuously transports and deposits eroded sediments along floodplains of the Sacramento River (TCRCD 2006).

For further information on the geology of the Thomes Creek Watershed, refer to the Tehama West Watershed Assessment (TCRCD 2006).

Hydrology

Thomes Creek drains a watershed of approximately 188 square miles and contributes a mean annual run-off of about 200,000 acre-feet (TCRCD 2006). Although there are two seasonal diversion dams located near Paskenta and Henleyville, Thomes Creek does not have any major dams (TCRCD 2006).

Headwaters of the streams in the Tehama West Watershed, including Thomes Creek, have relatively little, if any, drainage area with significant snowpack (TCRCD 2006). However, the upper-most elevation of Thomes Creek exceeds 5,000 feet and during some years may have significant snowpack. In the lower portion of the drainage, snowfall is infrequent and does not significantly contribute to streamflow in Thomes Creek (TCRCD 2006). Thomes Creek is usually dry or intermittent below the USGS stream gauge near Paskenta until the initial heavy Fall rains occur (DWR 2009). Hence, Thomes Creek exhibits rapid responses to storms, and flow levels fluctuate greatly between storm-periods and intervening dry spells (TCRCD 2006). Peak flows in Thomes Creek generally occur during the month of February (Table 24).

Due to the hydrology of the Tehama West Watershed, including Thomes Creek, groundwater is the primary water supply, and because surface water supplies are unpredictable and limited, future growth in the region and water demand during drought conditions will depend on the continued availability of groundwater (TCRCD 2006).

Table 24. Thomes Creek monthly stream flow

Month	Thomes Creek (1921 – 1996)		
	Mean	Minimum	Maximum
January	583	12.4	2,900
February	706	23.2	3,483
March	620	48.9	2,080
April	551	45.3	1,879
May	354	18.2	1,406
June	116	1.41	591
July	23.5	0	133
August	6.28	0	38.1
September	5.08	0	25.5
October	24.7	0	310
November	159	2.85	1,500
December	395	6.93	2,879
Average	295	-	-

Source: TCRCD 2006

Land Use

The Thomes Creek Watershed is largely rural, with isolated pockets of human inhabitants, primarily concentrated along Interstate 5 (TCRCD 2006). Land use in this watershed largely depends on ownership (TCRCD 2006). While most of the low- and mid-elevation lands are held by private individuals who use these areas primarily for agriculture (i.e., ranching and farming) and residential uses, the upper elevations are held by commercial timber companies and the U.S. Forest Service or the Bureau of Land Management (TCRCD 2006).

Fisheries and Aquatic Habitat

The physical and hydrologic characteristics of the Thomes Creek watershed determine the habitat availability to fishery resources. Flows tend to rise quickly following storm events, drop equally promptly following storms, and carry very large quantities of sediment (TCRCD 2006). The snowpack in this watershed results in relatively light warm-season runoff, resulting in perennial Coast Range stream reaches; mid-reach sections that may be dry in mid-summer; and lower reaches near the Sacramento River that may contain small amounts of water from irrigation run-off (TCRCD 2006). Thomes Creek has an unimpaired hydrologic pattern of flashy winter and spring flows and very low summer and fall flows, creating an environment of fairly inconsistent habitat (CALFED 2000a). Thomes Creek is usually dry or intermittent below the USGS stream gage near Paskenta until the first heavy fall rains occur (DWR Website 2007). Therefore, spring-run Chinook salmon utilization of Thomes Creek would likely only occur during wet years. Inconsistent flows, particularly during the fall and early winter months, promote an increased potential for redd dewatering.

There are no significant dams on Thomes Creek other than two seasonal diversion dams, one near Paskenta and the other near Henleyville. Several small pump diversions are seasonally operated in the stream (DWR Website 2007). These dams would be in place during the time when spring-run Chinook salmon would be immigrating to upstream areas and likely present obstacles to upstream immigration. Additionally, gravel mining downstream of the Tehama-Colusa Canal siphon crossing has reportedly resulted in a partial barrier to salmonids returning to Thomes Creek to spawn (Vestra Resources, Inc. 2006).

Thomes Creek has been evaluated in recent years with regards to its upper reach accessibility to anadromous fish. In May 2004 the California Department of Fish and Wildlife determined that an impassible barrier to Chinook salmon and steelhead exists at the point immediately above the confluence of the stream with Horse Trough Creek (Barron, F. Personal communications, as cited in TCRCD 2006). This location is approximately 9 miles upstream from Paskenta and at an elevation of approximately 1,500 feet (TCRCD 2006).

During most years, water temperatures during the summer months are likely too warm to support adult spring-run Chinook salmon holding. Chinook salmon utilizing Thomes Creek for spawning likely hold in the mainstem Sacramento River.

The lower reach of Thomes Creek has been significantly altered by the construction of flood control levees and bank protection measures (i.e., riprapping) (CALFED 2000a), resulting in reduced habitat availability for juvenile salmonids.

Spring-Run Chinook Salmon

GrandTab escapement data for Thomes Creek spring-run Chinook salmon is generally unavailable. However, in 1998 and 2002, spring-run Chinook salmon escapement was reported to be 1 and 2, respectively (CDFW 2009; D. Killam, pers. comm., 2009).

As reported in the Tehama West Watershed Assessment (TCRCD 2006), California Department of Fish and Wildlife files provide anecdotal information regarding Chinook salmon usage of Thomes Creek. In one memo, spring-run Chinook were reported in the stream in 1946 and 1961; however, the locations of the observations were not noted. In 1958 a rancher observed 30–40 spring-run Chinook salmon near Henleyville (TCRCD 2006).

Steelhead

As reported by TCRCD (2006), in 1982, 22 species of fish were recorded within various portions of Thomes Creek (Brown *et. al*. 1983 as cited in CALFED 2000). Steelhead were reported to be the most abundant fish species above the “Gorge”, however, these fish were likely rainbow trout, as there is an anadromous fish barrier a short distance above the “Gorge” (TCRCD 2006).

Cottonwood/Beegum Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon (Dependant population, not historically abundant)
Central Valley steelhead

Diversity Group

Northwestern California

Key Stressors

Key stressors to Central Valley spring-run Chinook salmon and steelhead in the Cottonwood/Beegum watershed include, but are not limited to the following:

- Loss of floodplain and riparian habitat and instream cover from gravel mining affecting juvenile rearing and outmigration\]
- Loss of natural river morphology from gravel mining (e.g., channel braiding) affecting adult immigration, juvenile rearing and outmigration
- Low flow conditions (i.e., low flows and flow fluctuations) associated with attraction and migratory cues in Cottonwood Creek affecting adult immigration, spawning and embryo incubation
- Natural elevated water temperatures and poor water quality affecting adult immigration and holding, spawning and embryo incubation
- Natural Spawning habitat availability affecting adult spawning

Watershed Description

Cottonwood Creek is the third largest watershed tributary west of the Sacramento River and the largest undammed tributary in the upper Sacramento River basin (CALFED 1997). The watershed is located within Shasta and Tehama counties on the north-west side of northern California's Central Valley, with a peak elevation of approximately 7,860 feet (CH2MHILL 2002, 2007) (Table 25). The lower two-thirds of the drainage lies in the Central Valley uplands, while the upstream portion includes the east slope of the North Coast Mountain Range and Klamath Mountains, and the southern slopes of the Trinity Mountains (CH2MHILL 2002). Cottonwood Creek is fed by three major branches (i.e., North, Middle, and South forks).

Cottonwood Creek itself does not contain suitable spawning habitat to support a spring-run Chinook salmon population. However, Beegum Creek, a tributary of Cottonwood Creek, does currently support a small persistent population (since 1998). Lindley *et al*. (2004) considers the Beegum Creek population to be dependant upon input of migrants from populations such as Deer, Mill and Butte creeks (thereby classified as a "dependent" population). Another possibility is that the group of streams in the Northwestern California Diversity Group operate as a metapopulation (Hanski and Gilpin, 1991), i.e., individual populations may not be viable on their own, but migration among members of the group maintains persistence of the whole group. Either way, the small area of available habitat argues against the existence of an independent population historically. The classification of these populations as dependent does not mean that they have no role to play in the persistence or recovery of the Central Valley spring-run Chinook salmon ESU. If these populations are adapted to their unusual spawning and rearing habitats, they may contain a valuable genetic resource (perhaps being more tolerant of high temperatures than other spring-run Chinook salmon). These habitats and populations may also serve to link other populations in ways that increase ESU viability over longer time scales (Lindley *et al*. 2004).

The prospects for spring-run Chinook salmon in Beegum Creek are dampened by global warming. Spring-run Chinook salmon in Beegum Creek are limited to low elevation habitat that is thermally marginal now, and will become intolerable within decades if the climate warms as expected (Williams 2006).

Table 25. Cottonwood Creek watershed characteristics

Characteristic	Value
Watershed Area	938 square miles
Cottonwood Creek Stream Length	68 miles
Headwater Elevation	7,680 feet
Mean Discharge	860 cubic feet per second (cfs)
10-year Flood	50,000 cfs
100-year Flood	93,000 cfs
Mean precipitation	36 inches

Source: CH2MHILL 2007

Beegum Creek is a major tributary to the Middle Fork Cottonwood Creek. The North, Middle, and South forks of Beegum Creek originate in the easternmost portion of the Shasta-Trinity National Forests and converge to form the mainstem of Beegum Creek before entering a remote, steep-sided canyon known as Beegum Gorge (CH2MHILL 2002).

Geology

The three principal geological provinces in the Cottonwood Creek watershed are the Great Valley Province, the Coast Range Province, and the Klamath Mountain Province. The Great Valley Province is a 400-mile-long by 60-mile-wide sedimentary basin that comprises the majority of the watershed (CH2MHILL 2002). The Coast Range Province and the Klamath Mountains Province consist of various highly erosive formations including South Fork Mountain

Schist, Rattlesnake Creek terrain, and North Fork terrain, in addition to the decomposed granitic soils of the Shasta Bally Batholith (CH2MHILL 2002).

The Coast Range fault, Stoney Creek fault, Cold Fork fault, Sulfur Spring fault, Oak Flat fault, Battle Creek fault, and numerous cross faults and thrust faults occur in the Cottonwood Creek watershed. Fault traces located east of South Fork are likely obscured by stream activity and agricultural practices (USGS 1988; WET 1991; Dupras 1997 *as cited in* CH2MHILL 2002). The most recent fault movement is believed to have occurred more than 125,000 years ago (DWR 1993 *as cited in* CH2MHILL 2002).

Large, active landslides that contribute to the sediment discharge are abundant in the South Fork Mountain Schist of the South Fork of Cottonwood Creek (DWR 1992 *as cited in* CH2MHILL 2002) and the Rattlesnake Creek terrain of Beegum Creek (USFS 1997 *as cited in* CH2MHILL 2002). A notable slide is located on Slide Creek, tributary to the South Fork of Cottonwood Creek; in 1995 this slide contributed a large amount of sediment to South Fork Cottonwood Creek. Cottonwood Creek is a major contributor of spawning gravel to the Sacramento River (P. Bratcher, pers. comm., 2009).

Hydrology

The entire Cottonwood Creek watershed is essentially unregulated, although a small reservoir, Rainbow Lake (capacity 4,800 acre-feet), is located on the NF Cottonwood Creek (Graham Matthews and Associates 2003). The hydrology of Cottonwood Creek is typical of watersheds found along the west side of the Sacramento Valley (CH2MHILL 2002). The relatively low elevation of the watershed limits the amount of snowpack that can accumulate in any given year, which results in a hydrologic regime closely correlated to storm events (CH2MHILL 2002). Mean annual runoff in Cottonwood Creek from 1941-2000 is approximately 645,000 acre-feet (Graham Matthews and Associates 2003). Cottonwood Creek is a source of flood flow in the Sacramento River between Shasta Dam and Ord Ferry. Groundwater development is largely limited to the alluvial area near the confluence with the Sacramento River (CH2MHILL 2002).

Land Use

Human impacts on Cottonwood Creek watershed began in the 1850's with gold mining operations. The gold mining in placer deposits commonly used dredge, hydraulic, and ground-sluicing techniques, resulting in the discharge of sediment to the watershed. Effects resulting from historical mining operations have generally dissipated, with the possible exception of the presence of residual mercury wastes in the tailings of historical mining sites (CH2MHILL 2007).

The Cottonwood Creek Watershed remains relatively undeveloped, and is generally characterized by tracts of harvestable timber in the upper reaches, irrigated pastureland in the middle reaches, and ranches, residential housing, and gravel mining operations in the lower reaches. Approximately 70 percent of land within the watershed is privately owned (CH2M HILL 2002). The Beegum Creek watershed is generally forest-covered and has not been significantly modified (D. Killam, CDFW, pers. comm. 2009).

Fisheries and Aquatic Habitat

The Cottonwood Creek watershed continues to provide habitat for anadromous fish, including spring-run Chinook salmon and steelhead. Within the Cottonwood Creek Watershed, spring-run Chinook salmon and steelhead are known to utilize the mainstem, North Fork, Middle Fork and South Fork of Cottonwood Creek, in addition to Beegum Creek (CH2MHILL 2002). However, Beegum Creek is the principal location for spring-run Chinook salmon holding and spawning in the Cottonwood Creek watershed. Refer to Table 26 for habitat characteristics of Cottonwood and Beegum Creeks. Environmental factors including hydrology, stream temperature, channel morphology, and gravel recruitment allow Cottonwood Creek to support significant fish populations on a seasonal and year-round basis (RMI 1987 *as cited in* CH2MHILL 2002).

Spring-Run Chinook Salmon

Historically, approximately 500 adult spring-run Chinook salmon may have spawned in Cottonwood and Beegum Creeks annually (CH2MHILL 2002). Recent Beegum Creek spring-run Chinook salmon escapement estimates are displayed in Table 27. The highest known spring-run Chinook salmon escapement in Beegum Creek is 477, occurring in 1998. Spring-run Chinook salmon escapement has generally exhibited a downward trend from 2001 through 2008.

Table 26. Habitat characteristics of Cottonwood and Beegum Creeks

Creek	Total Length (miles)	Anadromous Access (miles)	Maximum Elevation (feet)	Suitable Spawning Habitat (sq. ft.)
Mainstem	20.57	20.57	350	152,400
North Fork	28.0	20.24	5,720	37,400
Middle Fork	30.5	Unknown	7,860	36,600
South Fork	56.78	43.91	7,900	165,900
Beegum Creek	33.49	18.0	Unknown	Unknown

Source: CH2MHILL 2002. Data from CDFW (1978)

Table 27. Adult spring-run Chinook salmon population estimates for Cottonwood Creek from 1993 to 2011. Estimates are not available for all years.

Year	Adult Estimate	Year	Adult Estimate	Year	Adult Estimate
1993	1	**2000**	122	**2007**	34
1994		**2001**	245	**2008**	
1995	8	**2002**	125	**2009**	
1996	6	**2003**	73	**2010**	15
1997		**2004**	17	**2011**	2
1998	477	**2005**	47		
1999	102	**2006**	55		

Sources: CDFW Grandtab; personal communications with DFG and FWS biologists.

Steelhead

Cottonwood Creek is one of the major tributaries to the Sacramento River system that supports steelhead spawning (CH2MHILL 2002). Because they migrate during high flows, and it is difficult to distinguish juvenile steelhead from resident rainbow trout, few steelhead population estimates have been recorded in Cottonwood Creek (CH2MHILL 2002). The USFS and CDFW have observed populations of juvenile steelhead in the upper South Fork Cottonwood Creek Yolla Bolly Middle Eel Wilderness Area in the summer of 1976 (CH2MHILL 2002). Small runs of adult steelhead have been observed to migrate in the mainstem and lower reaches of the North, Middle, and South Fork Cottonwood Creek.

Clear Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Northwestern California

Key Stressors

Key stressors to spring-run Chinook salmon and steelhead in Clear Creek include, but are not limited to the following:

- ❖ Passage impediments/barriers at Whiskeytown Dam affecting adult immigration, and consequently holding, spawning, redd superimposition, competition for habitat, hybridization and genetic integrity
- ❖ Water temperatures and water quality affecting adult immigration and holding, spawning and embryo incubation
- ❖ Physical habitat alteration (particularly associated with limited supplies of instream gravel), affecting adult spawning habitat suitability
- ❖ Flow conditions (i.e., low flows) affecting juvenile rearing and outmigration
- ❖ Sedimentation affecting embryo incubation (*e.g*., recent fires)
- ❖ Loss of floodplain habitat and natural river morphology affecting juvenile rearing and outmigration

Watershed Description

Clear Creek is the first major tributary to the Sacramento River below Shasta Dam. Clear Creek originates in the mountains east of Clair Engle Reservoir and flows approximately 35 miles to its confluence with the Sacramento River at RM 289 near the south Redding city limits in Shasta County, California. Clear Creek drains approximately 238 square miles (USFWS 1995).

Whiskeytown Dam, constructed in 1963 near RM 18.1, stores and regulates run-off from the Clear Creek watershed and diversions from the Trinity River (USFWS 1995). The former McCormick-Saeltzer Dam was located approximately 12 miles downstream from Whiskeytown Dam at RM 6.4, and diverted water for irrigation use (USFWS 1995), but was removed in 2000.

The stream channel below Whiskeytown Dam can be divided into two predominant types at Clear Creek Road Bridge (RM 8.5) (USFWS 1995). Upstream, the creek is mainly confined by steep canyon walls and is characterized by falls, high gradient riffles, and deep pools (USFWS 1995). The substrate is mainly bedrock, large boulders, and fine sand. Downstream from RM 8.5 is the alluvial reach with a much lower gradient and a much wider valley relatively unconstrained by bedrock (USFWS 1995). Substrate is mainly a mixture of cobble, gravel, and sand (USFWS 1995).

The climate in the Clear Creek watershed is Mediterranean, with most precipitation occurring in the winter months (i.e., November through April), and dry summers with temperatures exceeding 100°F (McBain and Trush *et al*. 2000). Average annual precipitation in the Clear Creek watershed varies from 20 inches near the confluence with the Sacramento River to over 60 inches in the upper watershed (McBain and Trush *et al*. 2000). Precipitation is primarily rainfall, with snow occurring at the highest elevations of the watershed (McBain and Trush 2000).

The Clear Creek spring-run Chinook salmon and steelhead populations are currently considered persistent, dependent upon input of migrants from populations such as Deer, Mill and Butte creeks (thereby classified as a "dependent" population). Clear Creek historically was not known to support a large Central Valley spring-run population. Records from historical data sets are sparse, so the abundance that is seen in Clear Creek today for spring-run salmon and for steelhead does not have an adequate baseline to determine what the original carrying capacity was for this watershed. Since 1998, spring-run Chinook salmon have shown an increasing trend in abundance. In 2000 a small dam was removed which opened up 12 miles of prime spawning habitat for spring-run and steelhead. Increasing abundance is due in part to the reliable cool water source diverted from the Trinity River water, released at Whiskeytown Reservoir (Reclamation 2008). In addition, spring-run Chinook salmon and steelhead populations in Clear Creek have also responded to extensive restoration efforts by joint agency partnerships through such programs as CVPIA and CALFED.

Geology

Lower Clear Creek flows over Pleistocene age stream gravel that has been extensively mined. The historical pre-dam transport of gravel into lower Clear Creek is not known, and the present transport and recruitment of gravel in lower Clear Creek also is unknown. Lower Clear Creek, below Whiskeytown Dam can be grouped into two reaches. The upper canyon-bound reach of Clear Creek has stream slopes in the range of 0.6 to 2.0 percent, as measured from USGS 1:24,000 scale topographic quadrangles. The lower reach has an average stream gradient of 0.3 percent (Castro 1996 in Sacramento River Watershed Program 2008). Upstream tributaries to the canyon bound reach typically have stream slopes greater than 4 percent (Sacramento River Watershed Program 2008). The lower reach has lost its natural meander pattern. In places, the stream runs in straight highly entrenched channel dugs to facilitate gravel mining. Steep bluffs, composed of the Pleistocene epoch Riverbank and Red Bluff formations (Helly and Harwood 1985) occur where Clear Creek has cut into these formations and where hydraulic placer mining historically occurred (Sacramento River Watershed Program 2008).

The impoundment-induced coarse sediment deficit and concomitant reduction in habitat quality in Clear Creek below Whiskeytown Dam has been well documented by various investigators (Coots 1971 as cited in McBain and Trush 2001, GMA 2003). Effects of reduced coarse sediment supply include: riffle coarsening, fossilization of alluvial features, loss of fine sediments available for overbank deposition and riparian re-generation, and a reduction in the amount and quality of spawning gravels available for anadromous salmonids.

Below Whiskeytown Dam to Clear Creek Road, the channel exhibits typical inner-gorge, bedrock dominated, morphology with a high degree of confinement and little alluvial storage. However, exhibits remnant alluvial features and hence, demonstrates potential for alluvial processes to develop. Tributary sources of coarse sediment for the first 1.8 miles below the dam are extremely limited and contribute coarse sediment only during highly infrequent stochastic events (Rasmussen 2006; Steensen 1997). Colluvial sources (canyon walls) contribute very little within practical management timeframes and such material is of limited ecological value until is transported and rounded over some distance. Gravel bars, coarse-cobble riffles and (post-dam) abandoned floodplains alternate with deep scour pools and bedrock-constricted chutes. Most spawning riffles in this reach have coarsened and appear relatively immobile at intermittent high flows from dam-spills and spring time pulse flows (NMFS 2009a), but lacking sediment input, do not replace finer material.

Below Clear Creek Road, the combination of over-extraction and reduced coarse sediment supply led to channel down-cutting and a loss of floodplain connectivity (McBain and Trush 2001). Many of these effects are exacerbated in the lower parts of the watershed by the legacy of dredging and gravel extraction overlain by the increase in fine sediment production from impacted tributaries and by the removal of a relic dam (McCormick -Saeltzer Dam).

Hydrology

The median historical unimpaired run-off in Clear Creek is 69 thousand acre-feet (TAF), with a range of 0-421 TAF (USFWS 1995). Construction of Whiskeytown Dam greatly reduced the volume and magnitude of historic flows (McBain and Trush *et al*. 2000).

Since 1964, a portion of the flow from the Trinity River Basin has been exported to the Sacramento River Basin through Whiskeytown Reservoir (Reclamation 2008). Water is diverted from the Trinity River at Lewiston Dam via the Clear Creek Tunnel and passes through the Judge Francis Carr Powerhouse as it is discharged into Whiskeytown Lake on Clear Creek (Reclamation 2008). From Whiskeytown Lake, water is released through the Spring Creek Power Conduit to the Spring Creek Powerplant and into Keswick Reservoir. All of the water diverted from the Trinity River, in addition to a portion of Clear Creek flows, is diverted through the Spring Creek tunnel into Keswick Reservoir (Reclamation 2008). A larger volume of water from the Trinity River goes to the Sacramento River through the Spring Creek Power Conduit than goes to Clear Creek (Reclamation 2008). On average, 1.2 maf (up to 2,000 cfs) of water from the Trinity River is diverted each year into Keswick Reservoir compared to 200 cfs released to Clear Creek for fishery needs (NMFS 2008) between the Fall and Spring. Flows provided to Clear Creek below Whiskeytown Dam are consistently at least 200 cfs from October through June. During the summer months, flows are increased to provide adequate water temperatures for holding adult spring-run Chinook salmon and water temperatures for rearing steelhead per the 2004 OCAP Biological Opinion (NMFS 2008). The Spring Creek Power Conduit water is used primarily to deliver agricultural, municipal and industrial water, and generate power. This water helps cool the Sacramento River during the spring for winter-run Chinook salmon spawning and embryo incubation (Reclamation 2008).

Land Use

As reported in the Lower Clear Creek Floodway Rehabilitation Project Design Document (McBain and Trush *et al.* 2000), lower Clear Creek has undergone significant changes due to land use beginning with the discovery of gold at Reading Bar in 1848. Various forms of gold mining transformed the natural landscape into piles of placer, hydraulic, and dredger tailings. In most locations, the entire lower Clear Creek floodway was "turned upside down" in the search for gold. Gold mining also brought secondary impacts to the creek, including road building, deforestation, and urban development. Dredger tailings adjacent to the creek between the former Saeltzer Dam and Clear Creek Road Bridge are the most pronounced relics of historic gold mining activity, with the tailings confining the river and providing very little value as floodplain or riparian habitat (McBain and Trush *et al.* 2000).

The most recent significant land use impact to lower Clear Creek was instream and off-channel gravel mining, occurring from 1950 to 1978 (McBain and Trush *et al*. 2000). Impacts to channel morphology and salmonid habitat were significant; the bankfull channel was destroyed and floodplains removed, leaving wide shallow channels and interspersed deep pits (McBain and Trush *et al*. 2000).

Fisheries and Aquatic Habitat

Historically, there were approximately 25 river miles of Chinook salmon habitat available for use in Clear Creek of which only 18.1 are currently accessible (NMFS Website 2005) because of the construction of a dam to create power and water for the Redding area. Whiskeytown Dam is a complete barrier to fish passage and is the uppermost boundary of habitat available to anadromous salmon and steelhead.

Other negative effects to the spring-run and the steelhead fishery resulted from Whiskeytown Reservoir being "stretched" across this wild river. The construction of Whiskeytown Dam, gold mining, and gravel mining in the Clear Creek watershed has diminished suitable spawning gravel substrate and reduced riparian habitat along the lower sections of Clear Creek (CDFW 2004). Excessive gravel removal exposed a clay hardpan over much of the channel bottom, directly removing salmonid spawning and fry rearing habitat (McBain and Trush *et al*. 2000). Gravel mining also resulted in lost channel confinement, allowing both adult and juvenile salmonids to stray into adjacent pits and become stranded (McBain and Trush *et al*. 2000). Construction of Whiskeytown Dam reduced the magnitude and frequency of high flow events responsible for creating and maintaining lower Clear Creek, which allowed fine sediment to accumulate in the channel and allowed riparian vegetation to establish and mature along the low flow channel (McBain and Trush *et al*. 2000). As the vegetation matured, the combined root strength of the riparian band "fossilized" gravel deposits and reduced the quantity and quality of aquatic habitat in some areas (McBain and Trush *et al*. 2000).

One of the keys to success for recovery of both populations of salmonids includes a good supply of cold water from Whiskeytown Reservoir. Water temperatures in Clear Creek at the USGS Igo gaging station (RM 10.85) are maintained below 60°F from June through September and 56°F from September to October for steelhead and spring-run spawning and rearing (NMFS 2009a). The spring-run Chinook salmon population in Clear Creek does not appear to be currently habitat-limited as long as water temperatures are suitable (Reclamation 2008).

In recent years, a multi-phase restoration project on lower Clear Creek (i.e., The Lower Clear Creek Floodway Rehabilitation Project) *recreated a defined channel and floodplain, and included construction of a natural bar (plug) to reduce stranding of juvenile salmon and improve passage conditions for adult salmon migrating upstream* (California Association of Resource Conservation Districts 2005). In addition, aggregate extraction pits within the stream channel and floodplain were filled, and active rehabilitation was conducted including improving floodplain connectivity, and re-vegetation of natural riparian communities (California Association of Resource Conservation Districts 2005).

Success in increasing population abundance has occurred in part because of the numerous gravel augmentation projects (per CVPIA requirements) that have been implemented in lower Clear Creek, resulting in the addition of over 100,000 tons of gravel (Table 28). Spawning gravel is routinely added every year at various sites to compensate for channel down-cutting. Spawning gravel augmentation has greatly improved suitable habitat for spring-run Chinook salmon and steelhead (NMFS 2009a). Additional gravel augmentation at 11 sites along lower Clear Creek is being proposed by the National Park Service and the Bureau of Land Management (NPS and BLM 2008). Up to 25,000 tons of gravel would be placed system-wide annually for ten years (NPS and BLM 2008).

Table 28. Past gravel augmentation totals in Clear Creek (as of April 2007)

Placement Site	Total Quantity (Tons)	Jurisdiction
Whiskeytown Dam	23,258	BOR
Below NEED Camp	3,602	NPS
Placer Road Bridge	19,802	Non-Federal
Clear Creek Road	3,003	BLM
Reading Bar	999	BLM
Saeltzer Gorge	36,953	BLM
Above Phase 3A	1,730	BLM
Floodway	11,721	BLM
Phase 2B Exchange	1,404	BLM
TOTAL	102,470	

Source: Graham Matthews & Associates 2007a, as cited in NPS and BLM 2008

Spring-run Chinook Salmon

Historically, Clear Creek supported spring-run Chinook salmon (Reclamation 2008). However, historical accounts of spring-run Chinook in Clear Creek are sparse and population estimates are nonexistent (Reclamation 2008). Since 1998, spring-run Chinook salmon have shown an increasing trend in abundance from 50 (in 1998) to about 200 adults (highest number on record) in 2008 (Table 29). From 2005 through 2008, Clear Creek spring-run Chinook salmon escapement was estimated at 69, 77, 194 and 200 adults, respectively (CDFW 2009).

Some spring-run Chinook salmon in Clear Creek may be descendants of Chinook salmon from the Feather River Hatchery (FRH), which were stocked into Clear Creek in the early 1990's (Newton and Brown 2004). In order to re-establish spring-run Chinook salmon in Clear Creek, approximately 200,000 juveniles from the FRH were planted in Clear Creek annually in 1991, 1992 and 1993 (Brown 1996, as cited in Newton and Brown 2004). Contribution by the stocked FRH fish to the current spring-run Chinook salmon population may be limited due to: 1) a lack of suitable water temperatures during their holding and early spawning periods; and 2) probable hybridization with fall-run Chinook salmon (Newton and Brown 2004).

Table 29. Adult spring-run Chinook salmon population estimates for Clear Creek from 1993 to 2012 from USFWS. Estimates are not available for all years.

Year	Adult Estimate	Year	Adult Estimate	Year	Adult Estimate
1993	1	**2000**	19	**2007**	194
1994	0	**2001**	0	**2008**	200
1995	2	**2002**	66	**2009**	120
1996		**2003**	25	**2010**	21
1997		**2004**	98	**2011**	8
1998	47	**2005**	69	**2012**	68
1999	35	**2006**	77		

Sources: CDFW Grandtab; personal communications with DFG and FWS biologists.

Since 2003, the USFWS has separated fall-run Chinook salmon adults from spring-run Chinook salmon adults holding in the upper reaches of Clear Creek with the use of a picket weir located at either RM 8.1 or 7.4 (S. Giovannetti, USFWS, pers. comm., 2009). The weir is operated from approximately August 23 to November 1 to prevent fall-run Chinook from spawning in spring-run Chinook spawning areas to reduce hybridization, superimposition and competition. After November 1, fall-run Chinook salmon have access to the entire river for spawning, but rarely move upstream into spring-run Chinook salmon spawning areas.

Under dry and warm climate conditions, water temperatures above 60° F occur in Clear Creek. Lindley *et al*. (2004) suggested that Clear Creek appears to offer habitat of marginal suitability to spring-run, having limited area at higher elevations and being highly dependent on rainfall.

Steelhead

Historically, steelhead probably ascended Clear Creek past the French Gulch area, but access to the upper basin was blocked by Whiskeytown Dam in 1964 (Yoshiyama *et al.* 1996). Operation of Whiskeytown Dam can produce suitable coldwater habitat downstream to Placer Road Bridge depending on flow releases (DFG 1998, as cited in (Reclamation 2008)). Removal of the McCormick-Saeltzer Dam in 2000 has provided steelhead access to an additional 12 miles of habitat (NMFS 2009a). Steelhead have re-colonized this area and taken advantage of newly added spawning gravels.
Recent redd surveys conducted since 2001 indicate a small but increasing population resides in Clear Creek (Figure 18), with the highest density in the first mile below Whiskeytown Dam (USFWS 2007, as cited in NMFS 2009a). Spawning distribution has recently expanded from the upper 4 miles to throughout the 18 miles of Clear Creek, although it appears to be concentrated in areas of newly added spawning gravels (NMFS 2009a).

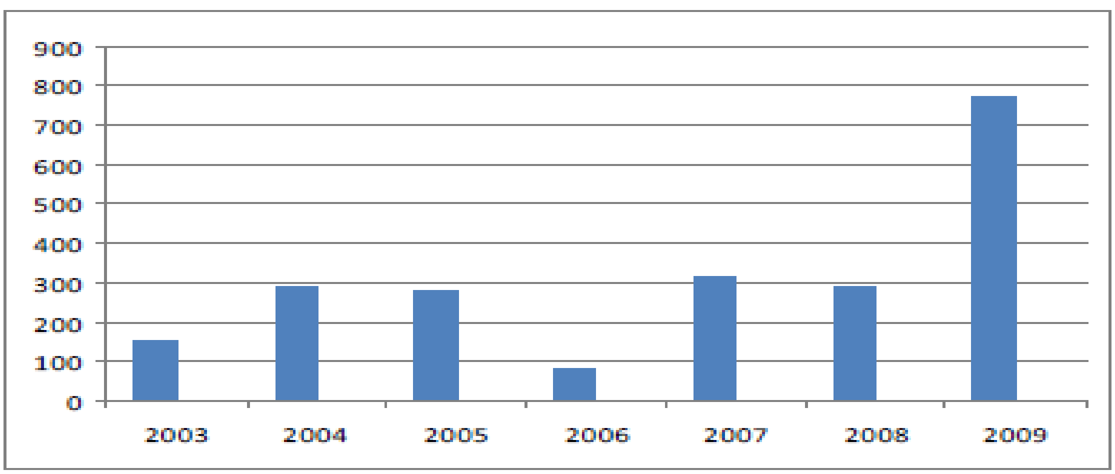

Figure 18. Abundance of steelhead in Clear Creek based on annual redd counts 2003-2009. Spawning population based on average 1.23 males per female on the American River (Hannon and Deason 2007). 2009 estimate is preliminary based on 4 surveys (USFWS 2008, Brown 2009) Source: NMFS 2009a.

In addition to the anadromous form of *O. mykiss*, many resident trout reside in Clear Creek, making it difficult to identify CV steelhead except when they are spawning (*i.e.*, resident trout spawn in the spring and have smaller size redds). Large riverine *O. mykiss* that reside in the Sacramento River can migrate up Clear Creek to spawn with either the anadromous or resident forms. No hatchery steelhead (*i.e.*, presence of adipose fin-clip) were observed during the 2003-2007 kayak and snorkel surveys in Figure 17, indicating that straying of hatchery steelhead is probably low in Clear Creek (USFWS 2008).

SOUTHERN SIERRA NEVADA DIVERSITY GROUP

Calaveras River Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley steelhead

Diversity Group

Southern Sierra Nevada

Key Stressors

Key stressors to Central Valley steelhead in the Calaveras River include, but are not limited to the following:

- ❖ Fish passage impediments/barriers at Mormon Slough, the Old Calaveras River channel, Camanche Dam, Pardee Reservoir Dam, Bellota Weir and other locations affecting adult immigration and holding, and juvenile rearing and outmigration
- ❖ Flow conditions (i.e., low flows) affecting passage, attraction and migratory cues for adult immigration and holding
- ❖ Water quality conditions (i.e., urban and agricultural runoff) in the Calaveras River affecting adult immigration and holding
- ❖ Physical habitat alteration associated with limited supplies of instream gravel affecting spawning
- ❖ Water temperatures affecting spawning and embryo incubation, and juvenile rearing and outmigration
- ❖ Hatchery effects related to redd superimposition, competition for spawning habitat, and genetic integrity
- ❖ Flow dependent habitat availability affecting juvenile rearing and outmigration
- ❖ Hatchery effects related to juvenile rearing and outmigration

Watershed Description

In the San Joaquin River system, the Calaveras River is a relatively small Sierra watershed between the Mokelumne and Stanislaus rivers, and encompasses parts of Calaveras, Stanislaus, and San Joaquin counties (USFWS 2003). The Calaveras River watershed (Figure 19) is approximately 600 square miles with an average historic unimpaired runoff of 150,000 acre-feet per year and a minimum of about 12,000 acre-feet per year. The North Fork begins at Pine Ridge at an elevation of about 4,000 feet. The headwaters of the South Fork, San Antonio Creek, begins at Summit Level Ridge at an elevation of 6,000 feet (USFWS 2003).

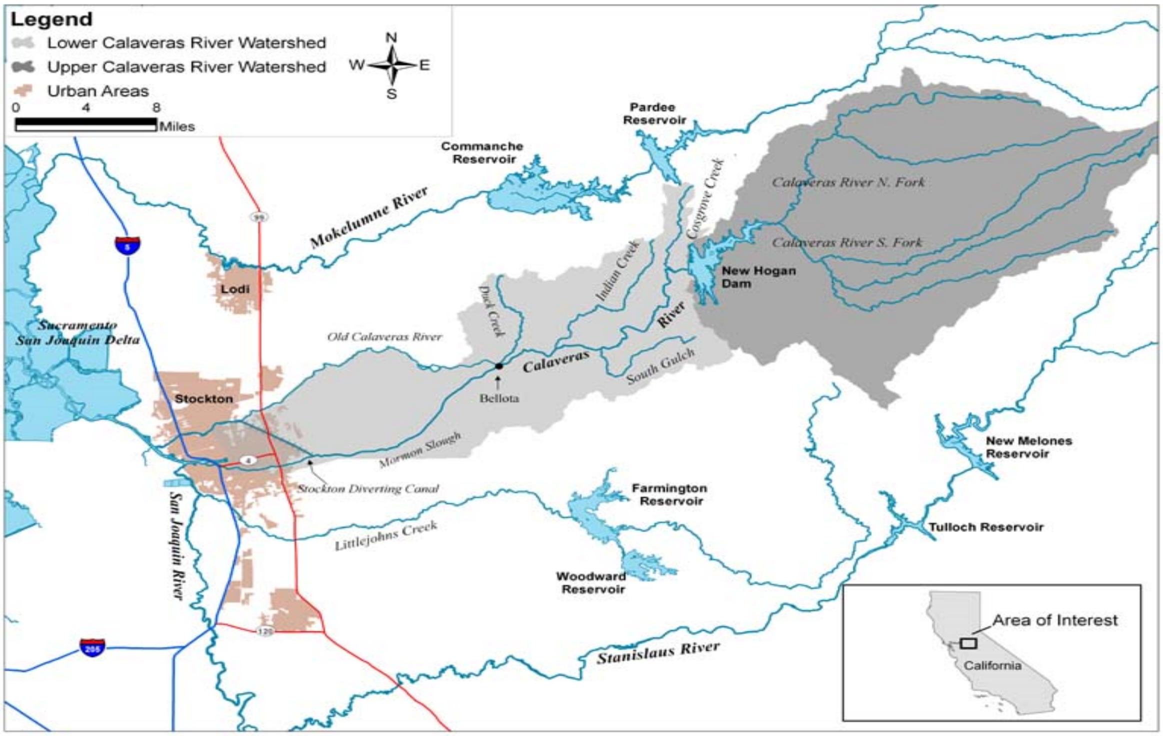

Figure 19. Calaveras River Watershed Source: Calaveras River Watershed Stewardship Group 2007

Geology

The Eastern San Joaquin Subbasin underlies a large portion of the eastern area of San Joaquin County. This basin is drained from the San Joaquin River and several of its tributaries including the Stanislaus, Calaveras and Mokelumne Rivers (California Department of Water Resources 2006a in San Joaquin Council of Governments 2007). Water bearing formations in this subbasin consists of the Alluvium and Modesto/Riverbank Formations, Flood Basin Deposits, Laguna Formation, and the Mehrten Formation (San Joaquin Council of Governments 2007). In the northern portion of Calaveras County, soils are reportedly coarse, very acidic, and nutrient-poor, mostly derived from the Eocene Ione formation (Holland 1986 in Calaveras County 2008).

Hydrology

Average precipitation ranges from about 20 inches a year in the western region to 60 inches in the northeast, and the rainy season extends from October 1 through May 1 (Calaveras Country 2008).

The most prominent manmade facility in the watershed is New Hogan Dam and Reservoir at river mile (RM) 42 (measured via the Mormon Slough route) which controls flows on the lower Calaveras River. Streamflow in the lower watershed is controlled by releases from New Hogan Reservoir, a 317,000 acre-foot U.S. Army Corps of Engineers (Corps) flood control and water supply reservoir formed by New Hogan Dam, which was constructed in 1964 and is located 38 miles upstream from the mouth of the river (USFWS 2003). Prior to construction of New Hogan Dam, the hydrology of the Calaveras River exhibited higher flow during the winter and spring, as well as periods of low-to-no flow during the late summer and fall. After New Hogan Reservoir was constructed in 1964, winter and spring flow peaks have been reduced and water now flows year round between New Hogan Dam and Bellota Weir (Marsh 2006). Because of the paucity of high elevation habitat capable of holding snowpack, the Calaveras watershed is a rain-driven system unlike other surrounding watersheds. Thus, New Hogan Reservoir captures most of the rainfall into the watershed, and local runoff in the lower Calaveras River below New Hogan Dam seeps quickly into the groundwater table (USFWS 2003).

The four main tributaries below New Hogan Dam are Cosgrove Creek, South Gulch, Indian Creek, and Duck Creek. Cosgrove Creek provides the largest contribution of runoff to the Calaveras River, as much as 8,500 acre-feet in some years (Calaveras River Watershed Stewardship Group 2007). The lower Calaveras River Mormon Slough area below New Hogan Dam encompasses approximately 115,000 acres and receives up to 90,000 acre-feet of surface water supply from the lower Calaveras River.

Releases from the New Hogan Reservoir provide year-round flows downstream to Bellota (USFWS 2003). Releases from the spring through early fall irrigation season generally range from 150 to 250 cfs. Non-irrigation season releases in non-drought years range from a minimum of 20 to 50 cfs to meet downstream municipal water supply demands. In drought years, non-irrigation season releases may be less, dependent on adaptive management determinations that will be made between SEWD and NMFS during implementation of the Calaveras River Habitat Conservation Plan. Water diversions from New Hogan Dam downstream to Bellota, including those of Stockton East Water District (SEWD) and the Calaveras County Water District (CCWD), remove most of the river flow, except during the rainy season. Water is released into the Old River channel and Mormon Slough at Bellota during the irrigation season for downstream users including groundwater recharge; however, the lower channels near Stockton are usually dry except during the rainy season. The two main water diversions are the CCWD diversion just below New Hogan Dam, which diverts water via an infiltration gallery, and the SEWD Bellota Intake diversion that feeds the Dr. Joe Waidhofer Water Treatment Plant via the Bellota Pipeline. In addition there are 29 operating agricultural water diversions between New Hogan Dam and Bellota Weir, and several more in each channel below the Bellota Weir (USFWS 2003).

Most of the water entering the lower Calaveras system at Bellota is diverted to Mormon Slough for irrigation and flood control purposes (USFWS 2003). Only during flood flows does water pass over the weir into the Old Calaveras River channel. Some water is diverted into the Old River channel through gated culverts during the irrigation season. Near Stockton, Mormon Slough flows are diverted to the Stockton Diverting Canal back to the Old Calaveras River channel, where water flows downs to the San Joaquin River. Below the Bellota Weir, the Calaveras River system has been reconfigured as a flood control and storm drainage system with Mormon Slough and the Diverting Canal being the principle water conveyance channels. During the dry season, both Mormon Slough and the Old River Channel serve as conveyance for local irrigation supplies (USFWS 2003).

The river reach above the Bellota Weir upstream to New Hogan Dam is a natural stream channel confined in most places by a foothill canyon. The lower section of the river immediately above Bellota has a lower gradient and its floodplain has been altered for agriculture. The channels below Bellota are essential ditches designed to carry irrigation water during the irrigation season and flood flows in winter and spring (USFWS 2003).

Land Use

Near its confluence with the San Joaquin River, the Calaveras River is bordered on both banks by the City of Stockton, passing through housing subdivisions, the University of the Pacific campus, and parks (USFWS 1998, as cited in Marsh 2006). The Calaveras River serves as an important source of water for agricultural and municipal uses in Calaveras and San Joaquin counties. Levees along Mormon Slough and the Stockton Diverting Canal are covered with sparse grass or shrubs, and adjacent to the old Calaveras River channel are orchards or light industry (Marsh 2006). Additionally, local stakeholder groups have expressed concerns regarding potential effects to water quality and aquatic habitats resulting from storm water runoff, agriculture, recreation, mining, unscreened diversion operations, and other land uses in the basin (The Calaveras River Watershed Stewardship Group 2007).

Fisheries and Aquatic Habitat

While very few studies of the fishery resources in the Calaveras River have been conducted to date, recent monitoring indicates that steelhead opportunistically use the watershed when sufficient rainfall produces passage flows in the system (Fishbio 2008). As reported by Marsh (2006), anadromous fish have access to 36 miles of the Calaveras River between New Hogan Dam and the San Joaquin River, when flows permit. Downstream of New Hogan Dam there is a dense riparian corridor bordering the river along the 18 miles down to Bellota Weir (USFWS 1998, as cited in Marsh 2006). Eighteen river miles upstream from the mouth, Bellota Weir splits the Calaveras River into two channels, Mormon Slough and the Old Calaveras River channel. Mormon Slough and the Stockton Diverting canal downstream are the primary channels used by migrating anadromous fish to access upstream spawning areas in the mainstem Calaveras River upstream of Bellota Weir (Figure 20). Fall flows in Mormon Slough, following the end of the irrigation season, frequently are reduced to levels less than 20 to 30 cubic feet per second (cfs) and may prevent spawning migration (FFC 2004, as cited in Marsh 2006). Mormon Slough, the primary salmonid migration channel, still experiences dry periods during summer and early fall as it did under the pre-1964 unregulated hydrologic regime (Marsh 2006).

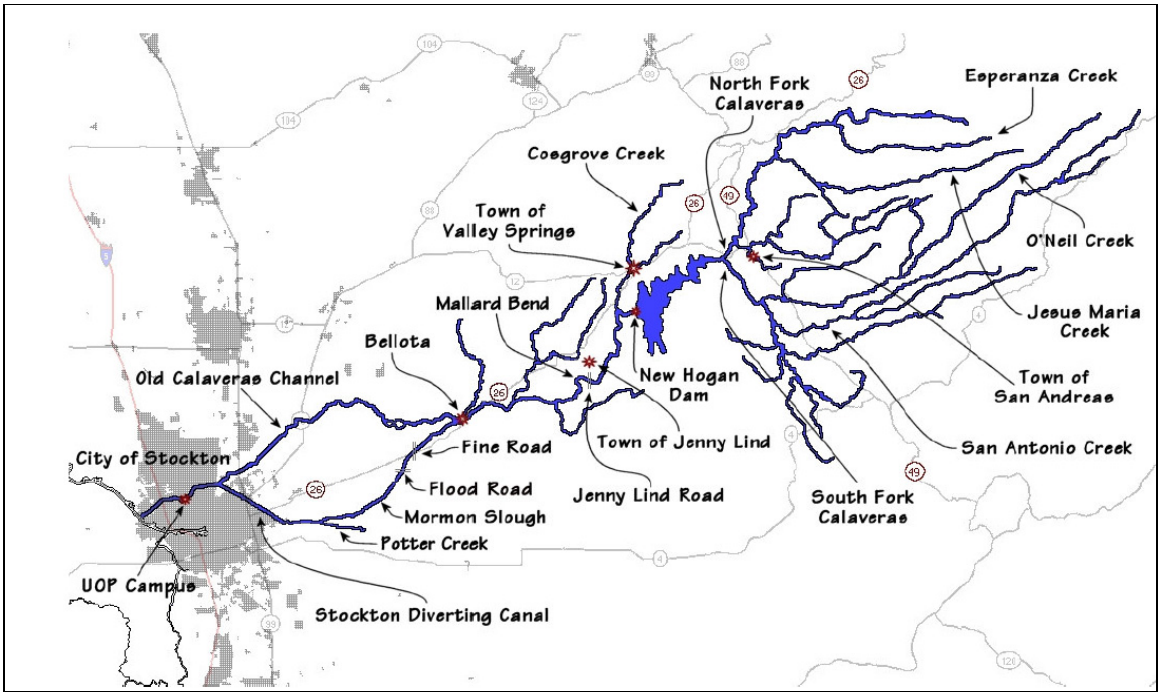

Figure 20. Primary barriers and features of the Calaveras River Watershed Source: Marsh 2006.

Historically, salmon and steelhead production in the Calaveras River was limited by low, intermittent flows during summer and fall. Chinook salmon have not been observed in the Calaveras River since 1984 (USFWS 1995). Although the duration and magnitude of peak winter/spring flows have been reduced due to reservoir operations, salmonids are able to opportunistically access the reach between the Bellota Weir and New Hogan Dam for spawning whenever adequate naturally occurring migration flows are available and no structural barriers are installed (i.e., flashboard dams). Upstream and downstream migration opportunities are currently limited to occasions between November and early April when passage conditions are created by substantial precipitation events that result in flood control releases and/or run-off events below the dam. In many years, precipitation events resulting in passage conditions do not begin until December because rainfall from initial storm events is generally absorbed into the ground through infiltration and run-off does not occur until the ground becomes saturated.

Currently, little data has been collected regarding the abundance, life-history preferences, and migration success of *O. mykiss* in the Calaveras River (Fishbio 2008). As reported by Marsh (2006), the Calaveras River does have the potential to support anadromous fish based on habitat qualities such as geomorphology (i.e., 22 feet per mile gradient, numerous riffles and pools), adequate spawning gravels, and a dense riparian canopy (USFWS 1993, CALFED Bay-Delta Program 2000, as cited in Marsh 2006). Spawning gravels occur in the lower Calaveras River in the first mile of river below New Hogan Dam and further downstream in the canyon and Jenny Lind reaches. In addition there are small areas of gravel riffles in Mormon Slough below Bellota Weir. Spawning gravels in the first mile below New Hogan Dam suffer from low permeability, but are adequate for several hundred pairs of salmon (USFWS 2003). Spawning gravels are similar in the middle reach between New Hogan Dam and the Bellota Weir. Below Bellota Weir the spawning gravels are limited and have poor permeability, but have produced some fry salmon in recent years. Several steelhead redds in this area in the spring of 2002 were likely unsuccessful as water temperatures reached lethal levels for trout eggs in the redds during the spring (USFWS 2003).

Adult steelhead entering the Calaveras River system are likely to move up the mainstem San Joaquin River channel before branching off into the channels of their natal rivers (NMFS 2008). Adult salmonid upstream passage problems include blockage at structural barriers and adequacy of stream flows for upstream adult migration (USFWS 2003). Juvenile salmonid downstream passage problems include structural barriers, lack of streamflow, and unscreened water diversions. Habitat concerns include: (1) instream flows for spawning and rearing; (2) adequacy of gravel spawning habitat; (3) adequacy of cool water rearing habitat; and (4) competition and predation by non-native warm-water fishes (USFWS 2003). There are many barriers to salmonid passage in the lower Calaveras River channels including several each in the Old Calaveras channel, the Diversion Canal, and Mormon Slough. Weirs at Bellota including one at the head of Mormon Slough, and one at the head of the Old River Channel are virtually impassable at many flows (USFWS 2003). However, two fish ladders have been placed at the Bellota Dam to assist with fish movement along the Calaveras River, and a hydraulic analyses of both ladders was conducted in 2005 (Fishery Foundation of California 2005).

Artificial structures (e.g., low-flow road crossings with culverts, low-flow road crossings without culverts, bridges, permanent dams and weirs, and flashboard dams with the flashboards removed) play a major role in reducing the Calaveras River's fisheries productivity (DWR 2007). Although the importance of the Calaveras River for steelhead production is currently unknown, opportunities to improve fish passage and aquatic habitat for anadromous salmonids have been identified at several locations, including the Mormon Slough flood control channel, the Old Calaveras River channel, and at the SEWD and the CCWD facilities (Fishbio 2008). SEWD and CCWD are working cooperatively with NMFS to improve the conditions for salmonids in the Calaveras River by including appropriate conservation measures and an adaptive management plan as part of this Calaveras River Habitat Conservation Plan. SEWD also is continuing to implement interim fish passage improvements until long-term fish passage and screening solutions are identified and put into operation (Fishbio 2008).

Steelhead

Although it is likely that steelhead once inhabited most of the San Joaquin River Basin streams used by Chinook salmon for spawning, they probably traveled farther upstream into smaller tributaries (Moyle *et al*. 1996). These passages are now blocked by dams. There is also little or no historic record of escapement available. Current annual escapements of steelhead in the San Joaquin River Basin, including the Calaveras River, are limited due to the long-term scarcity or absence of steelhead in the basin (Reclamation 2001)Lindley *et al*. (2006) concluded that several Calaveras River tributaries upstream of New Hogan Dam historically supported summer rearing habitat for steelhead and an independent population of steelhead. This conclusion is supported bythe collected anecdotal and documented information presented by Marsh (2006).

Flow is reported to be a principal factor currently limiting salmonids in general in the Calaveras River (CALFED Bay-Delta Program 2000, as cited in Marsh 2006). However, a small, apparently self-sustaining population of steelhead exists in the Calaveras River (NMFS 2008). Steelhead opportunistically use the watershed when sufficient flow provides suitable passage to spawning habitats. Surveys on the Calaveras River over the past several years indicate that small numbers of steelhead continue to run up the river with the first fall rains and during the winter (USFWS 2003).

The Calaveras River has historically experienced hatchery influences; *O.mykiss* have been stocked upstream and downstream of New Hogan Dam. In an analysis of the population genetic structure of Central Valley *O.mykiss*, Garza and Pearse (2008) reported that Calaveras River O.mykiss consistently grouped with "…the Junction Kamloops hatchery strain, possibly indicating some introgression from this strain into Calaveras River steelhead." Carcasses of several steelhead collected below Bellota Weir were too deteriorated to determine if the adipose fins were clipped (USFWS 2003).

Restoration opportunities exist on the Calaveras River to improve fish passage and aquatic habitat for anadromous salmonids. Several have been identified at several locations, including the Mormon Slough flood control channel, the Old Calaveras River channel, and at the SEWD and CCWD diversion facilities (Fishbio 2008). SEWD and CCWD are working cooperatively with NMFS to improve the conditions for salmonids in the Calaveras River by including appropriate conservation measures and an adaptive management plan as part of the Calaveras River Habitat Conservation Plan. SEWD also is continuing to implement interim fish passage improvements until long-term fish passage and screening solutions are identified and put into operation (Fishbio 2008). Further instream and riparian habitat improvements such as an increase in shade and channel complexity, which over time could support better steelhead rearing.

Stanislaus River Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Southern Sierra Nevada

Key Stressors

Key stressors to steelhead in the Stanislaus River include but are not limited to the following:

- Passage impediments/barriers at Goodwin, New Melones and Tulloch dams affecting adult immigration and holding
- Flow conditions (i.e., low flows) associated with attraction and migratory cues into the Stanislaus River affecting adult immigration
- Physical habitat alteration associated with limited supplies of instream gravel, habitat suitability and spawning habitat availability affecting adult spawning
- Flow conditions (i.e., flow fluctuations), particularly during flood releases, affecting spawning and embryo incubation
- Flow dependent habitat availability affecting juvenile rearing and outmigration
- Changes in hydrology and channel morphology (e.g., reduced instream gravel recruitment, reduced channel complexity, increased predator habitats) affecting juvenile rearing and outmigration
- Loss of riparian habitat, floodplain and side-channel habitat, and instream cover affecting juvenile rearing and outmigration

Watershed Description

The habitat currently available to salmonids on the Stanislaus River has been severely limited and impacted as a result of human activities over the past hundred years. Because of the significant impacts to habitat on the Stanislaus River, spring-run Chinook and viable populations of steelhead have been extirpated from the watershed. Steelhead are present but only in low numbers. Installation of the Goodwin, Tulloch, and New Melones Dams has been the primary cause of depleted, degraded habitat. The dams are physical barriers between migrating adult salmonids and their historic spawning habitat as well as a physical barrier that impedes the natural downstream transport of spawning gravel. The operation of the dams has resulted in decreased and more uniform flow. This has resulted in many negative effects including degraded water quality, channel incision and a loss in habitat diversity due to inhibiting geomorphic processes, and a lack in connectivity to floodplain rearing habitat.

In addition to the installation and operation of the dams, other human impacts have an effect of the river. This would include gravel mining activities. Although this does not occur as frequently today in the watershed, remnant gravel mining pits provide warm-water refugia for non-native predators. This activity has also depleted gravel abundance needed to replenish spawning habitat downstream. In addition, gravel and gold mining activities have contributed to the Lower Stanislaus River's listing as an impaired water body for mercury (2006 Clean Water Act section 303(d) list). Agricultural and urban landscape runoff contribute pesticide, herbicide, and fertilizer pollutants into the watershed.

Some restoration has been occurring to address the dearth in good flow and good gravels. In the spring, the Vernalis Adaptive Management Program (VAMP) flows are designed to stimulate outmigration for juvenile fall-run Chinook salmon, and consequently steelhead, into the Delta. CVPIA funding has provided funding for gravel augmentation to the river; however, more gravel is needed to replenish past losses as well as maintain current annual losses (NMFS 2009a). Restoration actions that would restore viability: release of more flow to lower water temperature, dilute pollutants, and carry juveniles downstream to more suitable rearing habitat, and vary flow rates to provide more geomorphic function and increase habitat diversity. Restoration of riparian habitat in the lower river would also increase good habitat for steelhead and provide much needed refugia that is missing because of the off channel opportunities that are denied because of the lack of access to upper habitats.

Watershed Description

The Stanislaus River originates in the western slopes of the Sierra Nevada and is one of the largest tributaries of the San Joaquin River. The Stanislaus River is approximately 113 miles long and covers an area of approximately 1,075 square miles (USFWS 2008) (Figure 21).

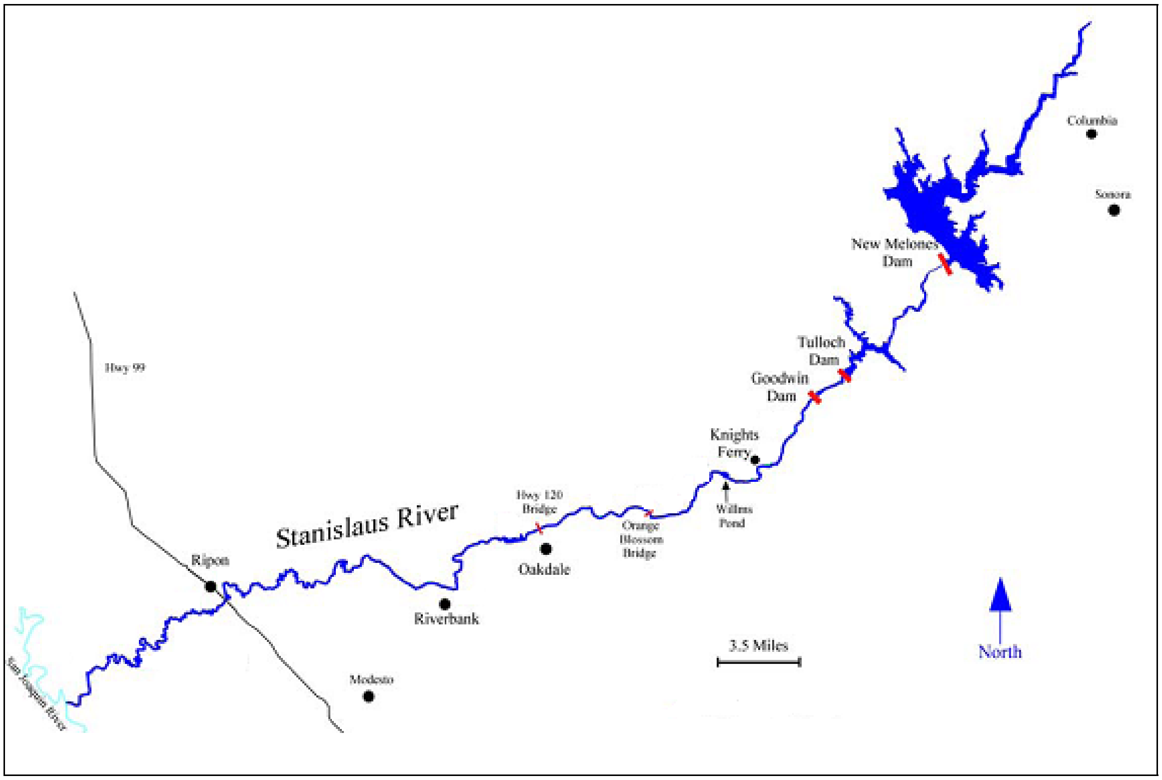

Figure 21. The Lower Stanislaus River between New Melones Reservoir and the San Joaquin River confluence Source: Modified from SRFG 2003

The Stanislaus River is extensively dammed and diverted. Donnells Dam on the middle fork forms Donell Lake, high in the Sierra Nevada. Downstream is Beardsley Dam, which forms Beardsley Lake. McKays' Point Diversion Dam diverts water on the north fork for hydroelectricity production and domestic use. The New Melones Dam blocks the river after the confluence of all three forks. Downstream from New Melones Lake, there is Tulloch Dam, which forms Tulloch Reservoir, and Goodwin Dam (RM 58), which is the first major barrier for anadromous fish on the Stanislaus River.

Geology

In the upper Stanislaus River watershed, the geology is primarily glaciated granite with mid-river reaches of metamorphic rock. Between Goodwin Dam and Knights Ferry, the rock is predominately volcanic. Below Knights Ferry, the river flows through Holocene alluvial deposits adjacent to late Pleistocene fill terraces.

Hydrology

The average unimpaired runoff in the watershed is about 1.2 million acre-feet (maf) (Reclamation 2008). The median historical unimpaired runoff is 1.1 maf per year, with a range of between 0.2 and 3.0 maf (USFWS 1995). Snowmelt contributes the largest portion of the flows in the Stanislaus River, with the highest runoff occurring in the months of April, May, and June (Reclamation 2008). Agricultural water supply development in the Stanislaus River watershed began in the 1850s and has significantly altered the basin's hydrologic conditions. The 32 dams within the Stanislaus River watershed large enough to be regulated by the Division of Safety of Dams have a total capacity of about 2.85 maf, or 237 percent of the average unimpaired runoff (SRFG 2003). The current hydrograph differs greatly from unimpaired flow conditions. Spring and summer flows are capped at 1,500 cfs (barring flood releases), while summer flows are increased to maintain downstream water quality.

Currently, New Melones Dam and Reservoir, completed by the Corps in 1979, is now the largest storage reservoir in the basin with a storage capacity of 2.4 maf, and was designed to control floods up to the 100-year-flood (Kondolf *et al*. 2001). New Melones Dam and Reservoir is located approximately 60 miles upstream from the confluence of the Stanislaus River and the San Joaquin River.

Another major water storage project in the Stanislaus River watershed is the Tri-Dam Project, a power generation project that consists of Donnells and Beardsley Dams, located upstream of New Melones Reservoir on the middle fork Stanislaus River, and Tulloch Dam and Powerplant, located approximately 6 miles downstream of New Melones Dam on the mainstem Stanislaus River (Reclamation 2008). New Spicer Reservoir on the north fork of the Stanislaus River has a storage capacity of 189,000 af and is used for power generation. Releases from Donnells and Beardsley Dams affect inflows to New Melones Reservoir. Under contractual agreements between Reclamation, the Oakdale Irrigation District (OID), and South San Joaquin Irrigation District (SSJID), Tulloch Reservoir provides afterbay storage to reregulate power releases from New Melones Powerplant (Reclamation 2008).

The main water diversion point on the Stanislaus River is Goodwin Dam, located approximately 1.9 miles downstream of Tulloch Dam. Goodwin Dam, constructed by OID and SSJID in 1912, creates a re-regulating reservoir for releases from Tulloch Powerplant and provides for diversions to canals north and south of the Stanislaus River for delivery to OID and SSJID. Water impounded behind Goodwin Dam may be pumped into the Goodwin Tunnel for deliveries to the Central San Joaquin Water Conservation District and the Stockton East Water District (Reclamation 2008).

Twenty ungaged tributaries contribute flow to the lower portion of the Stanislaus River, below Goodwin Dam (Reclamation 2008). These streams provide intermittent flows, occurring primarily during the months of November through April. Agricultural return flows, as well as operational spills from irrigation canals receiving water from both the Stanislaus and Tuolumne Rivers, enter the lower portion of the Stanislaus River. In addition, a portion of the flow in the lower reach of the Stanislaus River originates from groundwater accretions (Reclamation 2008).

The New Melones Reservoir flood control operation is coordinated with the operation of Tulloch Reservoir. The flood control objective is to maintain flood flows at the Orange Blossom Bridge at less than 8,000 cfs. When possible, however, releases from Tulloch Dam are maintained at levels that would not result in downstream flows in excess of 1,250 cfs to 1,500 cfs because of seepage problems in agricultural lands adjoining the river associated with flows above this level (Reclamation 2008).

As part of the East Side Division of the Central Valley Project (CVP), New Melones Dam and Reservoir are operated by the Bureau of Reclamation (Reclamation). Flows in the lower Stanislaus River serve multiple purposes concurrently. The purposes include water supply for riparian water right holders, fishery management objectives, and dissolved oxygen (DO) requirements per State Water Resources Control Board Decision (D)-1422. Issued in 1973, SWRCB D-1422 provided the primary operational criteria for New Melones Reservoir and permitted Reclamation to appropriate water from the Stanislaus River for irrigation and M&I uses. Under D-1422, Reclamation was required to release up to 98 thousand acre-feet (taf) of water per year from New Melones Reservoir to the Stanislaus River on a distribution pattern to be specified each year by CDFW for fish and wildlife purposes (SRFG 2003). In addition, water from the Stanislaus River enters the San Joaquin River where it contributes to flow and helps improve water quality conditions at Vernalis. D-1422 requires the operation of New Melones Reservoir include releases for existing water rights, fish and wildlife enhancement, and the maintenance of water quality conditions on the Stanislaus and San Joaquin rivers (Reclamation 2008).

More recently, CVP operations on the Stanislaus River have been guided by the New Melones Interim Plan of Operation (NMIPO) (Reclamation 2008). The NMIPO was developed as a joint effort between Reclamation and USFWS, in conjunction with the Stanislaus River Basin Stakeholders over a period of several years (SRFG 2003). The process of developing the plan began in 1995 with a goal to develop a management plan with clear operating criteria, given a fundamental recognition by all parties that New Melones Reservoir water supplies are overcommitted on a long-term basis, and consequently, unable to me*et al*l the potential beneficial uses designated as purposes (Reclamation 2008). Although meant to be a short-term plan, it continues to be in effect and defines categories of water supply and operations criteria for the annual planning to meet beneficial uses from New Melones Reservoir storage (Reclamation 2008).

Instream fishery management flow volumes on the Stanislaus River, as part of the NMIPO, are based on a combination of fishery flows pursuant to the 1987 CDFW Agreement and the USFWS AFRP in-stream flow goals (Reclamation 2008). Dedication of (b)(2) water on the Stanislaus River also provides actual in-stream flows below Goodwin Dam greater than the fish and wildlife requirements previously identified for the East Side Division, and in the past has been generally consistent with the NMIPO (Reclamation 2008). Actual in-stream fishery management flows below Goodwin Dam will be determined in accordance with the Decision on Implementation of Section 3406 (b)(2) of the CVPIA. Reclamation has begun a process to develop a long-term operations plan for New Melones Reservoir, which will be coordinated with B2IT members, along with the stakeholders and the public before it is finalized (Reclamation 2008).

The operating criteria for New Melones Reservoir are affected by (1) water rights; (2) in-stream fish and wildlife flow requirements; (3) SWRCB D-1641 Vernalis water quality requirements; (4) dissolved oxygen (DO) requirements on the Stanislaus River; (5) SWRCB D-1641 Vernalis flow requirements; (6) CVP contracts; and (7) flood control considerations. Water released from New Melones Dam and Powerplant is re-regulated at Tulloch Reservoir and is either diverted at

Goodwin Dam or released from Goodwin Dam to the lower Stanislaus River (Reclamation 2008).

Land Use

The lower Stanislaus River has been extensively developed to provide water, hydroelectric power, gravel, and conversion of floodplain habitat for agricultural and residential uses (SRFG 2003). While the upper reaches of the lower Stanislaus River (below Goodwin Canyon) remain relatively undeveloped, the river floodplain below Knights Ferry (with the exception of a narrow riparian border) has been converted to urban and rural development or used for agriculture (Wikert pers. comm. 2009). By 1994, it was estimated that approximately 50 percent of the riparian corridor along the lower Stanislaus River had been converted for agricultural, mining, and urban uses (USFWS 1995, as cited in KDH Environmental Services 2008).

Fisheries and Aquatic Habitat

The Stanislaus River historically had 113 miles of anadromous fish habitat (USFWS 2008), but currently only the lower 58 river-miles are accessible to anadromous fish, with access terminating at Goodwin Dam (KDH Environmental Services 2008). Historically, spring-run Chinook salmon were believed to be the primary salmon run in the Stanislaus River, but the fall-run population became dominant following construction of Goodwin Dam, which blocked upstream migration between 1913 and 1929 (in Yoshiyama *et al*. 1996). It is likely that hydraulic mining caused the initial decline of the salmon and steelhead runs in the Stanislaus River, because the early dams were too small to substantially affect flows and they did not completely block the salmon's upstream migration until Old Melones Dam was constructed in 1926 (SRFG 2003).

Although records on anadromous salmonids in the San Joaquin tributaries are sparse (Yoshiyama *et al*. 1998), the Stanislaus River still provides valuable spawning and rearing habitat for fall-run Chinook salmon and steelhead (NMFS 2004). Spawning is focused on the extensive gravel beds located from the town of Riverbank to Knights Ferry, with 95 percent of fall-run Chinook salmon spawning occurring from Orange Blossom Road to Knights Ferry (NMFS 2008). One mile upstream of Knights Ferry, spawning is concentrated at Two-Mile Bar (NMFS 2008).

Compared to historic conditions, the area of suitable salmonid spawning and rearing habitats has been substantially reduced due to anthropogenic influences including dam construction, in-river aggregate mining, and the conversion of floodplain habitat for agricultural uses (KDH Environmental Services 2008). A series of dams in the Stanislaus River has blocked access to spawning habitat in the upper river, and has blocked the transport of gravel to downstream reaches (KDH Environmental Services 2008). Gravel recruitment was reduced by 92 percent following construction of Goodwin Dam in 1912 (KDH Environmental Services 2008). Mobilization of gravel and fines below Goodwin Dam was further reduced in 1981 when the expansion of New Melones Dam reduced the frequency and magnitude of flooding in the lower reaches (Kondolf *et al*. 2001, as cited in KDH Environmental Services 2008), inhibiting the flushing of fine particles from coarser bed materials (CDWR 1994, as cited in KDH Environmental Services 2008). Along most of the lower Stanislaus River, agricultural and urban encroachment has separated the river from its floodplain. As a result, the channel is incised, which prevents the river from developing and maintaining shallow spawning and rearing habitats necessary for salmonids.

Gold and aggregate mining also have had a detrimental effect on spawning and rearing habitats in the Stanislaus River (KDH Environmental Services 2008). Approximately 40 percent of historic gravel beds were excavated from the 13.6-mile reach between Goodwin Dam and Orange Blossom Bridge between the years 1939 and 1980 for gold and aggregate mining purposes (Mesick 2003, as cited in KDH Environmental Services 2008). Mining activities left instream pits and long, uniform ditches 5 to 10 feet deep and 100 to 165 feet wide in the active channel near Lover's Leap from RM 53.4 downstream to RM 51.8. Gravels entering the river from tributaries below Goodwin Dam, or mobilized in high flow events become trapped in these pits rather than replenishing downstream riffles (SRFG 2003). Furthermore, these ditches sustain large populations of predatory fish, but provide little habitat for salmonids (KDH Environmental Services 2008).

Isolation of floodplain and riparian habitats from the Stanislaus River by dikes also has had a negative impact on salmonid spawning and rearing habitats (KDH Environmental Services 2008). Dikes confine flood flows to the river channel, increasing the rate of scouring of gravel from spawning and rearing habitat (KDH Environmental Services 2008).

Reduced gravel recruitment, in-river gravel mining, and the loss of functional floodplain, have severely reduced the quality and quantity of the spawning and rearing habitat for anadromous salmonids in the lower Stanislaus River (KDH Environmental Services 2008). The limited riffle habitat that remains has become armored and shortened due to erosion and the blockage of gravel recruitment (Mesick 2001, as cited in KDH Environmental Services 2008).

Restoration actions conducted to date have been limited to spawning gravel augmentation and providing additional water to supplement Stanislaus River flows in accordance with Section 3406(b)(2) and 3406(b)(3) provisions of the Central Valley Project Improvement Act (CVPIA)[8]. Additional restoration work is needed to replace gravel lost to mining and dams, and to provide additional floodplain habitat to replace that which has been lost due to the flattening of the hydrograph (USFWS 2008).

In September 2007, the Lover's Leap Restoration Project was implemented in the lower Stanislaus River near Lover's Leap, and was intended to replenish spawning gravel at existing and new restoration sites and to restore riverbed topography (KDH Environmental Services 2008). The overall objective was to increase and improve steelhead (and Chinook salmon) spawning and rearing habitat by adding approximately 18,000 tons of cleaned spawning-sized

[8] Section 3406(b)(2) of the CVPIA directs the Secretary of the Interior to dedicate and manage annually eight hundred thousand acre-feet of Central Valley Project yield for the primary purpose of implementing the fish, wildlife, and habitat restoration purposes and measures authorized by the CVPIA. The 800,000 acre-feet of water dedicated by the CVPIA is referred to as "(b)(2) water."

gravels and roughly 7,000 tons of larger cobble to degraded areas within the 25.5 mile salmonid spawning reach. (KDH Environmental Services 2008) Increasing the area of suitable spawning habitat should increase the abundance and condition of Chinook salmon and steelhead by reducing the effect of density dependent factors such as redd superimposition and by decreasing the area of habitat available for predatory fish (KDH Environmental Services 2008).

Steelhead

Central Valley steelhead were thought to be extirpated from the San Joaquin River system. However, monitoring has detected small self-sustaining (i.e., non-hatchery origin) populations of steelhead in the Stanislaus River and other streams previously thought to be devoid of steelhead (McEwan 2001). In 2004, a total of 12 steelhead smolts were collected at Mossdale, which indicates steelhead production is occurring in the San Joaquin River tributaries (CDFW unpublished data).

A fish counting weir operated in the river near the town of Riverbank has documented the passage of large *Oncorhynchus mykiss* upstream. In the 2006-7 season 12 steelhead were observed passing through a Stanislaus River counting weir (Anderson *et al*. 2007). However, surveys have not been conducted to determine where steelhead spawn in the Stanislaus River, but it is presumed that a majority of spawning occurs between Goodwin Dam and the Orange Blossom Bridge (SRFG 2003). The potential spawning sites with holding and feeding habitat, and spawning-sized gravel where large adults are frequently caught with hook-and-line include the four gravel addition sites in Goodwin Canyon, eight of the Knights Ferry Gravel Replenishment sites near Lovers Leap, Horseshoe Road, and Honolulu Bar, and four riffles adjacent to deep mine pits near Frymire Ranch, "Willms Pond", and Button Bush Park. Although the abundance of steelhead is not surveyed in the Stanislaus River, the catch of adult steelhead using hook-and-line began to increase in 1997 and again in 1999 (SRFG 2003).

Juvenile salmonid monitoring has been conducted at Oakdale and/or Caswell on the Stanislaus River since 1995, and is used to estimate abundance of out-migrating fall-run juvenile Chinook salmon (*O. tshawytscha)* and Central Valley steelhead/rainbow trout (*O. mykiss)* to the San Joaquin River as part of the U.S. Fish and Wildlife Service's Anadromous Fish Restoration Program (AFRP) (USFWS 2008; USFWS 2008a). Steelhead smolts also have been captured in the rotary screw traps at Caswell State Park and Oakdale each year since 1995 (Cramer and Associates Inc. 2000; 2001). Studies by CDFW also have documented juvenile *O. mykiss* in the river with maternal anadromy using SR:Ca ratios. More recently, Zimmerman *et al.* (2008) has documented steelhead in the Stanislaus River based on otilith microchemistry, while nearly 90 percent of O. mykiss sampled were offspring of resident adults.

Based on surveys conducted during 2000 and 2001, Fisheries Foundation (2002 in SRFG 2003) reports that young steelhead began to emerge from the gravel in the upper spawning reaches by April, and they were abundant from May through September. Juvenile fish were most abundant at the upper Goodwin Canyon site and Two-Mile Bar and least abundant at Oakdale (the lowermost study site). Trout parr were observed downstream to Honolulu Bar by June, where they remained common throughout the summer and fall. Few juvenile fish were observed at Oakdale where water temperature was the highest, ranging between 64.4 and 68°F (Fisheries

Foundation 2002 in SRFG 2003). Yearling and post-yearling trout were concentrated in the upper river for most of the 2000 and 2001 surveys at the upper Goodwin Canyon site and Two-Mile Bar (Fisheries Foundation 2002 in SRFG 2003). A few fish were observed in lower reaches whereas some were abundant at the experimental sites (Knight's Ferry, Lovers Leap, and Orange Blossom). Water temperatures rarely exceeded 59°F in the upper reaches, whereas downstream temperatures were near or at stressful levels of 64.4 and 68°F during most of the summer. Yearling trout were slightly more abundant in 2001 than in 2000 in downstream reaches as water temperatures were slightly lower with higher flows in 2001. Abundance at the upper Goodwin Canyon site and Two-Mile Bar appeared to increase over the summer, which may indicate a positive upstream movement of yearling trout to the cooler water below Goodwin Dam (Fisheries Foundation 2002 in SRFG 20030).

Tuolumne River Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon (ESU) – *Oncorhynchus tshawytscha*
Central Valley steelhead

Diversity Group

Southern Sierra Nevada

Key Stressors

Key stressors to Central Valley steelhead in the Tuolumne River include, but are not limited to, the following:

- ❖ Passage impediments/barriers in the Tuolumne River at La Grange and Don Pedro dams affecting adult immigration and holding
- ❖ Flow conditions (i.e., flow fluctuations, low flows) affecting attraction and migratory cues for adult immigration and holding, spawning and embryo incubation, and flow dependent habitat availability affecting juvenile rearing and outmigration
- ❖ Physical habitat alteration associated with limited supplies of instream gravel, and suitability of available habitat affecting adult spawning
- ❖ Water temperature and water quality effects on adult immigration and holding, spawning, and juvenile rearing and outmigration

Watershed Description

Draining an area of about 1,900 square miles, the Tuolumne River originates in Yosemite National Park and flows southwest through Yosemite, Stanislaus National Forest and private lands to its confluence with the San Joaquin River, approximately 10 miles west of Modesto, California (SFPUC 2009; TRTAC 1999). With its headwaters above the 10,000-foot level in Yosemite National Park, the Tuolumne River is one of the largest rivers in California's Sierra Nevada mountain range. The mainstem of the river begins in Tuolumne Meadows at the confluence of streams descending from the slopes of Mt. Lyell (13,100 feet) and Mt. Dana (13,155 feet). From there the river descends through the steep Yosemite wilderness, including the Tuolumne's own "Grand Canyon," before its flow is impounded by the O'Shaughnessy Dam in Hetch Hetchy Valley (3,500 feet). Similar to most major rivers in the Sierra Nevada, the Tuolumne River is dammed in several locations, principally to provide reliable water supplies for

California's farms and cities. La Grange Dam marks the upstream extent of currently accessible anadromous salmonid habitat. From La Grange Dam, the Tuolumne River flows in a westerly direction for approximately 50 miles before entering the San Joaquin River.

Geology

At higher elevations, the watershed is composed primarily of granitic bedrock that was scoured by glaciers during glacial periods down to the location of O'Shaughnessy Dam, resulting in mountainous terrain, patchy forests, and a variety of steep canyons and mountain meadows. The middle portion of the watershed from Don Pedro Reservoir to above Hetch Hetchy Reservoir is characterized by deep canyons and forested terrain. Near the town of La Grange, the river exits the Sierra Nevada foothills and flows through a gently sloping alluvial valley that is incised into Pleistocene alluvial fans (SFPUC 2009).

Hydrology

As reported by USFWS (1995), the median historical unimpaired runoff is 1.8 million acre-feet (maf), with a range of 0.4 maf to 4.6 maf. About 60 percent of the Tuolumne River flow occurs between April and June, when warm weather melts the Sierra snowpack. Similar to most other California rivers, flows in the Tuolumne River vary widely with annual precipitation. In about one out of every four years, the annual flow is less than 1.1 million acre-feet.

The Don Pedro Project is the largest reservoir located above the spawning reach on the Tuolumne River. Don Pedro Reservoir is owned by the Turlock Irrigation District (TID) and the Modesto Irrigation District (MID) and is licensed by the Federal Energy Regulatory Commission (FERC). TID and MID jointly regulate the flow to the lower river downstream of Don Pedro Reservoir, which has a gross storage capacity of 2.0 maf. In addition to providing power and irrigation, water storage in Don Pedro Reservoir is also managed to prevent the Tuolumne River from flooding Modesto and surrounding areas.

The river above Don Pedro Reservoir is regulated by three reservoirs (Cherry Lake, Lake Eleanor, and Hetch Hetchy Reservoir) owned and operated by the City and County of San Francisco. These reservoirs have a combined storage capacity of 800 thousand acre-feet (taf) or more. During each of the past 10 years, approximately 220 taf of Tuolumne River water has been annually exported to San Francisco. Hetch Hetchy Reservoir, with 360,000 acre-feet of storage capacity, is the largest reservoir in the upper watershed. Other small impoundments in the watershed include Modesto Reservoir (29 taf) and Turlock Lake (45.6 taf). LaGrange Dam, located downstream of Don Pedro Dam, diverts approximately 900 af per year for power, irrigation, and domestic purposes. LaGrange Dam is the upstream barrier to salmon migration (USFWS 1995).

Land Use

Agriculture, ranching, mining, and tourism dominate the region, and many people depend on the river for their sustained livelihoods (TRTAC 1999). The lower Tuolumne River has an extensive history of gold mining, municipal and agricultural water storage, power generation, agriculture, and recreation. Large dredges were used for gold mining and in recent years, the dredger tailings have been mined for gravel.

Fisheries and Aquatic Habitat

The San Joaquin River and its tributaries (e.g., Tuolumne River) once supported populations of both spring and fall-run Chinook salmon and steelhead (Yoshiyama *et al*. 1996, 1998, as cited in SRFG 2003). Spring-run Chinook salmon were extirpated from the San Joaquin Drainage by the late 1940's and it was believed that steelhead had been extirpated as well. Since then, fall-run salmon have declined by more than 90 percent and the populations remaining are in jeopardy of further decline (USFWS 2004). In recent years, a few confirmed reports of steelhead in the San Joaquin River drainage have been received, suggesting a viable but very small population (USFWS 2004).

Historically, the Tuolumne River Watershed is reported to have contained about 99 miles of anadromous fish habitat, and currently contains about 47 miles of habitat for fall-run Chinook salmon and steelhead (USFWS 2008). The lower Tuolumne River once hosted an extensive track of this riparian forest much of which has been removed due to growing urban settlement and extensive agriculture in the area (Tuolumne River Trust 2009). Past gravel-mining operations have reduced the low flow and bank-full channel capacity and changed the channel morphology of the Tuolumne River. In 1998, efforts to restore the lower Tuolumne River were initiated to restore the channel to its “pre-mining” condition.

Constructed in 1893, the La Grange Dam (RM 52.2) presents an impassable barrier to upstream migrating anadromous salmonids and marks the upstream extent of currently accessible steelhead habitat in the Tuolumne River. Dam construction ended the coarse sediment supply from the Tuolumne River Watershed upstream of the town of La Grange, and sediment transported during high flows has come from the bed itself or limited floodplain deposits (USFWS 2008a). Elimination of upstream sediment supply also has caused bed particle coarsening in the spawning reach near La Grange.

The Chinook salmon runs of the Stanislaus, Tuolumne, and Merced Rivers are perhaps the southernmost in the species range, and summer water temperatures appear to be among the primary factors determining the life-history strategies of these population, as well as those of steelhead (Hume 2005). Permanent upstream fish passage impairment dates back to dams constructed in the 19th century, eliminating access to cold-water refugia above the present dams. Unanticipated effects have resulted in the reduction of the timing window available for Chinook salmon and steelhead spawning because: (1) elevated water temperatures in the Delta, the San Joaquin River, and lower reaches of the tributaries usually prevent young salmon from migrating out of the tributaries much after May; (2) elevated water temperatures in the lower and middle reaches of the tributaries limit the effectiveness of life-history strategies which require over-summering by adults or juveniles; and (3) elevated water temperatures in the lower reaches of the tributaries usually prevent adult returns from spawning much before October (Hume 2005).

One of many stressors identified in recent studies on the Tuolumne River that limit salmonid populations are the aggregate extraction pits, which are a byproduct of extensive in-stream and off-channel mining (Turlock Irrigation District 2001). Many of these instream and off-channel pits have negatively impacted salmonid populations by stranding juveniles in ponds and fostering large populations of non-native predator fish (bass). Additionally, spawning and rearing habitats have been negatively impacted by either complete removal during aggregate extraction, degradation by channel encroachment from dikes along mining pits, or fine sediment infiltration. Many of the off-channel pits have only a small berm of undisturbed native material separating them from the river. Common floods (e.g., 1983, 1986, 1995, & 1998) of less than 8,000 cfs regularly breach some of these berms resulting in entrapment of salmon fry and smolts (Turlock Irrigation District 2001).

Given the large potential to make significant improvements in wild salmon production and the success of the TRTAC in promoting river-wide restoration goals, the CALFED – ERP has designated the Tuolumne River as one of three "Demonstration Streams" in the Central Valley. The problems that are the focus of the Tuolumne River restoration program fall into two major categories: (1) impairment of geomorphic and ecosystem processes caused by flow regulation, gold and aggregate mining, and land uses, and (2) reduction in fall-run Chinook salmon population abundance and resiliency (Turlock Irrigation District 2001).

Over the past several years, the Anadromous Fish Restoration Program (AFRP) has been working with the Tuolumne River Technical Advisory Committee (TRTAC) and the FERC Settlement Agreement framework to develop restoration and monitoring strategies (USFWS 2008). These strategies include utilizing an integrative approach to reestablish critical ecological functions, processes and characteristics that, under regulated flow and sediment conditions, promote recovery and maintenance of a resilient, naturally reproducing salmon population and the river's natural animal and plant communities (USFWS 2008). Initial priorities include: (1) continue to develop and fund the remaining two segments within the 6-mile Mining Reach; (2) complete restoration of two large in-channel pits; (3) develop a sediment management plan that will protect and restore critical spawning and rearing areas in the upper Tuolumne River; (4) work with agriculture and municipal interests in the lower river to establish and restore a riparian corridor for river function; and (5) continue to work with local interests and the U. S. Army Corps of Engineers (Corps) on a flood protection strategy (USFWS 2008). The AFRP also is working with the TRTAC to finalize river-wide and project-specific monitoring strategies that will guide adaptive management and allow the TRTAC to evaluate efficacy of FERC Settlement Agreement actions (USFWS 2008).

Steelhead

The California Department of Fish and Wildlife (CDFW) has conducted fall-run Chinook salmon spawning surveys on the Tuolumne River since 1971, as required under the cooperative fish study program for the Don Pedro Project FERC license (TID/MID 2009). Incidental catches and observations of juvenile steelhead have occurred on the Tuolumne River during fall-run Chinook salmon monitoring activities (Good *et al.* 2005).

Although some steelhead reportedly persist in the Tuolumne River, debate over historical distribution and less emphasis on commercial value have shifted the primary focus of restoration efforts from steelhead to fall-run Chinook salmon in the Tuolumne River Basin (McBain and

Trush 2000). However, more recent fisheries monitoring for the Don Pedro Project (FERC Project No. 2299) by the TID and MID has documented the presence of *Oncorhynchus mykiss* in the lower Tuolumne River (TID/MID 2005). Additionally, as part of the April 3, 2008 FERC Order on Ten-Year Summary Report Under Article 58, TID and MID were required to start conducting *O. mykiss* population estimate surveys during the summer (June/July) and winter (February/March) of 2008 to determine population abundance by habitat type. The purpose of the *O. mykiss* population surveys is to provide population size estimates over several sampling seasons of differing environmental conditions to determine habitat use and needs within the lower Tuolumne River. Reportedly, a total of 135 young-of-the-year (YOY)/juvenile (< 150 mm FL) and 45 adult (> 150 mm FL) (180 total) *O. mykiss* were observed from RM 51.8 to RM 41.1 within the study reach extending down to RM 39.6 (TID/MID 2009a). Most juveniles were found in riffles and the upstream end (heads) of run habitat, while adults mainly were found within pool heads and riffles. Using a bounded counts population estimator, approximately 3,096 *O. mykiss* were estimated within the survey reach, with 95% confidence bounds of 1,905–3,047 and 325–914 YOY/juvenile and adult size classes, respectively (TID/MID 2009a).

Merced River Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon (ESU) – *Oncorhynchus tshawytscha*
Central Valley steelhead

Diversity Group

Southern Sierra Nevada

Key Stressors

Key stressors (i.e., identified as "Very High") to Central Valley steelhead in the Merced River include, but are not limited to, the following:

- Passage impediments/barriers at the Crocker Huffman, McSwain, Merced Falls and New Exchequer dams blocking/impeding adult immigration
- Flow conditions (i.e., low flows) associated with attraction, migratory cues, flood flows and the attraction of non-natal fish into the Merced River affecting adult immigration and holding
- Physical habitat alteration associated with limited supplies of instream gravel, habitat suitability and spawning habitat availability affecting spawning
- Water temperatures affecting adult immigration and holding, and spawning
- Flow fluctuations affecting spawning and embryo incubation
- Changes in hydrology affecting juvenile rearing and outmigration
- Flow dependent habitat availability affecting juvenile rearing and outmigration
- Loss of riparian habitat and instream cover affecting juvenile rearing and outmigration

Watershed Description

The Merced River is a tributary to the San Joaquin River in the southern portion of California's Central Valley. The Merced River originates in Yosemite National Park and drains an area of 1,276 square miles as it flows down the western slope of the Sierra Nevada range into the Central Valley, eventually joining the San Joaquin River about 87 miles south of Sacramento, California (Figure 22). Elevations in the watershed range from 4,000 m at its headwaters to 15 m at the San Joaquin River confluence (USFWS 2007).

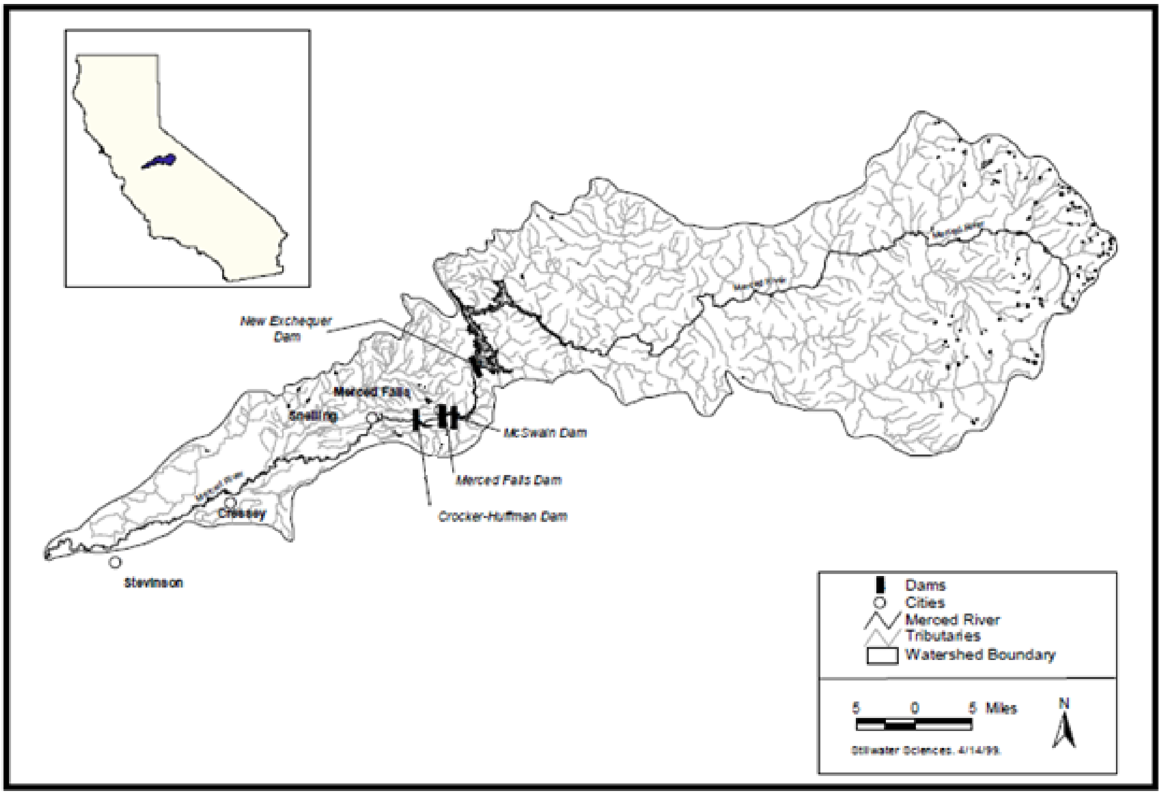

Figure 22. The Merced River Watershed Source: Modified from Stillwater Sciences 2001

The upper Merced River watershed encompasses approximately 700,000 acres from the headwaters near Triple Divide Peak to the New Exchequer Dam on Lake McClure, the main storage reservoir on the river (capacity 1 million acre-ft.). A significant part of the Merced River headwaters lies within Yosemite National Park (312,334 acres), while about 272,000 acres lie within the jurisdiction of lands managed by the United States Forest Service and the Bureau of Land Management. Downstream of New Exchequer Dam, the floodplain extent and connectivity in the Merced River have been affected by both flow regulation and levee construction. Flow regulation has reduced flood magnitude and, thus, reduced the extent and frequency of floodplain inundation. In addition, in the reach from Crocker-Huffman Dam to Shaffer Bridge, the river has been converted from a multiple-channel system to a single-channel system, and remnant sloughs have been converted to irrigation canals and drains.

Prior to the arrival of European pioneers and explorers, steelhead trout occurred throughout the upper Merced River drainage, occupying aquatic habitat as far upstream as Yosemite Valley on the mainstem, and probably, as far upstream on the South Fork, beyond Wawona, and most of its lower elevation tributaries (such as Skeleton Creek) as reported by Miller 2008. Currently, steelhead are present in the Merced River and spawn between Crocker Huffman Dam (RM52) and Highway J59 Bridge Crossing (RM42). Steelhead populations in the Stanislaus, Tuolumne, Merced, and Calaveras rivers are considered to be non-viable at this time (Lindley *et al*. 2007). The Merced River in particular is considered to be the most impacted of these southern rivers in terms of loss of flow, good gravels for steelhead, as well as poor water quality as a result of development and agriculture, so much habitat and hydrologic restoration is needed to ever see viable populations of steelhead again in the lower Merced River.

At this time, there are three obstructions to migrating fish: Crocker Huffman irrigation diversion near Snelling, McSwain, Merced Falls Dam, and New Exchequer. The direct and cumulative effect of these dams is that access to greater than 96% of the original historically available spawning and rearing habitat on the Merced River for *O. mykiss* (Steelhead trout) and other anadromous fishes (spring-run, fall-run and late fall-run Chinook salmon, lamprey) has been eliminated by impassable barriers and/or inundation. (Martin 2008, Schick *et al* 2005). Suitable *O. mykiss* and *O. tshawytscha* spawning and juvenile rearing habitat is now restricted to the Merced River reach between Crocker-Huffman Diversion Dam (RM 52) and the Highway J59 Bridge Crossing (RM 42). Reduction and modification of seasonal flow from the operation of the Project dams has adversely impacted the restricted *O. mykiss* accessible spawning and rearing habitat in this reach through interference with spawning gravel replenishment and armoring of gravel beds and instream flow regimes.

Little is known about steelhead numbers and current habitat uses in the southern sierra diversity group. Lindley *et al*. (2007) recommend that in order to assess the risk of extinction or develop effective recovery actions for steelhead in the Central Valley, determining the distribution of steelhead and assessing the relationship between resident and anadromous forms of *O. mykiss* is a fundamental need. Lindley *et al*. (2007) stress that any quantitative assessment of population viability would be inadequate unless the role resident fish play in population maintenance and persistence of *O. mykiss* in the Central Valley is known.

How will the Merced River help to buffer the negative effects of climate change for salmonids in the Central Valley?

Under the expected climate warming of around 5°C, substantial salmonid habitat would be lost in the Central Valley, with significant amounts of habitat remaining primarily in the upper Feather and Yuba rivers, and remnants of habitat in the upper Sacramento, McCloud, and Pit rivers, Battle and Mill creeks, and the Stanislaus River (Lindley *et al*. 2007). Under the less likely but still possible scenario of an 8°C warming, spring-run Chinook salmon habitat would be found only in the upper-most reaches of the north fork Feather River, Battle Creek, and Mill Creek (Lindley *et al*. 2007).

In addition, while warming may pose as a key threat to spring-run Chinook salmon in the Central Valley, suitable water temperature conditions should persist longer in areas where fish can reach higher altitudes (Williams 2006). Some existing or potential habitat should also remain for some time below various dams that currently release cool water through the summer (Williams 2006).

Geology

The following information on geology in the Merced River is taken directly from the *Merced Wild and Scenic Revised Comprehensive Management Plan and Supplemental EIS* (National Park Service 2005).

The Merced River gorge begins at the west end of Yosemite Valley where the gradient of the Merced River abruptly increases and the river enters the gorge. The gorge has remained an incised, V-shaped feature because the most recent glacial events did not extend down the Merced River beyond Yosemite Valley. The transition from the U-shaped, glaciated Yosemite Valley to the steep-gradient, V-shaped, incised Merced River gorge, is identified a feature of the geologic Outstandingly Remarkable Value.

The granitic rocks within the Merced River gorge consist primarily of tonalite; the Bass Lake tonalite is the dominant bedrock feature. Among some of the oldest rocks found in the Sierra Nevada are those just east of El Portal, in the walls of the Merced River gorge. These rocks are metamorphic and remnants of ancient sedimentary and volcanic rocks that were deformed and metamorphosed, in part by granitic intrusions (Huber 1989). This metamorphosed sedimentary rock (which includes banded chert) was once part of the ocean floor that covered the region about 200 million years ago (Huber 1989). The transition from igneous to metasedimentary rocks is identified as a feature of the geologic Outstandingly Remarkable Value in the El Portal segment of the river.

The soils in relatively flat topographic positions in the Merced River gorge and El Portal form from glacial and alluvial sediment deposition processes originating in Yosemite Valley, or by alluvial and colluvial deposition occurring locally within the gorge or near El Portal. Soils that formed in old river channels consist of alluvial boulders, cobbles, river wash, and loamy sands.

Hydrology

The overall climate in the Merced River Basin is temperate, with hot, dry summers and cold, wet winters. The average annual precipitation in Yosemite Valley is 36.5 inches. Annual precipitation decreases to 25 inches in El Portal (2,000 feet) and increases to 70 inches in the red fir forest at 6,000 to 8,000 feet (Eagan 1998, as cited in National Park Service 2005). At elevations above 5,000 feet, 80 percent of the annual precipitation falls as snow.

Similar to other rivers originating from the west side of the Sierra Nevada mountains, flow in the Merced River is typified by late spring and early summer snowmelt, fall and winter rainstorm peaks and low summer base flows (Stillwater Sciences 2001). Snowmelt drives the peak stream flows that occur in May and June, and minimum river flow is observed in September and October (National Park Service 2005). About 85 percent of precipitation falls between November and April, and the highest average precipitation generally occurs during December, January, and February (National Park Service 2005).

Four mainstem dams affect flow conditions in the lower Merced River. The two largest dams are New Exchequer Dam (which impounds Lake McClure) and McSwain Dam (which impounds Lake McSwain) (USFWS 2007; USFWS 1995; Stillwater Sciences 2001). These dams, which are known collectively as the Merced River Development Project, are owned by Merced Irrigation District (Merced ID) and are licensed by the Federal Energy Regulatory Commission. Merced Falls Dam and Crocker-Huffman Dam are low diversion dams which divert flow into the Merced ID Northside Canal and Main Canal, respectively. Merced Falls Dam is owned by Pacific Gas and Electric; Crocker-Huffman Dam is owned by Merced ID. Three additional small dams (i.e., MacMahon, Green Valley, and Metzger) are located on tributaries upstream of the New Exchequer Dam. These dams have a combined reservoir capacity of 835 acre-feet. Also, Kelsey Dam impounds a small (972 acre-feet) reservoir on Dry Creek, the only major tributary to the Merced River downstream of the mainstem dams (Stillwater Sciences 2001).

The New Exchequer Dam (located at RM 62.5) controls runoff from 81 percent of the basin and creates the largest storage reservoir in the system, Lake McClure. The maximum reservoir storage capacity at Lake McClure is 1,024,600 acre-feet, equivalent to 103 percent of the average annual runoff from the basin (as measured below Merced Falls Dam, near Snelling). The New Exchequer Dam provides agricultural water supply, power generation, flood control, recreation, and environmental flows including in-stream fisheries flows and flows to the Merced National Wildlife Refuge (Stillwater Sciences 2001).

McSwain Dam (RM 56) is located 6.5 river miles downstream of the New Exchequer Dam, and is operated as a re-regulation reservoir and hydroelectric facility. Storage capacity in Lake McSwain is 9,730 acre-feet.

The Merced Falls Dam (RM 55) and the Crocker-Huffman Dam (RM 52) are low-head irrigation diversion facilities. The Merced Falls Dam diverts flow into the Merced ID's Northside Canal (capacity = 90 cfs) to the north of the river and generates electricity. The Crocker-Huffman Dam diverts flow into the Merced ID's Main Canal (capacity = 1,900 cfs). In addition to the Merced ID diversions, the Merced River Riparian Water Users maintain seven riparian diversions between Crocker-Huffman Dam and Shaffer Bridge. Between Crocker-Huffman Dam and Shaffer Bridge, Cowell Agreement and riparian water users divert up to approximately 94,000 acre-feet annually and have maintained seven main channel diversions since about the 1850s (Stillwater Sciences and EDAW 2001). These diversions are small wing dams consisting of rock and gravel, which can be transported downstream during high winter river flows. In addition to these diversions, CDFW has identified a large number of diversions, primarily pumps, in the 52 river miles between the Crocker-Huffman Dam and the San Joaquin confluence. During field surveys, CDFW recorded 244 diversions, which are predominantly used to supply water for agricultural use (206 diversions) (Stillwater Sciences and EDAW 2001).

Land Use

The Merced River Watershed has been significantly modified by dams and flow regulation, flow diversion, gold and aggregate (sand and gravel) mining, levee construction, land use conversion in the floodplain, and clearing of riparian vegetation (Stillwater Sciences 2001). As reported by USFWS (1995), agricultural development began in the 1850s, and significant changes have been made to the hydrologic system since that time. As early as the 1870's, large canal systems were built to divert Merced River water for agricultural uses including, row crops, cattle grazing and orchard crops. Mining for gold and aggregate downstream of the dams has been extensive, leaving tailings and numerous pits within the river corridor (USFWS 2001). Today, the lands within watershed are comprised of rural and privately owned areas, and the primary land use is agricultural and aggregate mining. Many tracts are under active cultivation with orchards and vineyards, and several actively grazed annual grassland pastures abut the river's edge. There is also an expansive gravel mining plant on the north section of the lower Merced River (USFWS 2001).

Fisheries and Aquatic Habitat

Historically, the Merced River supported spring and fall-run Chinook salmon, and occasionally steelhead trout. Over time, the manipulation of the Merced River has led to loss and degradation of native habitat. With the building of dams, access to spawning grounds upstream has been lost and gravel recruitment is greatly reduced in reaches below the dams. The large in-stream ponds left by mining create habitat for introduced predator fish species that prey upon juvenile salmon (USFWS 2005). Despite this loss and degradation of riverine habitat, the Merced River has supported a large population of fall-run Chinook salmon in the San Joaquin Valley. Steelhead have been largely extirpated from the project area, but sporadically use the Merced River for spawning and rearing (USFWS 2000).

Both the Merced Falls Dam and the Crocker-Huffman Dam are equipped with fish ladders, but the ladders were blocked by CDFW in the early 1970s in association with the Merced ID's construction of an artificial salmon spawning channel immediately downstream of Crocker-Huffman Dam. As reported in Stillwater Sciences (2001), anadromous fish generally do not pass upstream of Crocker-Huffman Dam, although some fall Chinook salmon may surmount the dam during high flows. Thus, the Crocker-Huffman Dam presents an impassable barrier to upstream migration, and demarcates the upstream extent of currently accessible steelhead habitat. Salmon spawn in the 24-mile reach between Crocker-Huffman Dam and the town of Cressy (USFWS 1995), with the primary spawning reach occurring between RM 32 and RM52) (Stillwater Science 2001). Rearing habitat extends downstream of the designated spawning reach, requiring the protection of the entire tributary from Crocker-Huffman Dam to its mouth (USFWS 1995).

Thermographs are used by CDFW to record temperature at several points along the river. Downstream of Crocker-Huffman dam substrate is dominated by gravel and cobble with downstream fining to eventual sand and silt below the lowest spawning area (USFWS 2007.)

Water resource demands and flood control issues on the Merced River will largely determine the extent and types of restoration implemented in the corridor (Stillwater Sciences and EDAW 2001). The Merced River is heavily allocated for agricultural water use. The Merced ID holds pre-1914 appropriative water rights to divert flow from the river. In addition, riparian water users divert flows through seven diversion channels between Crocker-Huffman Dam and Shaffer Bridge and numerous riparian pumps throughout the river. Minimum instream flow requirements in the river are defined under Merced ID's current licenses and agreements and are intended to provide adequate flows for Chinook salmon and for the Merced River Riparian Water Users Association diversions. In addition, under current U.S. Army Corps of Engineers flood control operations rules, the maximum allowable release to the Merced River from New Exchequer Dam is 6,000 cfs. For the above reasons, restoration projects developed within the Merced River Corridor Restoration Plan must, therefore, be designed to function within the current minimum flow requirements and this 6,000 cfs flood control limitation (Stillwater Sciences and EDAW 2001).

There are many opportunities for improving geomorphic and riparian ecosystem conditions in the Merced River. As reported in the Geomorphic and Riparian Vegetation Investigations Report for the Merced River Corridor Restoration Plan (Stillwater Sciences 2001), the major constraints to restoring geomorphic and riparian ecological processes and attributes in the Merced River include: (1) drastic reduction in the flood magnitude, frequency, and duration and the resulting reduction in bedload transport under current dam operations; (2) elimination of floods exceeding 6,000 cfs that will likely continue due to the Corps of Engineers limit to flood releases; (3) the presence of vulnerable structures (such as the City of Livingston sewage treatment plant) and vulnerable land uses in the floodplain; (4) lack of coarse sediment supply due interception of bedload by the large dams; (5) limits to channel migration caused by reduced flows, bank revetment, and development in the floodplain; (6) the extent of bedload impedance reaches throughout the Gravel Mining 1 and Gravel Mining 2 reaches; and (7) chronic fragmentation and clearing of riparian vegetation for floodplain development. To date, numerous projects to restore and protect floodplain function, as well as channel and riparian habitat have been initiated or completed on the Merced River as a result of the CVPIA and the Merced River Corridor Restoration Plan; however, consistent monitoring of juvenile Chinook salmon and steelhead emigration has been lacking (Stillwater Sciences 2001; USFWS 2007).

The Merced River Fish Hatchery (RM 52), operated by CDFW, is located immediately downstream of Crocker-Huffman dam. Crocker-Huffman Dam is the upstream terminus of fish migration on the Merced River. (USFWS 2007).

Steelhead

Prior to 2007, incidental catches and observations of steelhead juveniles have occurred on the Merced (and Tuolumne) rivers during fall-run Chinook salmon monitoring activities (Good *et al.* 2005). Zimmerman *et al.* (2008) also has documented Central Valley steelhead in the Merced River based on otilith microchemistry.

During 2007, Cramer Fish Sciences began juvenile Chinook salmon and *O. mykiss* population monitoring on the Merced River at George Hatfield State Park (RM 2) under contract with Anadromous Fish Restoration Program. The monitoring effort continues previous work by CDFW at Hagaman State Park (RM 12), and uses rotary screw traps, an established method for measuring juvenile out-migration abundance, to capture juvenile salmonid species while monitoring environmental variables (USFWS 2007). The new site was established to obtain a more accurate estimate of fish contribution to the San Joaquin River. Result from surveys conducted during 2007 indicate that out-migration timing of natural fish strongly coincided with hatchery releases upstream, and weaker associations were observed with temperature and lunar cycle (USFWS 2007). Observations during the 2007 appear to indicate poor natural production of Chinook salmon, however subsequent monitoring of population trends over several seasons is required before conclusions or management decisions can be made (USFWS 2007). No *O. mykiss* were captured during the 2007 sampling season. A more thorough understanding of *O. mykiss* populations on the Merced River may by necessary to explain the lack of out-migration observed during the 2007 season (USFWS 2007).

Upper San Joaquin River Watershed Profile

Listed Species Present in the Watershed

Currently unoccupied

Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon (ESU) – *Oncorhynchus tshawytscha*
Central Valley steelhead

Watershed Description

CV spring-run Chinook salmon and CV steelhead no longer occur in the San Joaquin River south the of the Merced River. According to DFG (1998), the San Joaquin River once supported a very large population. Clark (1929) wrote that in the late 1800s, salmon were very numerous, and Fry (1961) estimated a run of 56,000 spring-run in 1945. The extent of steelhead presence in the San Joaquin River is not well known.

The upper San Joaquin River, a 153-mile stretch of river from the Merced confluence upstream to Friant Dam, has been significantly altered over the past century due to changes in land and water use. The historical populations of Central valley spring-run salmon were extirpated due to several changes caused by development including the building of Friant dam that blocked fish passage to upper San Joaquin River habitats. As well, major agricultural water diversions were built in the last 150 years which lowered the water quality and quantity and caused areas of entrainment, further reducing the population of spring-run salmon and steelhead to the level of extirpation.

Because of these developments, which caused the extinction of the San Joaquin spring-run salmon population, several legal actions were taken which resulted in a Settlement in October of 2006 that was reached in the case of *NRDC et al. v. Kirk Rodgers et al.*, and was termed: the San Joaquin River Restoration Program (SJRRP). The following restoration goals were produced from this settlement:

> **Restoration Goal** – To restore and maintain fish populations in “good condition” in the mainstem San Joaquin River below Friant Dam to the confluence with the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish.
>
> **Water Management Goal** – To reduce or avoid adverse water supply impacts to all of the Friant Division long-term contractors that may result from the Interim Flows and Restoration Flows provided for in the Settlement.

The Settlement establishes a framework for accomplishing the Restoration and Water Management goals that will require environmental review, design, and construction of projects over a multiple-year period. To achieve the Restoration Goal, the Settlement calls for a combination of channel and structural modifications along the San Joaquin River below Friant Dam, releases of water from Friant Dam to the confluence of the Merced River, and the reintroduction of Chinook salmon. With these actions, the prognosis for spring-run populations to returns is high. However, for steelhead, since the main channel San Joaquin does not have suitable habitats that fulfill life history requirements for steelhead such as good off channel and side channel habitats as well as smaller spawning gravels, more restoration will need to be focused on these life history requirements before steelhead would reoccur.

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Appendix B

Threats Assessment for the Evolutionarily Significant Units of Winter-run Chinook Salmon *(Oncorhynchus tshawytscha)* and Central Valley Spring-run Chinook Salmon *(O. tshawytscha)*, and the Distinct Population Segment of Central Valley Steelhead *(O. mykiss)*

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List of Acronyms

ACID	Anderson-Cottonwood Irrigation District
AFRP	Anadromous Fish Restoration Program
AMP	Ambient Monitoring Program
Bay-Delta	San Francisco Bay/Sacramento-San Joaquin Delta
Bays	San Francisco, San Pablo, and Suisun bays
BML	Bodega Marine Laboratory
BO	biological opinion
BRT	Biological Review Team
CDFG	California Department Fish and Game
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
cfs	cubic feet per second
cm	centimeter
cm/sec	centimeters per second
CMP	Sacramento Coordinated Monitoring Program
CNFH	Coleman National Fish Hatchery
CRR	Cohort Replacement Rate
CVI	Central Valley Index
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CWA	Clean Water Act
CWT	coded wire tag
DDT	Dichloro-Diphenyl-Trichloroethane
Delta	Sacramento-San Joaquin Delta
DPS	Distinct Population Segment
DWR	California Department of Water Resources
EEZ	U.S. Exclusive Economic Zone
ENSO	El Niño-Southern Oscillation
EPA	U.S. Environmental Protection Agency
ERP	Ecosystem Restoration Program
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FERC	Federal Energy Regulatory Commission
FL	Fork Length
FMP	Salmon Fishery Management Plan
FRFH	Feather River Fish Hatchery
ft/sec	feet per second
GCID	Glenn-Colusa Irrigation District
GCMs	General Circulation Models
HCP	habitat conservation plan
HCPP	Hamilton City Pumping Plant
km	kilometers
LSNFH	Livingston Stone National Fish Hatchery
mm	millimeter
MSA	Magnuson-Stevens Fishery Conservation and Management Act

NCCP	Natural Communities Conservation Plan
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
MRFH	Mokelumne River Fish Hatchery
MRH	Merced River Hatchery
NAHB	National Association of Home Builders
NOAA	National Oceanic and Atmospheric Administration
OCAP	Operations Criteria and Plan
PBDEs	Polybrominated diphenyl ethers
PCBs	polychlorinated biphenyls
PFMC	Pacific Fishery Management Council
PDO	Pacific Decadal Oscillation
PG&E	Pacific Gas and Electric Company
ppt	parts per thousand
PSMFC	Pacific States Marine Fisheries Commission
RBDD	Red Bluff Diversion Dam
RCRA	Resource Conservation and Recovery Act
Reclamation	Bureau of Reclamation
RM	River Mile
RMIS	Regional Mark Information System
RWQCB	Regional Water Quality Control Board
SDWSC	Sacramento Deep Water Ship Channel
SMSCS	Suisun Marsh Salinity Control Structure
SRA	shaded riverine aquatic
SSIDD	South Sutter Irrigation District Dam
SVRIC	Stanford Vina Ranch Irrigation Company
SWP	State Water Project
SWRCB	State Water Resources Control Board
TCC	Tehama-Colusa Canal
TCD	temperature control device
TMDL	Total Maximum Daily Load
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VAMP	Vernalis Adaptive Management Plan
WTP	water treatment plant
WUA	weighted usable area
WWTP	wastewater treatment plant

1.0 INTRODUCTION

Past recovery plans generally have focused on the abundance, productivity, habitat and other life history characteristics of a species. While knowledge of these characteristics is certainly important for making sound conservation management decisions, the long-term sustainability of a species in need of recovery can only be ensured by alleviating the threats that are contributing to the status of the species as threatened or endangered. Therefore, the identification of the threats to the species should be a key component of any recovery plan and program (NMFS 2006a).

To be most useful for recovery planning, a threats assessment should be used to determine the relative importance of various threats to a species. A threats assessment includes (1) identifying threats and their sources, (2) evaluating the effects of threats, and (3) ranking each threat based on relative effects. The Interim Endangered and Threatened Species Recovery Planning Guidance (NMFS 2006a) recommends "*…using a threats assessment for species with multiple threats to help identify the relative importance of each threat to the species' status, and, therefore, to prioritize recovery actions in a manner most likely to be effective for the species' recovery*."

Applying this recommended approach for the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Services' (NMFS) recovery planning process in the Central Valley, threats assessments were conducted for the Sacramento River winter-run Chinook salmon Evolutionarily Significant Unit (ESU), the Central Valley spring-run Chinook salmon ESU, and the Central Valley steelhead Distinct Population Segment (DPS). The threats assessments identified, evaluated, and ranked factors affecting these two ESUs and DPS in the ocean, in the San Francisco Bay/Sacramento-San Joaquin Delta (Bay-Delta) (**Figure 1-1**), and in Central Valley rivers and tributaries that currently support populations of winter-run Chinook salmon, spring-run Chinook salmon, and/or steelhead.

Threats to winter-run Chinook salmon, spring-run Chinook salmon, and steelhead in the Bay-Delta were geographically distinguished between the Bay and the Delta using the legal definition of the Delta described in Section 12220 of the California Water Code. This places the Delta's western boundary approximately four miles west of the confluence of the Sacramento and San Joaquin Rivers. The legal Delta extends northward to the I Street Bridge near Sacramento and southward to near Vernalis.

Threats in the mainstem Sacramento River were geographically distinguished among the lower, middle, and upper part of the river (**Figure 1-2)**. The lower section extends from the I Street Bridge upstream to Princeton (River Mile [RM] 163), the middle section extends from Princeton to Red Bluff Diversion Dam (RBDD) (RM 243), and the upper section extends from RBDD up to Keswick Dam (RM 302).

In-river threats to winter-run Chinook salmon were assessed in the mainstem Sacramento River, which represents the only extant population in the ESU. The threats assessments for the Central Valley spring-run Chinook salmon ESU included rivers that currently support spring-run

Chinook salmon populations[1]. Lindley *et al.* (2004), which describes the population structure of threatened and endangered Chinook salmon ESU's in California's Central Valley Basin was used to identify 12 individual rivers that historically supported and currently support spring-run Chinook salmon populations. These 12 spring-run Chinook salmon populations were categorized into three diversity groups as described by Lindley *et al.* (2007) (**Table 1-1**).

[1] Although the San Joaquin River system historically supported spring-run Chinook salmon, this river system was not included in the threats assessment because: (1) the current absence of spring-run Chinook salmon from the system prevents direct data collection of stressors; and (2) the system is not included in the ESU listing.

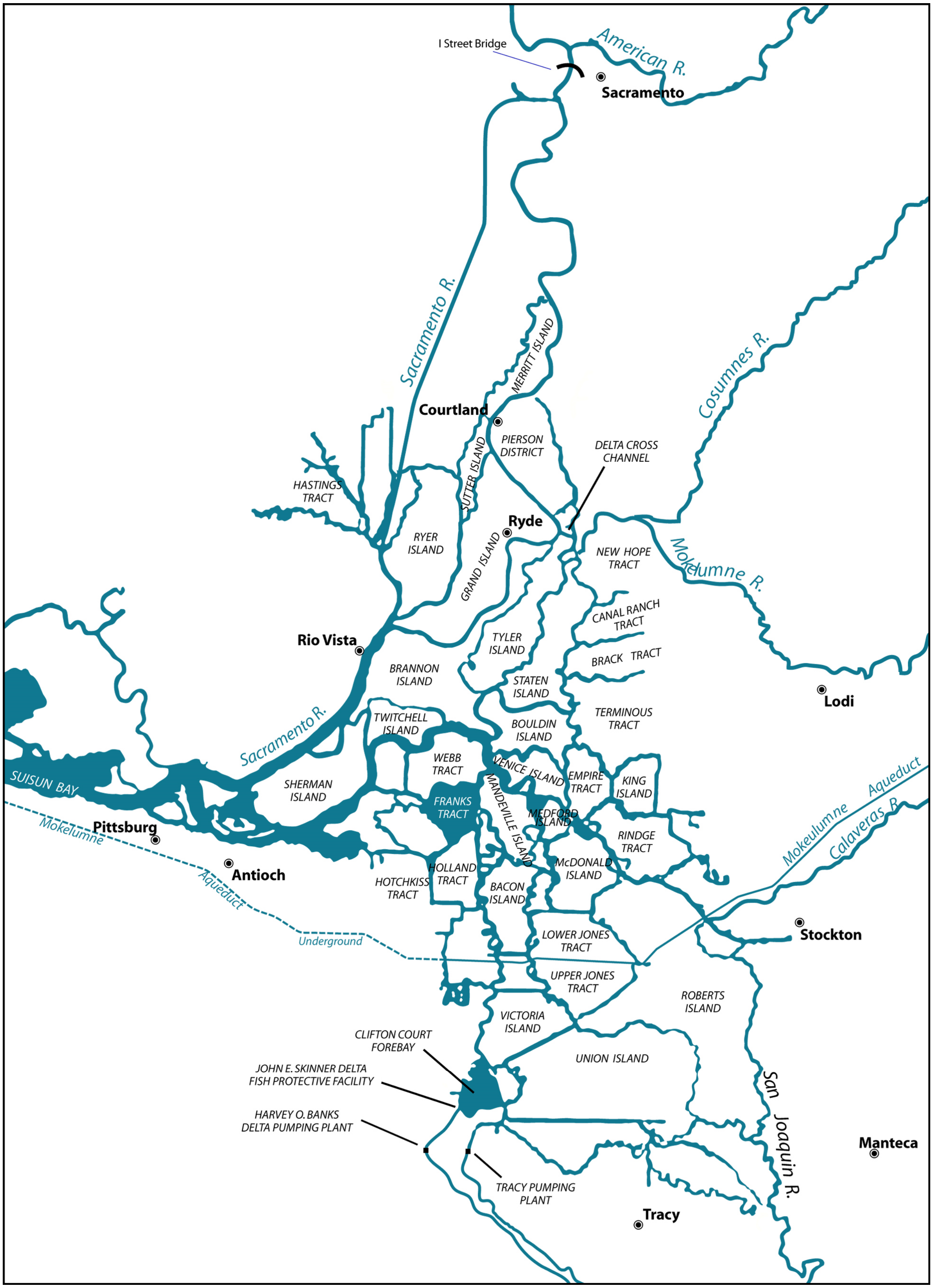

Figure 1-1. San Francisco Bay/Sacramento-San Joaquin Delta

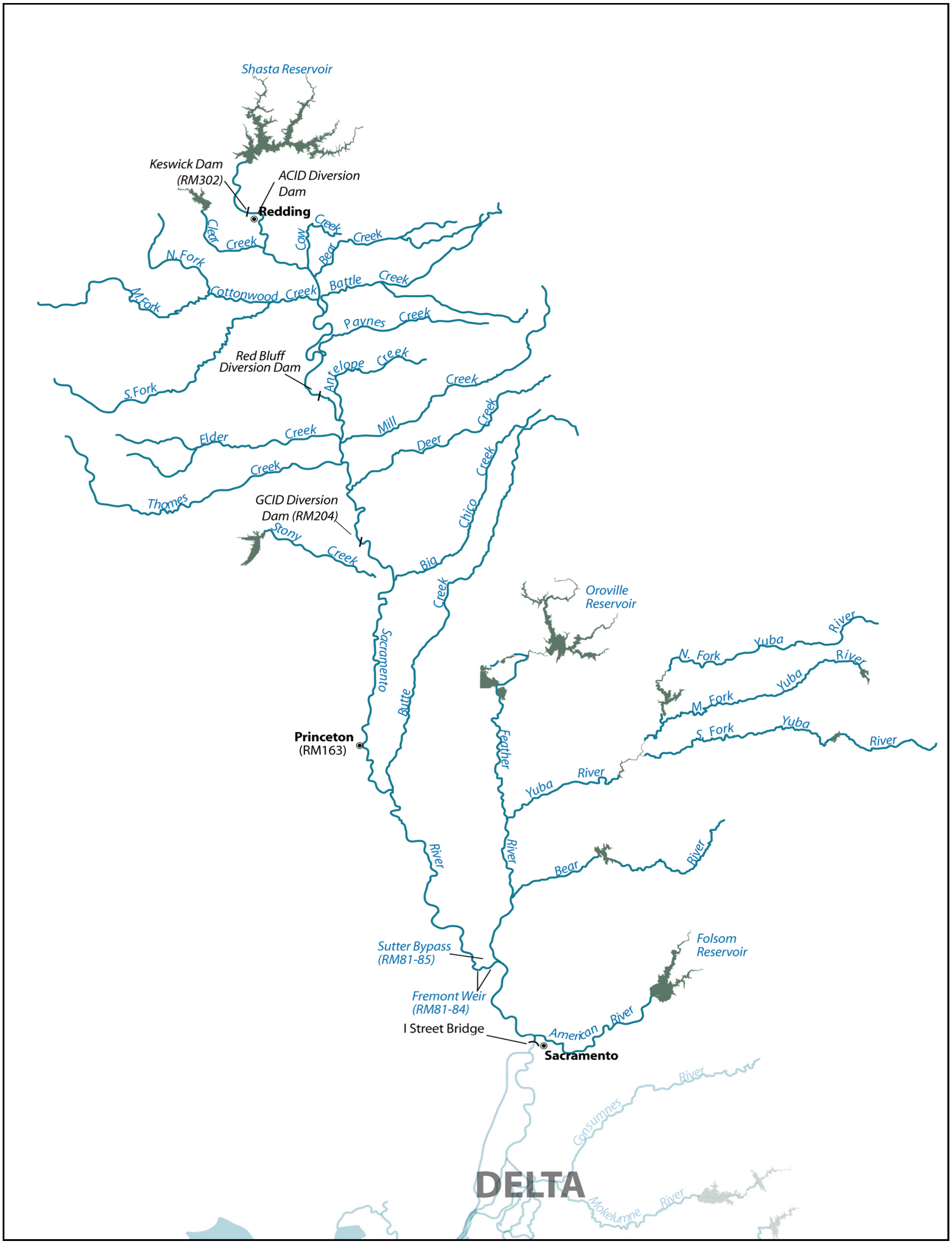

Figure 1-2. Mainstem Sacramento River and Tributaries

Table 1-1. Extant Central Valley Spring-run Chinook Salmon Populations Included in the Threats Assessment Categorized by Diversity Group

Northern Sierra Nevada Diversity Group	Basalt and Porous Lava Diversity Group	Northwestern California Diversity Group
Feather River Yuba River Butte Creek Big Chico Creek Deer Creek Mill Creek Antelope Creek	Battle Creek Upper Sacramento River	Thomes Creek Cottonwood/Beegum Creek Clear Creek

Source: (Lindley *et al.* 2007)

For the Central Valley steelhead threats assessment, 26 individual rivers/watersheds[2] in the Sacramento and San Joaquin (**Figure 1-3**) river systems that historically supported and currently support populations of steelhead were identified using literature describing the historical population structure of steelhead in the Central Valley (Lindley *et al.* 2006) and by using the best professional knowledge of Central Valley salmonid biologists regarding the current distribution of steelhead. These 26 steelhead populations were categorized into four diversity groups based on the geographical structure described in Lindley *et al.* (2007) **Table 1-2**.

Table 1-2. Extant Central Valley Steelhead Populations Included in the Threats Assessment Categorized by Diversity Group

Northern Sierra Nevada Diversity Group	Basalt and Porous Lava Diversity Group	Northwestern California Diversity Group	Southern Sierra Nevada Diversity Group
American River Auburn/Coon Creek Dry Creek Feather River Bear River Yuba River Butte Creek Big Chico Creek Deer Creek Mill Creek Antelope Creek	Battle Creek Cow Creek Small tributaries to the Upper Sacramento River[3] Upper Sacramento River (mainstem)	Stony Creek Thomes Creek Cottonwood/Beegum Creek Clear Creek Putah Creek	Mokelumne River Calaveras River Stanislaus River Tuolumne River Merced River San Joaquin River (mainstem)

Source: (Lindley *et al.* 2007)

This appendix is comprised of three major sections – one for the Sacramento River winter-run Chinook salmon ESU, one for the Central Valley spring-run Chinook salmon ESU, and one for the Central Valley steelhead DPS. Narrative descriptions of the threats affecting each ESU/DPS (Sections 2.3, 3.3, and 4.3, respectively) are organized hierarchically going from location/population to life stage to threats. In addition to narrative descriptions, matrices were developed in order to structure the life stage, population, and threats information so that the threats affecting each ESU/DPS could be ranked, sorted, and prioritized.

[2] It is recognized that more than 26 rivers/watersheds that historically supported and currently support steelhead exist in the Central Valley, however it is assumed that recovery of the Central Valley steelhead DPS is primarily dependent on the 26 populations included in the threats assessment.
[3] Includes steelhead utilizing small tributaries in the Redding area including Stillwater, Churn, Sulphur, Salt, Olney, and Paynes creeks.

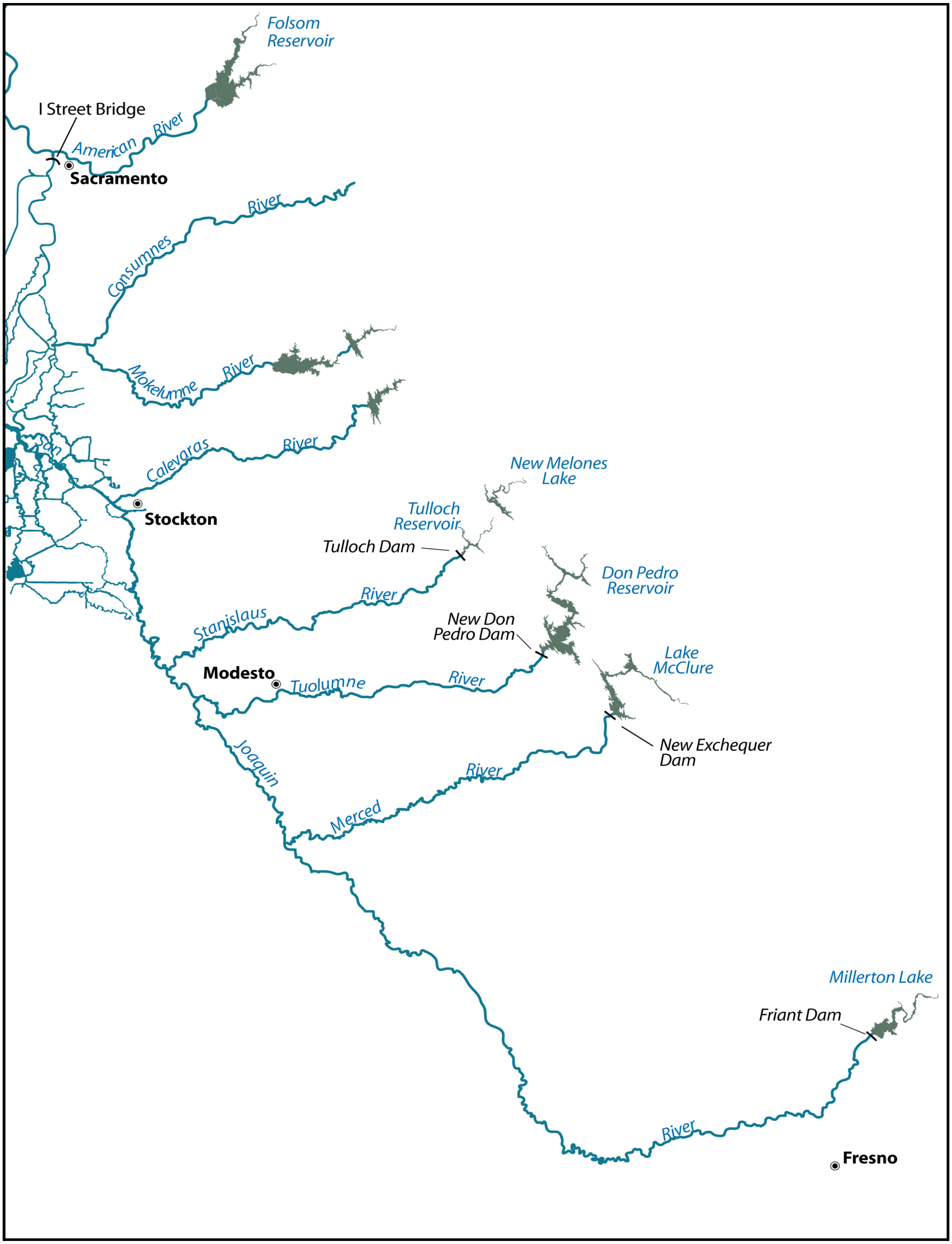

Figure 1-3. San Joaquin River and Tributaries

The prioritization of threats was identified as an integral piece in the recovery planning process in NMFS' recovery planning guidance document titled, "*Interim Endangered and Threatened Species Recovery Planning Guidance*" (NMFS 2006a).

The prioritized ranking of threats provides a recovery planning tool to help guide the identification of diversity group- and/or population- specific actions to recover each ESU/DPS. Detailed descriptions of how the stressor matrices were developed for each ESU/DPS are presented in Sections 2.4, 3.4, and 4.4, while the diversity group- and population-specific prioritized lists of stressors are displayed in Attachments A through C, respectively.

2.0 SACRAMENTO RIVER WINTER-RUN CHINOOK SALMON

2.1 BACKGROUND

2.1.1 LISTING HISTORY

NMFS listed the Sacramento River winter-run Chinook salmon ESU as a threatened species under emergency provisions of the Endangered Species Act (ESA) in August 1989 (54 FR 32085 (August 4, 1989)) and formally listed it as a threatened species in November 1990 (55 FR 46515 (November 5, 1990)). In June 1992, NMFS proposed that winter-run Chinook salmon be reclassified as an "endangered"[4] species (57 FR 27416 (June 19, 1992)). NMFS finalized its proposed rule to re-classify winter-run Chinook salmon as an endangered species on January 4, 1994 (59 FR 440 (January 4, 1994)). NMFS concluded that winter-run Chinook salmon in the Sacramento River warranted listing as an endangered species due to several factors, including: (1) the continued decline and increased variability of run sizes since its first listing as a threatened species in 1989; (2) the expectation of weak adult returns resulting from two small year classes in 1991 and 1993; and (3) continued "take"[5] of winter-run Chinook salmon (65 FR 42421 (July 10, 2000)). On June 14, 2004, NMFS issued a proposed rule to downgrade the listing status of winter-run Chinook salmon from endangered to threatened (69 FR 33102 (June 14, 2004)). To prevent further decline of the ESU, NMFS proposed to apply the ESA Section 9(a) take prohibitions as the Section 4(d) limits to winter-run Chinook salmon (69 FR 33102 (June 14, 2004)) after this proposed downgrade. Following a series of extensions to the public comment period on the proposed listing determinations, the public comment period closed in November 2004 (69 FR 61348 (October 18, 2004)). On June 28, 2005 NMFS issued a final listing determination for the Sacramento River winter-run Chinook salmon ESU, which concluded that the Sacramento River winter-run Chinook salmon ESU is "in danger of extinction" due to risks to the diversity and spatial structure of the ESU, and therefore, continues to warrant listing as an endangered species under the ESA (70 FR 37160 (June 28, 2005)).

The Sacramento River winter-run Chinook salmon ESU includes winter-run Chinook salmon spawning naturally in the Sacramento River and its tributaries as well as winter-run Chinook salmon that are part of the artificial propagation program at the Livingston Stone National Fish Hatchery (LSNFH) (70 FR 37160 (June 28, 2005)).

2.1.2 CRITICAL HABITAT

Critical habitat for listed salmonids is comprised of physical and biological features essential to the conservation of the species including: (1) space for the individual and population growth and for normal behavior; (2) cover; (3) sites for breeding, reproduction, and rearing of offspring; and (4) habitats protected from disturbance or are representative of the historical geographical and

[4] Under the ESA, an "endangered species" is *"…any species which is in danger of extinction throughout all or a significant portion of its range…"* (16 USC § 1533(20)).
[5] Section 9 of the ESA makes it illegal to "*take*" (harass, harm, pursue, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct) any endangered species of fish or wildlife with similar provisions for most threatened species of fish and wildlife (16 USC 1538).

ecological distribution of the species. The primary constituent elements considered essential for the conservation of listed Central Valley salmonids are: (1) freshwater spawning sites; (2) freshwater rearing sites; (3) freshwater migration corridors; (4) estuarine areas; (5) nearshore marine areas; and (6) offshore marine areas.

On August 14, 1992, NMFS published a proposed critical habitat designation for winter-run Chinook salmon (57 FR 36626 (August 13, 1992)). The habitat proposed for designation included: (1) the Sacramento River from Keswick Dam, Shasta County (RM 302) to Chipps Island (RM 0) at the westward margin of the Delta; (2) all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait; (3) all waters of San Pablo Bay westward of the Carquinez Bridge; and (4) all waters of San Francisco Bay to the Golden Gate Bridge (NMFS 1997).

On June 16, 1993, NMFS issued the final rule designating critical habitat for winter-run Chinook salmon (58 FR 33212 (June 16, 1993)). The habitat identified in the final designation is identical to that in the proposed ruling except that critical habitat in San Francisco Bay is limited to those waters north of the San Francisco-Oakland Bay Bridge.

2.1.3 UNIQUE SPECIES CHARACTERISTICS

2.1.3.1 LIFE HISTORY STRATEGY

Chinook salmon life history strategies are divided into two basic types: stream-type Chinook salmon and ocean type Chinook salmon. Stream-type Chinook salmon adults migrate to freshwater streams before they reach full maturity, in spring or summer, and juveniles spend a relatively long time (usually more than one year) rearing in fresh water. Ocean-type Chinook salmon adults spawn soon after entering fresh water, in late-summer and fall, and juveniles spend a relatively short time (3 to 12 months) rearing in freshwater (Moyle 2002).

Winter-run Chinook salmon are unique to the Sacramento River and exhibit behaviors characteristic of both stream- and ocean-type Chinook salmon (Healey 1991). They typically migrate upstream as immature silvery fish during winter and spring and then spawn several months later in early summer. Specifically, adult winter-run Chinook salmon enter freshwater in winter or early spring, (December through July with peak upstream migration occurring during March) and delay spawning until spring or early summer (a stream-type trait); whereas, juvenile winter-run Chinook salmon exhibit more ocean-type Chinook salmon behavior by migrating to the ocean after spending as few as five months up to nine months of river life (NMFS 1997). They tend to be smaller than the rest of the runs of Chinook salmon and have low fecundity, mainly because most winter-run Chinook salmon return to spawn as three-year olds.

In the Sacramento River reach between Keswick Dam and RBDD, spawning occurs from mid-April to mid-August, peaking in June and July (Killam 2206). Chinook salmon spawn in clean, loose gravel in swift, relatively shallow riffles; or along the margins of deeper river reaches where suitable water temperatures, depths, and velocities favor redd construction and oxygenation of incubating eggs. Winter-run Chinook salmon are adapted for spawning and rearing in the clear, spring-fed rivers of the upper Sacramento River Basin, where summer water temperatures are typically between 50ºF to 59ºF. Historically, these conditions were created by glacial and snowmelt water percolating through porous volcanic formations that surround Mt. Shasta and Mt. Lassen and that cover much of northeastern California. Today, Shasta Dam denies access to winter-run Chinook salmon historical habitats and they persist mainly because water released from Shasta Reservoir during the summer is for the most part cold.

Sacramento River winter-run Chinook salmon migration corridors begin downstream of the spawning area and extend through the lower Sacramento River and the Delta. Fry emergence generally occurs at night. Upon emergence from the gravel, fry swim or are displaced downstream (Healey 1991). Fry seek habitats containing beneficial aspects such as riparian vegetation and associated substrates that provide aquatic and terrestrial invertebrates for food, cover for predator avoidance, and slower water velocities for resting (NMFS 1996b). These shallow water habitats have been described as more productive juvenile salmon rearing habitat than deeper main river channels. Higher juvenile salmon growth rates, partially due to greater prey consumption rates, as well as favorable environmental temperatures have been associated with shallow water habitats (Sommer *et al.* 2001c). Juvenile Chinook salmon migration rates vary considerably presumably depending on the physiological stage of the juvenile and hydrologic conditions. Kjelson (1982) found Chinook salmon fry traveled as fast as 30 kilometers (km) per day in the Sacramento River. Sommer *et al.* (2001a) found rates ranging from approximately 0.5 mile up to more than 6 miles per day in the Yolo Bypass.

As juvenile Chinook salmon grow they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures (Healey 1991). Catches of juvenile salmon in the Sacramento River near West Sacramento by the U.S. Fish and Wildlife Service (USFWS) exhibited larger juvenile captures in the main channel and smaller sized fry along the margins (USFWS 1997). Where the river channel is greater than 9 to 10 feet in depth, juvenile salmon tend to inhabit the surface waters (Healey 1980). Stream flow and/or turbidity increases in the upper Sacramento River basin are thought to stimulate emigration (Poytress 2007).

Similar to adult salmon upstream movement, juvenile salmon downstream movement is primarily crepuscular. Once downstream movement has commenced, salmon fry might continue this movement until reaching the Delta or they might reside in the stream for a time period that varies from weeks to a year (Healey 1991). The residence time of juveniles in streams is typically 5 to 10 months, followed by an indeterminate time in the Delta.

Emigration of juvenile Sacramento River winter-run Chinook salmon past RBDD may begin as early as mid-July, typically peaks in September, and can continue through March in dry years (NMFS 1997; Vogel and Marine 1991). From 1995 to 1999, Sacramento River winter-run Chinook salmon outmigrating as fry passed RBDD by October, and outmigrating pre-smolts and smolts passed RBDD by March (Martin *et al.* 2001). Rotary screw trap data collected by CDFW at Knights Landing from 1999 through 2011 indicate that winter-run Chinook salmon juveniles migrate past that location from October through March with the peak occurring in December and January.

As Chinook salmon begin the smoltification stage, they are found rearing further downstream where ambient salinity reaches 1.5 to 2.5 parts per thousand (ppt) (Healey 1980; Levy and

Northcote 1981). Emigration to the ocean begins as early as November and continues through May (Fisher 1994; Myers *et al.* 1998). The importance of the Delta in the life history of Sacramento River winter-run Chinook salmon is not well understood. However, juvenile Sacramento River winter-run Chinook salmon are believed to occur in the Delta primarily from November through early May based on data collected from trawls in the Sacramento River at West Sacramento (RM 57) (USFWS 2001). The timing of migration varies somewhat due to changes in river flows, dam operations, and water year type. Winter-run Chinook salmon juveniles remain in the Delta until they reach a fork length (FL) of approximately 118 millimeters (mm) (NMFS 1997).

Within the Delta, juvenile Chinook salmon forage in shallow areas with protective cover, such as tidally influenced sandy beaches and vegetated zones (Healey 1980; Meyer 1979). Cladocerans, copepods, amphipods, and larvae of diptera, as well as small arachnids and ants are common prey items (Kjelson *et al.* 1982; MacFarlane and Norton 2002; Sommer *et al.* 2001b).

Juvenile Chinook salmon movements within the estuarine habitat are dictated by the interaction between tidally driven salt water intrusions through the San Francisco Bay and fresh water outflow from the Sacramento and San Joaquin rivers. Juvenile Chinook salmon follow rising tides into shallow water habitats from the deeper main channels, and return to the main channels when the tides recede (Levy and Northcote 1981). Kjelson (1982) reported that juvenile Chinook salmon demonstrated a diel migration pattern, orienting themselves to nearshore cover and structure during the day, but moving into more open, offshore waters at night. The fish also distributed themselves vertically in relation to ambient light. During the night, juveniles were distributed randomly in the water column, but would school up during the day into the upper three meters of the water column. Juvenile Chinook salmon were found to spend about 40 days migrating from the confluence of the Sacramento and San Joaquin rivers through the San Francisco Estuary and grew little in length or weight until they reached the Gulf of the Farallones Islands (MacFarlane and Norton 2002).

Central Valley Chinook salmon begin their ocean life in the Gulf of the Farallones from where they distribute north and south along the continental shelf primarily between Point Conception and Washington State. Upon reaching the ocean, juvenile Chinook salmon feed voraciously on larval and juvenile fishes, plankton, and terrestrial insects (Healey 1991; MacFarlane and Norton 2002). Chinook salmon grow rapidly in the ocean environment with growth rates dependent on water temperatures and food availability (Healey 1991). The first year of ocean life is considered a critical period of high mortality for Chinook salmon that largely determines survival to harvest or spawning (Beamish and Mahnken 2001; Quinn 2005).

Data from the Pacific States Marine Fisheries Commission (PSMFC) Regional Mark Information System (RMIS) database indicate that Sacramento River winter-run Chinook salmon adults are not as broadly distributed along the Pacific Coast as other Central Valley Chinook salmon and tend to concentrate between San Francisco and Monterey. This localized distribution may indicate a unique life history strategy related to the observation that Sacramento River winter-run Chinook salmon also mature at a relatively young age (two to three years old) (Myers *et al.* 1998). Sacramento River winter-run Chinook salmon remain in the ocean environment for two to four years and tend to enter freshwater as immature fish.

2.1.3.2 HISTORIC SPAWNING HABITAT UTILIZATION

Distribution of winter-run Chinook salmon historically was limited to the upper Sacramento River and its tributaries where cool spring-fed streams supported successful salmon spawning, egg incubation, and juvenile rearing (Slater 1963 and Yoshiyama *et al.* 1998 *in* NMFS 2007). The historical distribution of winter-run Chinook salmon prior to construction of Shasta Dam included the headwaters of the McCloud, Pit, and Little Sacramento rivers and tributaries (e.g., Hat Creek and Fall River) (Myers *et al.* 1998). Since completion of Shasta Dam, the Sacramento River, Battle Creek and the Calaveras River are the only habitats where winter-run Chinook salmon have been reported to occur (USFWS 1987). Primary spawning and rearing habitat in the Sacramento River for winter-run Chinook salmon is now limited to the coldwater areas between Keswick Dam and RBDD. Fish still have access to Battle Creek through the Coleman National Fish Hatchery (CNFH) weir from a fish ladder that is opened during the peak of the winter-run Chinook salmon migration period (Ward and Kier 1999a). Currently, if a winter-run Chinook salmon population exists in Battle Creek; its population size is unknown and is likely very small. In addition, a winter-run Chinook salmon migration to the upper Calaveras River may have occurred between 1972 and 1984, but this information has not been confirmed. Nevertheless, the population seems to have been extirpated by drought, irrigation diversions, and blocked access by the New Hogan Dam (NMFS 1997).

2.1.4 STATUS OF WINTER-RUN CHINOOK SALMON

2.1.4.1 HISTORIC POPULATION TRENDS

Estimates of the Sacramento River winter-run Chinook salmon population (including both male and female salmon) reached nearly 100,000 fish in the 1960s before declining to under 200 fish in the 1990s (**Figure 2-1**) (Good *et al.* 2005 *in* NMFS 2007).

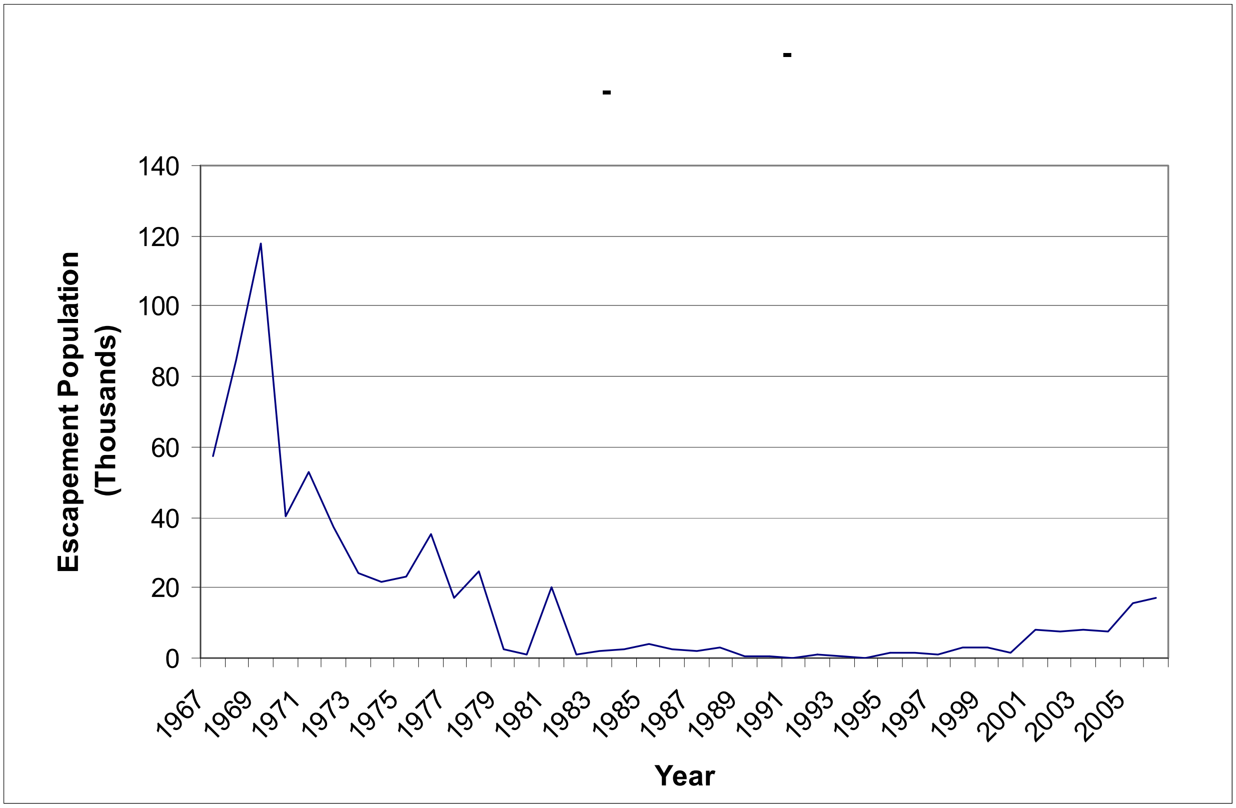

Figure 2-1. Annual Estimate of Sacramento River Winter-run Chinook Salmon Spawning Escapement from 1967-2006
Source: (CDFG 2007)

2.1.4.2 CURRENT STATUS

Shasta Dam blocks access to the entire historical spawning habitat of winter-run Chinook salmon. It was not expected that winter-run Chinook salmon would survive this habitat alteration (Moffett 1949). However, coldwater releases from Shasta Dam create conditions suitable for winter-run Chinook salmon for roughly 100 km downstream from the dam.

Although the Sacramento River winter-run Chinook population has shown improvement in recent years from levels observed in the 1990s, existing population abundance (exhibited by spawning escapement estimates) is far below historic numbers. The five-year moving average of the cohort replacement rate (CRR) has been greater than one since 1995, which is an indication of population growth (**Figure 2-2**). The CRR is a measure of population growth rate, and is generally defined as the ratio of naturally-produced returning adult spawners, to adult spawners that naturally-spawned in the river during the previous generation or brood year.

The population declined from an escapement of near 100,000 in the late 1960s to fewer than 200 in the early 1990s (Good et al. 2005). More recent population estimates of 8,218 (2004), 15,730 (2005), and 17,153 (2006) show a three-year average of 13,700 returning winter-run Chinook salmon (CDFG Website 2007). However, the run size decreased to 2,542 in 2007 and 2,850 in 2008 (**Figure 2-3**).

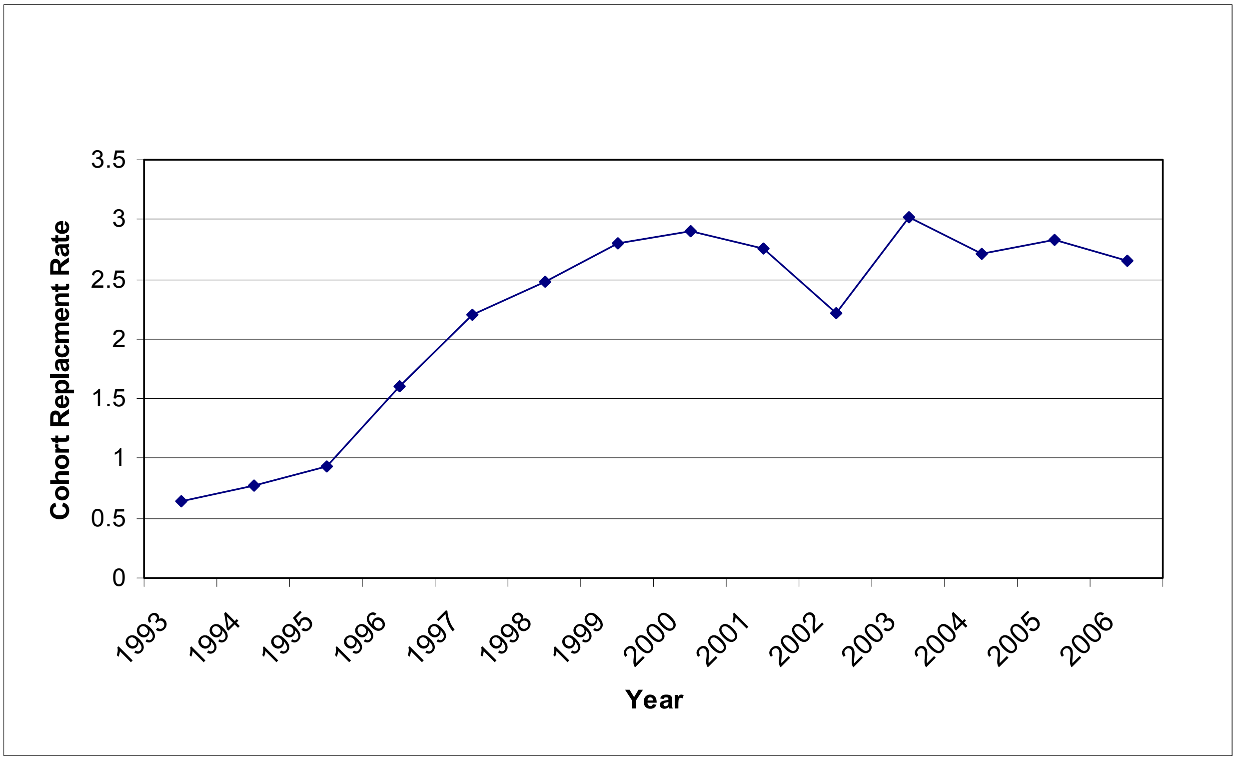

Figure 2-2. Five-year Moving Average of the Winter-run Chinook Salmon Cohort Replacement Rate

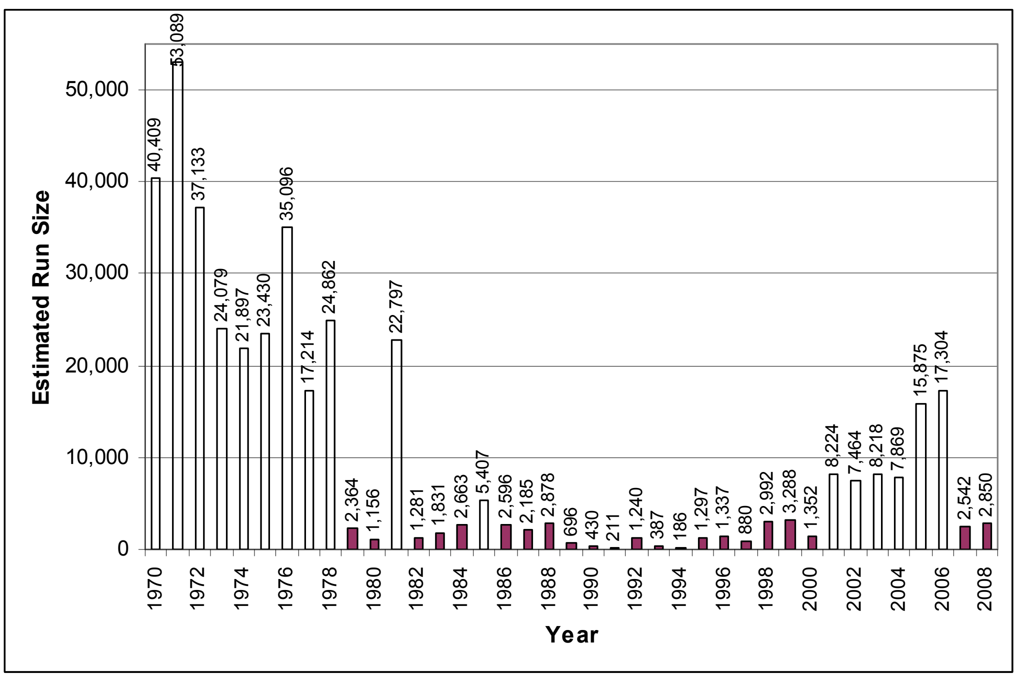

Figure 2-3. Estimated Sacramento River Winter-run Chinook Salmon Run Size (1970-2008). Total estimate includes mainstem in-river, tributaries, hatcheries, and angler harvest. Prior to 2001, mainstem in-river estimates upstream of RBDD were based on RBDD counts; subsequent estimates were based on carcass survey data.

Sacramento River winter-run Chinook salmon may be responding to a number of factors, including wetter than normal winters, changes in ocean harvest regulations since 1995 that have significantly reduced harvests, changes in RBDD operation, improved temperature management on the upper Sacramento River (including installation of a coldwater release device on Shasta Dam), water quality improvements due to remediation of Iron Mountain Mine discharges, changes in operations of the State Water Project (SWP) and federal Central Valley Project (CVP), and a variety of other habitat improvements.

2.1.4.3 EXTINCTION RISK ASSESSMENT

Although the status of the Sacramento River winter-run Chinook salmon population numbers has shown improvement over the lat six years, there is still only one naturally-spawned component of the ESU, and this single population depends on coldwater releases from Shasta Dam on the Sacramento River. Lindley *et al.* (2007) considers the Sacramento River winter-run Chinook salmon population at a moderate risk of extinction primarily due to the risks associated with only one existing population. The viability of an ESU that is represented by a single population is vulnerable to changes in the environment through a lack of spatial geographic diversity and genetic diversity that result from having only one population. A single catastrophe with effects persisting for four or more years could extirpate the entire Sacramento River winter-run Chinook salmon ESU (Lindley *et al.* 2007). Such potential catastrophes include volcanic eruption of Mt. Lassen, prolonged drought which depletes the coldwater pool in Shasta Reservoir or some related failure to manage coldwater storage, a spill of toxic materials with effects that persist for four or more years, or a disease outbreak. Moreover, an ESU that is represented by a single population is vulnerable to the limitation in life history and genetic diversity that would otherwise increase the ability of individuals in the population to withstand environmental variation.

2.2 LIFE HISTORY AND BIOLOGICAL REQUIREMENTS

2.2.1 ADULT IMMIGRATION AND HOLDING

2.2.1.1 GEOGRAPHIC AND TEMPORAL DISTRIBUTION

Adult winter-run Chinook salmon on their upstream migration enter San Francisco Bay from November through June and migrate past the RBDD from mid-December through early August (Hallock and Fisher 1985) (**Figure 2-4**). The majority of the winter-run Chinook salmon adults pass RBDD between January and May (Hallock and Fisher 1985), with the peak typically occurring during March and April (Snider *et al.* 2001).

2.2.1.2 BIOLOGICAL REQUIREMENTS

Suitable water temperatures for adult winter-run Chinook salmon migrating upstream to spawning grounds were reported to range from 57°F to 67°F (NMFS 1997). There is evidence suggesting that water temperatures above 70°F may present a thermal barrier to Chinook salmon upstream migration (Boles *et al.* 1988; USFWS 1995c). Water temperature requirements for adult Chinook salmon holding while eggs are developing are more restrictive with maximum temperatures reported at 59°F to 60°F (NMFS 1997). However, adults holding at 55°F to 56°F have substantially better egg viability (Boles *et al.* 1988; NMFS 1997).

Adult Chinook salmon require water deeper than 0.8 feet and water velocities less than 8 feet per second (ft/sec) for successful upstream migration (Thompson 1972). Adult Chinook salmon are less capable of negotiating fish ladders, culverts, and waterfalls during upstream migration than steelhead, due in part to slower swimming speeds and inferior jumping ability (Bell 1986; Reiser *et al.* 2006).

Adult winter-run Chinook salmon hold in deep, cool, well-oxygenated pools to escape warm water temperatures during the early summer months prior to spawning (DWR and Reclamation 2000). Pools utilized by Chinook salmon for holding are generally greater than 5 feet in depth that contain cover from overhanging vegetation, undercut banks, boulders or large woody debris (Lindsay 1985). Water velocities through these pools range from 0.5 to 2.0 ft/sec (Moyle 2002).

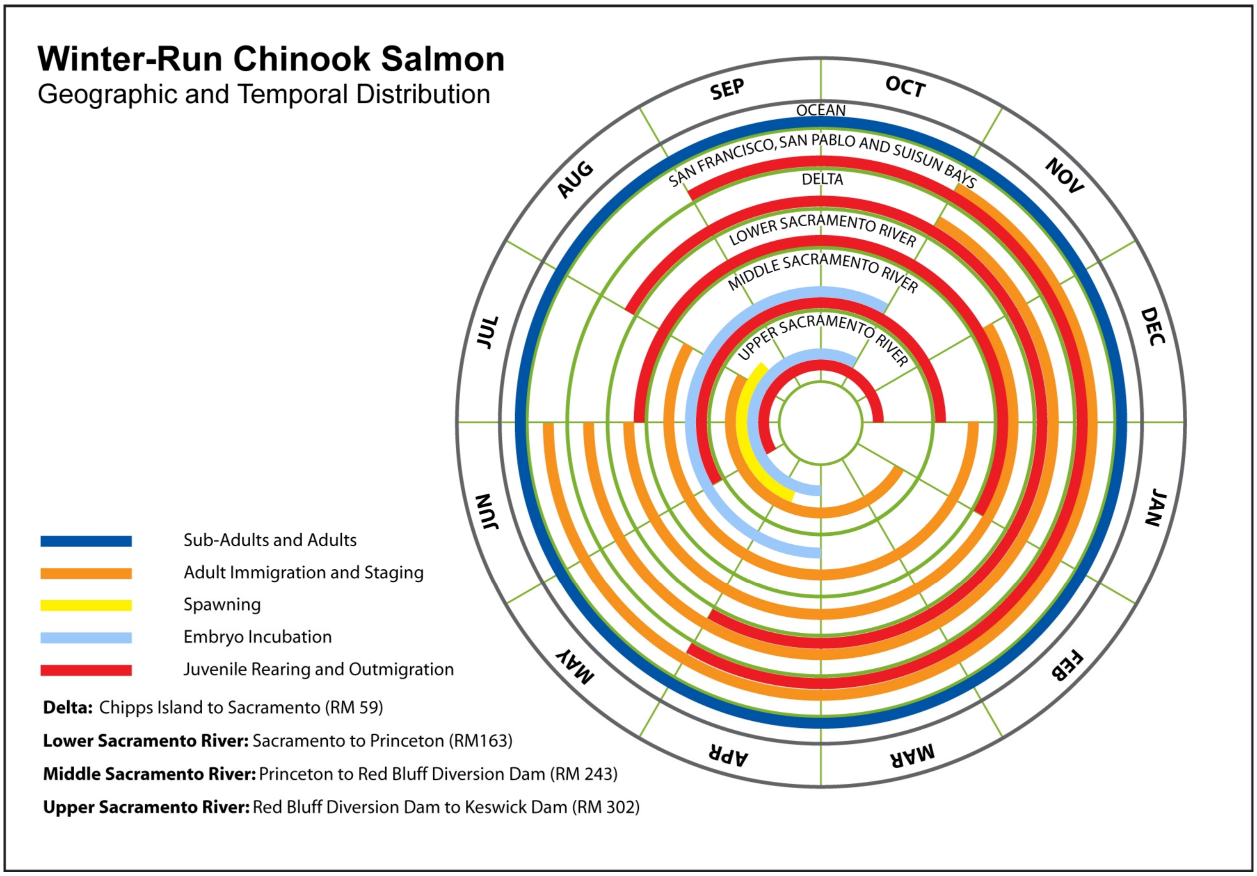

Figure 2-4. Geographic and Temporal Distribution of Sacramento River Winter-run Chinook Salmon

2.2.2 ADULT SPAWNING

2.2.2.1 GEOGRAPHIC AND TEMPORAL DISTRIBUTION

The primary spawning area for winter-run Chinook salmon extends 31 miles from Keswick Dam (RM 302) downstream to Battle Creek (RM 271) (Snider *et al.* 2001). Within this 31-mile reach, the majority of spawning occurs in the upper 14 miles from Keswick Dam to the Redding Water Treatment Plant (WTP) (Snider *et al.* 2001). Winter-run Chinook salmon primarily spawn from late-April through mid-August, with peak spawning activity in May and June (NMFS 1997).

2.2.2.2 BIOLOGICAL REQUIREMENTS

Generally, successful spawning for Chinook salmon occurs at water temperatures below 60°F (NMFS 1997). Both Chambers (1956), and Reiser and Bjornn (1979) report that upper preferred water temperatures for spawning Chinook salmon range from about 55°F to 57°F. The biological opinion (BO) on the Long-Term CVP and SWP Operations Criteria and Plan (OCAP) requires water temperatures to be maintained below 56°F in the upper Sacramento River above the RBDD (NMFS 2004a). The 56°F temperature criterion is measured as the average daily water temperature and as such, the criterion may allow water temperatures to exceed 56°F for some periods during a day. Chinook salmon spawn in riffles or runs with water velocities ranging from 0.5 to 6.2 ft/sec (DWR and Reclamation 2000; Healey 1991; Moyle 2002; Vogel and Marine 1991).

Spawning depths can range from as little as a few inches to several feet (Moyle 2002). Preferred water depths appear to range from 0.8 to 3.3 feet (Allen and Hassler 1986; Moyle 2002). Substrate is an important component of Chinook salmon spawning habitat, and generally includes a mixture of gravel and small cobbles (Moyle 2002). NMFS (1997) reports that preferred spawning substrate is composed mostly of gravels from 0.75 to 4.0 inches in diameter.

2.2.3 EMBRYO INCUBATION

2.2.3.1 GEOGRAPHIC AND TEMPORAL DISTRIBUTION

The winter-run Chinook salmon embryo incubation life stage primarily occurs between Keswick Dam and Battle Creek from April through October (NMFS 2004a; Vogel and Marine 1991).

2.2.3.2 BIOLOGICAL REQUIREMENTS

Water temperature, dissolved oxygen concentration, and inter-gravel flow are all important factors in successful embryo incubation of Chinook salmon. Within the appropriate water temperature range, eggs normally hatch in 40 to 60 days. Newly hatched fish (alevins) normally remain in the gravel for an additional four to six weeks until the yolk sac has been absorbed (NMFS 1997). Maximum embryo survival is reported at water temperatures ranging from 41°F to 56°F (Moyle 2002; USFWS 1995b). Yoshiyama *et al.* (2001) report good embryo survival at water temperatures up to 58°F. The USFWS reports decreased embryo survival occurs at water temperatures above 56°F, and no survival of eggs was observed at water temperatures above 62°F (USFWS 1995a).

Successful embryo incubation has been observed within a wide range of water depths and velocities, provided that intra-gravel flow is adequate for delivering sufficient oxygen to developing eggs and alevins (Healey 1991). The minimum intra-gravel percolation rate to ensure good survival of incubating eggs and alevins will vary, depending on flow rate, water depth, and water quality. Under controlled conditions, survival rates of 97 percent and greater have been observed with a percolation rate of 0.001 ft/sec (0.03 centimeters per second [cm/sec]), whereas 60 percent survival was observed at a 0.0001 ft/sec (0.0042 cm/sec) percolation rate (Gangmark and Bakkala 1960; Shelton 1955). Raleigh *et al.* (1986) report optimal embryo survival at dissolved oxygen concentration of 10.5 milligrams per liter.

2.2.4 JUVENILE REARING AND OUTMIGRATION

2.2.4.1 GEOGRAPHIC AND TEMPORAL DISTRIBUTION

Winter-run Chinook salmon fry emerge from the spawning gravels from mid-June through mid-October (NMFS 1997). The downstream migration of juvenile winter-run Chinook salmon past RBDD may begin in late-July, peak in September, and can continue until mid-March (Vogel and Marine 1991). Winter-run Chinook salmon juveniles occur between the RBDD and the confluence of Deer Creek (RM 220) from July through September. Their distribution slowly spreads downstream to Princeton (RM 164) between October and March (Johnson *et al.* 1992; NMFS 1997). Winter-run Chinook salmon juveniles move downstream past Glenn-Colusa Irrigation District's (GCID) Hamilton City Pumping Plant (HCPP) from July through March, with peak movement occurring in October and November (CUWA and SWC 2004). The presence of juvenile winter-run Chinook salmon in the Delta may extend from as early as September to as late as June, with a peak from January through April (NMFS 1997). The timing of emigration from the Delta to the Bays and ocean is not well known, but winter-run Chinook salmon juveniles reportedly reside in fresh and estuarine waters for five to nine months before migrating to the ocean from January (possibly late-December) through June (NMFS 1997). Data collected from the Chipps Island trawl show a winter-run sized Chinook salmon emigration peak in March and April (USFWS 2001).

2.2.4.2 BIOLOGICAL REQUIREMENTS

Optimal water temperatures for juvenile Chinook salmon are reported to range from 53.6°F to 57.2°F (NMFS 1997). A daily average water temperature of 60°F is considered the upper temperature limit for juvenile Chinook salmon growth and rearing (NMFS 1997). Inhibition of Chinook salmon smolt development in the Sacramento River reportedly may occur at water temperatures above 63°F (Marine 1997; Marine and Cech 2004).

Riparian vegetation, including shaded riverine aquatic (SRA) cover, provides juvenile salmon cover from predators, habitat complexity, a source of insect prey, and shade for maintaining water temperatures within suitable ranges for all life stages. Juvenile Chinook salmon prefer riverine habitat with abundant instream and overhead cover (e.g., undercut banks, submerged and emergent vegetation, logs, roots, other woody debris, and dense overhead vegetation) to provide refuge from predators, and a sustained, abundant supply of invertebrate and larval fish prey. On the Sacramento River, juvenile Chinook salmon are more commonly found in association with natural (as opposed to riprapped) riverbanks, and SRA cover (CDFG 1983).

Upon arrival in the Delta, it is likely that winter-run Chinook salmon will tend to rear in the more upstream freshwater portions of the Delta for about two months (Kjelson *et al.* 1981). Within the Delta, juvenile Chinook salmon forage in shallow areas with protective cover, such as intertidal and subtidal mudflats, marshes, channels, and sloughs. Maturing Chinook salmon fry and fingerlings prefer to rear further downstream where ambient salinity is up to 1.5 to 2.5 ppt (Levings and Bouillon 2005). In Suisun Marsh, Moyle *et al.* (1995) reported that Chinook salmon fry tend to remain close to the banks and vegetation, near protective cover, and in dead-end tidal channels. Winter-run Chinook salmon fry remain in the Delta until they reach a FL of about 118 mm (i.e., 5 to 10 months of age) and then begin emigrating to the ocean maybe as early as November and continue through May (Fisher 1994; Myers *et al.* 1998).

2.2.5 SUB-ADULT AND ADULT OCEAN RESIDENCE

2.2.5.1 GEOGRAPHIC AND TEMPORAL DISTRIBUTION

Winter-run Chinook salmon ocean residence normally lasts from one to three years. About one-fourth of the population returns to freshwater as two-year olds, two-thirds as three-year olds and the remainder as four-year olds (NMFS 1997). This age-of-return distribution varies - there are years when overwhelmingly two-year old males return to the upper Sacramento, and years such as 2007 when a substantial component of the returning population are four-year olds. The distribution of sub-adult and adult Sacramento River winter-run Chinook salmon in the ocean is believed to primarily extend from Monterey to Fort Bragg (NMFS 1997).

2.2.5.2 BIOLOGICAL REQUIREMENTS

The availability of food resources and cold water are likely the most important factors controlling the survival of sub-adult and adult Chinook salmon in the ocean. Food resource availability for these fish is largely dependent on the spatial distribution and abundance of plankton, which has been shown to be associated with coastal upwelling in the Pacific Northwest (Nickelson 1986; Pearcy 1997). Coastal upwelling occurs when offshore moving surface water is replaced by water which upwells along the coast from depths of 50 to 100 meters and more (NMFS 1996a). This upwelled water is cooler than the original surface water and typically has much higher concentrations of nutrients such as nitrate, phosphate and silicate that are key to sustaining biological production (NMFS 1996a). Generally, strong upwelling events lasting several months or more bring an abundance of plankton and cold water to the near shore surface waters of the ocean and have been associated with salmon abundance.

2.3 THREATS AND STRESSORS

2.3.1 SUMMARY OF ESA LISTING FACTORS

2.3.1.1 DESTRUCTION, MODIFICATION, OR CURTAILMENT OF HABITAT OR RANGE

The primary threats to the Sacramento River winter-run Chinook salmon ESU have remained the same as when the ESU was first listed in an emergency interim rule in 1989 and final rule in 1990. Dams in the Central Valley have blocked access to the entire historical spawning grounds, altered water temperatures, and reduced habitat complexity, thus resulting in severe risks to the abundance, productivity, and especially to the spatial structure and genetic diversity of the winter-run Chinook salmon ESU. These four components of abundance, productivity, spatial structure, and diversity are the basis of how NMFS determines population and ESU/DPS viability for salmonids, as defined in (McElhany *et al.* 2000). The construction and operation of Shasta Dam alone immediately reduced the winter-run Chinook salmon ESU from four independent populations to just one. The remaining available habitat for natural spawners is currently maintained artificially with cool water releases from Shasta and Keswick dams, thereby significantly limiting spatial distribution of this ESU.

RBDD, constructed in 1964, presents an impediment to upstream migrants. The construction and operation of the dam were considered one of the primary reasons for the decline of winter-run Chinook salmon in listing the ESU. The RBDD gates are now lowered on May 15, allowing for free passage of upstream migrants to access spawning habitats. An estimated 85% of the run has passed RBDD at that time. Red Bluff Diversion Dam is still partly passable when the gates are down, but the dam does delay migration and forces some fish to spawn below it where the river temperatures are warmer, and the habitat less suitable.

As described in the final listing determination for the ESU, prior to 2001, the flashboard gates at the Anderson-Cottonwood Irrigation District (ACID) Diversion Dam and the inadequate fish ladders blocked passage for upstream migrant fish. The seasonal operation of the dam created unsuitable habitat upstream of the dam by reducing flow over the eggs, which has led to reduced egg survival. In 2001, a new fish screen was placed at the diversion and a state-of-the-art fish ladder was installed to address the threats caused by the diversion dam. The new fish ladder appears to be effective for successful fish passage. For example, during the period 1987 through 2000 an average of 2.35% of winter-run spawning occurred above the ACID dam, and with post-ladder improvements an average of 42.13% of winter-run spawning has occurred above the ACID dam (Killam 2006).

In the first listing determination of the ESU, pollution from Iron Mountain Mine was considered one of the main threats to the ESU. Acid mine drainage produced from the abandoned mine degraded spawning habitat of winter-run Chinook salmon and resulted in high salmon and steelhead mortality. Remediation of Iron Mountain Mine and restoration efforts as outlined in the 2002 Restoration Plan (that was developed by the Iron Mountain Mine Trustee Council composed of several federal and state agencies) are considered to adequately mitigate the threats posed to the ESU. Pollution from Iron Mountain Mine is no longer considered a main factor threatening the ESU. Pollution from agricultural runoff carrying pesticides and fertilizers, however, is still a threat to winter-run Chinook salmon.

Bank stabilization structures to prevent bank erosion may affect the quality of rearing and migration habitat along the river. Juvenile salmon prefer natural streambanks as opposed to riprapped, leveed, or channelized sections of the Sacramento River. Bank stabilization projects in the Sacramento River are beginning to incorporate conservation measures in some areas to provide more suitable seasonal habitat for juvenile salmon as well as reduce predation in the artificially created habitat.

Additionally, the sediment balance of the Sacramento River is highly disrupted, resulting in reduced inputs of gravel due to dams and regulated flows, as well as gravel mining (The Nature Conservancy 2006).

2.3.1.2 Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Overutilization for commercial, recreational, scientific, or educational purposes no longer appears to have a significant impact on winter-run Chinook salmon populations, but warrants continued assessment. Commercial fishing for salmon is managed by the Pacific Fishery Management Council (PFMC) and is constrained by time and area to meet the Sacramento River winter-run ESA consultation standard, and restrictions requiring minimum size limits and use of circle hooks for anglers. Ocean harvest restrictions since 1995 have led to reduced ocean harvest of winter-run Chinook salmon (i.e., Central Valley Chinook salmon ocean harvest index, or Central Valley Index (CVI), ranged from 0.55 to nearly 0.80 from 1970 to 1995, and was reduced to 0.27 in 2001). While overutilization does not seem to be a significant factor under current ocean and terrestrial climate conditions, this could change due to global climate change implications.

Scientific and educational projects permitted under Sections 4(d) and 10(a)(1)(A) of the ESA stipulate specific conditions to minimize take of winter-run Chinook salmon individuals during permitted activities. There are currently four active permits in the Central Valley that may affect winter-run Chinook salmon. These permitted studies provide information about winter-run Chinook salmon that is useful to the management and conservation of the ESU.

2.3.1.3 DISEASE OR PREDATION

Naturally occurring pathogens may pose a threat to winter-run Chinook salmon, and artificially propagated winter-run Chinook salmon are susceptible to disease outbreaks such as the Infectious Hematopoietic Necrosis Virus (IHNV) and Bacterial Kidney Disease.

Predation is a threat to winter-run Chinook salmon, especially in the Delta where there are high densities of non-native fish (e.g., small and large mouth bass, striped bass, catfish, and sculpin) that prey on outmigrating salmon. The presence of man-made structures in the environment that alter natural conditions likely also contributes to increased predation by altering the predator-prey dynamics often favoring predatory species. In the upper Sacramento River, rising of the gates at the RBDD reduces potential predation at the dam by pikeminnow. In the ocean, and even the Delta environment, salmon are common prey for harbor seals and sea lions.

2.3.1.4 INADEQUACY OF EXISTING REGULATORY MECHANISMS

Over the past 10 to 15 years, many protective measures have been implemented to help increase the abundance and productivity of winter-run Chinook salmon.

FEDERAL EFFORTS

There have been several federal actions to reduce threats to the winter-run Chinook salmon ESU. Actions undertaken pursuant to Section 7 BOs have helped to increase the abundance and productivity of winter-run Chinook salmon. The BOs for the CVP and SWP have led to increased freshwater survival, and the BOs for ocean harvest have led to increased ocean survival and adult escapement. There have also been several habitat restoration efforts implemented under the Central Valley Project Impact Act (CVPIA) and CALFED programs that have led to increased abundance and productivity. There has been successful implementation of the artificial propagation program at LSNFH to supplement the abundance of naturally spawning winter-run Chinook salmon and preserve the ESU’s genetic resources. Section 10(a)(1)(B) of the ESA authorizes habitat conservation plans (HCP) for non-federal actions. However, many private parties are hesitant to engage in the HCP process because it can be costly and time-consuming. Developing an HCP is usually a voluntary process, thus, there are no guarantees that large-scale, long-term planning efforts will occur.

However, despite federal actions to reduce threats to the winter-run Chinook salmon ESU through conservation efforts, there is still a lack of diversity within the ESU and there still remains only one single extant population. Although there has been a marked increase in abundance of winter-run Chinook salmon over the last several years, the expansion of spatial distribution of winter-run Chinook salmon spawners has not been possible, as winter-run Chinook currently spawn within the only existing suitable habitat. It is uncertain whether ongoing efforts to restore habitat and passage to Battle Creek through the CALFED Ecosystem Restoration Program (ERP) will lead to successful establishment of a second independent population. The funding and implementation of that program remains uncertain. As noted in Lindley *et al*. (2006), at least two additional populations need to be successfully established to attain ESU viability for winter-run Chinook salmon, but there has not been an active push to establish additional populations. NMFS does not believe that current protective efforts being implemented for the winter-run Chinook salmon ESU provide sufficient certainty that the ESU will not be in danger of extinction in the foreseeable future.

NON-FEDERAL EFFORTS

A wide range of restoration and conservation actions have been implemented or are in the planning stages of development to aid in the recovery of the winter-run Chinook salmon ESU. Most of these actions are pursuant to implementation of conservation and restoration actions in the CALFED Bay-Delta Program, which is composed of 25 state and federal agencies, and has aided to increase abundance and productivity of winter-run Chinook salmon. The state of California listed winter-run Chinook salmon as endangered in 1989 under the California Endangered Species Act (CESA). The state's Natural Communities Conservation Plan (NCCP) involves long-term planning with several stakeholders. The state has also implemented freshwater harvest management conservation measures, and increased monitoring and evaluation efforts in support of conserving this ESU. Local governments, such as the City of Redding, and grassroots organizations, such as the Battle Creek Watershed Conservancy, are engaged in the development and implementation of conservation and recovery measures to improve conditions for winter-run Chinook salmon.

Despite federal and non-federal efforts and partnerships, the winter-run Chinook salmon ESU remains at risk of extinction because the existing regulatory mechanisms do not provide sufficient certainty that efforts to reduce threats to the ESU will be fully funded or implemented. The effectiveness of regulations depends on compliance, and tracking and enforcement of compliance has not occurred consistently within this ESU.

2.3.1.5 OTHER NATURAL AND MANMADE FACTORS AFFECTING THE SPECIES' CONTINUED EXISTENCE

Artificial propagation programs for winter-run Chinook salmon conservation purposes were developed to increase abundance and diversity of winter-run Chinook salmon, but it is still unclear what the effects of the program are to the productivity and spatial structure of the ESU (i.e., fitness and productivity). Global and localized climate changes, such as El Niño ocean conditions and prolonged drought conditions, may play a significant role in the decline of salmon, with unstable Chinook salmon populations potentially reaching lower levels. The ESU is highly vulnerable to drought conditions. During dry years, less cold water is available for release from Shasta Dam, which is the sole provider of cold water on which the fish are dependent. The resulting increased water temperature reduces availability of suitable spawning and rearing conditions.

Unscreened water diversions entrain outmigration juvenile salmon and fry. Unscreened water diversions and CVP and SWP pumping plants entrain juvenile salmon, leading to fish mortality. The cumulative effect of entrainment at these diversions and delays in outmigration of smolts caused by reduced flows may affect winter-run Chinook salmon survival.

Although the status of winter-run Chinook salmon is improving, there is only one population, and it depends on cold water releases from Shasta Dam, which would be vulnerable to a prolonged drought. Increasing the number of independent populations has yet to occur. With only one extant population of winter-run Chinook salmon, there is a need to ensure more diversity within this ESU, because it is more susceptible to catastrophic events arising from natural and/or anthropogenic processes. The need for a second naturally spawning population has been recognized and plans have been proposed to establish a second population in Battle Creek, but implementation of restoration in this watershed continues to be delayed. However, there is no guarantee that this planned protective effort will provide enough certainty to reduce the risk to the population of becoming extinct. Actions to minimize threats will require close collaboration with many agencies, stakeholders, and special interest groups.

2.3.2 NON-LIFE STAGE-SPECIFIC THREATS AND STRESSORS

Potential threats to the California Central Valley winter-run Chinook salmon population that are not specific to a particular life stage include the potential negative impacts of the current artificial propagation program utilizing the LSNFH; the small wild population size; the genetic integrity of the population due to both hatchery influence and small population size; and the potential effects of long-term climate change. Each of these potential threats is discussed in the following sections.

2.3.2.1 ARTIFICIAL PROPAGATION PROGRAM

A conservation hatchery program for winter-run Chinook salmon was initiated in 1989 at the CNFH on Battle Creek; a tributary of the upper Sacramento River above the RBDD. The purpose of the program is to reduce the risk of extinction by conservation of the winter-run Chinook salmon genome and supplementation of the wild winter-run Chinook salmon spawning population in the upper Sacramento River. Potential winter-run Chinook salmon broodstock have been collected in fish traps at Keswick Dam and RBDD, and were originally spawned at CNFH. As additional insurance, captive broodstock programs also were adopted to provide gametes for artificial propagation as needed, by rearing program winter-run juveniles to maturity in captivity. A captive rearing program was initiated in 1991 at the University of California Bodega Marine Laboratory (BML), where it played a role in winter-run research studies; and at Steinhart Aquarium, which provided a forum to educate the public to the status of the endangered Sacramento River winter-run Chinook salmon. All conservation hatchery winter-run Chinook salmon have been protected under the ESA and have been part of the Sacramento River winter-run Chinook salmon ESU.

The first release of hatchery-raised winter-run fry occurred in 1990, with an average annual release of 30,600 juveniles from CNFH between brood years 1991 and 1995. Although the intent of the program is to contribute winter-run adults to the spawning population in the upper Sacramento River, the CNFH winter-run juveniles imprinted on Battle Creek water and returned instead to Battle Creek as mature adults. In addition, genetic analyses indicated that 8 of the 129 Chinook salmon used for hatchery propagation in 1993, 1994 and 1995 were likely spring-run (NMFS 1997b). Hybrid fish inadvertently were included in program winter-run releases in 1993 and 1994, but were held back in 1995 (NMFS 1997b). At the time, the microsatellite locus, *Ots-2,* was being used exclusively to determine run assignment on captured fish; however, most of the major alleles at this locus are shared by both winter-run and spring-run Chinook salmon (Hedgecock *et al.* 1996). In response to the need to identify fish to run before being used as program broodstock, the genetics team at BML (Banks 1996) identified a number of highly polymorphic microsatellite loci in winter-run which have since been refined with multi-allelic gene markers. While these issues were being addressed, BML operations provided program fish from 1996 through 1998 while a conservation hatchery facility on the upper Sacramento River was being planned. The winter-run conservation program was moved to the LSNFH in 1998 and a third captive rearing program was established at LSNFH. Winter-run production fish are marked with coded wire tags (CWT) and adipose fin-clipped, and released in the upper Sacramento River as pre-smolts each winter in late January or early February. In the CALFED Science Conference of 2003 (Brown and Nichols 2003) it was reported that winter-run conservation program has contributed to the abundance of returning adult winter-run Chinook salmon. **Table 2-1** shows the annual number of winter-run Chinook salmon released from the facility from 1999 through 2005. The table also provides information based on data acquired during mark-recapture studies on the amount of time required by the smolts to migrate through the Delta.

Table 2-1. Winter-run Chinook Salmon Juvenile Releases from LSNFH (Broodyears 1998-2008) and Date of Initial Recapture at Chipps Island.

Brood Year	Upper Sacramento River Release Date	Number of Pre-Smolts Released[1]	Initial Date[2] of Recapture at Chipps Island
1998	1/28/1999	153,908	3/15/1999
1999	1/27/2000	30,840	3/18/2000
2000	2/01/2001	166,206	3/09/2001
2001	1/30/2002	252,684	3/20/2002
2002	1/30/2003	233,613	2/14/2003
2003	2/05/2004	218,617	2/20/2004
2004	2/03/2005	168,261	2/22/2005
2005	2/02/2006	173,344	2/17/2006
2006	2/08/2007	196,288	2/17/2007
2007	1/31/2008	71,883	3/12/2008
2008	1/29/2009	146,211	
Source: ([1]USFWS Red Bluff; [2]Paul Cadrett, USFWS, personal com.)			

There is evidence that hatchery fish may negatively affect the genetic constitution of wild fish (Allendorf *et al.* 1997; Hindar *et al.* 1991; Waples 1991). One indication of this is the observation of a reduction in wild fish populations following the initiation of a hatchery release program (Hilborn 1992; Washington and Koziol 1993). An explanation offered for this observation is that hatchery fish are adapted to the hatchery environment; therefore, natural spawning with wild fish reduces the fitness of the natural population to the natural environment. The winter-run conservation program has a broodstock collection target limit of 15 percent of the estimated upriver winter-run escapement, up to a maximum of 120 natural-origin winter-run but no fewer than 20 fish. The number of hatchery-origin winter-run Chinook salmon that may be incorporated as broodstock cannot exceed 10 percent of the total number of winter-run Chinook salmon being spawned. Broodstock collection is based on the historic migration timing of winter-run past RBDD. Collected adults are assessed for phenotypic indicators of winter-run classification and may be selected for the program only after tissue samples are genetically confirmed. The majority of winter-run hatchery releases have been F1 generation (progeny of wild fish crosses spawned at LSNFH). The annual production goal is a maximum of 250,000 pre-smolt winter-run Chinook salmon sub-yearlings for release, which was met in 2001 (Table 2-1). There may be a trade-off over time between reducing the demographic risks and increasing the genetic risks to the wild population with hatchery supplementation; conservation hatchery programs are intended to be phased out as the natural population recovers. USFWS has begun this process with the phase out of the winter-run captive rearing programs at BML and LSNFH in 2005 and 2006, respectively (Steinhart Aquarium discontinued as a captive broodstock site in 2001). Recently, NMFS reports that the rising proportion of hatchery fish among returning adults may threaten to shift the population from a low to moderate risk of extinction. Lindley *et al.* (2007) recommend that in order to maintain a low risk of genetic introgression with hatchery fish, no more than five percent of the naturally spawning population should be composed of hatchery fish. LSNFH provides a higher level of survival to winter-run at the egg, alevin and early juvenile salmon life stages than what is found in nature. Since 2001, hatchery origin winter-run Chinook salmon have made up more than five percent of the run and in 2005, the contribution of hatchery fish exceeded 18 percent (Lindley *et al.* 2007).

However, Since LSNFH is a Conservation Hatchery (using Best Management Practices), a more appropriate tool to determine associated genetic risk may be the Proportionate Natural Influence (PNI). PNI can be calculated as an approximate index by using the following formula:

$$PNI\ Approx = pNOB/(pNOB+pHOS)$$

Where pNOB is defined as the Proportion of Natural Origin Brood Stock, and pHOS as the Proportion of Hatchery Origin In-River Spawners.

The Hatchery Scientific Review Group (HSRG), an independent scientific review panel for the Pacific Northwest Hatchery Reform Project, developed guidelines as minimal requirements for mini-mizing genetic risks of hatchery programs to naturally spawning populations, and are as follows: PNI must exceed 0.5 in order for the natural environment to have a greater influence than the hatchery environment on the genetic constitution of a naturally-spawning population. In addition, maintaining PNI greater than 0.67 for natural populations considered essential for the recovery or viability of an ESU/DPS.

LSNFH has a calculated PNI average over the last six years (2003-2008) of 0.91, due to following strict management practices, which satisfies the guidelines (Bob Null, personal communication).

In summary, LSNFH is one of the most important reasons that Sacramento River winter-run Chinook salmon still persist, and the hatchery is beneficial to the ESU over the short term. However, if the continued existence of the ESU depends on LSNFH, it by any reasonable definition cannot be characterized as having a low risk of extinction, and therefore the ESU should not be delisted on that basis. The winter-run Chinook salmon ESU cannot be delisted until there are at least two viable populations (e.g., Battle Creek and Sacramento River above Shasta Dam). If the ESU has a high likelihood of persistence without LSNFH, the LSNFH winter-run Chinook program should be phased out and eventually terminated. To obtain long-term sustainability, ESUs need to have some low-risk populations with essentially no hatchery influence in the long run; they could have additional populations with some small hatchery influence, but there needs to be a core of populations that are not dependent on hatchery production.

2.3.2.2 Small Population Size Composed of a Single Extant Population

One of the main threats to the Central Valley winter-run Chinook salmon population is the small population size. The Biological Review Team (BRT) (Good *et al.* 2005) suggests that one of the chief threats to the winter-run Chinook salmon population in the Sacramento River is small population size. The population declined from an escapement of near 100,000 in the late 1960s to less than 200 in the early 1990s (Good *et al.* 2005). The California Department of Fish and Game (CDFG) estimated that 191 winter-run Chinook salmon returned in 1991 and that 189 returned in 1994 (Arkush *et al.* 1997). Runs increased to 1,361 in 1995 and 1,296 in 1996 (Arkush *et al.* 1997). Escapements increased to 8,120, 7,360 and 8,133 in 2001, 2002 and 2003 respectively (CDFG 2004b). However, a significant portion of these fish are likely returns from the winter-run Chinook salmon propagation program at the LSNFH.

A small population is particularly vulnerable to changes in environmental conditions such as droughts, El Niño events, and hazardous material spills, any of which could result in a year class failure. Magnifying the problem of a small population size of winter-run Chinook salmon in the Central Valley is that virtually all spawning activity occurs in the upper Sacramento River between the RBDD and Keswick Dam. A problem in this reach of the river could potentially destroy an entire year class. Historically, winter-run Chinook salmon spawned in several different tributaries of the upper Sacramento River including the McCloud, Pit and Little Sacramento rivers (NMFS 1997). Small population sizes are also vulnerable to adverse genetic effects as discussed in Section 2.3.2.3 below.

Botsford and Brittnacher (1998) propose a delisting criterion of >10,000 spawning females over any 13 consecutive years. Furthermore, due to the limited accuracy in measuring spawner abundance and the finite number of samples used to estimate population growth rate, estimates must be based on at least 13 years of data (Botsford and Brittnacher 1998).

2.3.2.3 Genetic Integrity

Available literature suggests several concerns with hatchery stocks reproducing with wild stocks. For example, Fleming and Gross (1992) documented the competitive inferiority of hatchery coho when attempting to spawn with wild stocks. Hatchery males were less aggressive, more submissive, and were denied access to spawning females; hatchery females spawned smaller portions of their eggs than did wild females and lost more eggs to redd destruction by other females. Busack and Currens (1995) report that raising fish in an artificial environment for all or part of their lives imposes different selection pressures on them than does the natural environment. Fish in hatchery environments may be exposed to higher densities, different food, flow regimes, substrate, protective cover, etc. These changes allow more fish to survive in the hatchery than in the wild but they also create an opportunity for genetic change in the overall population (Busack and Currens 1995). Doyle *et al.* (1995) report that the presence of a hatchery rearing stage in the life cycle of a fish will inevitably select for improved hatchery performance even when the hatchery broodstock is collected every generation from the wild. Because the correlation of hatchery fitness and fitness in nature is usually negative, this has created a problem in many enhancement programs. Lindley *et al.* (2007) recommend that in order to maintain a low risk of genetic introgression with hatchery fish, no more than five percent of the naturally spawning population should be composed of hatchery fish. Since 2001, hatchery-origin winter-run Chinook salmon have made up more than five percent of the run and in 2005, the contribution of hatchery fish exceeded 18 percent (Lindley *et al.* 2007).

In contrast to the concerns expressed above, Campton (1995) reviewed the literature on genetic effects of hatchery fish and wild stocks of Pacific salmon and steelhead and concluded that most genetic effects detected to date appear to be caused by hatchery or fishery management practices and not biological factors intrinsic to hatcheries or hatchery fish. Additionally, Olson *et al.* (1995) reported that based on data gathered on wild and hatchery spring-run Chinook salmon and summer steelhead in an Oregon stream, hatchery production is providing increased contribution to tribal and sport fisheries while not adversely affecting wild stock production.

Another potential problem of a small natural population is the potential for artificial propagation to reduce the effective size of the naturally spawning wild population. Ryman and Laikre (1991) suggest that supplementation may, under certain circumstances, decrease the overall effective population size and that the greatest danger of such a reduction occurs when the effective population of the natural proportion of the population is small. USFWS carefully manages the Livingston Stone Fish Hatchery program for winter-run Chinook salmon in order to help conserve the species and avoid any adverse impacts to the effective population size.

Small population sizes also reduce genetic variation in the population. Arkush *et al.* (2007) suggest that pathogen susceptibility in winter-run Chinook salmon will increase if further genetic variation is lost. These are the very circumstances that might occur in the case of an endangered or threatened salmonid species (NMFS 1997).

The winter-run captive broodstock program maintained representation of winter-run family groups and maximized genetic variation in spawning matrices. The artificial propagation program collects broodstock on the basis of historic run-timing and abundance of winter-run past RBDD. Collected adults are assessed for phenotypic indicators of winter-run classification and may be selected for the program only after tissue samples are genetically confirmed through molecular and statistical methods.

Adult hatchery winter-run returns are intended to contribute to the effective spawning population (N_e) by supplementing the abundance of the natural population. N_e is a measure of the rate of genetic drift within a population, and is directly related to the rate of loss of genetic diversity and the rate of increase in inbreeding within a population (Riemann and Allendorf 2001). USFWS conducts an annual analysis on the likelihood of loss of genetic variation in the winter-run effective population as a consequence of releases of hatchery-origin winter Chinook salmon. Two estimates of N_e are calculated for the winter-run population: one assumes genetic contribution by 10 percent of the run size estimate (Bartley *et al.* 1992) and one assumes genetic contribution by 33 percent of the run size estimate (R. Waples, NMFS Northwest Fisheries Science Center, pers. comm. to USFWS).

2.3.2.4 LONG-TERM CLIMATE CHANGE

California's Central Valley is located at the extreme southern limit of Chinook salmon distribution. The southern limit of Chinook salmon distribution is likely a function of climate. In California, observations reveal trends in the last 50 years toward warmer winter and spring temperatures, a smaller fraction of precipitation falling as snow, a decrease in the amount of spring snow accumulation in lower and middle elevation mountain zones and an advance in snowmelt of 5 to 30 days earlier in the spring (Knowles *et al.* 2006). Given this trend, it is likely that most species currently at the southern extent of their range, including Chinook salmon, will experience less desirable environmental conditions in the future.

Although current models are broadly consistent in predicting increases in global air temperatures, there are considerable uncertainties about precipitation estimates. For example, many regional modeling analyses conducted for the western United States indicate that overall precipitation will increase, but uncertainties remain due to differences among larger scale General Circulation Models (GCMs) (Kiparsky and Gleick 2003). Some researchers believe that climate warming might push the storm track on the West Coast further north, which would result in drier conditions in California. At the same time, relatively newer GCMs, including those used in the National Weather Assessment, predict increases in California precipitation (Roos 2003). Similarly, two popular models, including HadCM2 developed by the U.K. Hadley Center and PCM developed by the U.S. National Center for Atmospheric Research, also predict very different future scenarios. The HadCM2 predicts wetter conditions while the PCM predicts drier conditions (Brekke *et al.* 2004).

While much variation exists in projections related to future precipitation patterns, all available climate models predict a warming trend resulting from the influence of rising levels of greenhouse gasses in the atmosphere (Barnett *et al.* 2005). The potential effects of a warmer climate on the seasonality of runoff from snowmelt in California's Central Valley have been well-studied and results suggest that melt runoff would likely shift from spring and summer to earlier periods in the water year (Vanrheenen *et al.* 2004). Currently, snow accumulation in the Sierra Nevada acts as a natural reservoir for California by delaying runoff from winter months when precipitation is high (Kiparsky and Gleick 2003). Despite the uncertainties about future change in precipitation rates, it is generally believed that higher temperatures will lead to changes in snowfall and snowmelt dynamics. Higher atmospheric temperatures will likely increase the ratio of rain to snow, shorten and delay the onset of the snowfall season, and accelerate the rate of spring snowmelt, which would lead to more rapid and earlier seasonal runoff relative to current conditions (Kiparsky and Gleick 2003). Studies suggest that the spring streamflow maximum could occur about one month earlier by 2050 (Barnett *et al.* 2005).

If air temperatures in California rise significantly, it will become increasingly difficult to maintain appropriate water temperatures in order to manage coldwater fisheries, including winter-run Chinook salmon. A reduction in snowmelt and increased evaporation could lead to decreases in reservoir levels and, perhaps more importantly, coldwater pool reserves (California Energy Commission 2003). As a result, water temperatures in rivers supporting anadromous salmonids, including winter-run Chinook salmon, could potentially rise and no longer be able to support over-summering life stages (i.e., winter-run Chinook salmon embryo incubation, fry emergence, and juvenile emigration). The California Department of Water Resources (DWR) (2006) suggests that under a warmer climate scenario, water temperature standards in the upper Sacramento River likely could not be maintained.

2.3.3 San Francisco, San Pablo, and Suisun Bays

Adult winter-run Chinook salmon on their upstream migration enter San Francisco Bay from November through June (Hallock and Fisher 1985). Migration through the Delta and into the lower Sacramento River occurs from December through July, with a peak during the period extending from January through April (USFWS 1995a). The majority of the winter-run Chinook salmon adults pass the RBDD between January and May (Hallock and Fisher 1985), with the peak typically occurring during March and April (Snider *et al.* 2001). See Section 2.2.1 for a more complete description of the biological requirements and description of this life stage. Factors that may adversely affect winter-run Chinook salmon adult immigration and holding are similar in each of the three river reaches described below although the magnitude of the effects may differ.

2.3.3.1 Adult Immigration and Holding

Passage Impediments/Barriers

Suisun Marsh is one of the largest contiguous brackish water tidal marshes in the United States and is situated west of the Delta and north of Suisun Bay. In 1978, water salinity standards for Suisun Marsh were established by the State Water Resources Control Board's (SWRCB) Decision 1485 (D-1485) to improve waterfowl food plant production and to preserve the Suisun Marsh as a brackish water tidal marsh. In response to D-1485, DWR initiated a "Plan of Protection for the Suisun Marsh," which proposed actions to improve the water quality of the inner marsh. The Suisun Marsh Salinity Control Structure (SMSCS), which spans the entire 465-foot width of Montezuma Slough, includes permanent barriers adjacent to the levee on each side of the slough, gates with flashboards, and a boat lock. The SMSCS was installed in 1989 to control salinity levels in the marsh. The gates are operated from September through May, by closing on flood tides and opening on ebb tides (NMFS 2004a).

The SMSCS may delay and block immigration of adult Chinook salmon attempting to return to their natal spawning areas. Operation of the SMSCS reverses the net tidal flow within Montezuma Slough from a net eastward to a net westward flow. In addition, water flowing out of Montezuma Slough contains water from the Sacramento River. These hydrologic conditions may increase the attraction of adult Chinook salmon into the slough. Adult Chinook salmon that have entered the lower end of Montezuma Slough from the Delta cannot access spawning areas in the upper Sacramento River watershed and may be blocked or hindered by the SMSCS when they attempt to return to the Delta (NMFS 1997).

Several studies conducted to assess the effects of the SMSCS on adult salmon passage have confirmed that Chinook salmon may be attracted into Montezuma Slough and subsequently delayed or blocked from reaching spawning habitats in the Sacramento or San Joaquin rivers (CDFG 1996a; DWR and CDFG 2002). In an attempt to minimize passage problems associated with the SMSCS, the flashboards on the gates were modified by incorporating slots for fish to pass through. A SMSCS Steering Group analyzed data collected during salmon passage studies conducted in 1998 and 1999 and concluded that the modified flashboards were not improving salmon passage at the SMSCS (DWR Website 2007a). Results from ultrasonic telemetry studies conducted each year from 2001 through 2004 indicated that Chinook salmon were able to effectively pass upstream and downstream of the SMSCS when the boat lock was open. Subsequently, the OCAP BO included a term and condition stating that the boat lock will be held open when the flashboards are installed (NMFS 2004a). In addition, the OCAP BO states that the Bureau of Reclamation (Reclamation) and DWR should remove the flashboards on the SMSCS in a timely and efficient manner between September and May during periods when the operation of the SMSCS is not required to meet water quality standards in Suisun Marsh. In response to the OCAP BO, DWR and Reclamation developed a proposal describing the operational strategy for minimizing adverse effects of the SMSCS on Chinook salmon migration (DWR and Reclamation 2005).

HARVEST/ANGLING IMPACTS

Most fishery impacts on winter-run Chinook salmon occur in the recreational and commercial hook-and-line fisheries off the coast of California (NMFS 1997). Presumably, some harvest of winter-run Chinook salmon adults occurs within the Bays, but the effect of this harvest is likely negligible relative to the ocean harvest.

WATER TEMPERATURE

Water temperature at the U.S. Geological Survey (USGS) gage near Carquinez, which is located just east of San Pablo Bay, fluctuates annually between about 46°F and 73°F (USGS Website 2000). Because winter-run Chinook salmon reportedly immigrate through the Bay-Delta from November through June (Hallock and Fisher 1985), when water temperatures are seasonally cool, these fish are not expected to experience thermal stress migrating through this location. Although water temperatures at Carquinez during May and June may reach up to 68°F, a water temperature that reportedly has been stressful to Chinook salmon (Marine 1992; Ordal and Pacha 1963), the majority of winter-run Chinook salmon have already migrated through the Bay-Delta by this time (Yoshiyama *et al.* 1998).

WATER QUALITY[6]

Water quality in the Bay-Delta has improved because of regulations that followed the passage of the Clean Water Act (CWA) in 1972. Those regulations have largely have alleviated problems with organic waste and nutrients to led to algae blooms. However, Bay-Delta faces problems with industrial toxins and urban and agricultural runoff. According to the San Francisco Estuary

[6] The San Francisco Estuary Institute conducts a Regional Monitoring Program for Water Quality in San Francisco Bay and publishes an associated annual report title, *The Pulse of the Estuary*. Much of the information in this section was directly derived from the 2007 annual report, which is available at the following website: http://www.sfei.org/rmp/pulse/2007/Pulse2007_full_report_web2.pdf.

Institute, mercury (total mercury and methylmercury), polychlorinated biphenyls (PCBs), and dioxins are believed to have the most severe impacts on San Francisco Bay water quality because they are distributed throughout the entire bay at concentrations well above established thresholds. Selenium, legacy pesticides (i.e., Dichloro-Diphenyl-Trichloroethane (DDT), Dieldrin, and Chlordane), and polycyclic aromatic hydrocarbons (PAHs) are also of concern because, either the entire bay or several bay locations are included on the 303(d) list and concentrations are above established thresholds of concern. The 303(d) list refers to Section 303(d) of the CWA, which requires states to identify water bodies that do not meet water quality standards (SFEI 2007).

The SFEI classifies Polybrominated diphenyl ethers (PBDEs), pyrethroids, sediment toxicity, and pollutant mixtures as rising concerns because although water quality objectives have not yet been established for these pollutants in order to place them on the 303(d) list of impaired waters, there is a significant amount of concern about their impacts on the bay. These concerns are growing, either because of increasing rates of input into the bay or advances in understanding of their hazards (SFEI 2007).

Managers have recently shifted their attention toward implementing provisions originally included in the CWA that have not previously enforced. The CWA calls for the development of cleanup plans known as Total Maximum Daily Loads (TMDLs) for pollutants on the 303(d) List. A TMDL recently adopted for mercury and TMDLs in development for PCBs, dioxins, selenium, and legacy pesticides will address some of the most serious current threats to water quality. Implementation of the mercury TMDL is now beginning, with a major focus on the remaining challenge of reducing loads from urban runoff and other pathways that were not an emphasis in the first wave of implementation of the CWA (SFEI 2007).

Poor water quality has been demonstrated to affect many aquatic organisms in the Bay-Delta, and particularly has adversely affected organisms at lower trophic levels (e.g., benthic snails) (Thompson *et al.* 2006). The extent of contaminant effects on fish in the Bay-Delta is not well understood due to the lack of information on the effects of long-term, low-level exposures of fish to contaminants. However, some fairly recent studies (Bacey *et al.* 2005; Bennett *et al.* 1995; Kuivla and Moon 2004; Teh *et al.* 2005; Weston *et al.* 2004) have shown that contaminants are having some effects on Bay-Delta fish species, although the consequences for fish populations are uncertain (Thompson et al. 2007). Specific to salmonids, Clifford (2005) reported that juvenile Chinook salmon exposed to 100 ng/g of the pyrethroid pesticide esfenvalerate in sediment had reduced time to death compared to the controls after being exposed to the hemapoetic viral necrosis virus. Considering the water quality problems in the Bay-Delta resulting from industrial toxins and urban and agricultural runoff, and the associated effects that have been demonstrated to occur in the aquatic community, water quality is believed to be an important stressor to juvenile winter-run Chinook salmon. However, the adult immigration and holding life stage of winter-run Chinook salmon is likely not substantially affected by water quality problems in the Bay-Delta.

2.3.3.2 JUVENILE REARING AND OUTMIGRATION

WATER QUALITY

Poor water quality in the Bay-Delta, which results from both point- and non-point sources of pollution, introduces the risk of acute toxicity and mortality or long-term toxicity and associated detrimental physiological responses, such as reduced growth or reproductive impairment to Chinook salmon and other organisms utilizing the Bay-Delta (CALFED 2000a). Point source pollution in the Bay-Delta includes the discharge of selenium and contaminants from various municipal and industrial discharges. Non-point source pollution affecting the Bay-Delta includes high levels of suspended sediments and contaminants from stormwater runoff, and agricultural drainage containing high levels of nutrients, herbicides, and pesticides (NMFS 1997). Between both point- and non-point sources, an estimated 5,000 to 40,000 tons of contaminants enter the Bay-Delta annually (CALFED 2000a).

The major sources of selenium entering the Bay-Delta include (1) agricultural drainage via direct discharge to the Bay-Delta; (2) effluents from the North Bay oil refineries; (3) San Joaquin River inflows which include agricultural drainage; and (4) Sacramento River inflows (USGS Website 2007). Selenium dissolves in water as selenite and selenate. Effluents from North Bay oil refineries contain concentrations of selenite, while selenium from agricultural drainages is principally in the form of selenate (NMFS 1997). Several laboratory studies have documented the adverse effects of the bioaccumulation of selenium in Chinook salmon (Hamilton 2003). None of these studies were designed to mimic selenium concentrations found in the Bay-Delta, but the results indicate the potential for reduced growth and survival of Chinook salmon in the Bay-Delta.

Another factor which may contribute to reduced growth and survival of fish in the Bay-Delta is the effect that inputs of ammonium (NH_4) have on the food web. Dugdale *et al.* (2007) concluded that low annual primary production in San Francisco Bay is partially controlled by high concentrations of NH_4 that can prohibit phytoplankton from accessing nitrate (NO_3), effectively reducing the occurrence of phytoplankton blooms in the spring. Secondary production by higher trophic levels is adversely affected by this reduced spring phytoplankton production, which results from relatively high (i.e., > 4 µmol L^{-1}) NH_4 concentrations (Dugdale et al. 2007). Reducing anthropogenic inputs of NH_4 to help achieve target concentrations below 4 µmol L^{-1} may be a viable management action to promote increased primary and secondary production in the Bay-Delta.

LOSS OF TIDAL MARSH HABITAT

Reclamation of land at the edge of the Bay-Delta filled in or altered 85 to 95 percent of the wetlands in the Bay-Delta (SFEP 1999). In San Francisco Bay, remaining tidal marshes are located in isolated pockets or in linear strips along sloughs or bay-front dikes. The largest marshes in the Bay-Delta are in Suisun Bay, along the Petaluma, Sonoma, and Napa rivers, and along the northern shore of San Pablo Bay (NMFS 1997).

The importance of marsh habitat to juvenile Chinook salmon in the Bay-Delta is unclear. Some Chinook salmon have been collected in tidal marsh areas near Liberty Island and Little Holland Tract (NMFS 1997), but data supporting that juvenile Chinook salmon extensively rely on tidal marsh habitat in the Bay-Delta for rearing do not exist or at least have not been published. However, research in the Pacific Northwest has demonstrated that tidal marsh habitat is important to the growth and survival of juvenile Chinook salmon (Bottom *et al.* 2005; Levy and Northcote 1981). The benefits of tidal marshes to juvenile Chinook salmon include the availability of rich feeding habitat, refugia from predators, and increasing the overall productivity of tidal habitats. The lack of tidal marsh habitat in the Bay-Delta, relative to estuaries in the Pacific Northwest, may partially explain why juvenile Chinook salmon produced in the Central Valley spend little time rearing in the Bays and Delta, and exhibit slow growth and decreased condition while there (MacFarlane and Norton 2002).

The need to restore tidal marsh habitats in the Bay-Delta has been recognized. The first attempt to prescribe restoration needs for the entire Bay-Delta was in 1993, when the Governor and the U.S. Environmental Protection Agency (EPA) approved the Comprehensive Conservation and Management Plan for the Bay-Delta (San Francisco Estuary Project Website). Three North American Wetland Conservation Act grants totaling nearly $3 million have been allocated for wetland conservation actions in Suisun Marsh and in the Yolo and Delta basins. For a comprehensive list of wetland restoration projects that have been implemented around the San Francisco Bay, see the database and maps available at the Wetlands and Water Resources web site, www.swampthing.org (SFEP and CALFED 2006).

INVASIVE SPECIES/FOOD WEB CHANGES

Although there is a dearth of information on the feeding and growth of juvenile Chinook salmon as they migrate through the Delta and bays, the available data suggest that these fish may be food limited (Kjelson *et al.* 1982; MacFarlane and Norton 2002). MacFarlane and Norton (2002) examined the migration timing, diet, and growth of juvenile fall-run Chinook salmon collected at locations spanning from the confluence of the Sacramento and San Joaquin rivers to the Golden Gate Bridge and in the coastal waters of the Gulf of the Farallones. These fish migrated from the confluence to the Golden Gate Bridge in about 40 days and grew little compared to juvenile Chinook salmon in most estuaries to the north. Further evidence that residence in the Bays may not be beneficial to juvenile salmon is that their condition (K-factor) declined while migrating through the San Francisco Estuary. The authors argued that the decline in condition occurred because the quantity and/or quality of prey available to juvenile Chinook salmon was limited, not because of stomach fullness or metabolic state (e.g., smoltification). Once juvenile Chinook salmon reached the Gulf of the Farallones they began to grow rapidly and improve in condition (MacFarlane and Norton 2002).

Substantial food web alterations in the Bays and Delta that have occurred over the last few decades may have reduced the availability of preferred prey for juvenile Chinook salmon (and steelhead) rearing and migrating through those locations. These food web changes, which were primarily caused by unintentional introductions of non-native species (Carlton *et al.* 1990; Kimmerer *et al.* 1994), are one of several factors identified by the Interagency Ecological Program's Pelagic Organism Decline Team as causing the recent decline in the abundance of pelagic fish (i.e., longfin smelt, threadfin shad, juvenile striped bass, and delta smelt) in Suisun Bay and the Delta. Because the trophic feeding level of juvenile Chinook salmon overlaps with that of the pelagic fish species that are declining in abundance, at least partially due to food limitation, it is reasonable to assume that juvenile salmon in the San Francisco Estuary may also be food limited.

ENTRAINMENT

Entrainment of winter-run Chinook salmon in San Francisco, San Pablo, and Suisun bays (Bays) is not considered to be a major factor controlling this species' abundance. Although some level of entrainment may occur at pumping facilities in the Bays, the Delta is the region where entrainment is a serious threat that must be minimized or alleviated. Nevertheless, opportunities to decrease entrainment in the Bays should be identified and implemented.

PREDATION

Little is known regarding the level of predation on juvenile salmonids occurring in the Bays. Known predators of salmon occurring in abundance in the Bays include striped bass, water birds such as cormorants and terns, and pinnipeds. Further study is needed in order to develop quantitative information on the effect that these predators may be having on Chinook salmon in the Bays.

HATCHERY EFFECTS

Hatchery fish are assumed to utilize the Bay-Delta similar to wild salmonids, for some amount of time to complete acclimation to the marine environment. It does not appear that there is much opportunity for feeding within the habitat. Hatchery fish may aggressively compete with natural juveniles over limited available prey during their residency. Salmonid residence time in the Bays may be very short, which would limit the effects of hatchery winter-run on the natural population. Larger hatchery salmonids occupying the Bays such as juvenile or adult steelhead may predate on smaller-sized winter-run juveniles.

2.3.4 SACRAMENTO-SAN JOAQUIN DELTA

2.3.4.1 ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

The Sacramento Deep Water Ship Channel (SDWSC) branches off Cache Slough near Ryer Island and extends 25 miles to West Sacramento. At the upstream end of the SDWSC is an 86-foot wide, 640-foot long navigation lock. Adult salmon have been caught close to the lock at the upstream end of the channel and also have been observed to be blocked from migrating upstream by the lock (NMFS 1997). DWR conducted a study in 2003 to provide fish passage information to the Delta Cross Channel/Through Delta Facilities Team and CALFED. During this study, 35 Chinook salmon adults, categorized as winter-run based on month of capture (i.e., November through June) and size, were sampled at the upstream end of the SDWSC, indicating that the SDWSC is a threat to adult winter-run Chinook salmon migrating through the Delta.

Additionally, any adult winter-run Chinook salmon that migrate upstream through the central Delta rather than directly up the Sacramento River are blocked from entering the Sacramento River by the Delta Cross Channel gates, which are closed from December to May. These fish must turn around and migrate downstream through the San Joaquin River in order to locate the mouth of the Sacramento River. Thus, the Delta Cross Channel can be a passage barrier that delays winter-run Chinook salmon from reaching their spawning areas.

HARVEST/ANGLING IMPACTS

There is no commercial fishery for salmon in the Delta. Little information is available on the magnitude of harvest of winter-run Chinook salmon in the Delta, but it should be insignificant largely due to sportfishing regulations designed to protect winter-run Chinook salmon. If current fishing regulations are adhered to, freshwater harvest of winter-run Chinook salmon should be near zero. The extent of poaching of winter-run Chinook salmon in the Delta is unknown, although the potential for poaching is considered high as adult Chinook salmon do become concentrated behind ineffective passage facilities intended to allow fish that migrate up the Yolo and Sutter to pass back into the mainstem Sacramento River.

WATER TEMPERATURE

Water temperatures in the Delta are generally suitable throughout the winter-run Chinook salmon adult immigration and holding life stage period (i.e., December through July), except for during June and July (**Figure 2-5**). Water temperatures in the Delta during June and July are frequently warmer than 67°F, which is reported to be the upper limit of the range acceptable for adult Chinook salmon immigration (NMFS 1997). For example, mean daily water temperatures in the Sacramento River at Hood were warmer than 67°F for all of June and July in 2001, 2002, and 2004, and were warmer than 67°F for 46 days in 2003, 32 days in 2005, and 42 days in 2006. However, most winter-run Chinook salmon adults are expected to have migrated to cooler areas upstream of the Delta before warm water temperatures occur in the Delta.

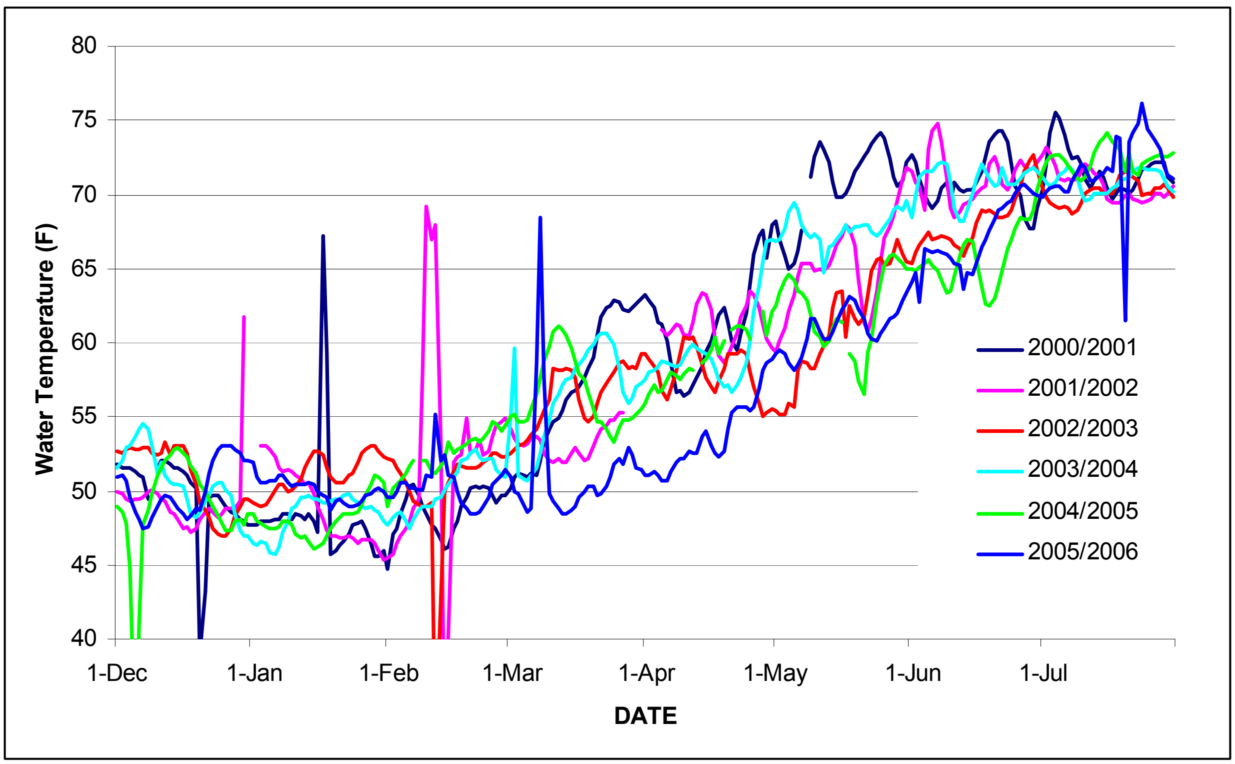

Figure 2-5. Mean Daily Water Temperatures in the Sacramento River at Hood during December Through July from 2000 to 2006. ***Source:*** ***http://cdec.water.ca.gov/***

WATER QUALITY

Like in the San Francisco, San Pablo, and Suisun bays, water quality is considered an important stressor to the aquatic community, but likely does not substantially affect adult winter-run Chinook salmon migrating through the Delta.

2.3.4.2 Juvenile Rearing and Outmigration

Juvenile winter-run Chinook salmon depend on the Delta for rearing and smoltification and may be present there from as early as September to as late as June (NMFS 1997). The highest numbers of juvenile winter-run Chinook salmon in the Delta occurs from January through April (NMFS 1997). The timing of emigration from the Delta to the San Francisco Bay and ocean is not well known but is believed to occur from late-December through June (NMFS 1997).

Water Temperature

Water temperatures in the Delta likely do not adversely affect winter-run Chinook salmon juveniles until the spring (April through June) (NMFS 1997).

Water Quality

An estimated 5,000 to 40,000 tons of contaminants enter the Bay-Delta system annually (CALFED 2000c). Contaminants entering the system are distributed by complex flow patterns influenced by inflow from the rivers and the amount of water being pumped from the Delta. Contaminants include inorganic substances such as heavy metals, nitrates and phosphates, organic contaminants such as PCBs, pesticides, plastics, detergents and fertilizers, and biological pathogens such as bacteria, viruses and protozoans (CALFED 2000c). The origin of these contaminants is from both point and non-point sources.

Currently there are several sources of point-source pollution in the Delta. The State Lands Commission identified two oil terminals, three paper processors, four oil production facilities, and several manufacturing facilities, all of which discharge into the Delta (NMFS 1997). Studies examining the uptake of contaminants by juvenile Chinook salmon indicate elevated levels of PCBs and other chlorinated pesticides. The source of these contaminants is not known but likely stem from non-point sources such as stormwater and urban runoff as well as agricultural drainage. The effects of these contaminants include the suppression of immune competence and reduced growth (NMFS 1997).

Increased regulation on organophosphate insecticide use has led to increased use of pyrethroid insecticides for both urban and agricultural uses. Pyrethroid use in the Central Valley in 2000-2003 was nearly double that in 1991-1995. Pyrethroid insecticides are hydrophobic compounds with a strong tendency to adsorb to sediments instead of dissolving in the water column. As such, pyrethroid transport likely occurs with mass transport of sediment and particulates during storm and irrigation runoff events. In addition, pyrethroids are most likely to cause toxicity to benthic organisms. Pyrethroids are very toxic to both fish and invertebrates. However, environmental pyrethroid concentration (exposure) data is needed to determine the risk to aquatic organisms in the Delta system. Although pyrethroids are relative insoluble in water, all are sufficiently soluble to cause adverse biological effects. Amphipods and copepods are among the most sensitive to pyrethroids insecticides. Pyrethroid insecticides have been detected in sediments from Central Valley agricultural and urban drainage dominated water bodies at concentrations high enough to contribute to toxicity to sensitive aquatic species. In agricultural drainage dominated water bodies the highest concentrations are detected shortly after their peak use in July (Oros and Werner 2005).

As described in Section 2.3.3.2, one factor that may contribute to reduced growth and survival of fish in the Bay-Delta is the effect that inputs of ammonium (NH_4) have on the food web. Dugdale *et al.* (2007) concluded that low annual primary production in San Francisco Bay is partially controlled by high concentrations of NH_4 that can prohibit phytoplankton from accessing nitrate (NO_3), effectively reducing the occurrence of phytoplankton blooms in the spring. Secondary production by higher trophic levels is adversely affected by this reduced spring phytoplankton production, which results from relatively high (i.e., > 4 µmol L^{-1}) NH_4 concentrations (Dugdale *et al.* 2007). Reducing anthropogenic inputs of NH_4 to help achieve target concentrations below 4 µmol L^{-1} may be a viable management action to promote increased primary and secondary production in the Bay-Delta.

Mercury contamination in the Bay/Delta and its tributaries has long been recognized as a serious problem. Water column mercury concentrations in the Bay/Delta often exceed the California state standard of 12 ng Hg L-1 (Choe *et al*. 2003). Although mercury exists in many forms in the aquatic environment, Methylmercury is the form of primary concern because it is readily accumulated in the food web and poses a toxicological threat to highly exposed species. A statewide review of fish monitoring data from the past 30 years concluded that methylmercury contamination is common in California aquatic food webs, with long-term trends indicating little change over the past few decades (SFEI 2007). Little research has been conducted exploring the effects of methylmercury accumulation on fish survival or behavior during any life stage.

FLOW CONDITIONS

CVP and SWP operations have changed the seasonal flow regimes in the Delta from historic conditions. Generally, the natural variability in flows has been reduced with flows in late spring and summer less than historic conditions and increased flows in the late summer and fall. Peak flows to the Delta generally occur in the winter and early spring when juvenile winter-run Chinook salmon are present.

During the winter and early spring, when both the Sacramento and San Joaquin rivers are at peak discharge, net flows in the Delta move downstream towards the west. During the year, as the quantity of water exported from the Delta increases relative to Sacramento River outflow, water can be drawn upstream through the lower channels of the San Joaquin River creating reverse flow conditions. Additionally, flow patterns are altered when the Delta Cross Channel is opened (generally June through November) and a proportion of the Sacramento River flow is diverted through the Delta Cross Channel. This water is conveyed in a southerly direction towards the CVP and SWP pumping plants. Historically, juvenile Chinook salmon migrated from the Sacramento River into the central Delta via Georgiana and Three Mile sloughs, in proportion to the amount of water transporting them, which was estimated to be about 20 percent (NMFS 1997). Now, with the Delta Cross Channel in operation, as much as 70 percent of Sacramento River flow may be diverted into the central Delta (NMFS 1997). Mark recapture studies with fall-run Chinook salmon have suggested that salmon smolts entering the central Delta via the Delta Cross Channel and Georgiana Slough have a much lower survival index than those remaining in the mainstem Sacramento River (NMFS 1997). Currently, the Delta Cross Channel gates are closed from the beginning of February through May and may be closed an additional 45 days at the discretion of the resource agencies from the beginning of October through January in order to protect juvenile salmonids (Brown and Nichols 2003). However, with the gates closed, large numbers of emigrating salmonids can be entrained into Georgiana Slough. Taking this route through the interior Delta as compared to remaining in the mainstem Sacramento River has been shown to increase mortality (Brown and Nichols 2003).

The primary factors causing mortality of winter-run Chinook salmon in the Delta are considered to be the diversion of juveniles from the mainstem Sacramento River into the central and southern Delta where environmental conditions are poor and reverse flow conditions exist which may move them into the lower San Joaquin River and into the south Delta waterways (NMFS 1997). Survival through central Delta migratory routes is substantially lower than through northern routes. The numbers of juveniles arriving at the export pumps is lower as river flows increase, pumping decreases, and the Delta Cross Channel gates are closed (Cramer *et al.* 2003). CVP and SWP operations have profoundly affected flow patterns in the Delta. These changes have resulted in a longer migration route to the ocean. The channel complexity and reverse flow conditions in the central Delta likely delay migration to the ocean thereby increasing the length of time that fish may be exposed to adverse conditions. Historically, the central Delta probably provided beneficial habitat for rearing juvenile Chinook salmon due to the extensive acreage of tidal marsh habitat and associated nutritional and cover benefits. However, degradation of the central Delta waterways have resulted in adverse conditions for the rearing and migration of juvenile Chinook salmon (NMFS 1997).

Potential temporary passage impediments also occur when levees protecting Delta islands breach in very wet years as a result of land subsidence and levee failures. A levee breach essentially creates a large-scale diversion that can draw several thousand acre-feet of water onto Delta islands. Levees are generally repaired while or after the islands are emptied. During drainage, fish can be stranded or are potentially harmed passing through the pumps. The magnitude of this potential problem has not been quantified, however, accounts of extensive fish stranding during the 1996 draining of Prospect Island following a levee breach suggest that mortality can be substantial (CALFED 2000c). In June of 2005, the Jones Tract levee broke causing fish to become trapped inside the tract. Althought this break occurred at a time that juvenile winter-run were not present, the probability for more Delta levee breaching and associated fish stranding is high. Mount and Twiss (2005) state that there is a two-in-three chance that a 100-year recurrence interval floods or earthquakes will cause catastrophic flooding and significant change in the Delta by 2050.

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Much of the historic riparian habitat in the Delta has been lost because of urban and agricultural development as well as levee construction for flood control and water delivery operations.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Prior to European colonization, the Delta was a vast marshland complex of multiple channels, natural levees, and frequently inundated islands composed largely of organic rich sediments (CALFED 2000b). Water delivery operations of the CVP and SWP, levee construction, agricultural and urban development have all served to change natural conditions in the Delta.

LOSS OF FLOODPLAIN HABITAT

Most of the historic flood plain habitat in the Delta has been converted to agriculture and urban uses. Agricultural and urban areas that were once part of the historic flood plain are now protected by levees.

LOSS OF TIDAL MARSH HABITAT

Few empirical studies on the importance of tidal marsh habitat have been conducted in the Delta. Some monitoring in the Delta has verified the use of this habitat by juvenile Chinook salmon (NMFS 1997). Research conducted in the Pacific Northwest has found that tidal marsh habitat is important to juvenile salmonids (NMFS 1997). Of all the salmonid species, juvenile Chinook salmon show the highest tendency to utilize this habitat type. The benefits of tidal marshes to juvenile Chinook salmon include: (1) the contribution of nutrients to the detritus-based food chain, (2) the availability of rich feeding habitat, (3) refugia from predators, and (4) the provision of suitable habitat for juveniles to undergo smoltification.

Historically, tidal marsh was one of the most common habitat types in the Delta. At present, only two percent of historical tidal marsh habitat remains in the Delta (NMFS 1997). In the Delta, tidal marsh habitat is now restricted to remnant patches mainly in channels where the area between levees is wide enough or where substrate has been deposited high enough for tules and reeds to survive.

The relative importance of tidal marsh habitat to juvenile winter-run Chinook salmon likely depends on water year type. This habitat may be more important in wetter years or in storm events during dry years when fry may be flushed into the Delta with early storms and require more time for rearing prior to undergoing the smoltification process.

INVASIVE SPECIES/FOOD WEB CHANGES

Historically, the San Joaquin River has been an important source of nutrients to the Delta. Most of the San Joaquin River is now being diverted from the south Delta by CVP/SWP operations. The resultant loss in nutrients has likely contributed to an overall decrease in fertility of the Delta, limiting its ability to produce food (NMFS 1997). Additionally, pumping operations may result in a loss of zooplankton reducing their abundance in the Delta. Poor food supply may limit the rearing success of winter-run Chinook salmon.

Extensive areas of the Delta are below mean high tide, but because of levees and flapgates installed throughout the Delta, these areas are no longer subject to tidal action. This effectively reduces the volume of water subject to tidal mixing and the size of the Delta floodplain. Reduced residence time of Delta water and associated nutrients restricts the development of foodweb organisms (CALFED 2000c).

Invasive species include both plants and animals, most of which have been introduced to the Delta unintentionally through ship ballast. However, some species have been introduced intentionally by resource agencies for sportfishing or forage.

Invasive aquatic plants have become established in many areas of the Delta. Establishment of invasive aquatic plants can harm or kill native aquatic species because they form dense mats that block sunlight and deplete oxygen supplies. Most of these aquatic weeds were introduced to the Delta unintentionally and include water hyacinth (*Eichhornia crassipes*), hydrilla (*Hydrilla verticillata*) and egeria (*Egeria densa*). Within the Delta, the construction of levees and the conversion of adjacent riparian communities to other land uses have substantially changed the ecosystem. These changes have stressed native aquatic flora and fauna allowing infestation of invasive aquatic weeds. Invasive weeds flourish in the disturbed environment and may reduce foodweb productivity potentially harming fish and wildlife (CALFED 2000c).

The majority of clams, worms and bottom dwelling invertebrates currently inhabiting the Delta are non-native species. Non-native species also comprise an increasing proportion of the zooplankton and fish communities in the Bay-Delta system. It is estimated that a new non-native species is identified in the Bay-Delta every 15 weeks (CALFED 2000c). Many fish known to prey on juvenile anadromous salmonids were introduced by resource agencies to provide sportfishing. These fish include striped bass, American shad and largemouth bass.

Although introductions have increased diversity in the Bay-Delta system, this increase in diversity has been at the expense of native species, many of which have declined precipitously or become extinct through predation and competition for resources (CALFED 2000c). At the same time, many non-native species are performing vital ecological functions such as serving as primary consumers of organic matter or as a food source for native fish and other wildlife populations (CALFED 2000c).

ENTRAINMENT

Fish in the Delta are vulnerable to entrainment in flows leading to export facilities in the southern Delta. Although facilities associated with the export facilities are designed to salvage fish from the water and return them to the Delta, the process is not very efficient (Kimmerer 2006). The efficiency of the fish salvage facilities varies from 14 to 80 percent depending on the size of the fish. For salmonids, unknown losses occur due to predation and cleaning operations, when fish screens are lifted out of the water. Mortality of fish associated with export pumping has been blamed in part for declines of numerous fish species including delta smelt and Chinook salmon. Additionally, many fish are lost to predation in waterways leading to the fish facilities (Kimmerer 2006).

According to NMFS (1997), entrainment of juvenile winter-run Chinook salmon is one of the most ubiquitous causes of mortality in the Sacramento River and Delta. A primary source of entrainment is unscreened or inadequately screened diversions. Diversion facilities in the Delta range from small siphons diverting 20 cubic feet per second (cfs) or less to the large export facilities operated by Reclamation and DWR in the southern Delta with a combined capacity of up to 12,000 cfs. A survey by CDFG indicated that a minimum of 2,050 unscreened diversions are present in the Delta (NMFS 1997). Some of these diversions include the Jones Pumping Plant, Banks Pumping Plant, Contra Costa Water District's unscreened Rock Slough, West Stanislaus Water District's unscreened diversion, Barker Slough (which is screened but not monitored), as well as numerous agricultural diversions. However, the magnitude of these diversions and the extent to which these diversions cause juvenile losses has not been adequately studied (NMFS 1997). There have been some extensive screening program efforts in the past ten years, however, there are still currently over 2,000 unscreened diversions within the Delta (Calfish Website).

Under current CVP/SWP operations, many juvenile salmon are entrained in the Clifton Court Forebay. The Clifton Court Forebay serves as a regulating reservoir providing a reliable water supply for pumping operations at the Banks Pumping Plant (DWR and Reclamation 1996). The forebay has a maximum capacity of 31,000 acre-feet. Five radial gates are opened at high tide to allow the forebay reservoir to fill and closed at low tide to retain water that supplies the pumps. Fish that enter the forebay may take up residence, be eaten by other fish, taken by anglers, further entrained at the Banks Pumping Plant, impinged on fish screens at the Skinner Fish Protection Facility or bypassed and salvaged at the fish protection facility.

Two large fossil fuel power plants are operated in the Bay-Delta, one is located in Antioch and the other in Pittsburg. Each of these plants utilizes large screened intake systems for cooling. The screens utilize 1950s technology and do not effectively screen juvenile fish. Although the water is returned to the Delta, many entrained juvenile fish are killed by mechanical damage or heat stress (CALFED 2000c).

PREDATION

Most of the predation on juvenile Chinook salmon in the Delta likely occurs from introduced species such as striped bass, black crappie, white catfish, largemouth bass and bluegill. Native Sacramento pikeminnow and steelhead also occur in the Delta and are known to prey on juvenile salmonids. Of these non-native predatory species, striped bass bass are likely the most important predators because: (1) the estimated abundance of striped bass in the Sacramento-San Joaquin system greater than 18 inches in length has ranged from about 600,000 to about 1,900,000 during the period between 1969 to 2005; (2) the total number of striped bass preying upon juvenile Chinook salmon in the system is greater than these estimated population sizes because striped bass smaller than 18 inches in length feed on juvenile Chinook salmon; (3) anectodal information indicates that striped bass movements up the Sacramento River coincide with juvenile Chinook salmon emigration, resulting in a co-occupancy of habitat; and (4) striped bass are opportunistic feeders, and almost any fish or invertebrate occupying the same habitat eventually appears in their diet (Moyle 2002).

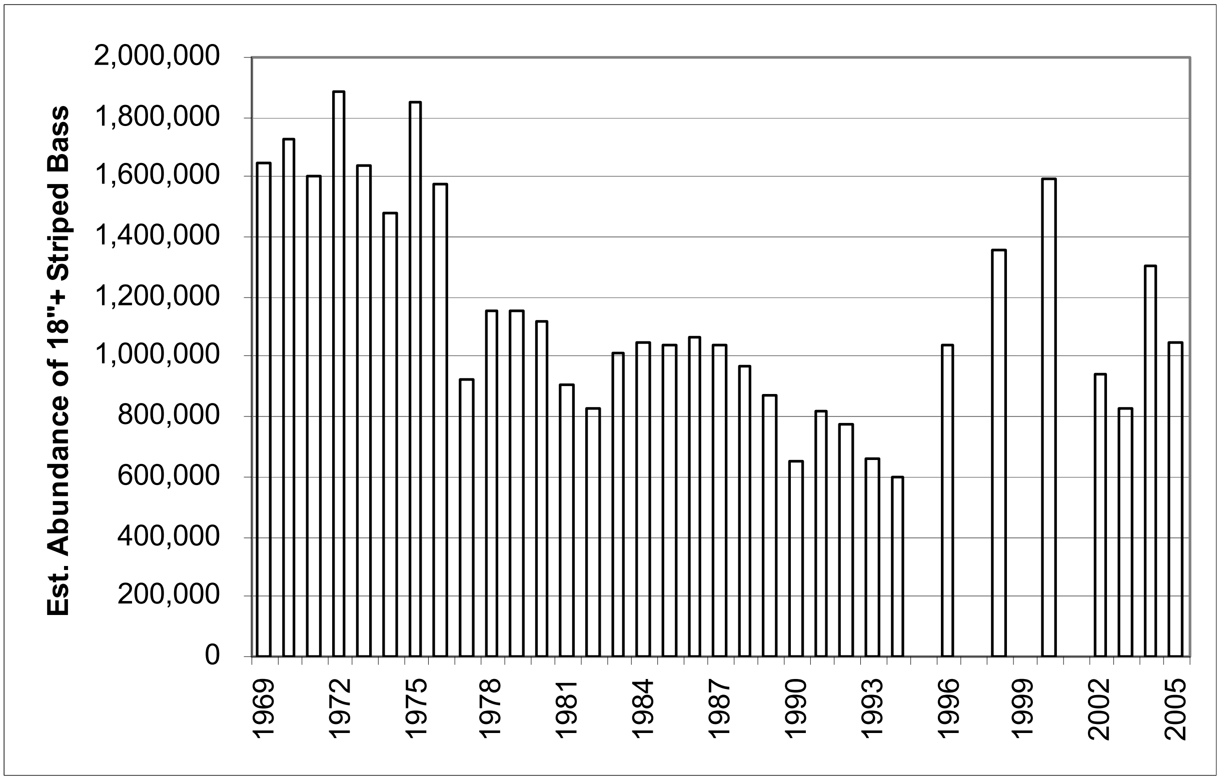

Figure 2-6. Striped Bass Population Estimates from 1969 to 2005 for Fish Greater than 18 Inches in Length in the Sacramento-San Joaquin River System. *Data were obtained from Marty Gingras (CDFG)*

Early studies in the Delta indicate that Chinook salmon comprise one to six percent of striped bass diet (NMFS 1997). However, predation at fish salvage release sites is particularly heavy. For example, Orsi (1967) found that predation occurred on approximately 10 percent of the fish released and that 80 percent of that predation was by striped bass. Similarly, Pickard *et al.* (1982 cited *in* NMFS 1997) conducted predator studies at salvage release sites and found high densities of striped bass and Sacramento pikeminnow. Additionally, pre-screen loss rates for salmon smolts entering the Clifton Court Forebay have been estimated to range from 68 to 99 percent. In mark recapture studies, mortality rates for juvenile salmon were estimated at 91.3 percent per mile compared to 2.7 percent in the central Delta. This difference in mortality rates was thought to be due to the higher number of predators, primarily striped bass, as well as hydraulic conditions and the operational characteristics of the Clifton Court Forebay (NMFS 1997).

HATCHERY EFFECTS

Winter-run hatchery production is released in the upper Sacramento River in late-January or early-February, and has been documented as reaching the Delta pumps within 14 days of release (B. Oppenheim, NMFS, pers. comm.). Up to 250,000 pre-smolt winter-run are released on average at 85 mm FL and may reach 100 mm FL in size by the time they reach the Delta pumps (B. Oppenheim, NMFS, pers. comm.). Natural-produced winter-run begin to appear at the Delta pumps in December through March at 100 to 150 mm FL, peaking in early March. There is likely some competition between hatchery- and naturally-produced winter-run over prey sources and refugia; it is unclear if there are behavioral differences between hatchery and wild winter-run during residency in the Delta. The Delta serves primarily as a migration corridor for winter-run, and in general, it is thought that salmonids do not remain in the Delta for any significant length of time. The USFWS is currently providing fish tissue, scale and otolith samples for a study that has the potential to determine residency time of salmon in the Delta (K. Niemela, USFWS, pers. comm.).

2.3.5 LOWER SACRAMENTO RIVER (PRINCETON [RM 163] TO THE DELTA)

2.3.5.1 ADULT IMMIGRATION AND HOLDING

In the lower section of the Sacramento River, the potential threats to the adult immigration and holding life stage of winter-run Chinook salmon include passage impediments, harvest in the sportfishery and poaching, adverse water temperatures, poor water quality, and adverse flow conditions.

PASSAGE IMPEDIMENTS/BARRIERS

The SDWSC branches off Cache Slough near Ryer Island and extends 25 miles to West Sacramento. At the upstream end of the SDWSC is an 86-foot wide, 640-foot long navigation lock. Adult salmon have been caught close to the lock at the upstream end of the channel and also have been observed to be blocked from migrating upstream by the lock (NMFS 1997). DWR conducted a study in 2003 to provide fish passage information to the Delta Cross Channel/Through Delta Facilities Team and CALFED. During this study, 35 Chinook salmon adults, categorized as winter-run based on month of capture (i.e., November through June) and size, were sampled at the upstream end of the SDWSC, indicating that the SDWSC presents a potential passage barrier and may delay upstream migration of winter-run Chinook salmon (NMFS 1997).

HARVEST/ANGLING IMPACTS

There is no commercial fishery for salmon in the Sacramento River. The in-river sportfishery allows for the taking of salmon generally from mid-July through January 1. Little information is available on the magnitude of in-river harvest of winter-run Chinook salmon. Hallock and Fisher (1985) report that the freshwater sport fisheries caught an average of 10 percent of the winter-run Chinook salmon run for the 1968 to 1975 period. More recently, the PFMC's Sacramento River Winter- and Spring Chinook Salmon Workgroup calculated a harvest rate of 24 percent based on the 1998 cohort reconstruction (PFMC 2003). Currently, sportfishing regulations in the Sacramento River are designed to prevent the taking of salmon during the time periods that adult winter-run Chinook salmon are present. However, Sacramento River regulations allow for the taking of salmon up to January 1 and some early migrating winter-run Chinook salmon are likely taken. For example, CDFG's Central Valley Salmon and Steelhead Harvest Monitoring Project indicated that a relatively high inland sport harvest of winter-run Chinook salmon may have occurred in late December 2000 and early January 2001. Winter-run Chinook salmon were identified by CWT hatchery-origin fish (CDFG 2004c). However, since the no-retention of salmon regulation was changed from January 15 to January 1 in 2003, no additional CWT winter-run Chinook salmon have been recovered in the CV angler survey.

The extent of poaching of winter-run Chinook salmon in this reach of the river is unknown. There are no terminal barriers that would unnaturally increase densities allowing for easy poaching. However, some level of poaching likely occurs at the Fremont, Colusa, and Tisdale weirs.

WATER TEMPERATURE

Suitable water temperatures for adult winter-run Chinook salmon migrating upstream to spawning grounds range from 57°F to 67°F (NMFS 1997). However, winter-run Chinook salmon are immature when upstream migration begins and need to hold in suitable habitat for several months prior to spawning. The maximum suitable water temperature for holding is 59°F to 60°F (NMFS 1997). Because water temperatures in the lower Sacramento River generally begin exceeding 60°F in April, it is likely that little if any suitable holding habitat exists in this reach and that it is only used by adults as a migration corridor. Adult Chinook salmon migrating into the lower Sacramento River after April may experience water temperatures exceeding 65°F which may result in reduced energy supplies needed for spawning, pre-spawning mortality, and reduced gamete viability (NMFS 1997). The potential for diseases in adults also increases as water temperatures increase.

NMFS (1997) reports that water temperatures in the lower Sacramento River may have risen by as much as 4°F to 7°F since the late 1970s. The cumulative losses of riparian habitats and associated shade along the river may have influenced water temperatures in this reach.

WATER QUALITY

Agricultural runoff and low water velocities in the lower Sacramento River can lead to poor water quality conditions, especially during late spring and summer. Because adult winter-run Chinook salmon use the lower Sacramento River strictly as a migration corridor on their way to upstream holding and spawning habitats, they likely are not substantially affected by water quality in the lower river. Furthermore, most winter-run adults have migrated upstream to the middle and upper sections of the Sacramento River before the worst water quality conditions set in during the summer months.

FLOW CONDITIONS

During high flow or flood events, water is diverted into the Sutter and Yolo bypasses upstream of the City of Sacramento. Adult winter-run Chinook salmon migrating upstream may enter these bypasses, where their migration may be delayed or blocked by control structures. To date, there have not been any measures implemented to protect adult winter-run Chinook salmon from entrainment into the flood control bypasses (NMFS 1997).

The lower Sacramento River flows through both agricultural land and a large and growing metropolitan region. This area often is affected by in-water or near-river construction projects. These construction activities have the potential to adversely affect fisheries and aquatic resources through the inadvertent discharge of toxic substances, increased sedimentation, aquatic habitat modification, and vibration and hydrostatic pressure waves generated by blasting activities. Because of the number of construction projects that take place in the area, there is potential for adverse impacts on fish species occurring in the area, including winter-run Chinook salmon. However, this potential is minimized by key environmental regulations governing environmental degradation, species protection, water pollution, hazardous wastes, and reporting requirements including the ESA, CEQA, NEPA, CESA, the CWA, the Porter-Cologne Act, RCRA, the Hazardous Control Law, the Comprehensive Environmental Response, Compensation, and

Liability Act, the Hazardous Substances Account Act, and the Toxic Substances Control Act. As such, short-term in-water construction in the area is not considered to be a major threat to the adult immigration and holding life stage of winter-run Chinook salmon.

2.3.5.2 JUVENILE REARING AND OUTMIGRATION

Factors that may adversely affect the juvenile rearing and outmigration of winter-run Chinook salmon in this reach of the river include fluctuating flow regimes; physical habitat alteration; water quality parameters including temperature and both point and non-point source pollution; predation; and entrainment into water diversions. Each of these factors is described below.

WATER TEMPERATURE

Optimal water temperatures for juvenile Chinook salmon range from 53.6°F to 57.2°F (NMFS 1997). A daily average water temperature of 60°F is considered the upper temperature limit for juvenile Chinook salmon growth and rearing (NMFS 1997). Winter-run Chinook salmon juveniles are most abundant in the lower Sacramento River during winter months when average water temperatures are normally less than 60°F. It is possible that early or late outmigrating juveniles are exposed to water temperatures above 60°F. Additionally, late outmigrating winter-run Chinook salmon may be exposed to warmwater releases from the Colusa Drain at Knights Landing. Warm water is released from the drain to the river mainly from April through June. Releases from the drain can exceed 2,000 cfs and 80°F.

WATER QUALITY

The major point source threat of pollution in the Sacramento River is the Iron Mountain Mine as described below in Section 2.3.7.3. However, because the Iron Mountain Mine is located many miles north of the lower Sacramento River section, most heavy metal contaminants from the mine have likely either settled out or have been diluted to acceptable EPA standards by the time water reaches this reach of the river. Another point source is the NH_4 in the discharge from the Sacramento regional waste treatment facilities.

The main non-point sources of pollution in the lower Sacramento River are urban runoff and agricultural drainage. Stormwater runoff from the city of Sacramento has been shown to be acutely toxic to aquatic invertebrates (NMFS 1997). Significant urban runoff also occurs during the dry season and is created from domestic/commercial landscape irrigation, groundwater infiltration, pumped groundwater discharges and construction projects (NMFS 1997). The Colusa Basin Drain is the largest source of agricultural return flow in the Sacramento River. It drains agricultural areas serviced by the Tehama-Colusa and Glenn-Colusa Irrigation districts and discharges to the Sacramento River below Knights Landing. The drain has been identified as a major source of warm water, pesticides, turbidity, suspended sediments, dissolved solids, nutrients and trace metals (NMFS 1997).

FLOW CONDITIONS

Flood control structures in the lower Sacramento River are designed to divert water from the river during a major flood event into the Butte Creek basin and the Sutter and Yolo bypasses. The diversions can be significant. For example, the flood control system can divert as much as four to five times more flow down the bypasses than remains in the river (NMFS 1997). Juvenile winter-run Chinook salmon migrating down the river may enter the diversions during storm events. Studies conducted on the Sutter Bypass show that the highest proportion of flows are diverted from December through March with a peak occurring in February, corresponding to the range and peak outmigration patterns for juvenile winter-run Chinook salmon (NMFS 1997). Juveniles diverted into the bypasses may experience migration delays, potential stranding as flood flows recede and increased rates of predation. However, both the Sutter and Yolo bypasses provide high quality rearing habitat for juveniles, potentially resulting in greater survival relative to fish that stay in the Mainstem (Sommer *et al.* 2001).

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

The lower Sacramento River has been channelized for flood control measures. Channelization of the lower river has involved rip-rapping the banks in many areas. Rip-rapping the river bank involves removing vegetation along the bank and upper levees which removes most instream and overhead cover in nearshore areas. Woody debris and overhanging vegetation within SRA habitat provide escape cover for juvenile salmonids from predators. Aquatic and terrestrial insects are an important component of juvenile salmon diet. These insects are dependent on a healthy riparian habitat.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Flood control measures, regulated flow regimes and river bank protection measures have all had a profound effect on riparian and instream habitat in the lower Sacramento River. Levees constructed in this reach are built close to the river in order to increase streamflow, channelize the river to prevent natural meandering, and maximize the sediment carrying capacity of the river (NMFS 1997). Additionally, nearshore aquatic areas have been deepened and sloped to a uniform gradient, such that variations in water depth, velocity and direction of flow are replaced by consistent moderate to high velocities. Juvenile Chinook salmon prefer slow and slack water velocities for rearing and the channelization of the river has removed most of this habitat type.

LOSS OF FLOODPLAIN HABITAT

The process of channelizing the lower Sacramento River has resulted in a loss of connectivity with the floodplains which serves as an important source of woody debris and gravels that aid in establishing a diverse riverine habitat, as well as providing juvenile salmon rearing habitat.

ENTRAINMENT

Entrainment is defined as the redirection of fish from their natural migratory pathway into areas or pathways not normally used. Entrainment also includes the take, or removal, of juvenile fish from their habitat through the operation of water diversion devices and structures such as siphons, pumps and gravity diversions (NMFS 1997). A primary source of entrainment is unscreened or inadequately screened diversions. A survey by CDFG identified 350 unscreened diversions along the Sacramento River downstream of Hamilton City.

Entrainment of juvenile winter-run Chinook salmon has been identified as one of the most significant causes of mortality in the Sacramento River and Delta (NMFS 1997). In addition, a program to flood rice field stubble during the winter has been implemented extending the period for potential entrainment (NMFS 1997). Outmigrating juvenile winter-run Chinook salmon also may be diverted into the Yolo or Sutter bypasses during high flow or flood events and stranded as flood waters recede. Additionally, Sacramento River water is diverted into the SDWSC, and outmigrating juvenile Chinook salmon may enter the channel where water quality, flow levels and rearing conditions are extremely poor (NMFS 1997).

PREDATION

Only limited information on predation of winter-run Chinook salmon juveniles is available. Native species that are known to prey on juvenile salmon include Sacramento pikeminnow and steelhead. Predation by pikeminnow can be significant when juvenile salmon occur in high densities such as below dams or near diversions. Although Sacramento pikeminnow are a native species and predation on juvenile winter-run Chinook salmon is a natural phenomenon, loss of SRA habitat and artificial instream structures tend to favor predators and may change the natural predator-prey dynamics in the system favoring predatory species (CALFED 2000c). Non-native striped bass may also be a significant predator on juvenile salmon. Although no recent studies of striped bass predation on juvenile salmon have been completed, Thomas (1967 *in* NMFS 1997) found that in the lower Sacramento River, salmon accounted for 22 percent of striped bass diet. Lindley and Mohr (2003) estimate that a striped bass population of one million fish could consume about nine percent of juvenile winter-run Chinook salmon outmigrants.

HATCHERY EFFECTS

In the lower Sacramento River, hatchery steelhead from the Feather River Fish Hatchery (FRFH) are planted in the Feather River below Yuba City at a large enough size and at a time when they could intercept outmigrating winter-run Chinook salmon juveniles (NMFS 1997).

SRA habitat along this river reach is severely limited and would be competed over by salmonids for rearing and outmigrating refugia. Hatchery fish are more aggressive and typically larger than their wild counterparts, and have a greater chance to displace them from SRA habitat, forcing smaller juveniles into fast-moving flows and leaving them vulnerable to predation and detrimental environmental variables.

2.3.6 MIDDLE SACRAMENTO RIVER (RED BLUFF DIVERSION DAM [RM 243] TO PRINCETON [RM 163])

2.3.6.1 ADULT IMMIGRATION AND HOLDING

In the middle section of the Sacramento River, the potential threats to the adult immigration and holding life stage of winter-run Chinook salmon include passage impediments, harvest in the sportfishery and poaching, adverse water temperatures, poor water quality, and adverse flow conditions.

PASSAGE IMPEDIMENTS/BARRIERS

There are no known passage impediments or barriers in the middle section of the Sacramento River. Although the GCID HCPP (~RM 205) and associated water diversions may present problems for emigrating juvenile salmonids, adults are likely not affected.

HARVEST/ANGLING IMPACTS

Adverse effects due to harvest and poaching in this reach of the river are likely similar to those occurring in the lower Sacramento River as described above in Section 2.3.5.1.

WATER TEMPERATURE

Water temperatures in the middle section of the Sacramento River are similar to, and sometimes slightly cooler than those occurring in the lower Sacramento River. However, some holding of adult winter-run Chinook salmon may occur downstream of the RBDD in deep coldwater pools. With the installation of the temperature control device at Shasta Dam in 1997, water temperatures have cooled slightly and suitable water temperatures for adult holding likely extend downstream of the RBDD for a short distance.

WATER QUALITY

Water quality in the Sacramento River has been identified by the State of California as impaired by copper, mercury, toxicity and more than 15 pesticides including diazinon chlorpyrifos and lindane. The effect of these impairments on the adult immigration of winter-run Chinook salmon is unknown.

FLOW CONDITIONS

Flows in the middle Sacramento River are sufficient to support upstream migration of adult winter-run Chinook salmon.

2.3.6.2 JUVENILE REARING AND OUTMIGRATION

Factors that may adversely affect juvenile winter-run Chinook salmon in the middle Sacramento River are similar to those that occur in the lower river as described above. However, in addition to those factors there is a potential downstream passage impediment at the GCID HCPP at RM 205.

WATER TEMPERATURE

Water temperatures in the middle Sacramento River are similar to those described above in the lower Sacramento River. Water temperatures normally exceed 60°F from July through September and in dry years can often exceed 66°F (NMFS 1997).

WATER QUALITY

The only point source pollution that has been identified and may potentially affect this reach of the river is the Iron Mountain Mine described in Section 2.3.7.3. Non-point source pollution sources include both urban and agricultural runoff similar to that described above for the lower Sacramento River. Urban runoff is likely not as great in this reach of the river as that occurring in the lower Sacramento River but agricultural runoff is likely similar or greater.

FLOW CONDITIONS

Historically, the GCID HCPP at RM 205 has created downstream migration problems for winter-run juvenile Chinook salmon. The GCID pumping plant may divert up to 20 percent of the Sacramento River. Rotary drum fish screens were installed in 1972 to help protect juvenile salmon but they were largely ineffective and never met NMFS or CDFG screen design criteria. Flat plate screens were installed in front of the rotary screens in 1993 to help alleviate the problem until a more permanent solution could be found. Juvenile winter-run Chinook salmon are exposed to the GCID pumping plant facilities as early as mid-July extending through their peak downstream movement during August and September, and into late-November when the diversion season ends.

The interim flat-plate screens are an improvement over the rotary drum screens but are still likely to subject juvenile salmon to impingement due to high approach velocities along the screens, inadequate sweeping to approach velocities, and long exposure time at the screen (USFWS 1995 *in* NMFS 1997). Construction of a new screening facility was completed in 2001 and the testing and monitoring program for the facility are now underway (Reclamation 2007). The testing and monitoring of the new facility has indicated that the screen is functioning to protect juvenile entrainment and impingement, but predation rates in the project area remain high. The TAC is studying predation effects and developing designs to reduce these effects (Howard Brown, personal communication).

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Loss of riparian habitat and instream cover in the middle reach of the Sacramento River is similar to that described above for the lower reach.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Physical habitat alteration that has occurred in the middle Sacramento River is similar to that described above for the lower Sacramento River. The river is not quite as confined in this reach as levees are constructed further from the channel than those occurring in the lower river.

LOSS OF FLOODPLAIN HABITAT

Similar to the lower Sacramento River, the channelization and construction of levees along the middle reach of the Sacramento River has caused the river to become disconnected from the floodplain.

ENTRAINMENT

The exact number of unscreened diversions in this reach of the river is not known. A study by the California Advisory Committee on Salmon and Steelhead Trout completed in 1987 reported that over 300 unscreened irrigation, industrial, and municipal water supply diversions occur on the Sacramento River between Redding and Sacramento (NMFS 1997). Although most of these diversions are small, cumulatively they likely entrain a large number of outmigrating juvenile salmonids.

Studies are currently underway to determine the effectiveness of new fish screens at the GCID HCPP to determine the effectiveness of new fish screen installed in 2001 (Reclamation 2007). Historically, of the four Sacramento River Chinook salmon races, winter-run Chinook salmon have probably been the most vulnerable to entrainment because newly emerged fry occur in the vicinity of the pumping plant's intake facility during the July through August time periods of high diversion (NMFS 1997). However, juvenile emigration data suggest that peak winter-run Chinook salmon movement past the GCID facility occurs in October and November, when pumping volume is low or has ceased for the season (CUWA and SWC 2004).

PREDATION

Predation on juvenile winter-run Chinook salmon in the middle Sacramento River is likely occurring from native Sacramento pikeminnow, native and hatchery-reared steelhead and striped bass. Although the extent of predation is unknown, predation from Sacramento Pikeminnow and striped bass is likely similar to that occurring in the lower Sacramento River as described above.

Opportunities for high predation rates also may be present at the GCID HCPP. The plant is described above as a passage impediment. Studies have indicated that Sacramento pikeminnow are the primary predator at the pumping plant, although striped bass were also found with Chinook salmon in their stomachs (CALFED 2000c). Vogel and Marine (1995) report that predation is likely in the vicinity of the fish screens associated with the diversion.

HATCHERY EFFECTS

Predation from hatchery steelhead is likely somewhat less than that occurring in the lower Sacramento River because the Feather River hatchery-reared steelhead enter the Sacramento River downstream of this reach. Additionally, steelhead released from the CNFH are likely more evenly distributed throughout the river by the time they reach this section.

SRA habitat is not as limiting along this stretch of the river, and competition between hatchery and natural fish for SRA may not be as intense in years other than dry years when river flow may be limiting and temperatures higher than normal. In those cases, the effects would be the same as previously described for the lower stretch.

2.3.7 UPPER SACRAMENTO RIVER (KESWICK DAM [~RM 302] TO RED BLUFF DIVERSION DAM)

2.3.7.1 ADULT IMMIGRATION AND HOLDING

In the upper section of the Sacramento River, the primary threats to the adult immigration and holding life stage of winter-run Chinook salmon include potential passage impediments at the RBDD, harvest in the sportfishery and poaching. Keswick Dam, at the upstream terminus of this reach of the river presents an impassable barrier to upstream migration.

PASSAGE IMPEDIMENTS/BARRIERS

Keswick Dam (~RM 302) presents an impassable barrier to the upstream migration of all winter-run Chinook salmon in the Sacramento River. The ACID Dam (RM 298.5) was constructed in 1917 about three river miles downstream of the current Keswick Dam. Originally the dam was a barrier to upstream fish migration until 1927 when a poorly designed fish ladder was installed (NMFS 1997). The dam is a 450-foot long flashboard structure which has the capability of raising the backwater level 10 feet. The dam is only installed during the irrigation season which typically runs from early April to October or early November. As mentioned above, the fish ladder providing passage around the dam was poorly designed and although winter-run Chinook salmon were able to negotiate the ladder, it did present a partial impediment to upstream migration. In 2001, a new fish ladder was installed. Post-project monitoring indicates that the new fish ladder is operating effectively (CDFG 2004c). Another potential problem associated with the facility is that high volume releases from the ACID's canal downstream of the dam may create false attraction flows for migrating adult salmon where they could be stranded (NMFS 1997).

The proportion of the spawning run that is affected by ACID Dam is uncertain. Although data on the spatial distribution of winter-run Chinook salmon spawning indicate that since the ladder improvements in 2001, an average of 42.13% spawn between Keswick Dam and ACID Dam (CDFG 2004), data on the temporal distribution of winter-run Chinook salmon upstream migration suggest that in wet years about 50 percent of the run has passed the RBDD by March, and in dry years, migration is typically earlier, with about 72 percent of the run having passed the RBDD by March (CUWA and SWC 2004).

The RBDD at RM 243 is a concrete structure 52 feet high and 740 feet long. The dam has 11 gates which are raised or lowered to control the level of Lake Red Bluff enabling gravity diversion into the Tehama Colusa Canal (TCC). Permanent fish ladders are located on each abutment of the dam. The fish ladders are inefficient in allowing upstream migration of adult salmonids (NMFS 1997). In several radio tagging studies of adult winter-run Chinook salmon, 43 to 44 percent of tagged fish were blocked by the dam (Vogel *et al.* 1988, Hallock *et al.* 1982 *in* NMFS 1997). Tagged winter-run Chinook salmon that eventually passed the dam were delayed by an average of 125 hours in one study (Vogel *et al.* 1988 *in* NMFS 1997) and 437 hours in a previous study (Hallock *et al.* 1982 *in* NMFS 1997). At present, the dam gates are kept in the raised position from September 15 through May 14 allowing free passage for about 85 percent of the run (NMFS 1997). However, there are intermittent closures during this time period of up to 10 days. The remaining portion of the run (migrating upstream past May 15) is likely to be delayed or blocked from passing the dam.

HARVEST/ANGLING IMPACTS

Although California sportfishing regulations are designed to protect winter-run Chinook salmon from recreational harvest, early arriving fish may still be harvested prior to January 1. Additionally, higher densities of fish in this portion of the river may lead to higher early harvest rates. Higher densities of fish, particularly below dams, likely create opportunities for both illegal poaching of salmon and the inadvertent or intentional snagging of fish. In addition, the upper Sacramento River supports substantial angling pressure for rainbow trout. Rainbow trout fishers tend to concentrate in locations and at times where winter-run Chinook are actively spawning (and therefore concentrated and more susceptible to impacts). By law, any winter-run Chinook inadvertently hooked in this section of river must be released without removing it from the water, however, winter-run Chinook are impacted as a result of disturbance and the process of hook-and-release.

WATER TEMPERATURE

Following the installation of the Temperature Control Device (TCD) at Shasta Dam in 1997, water temperatures in this reach of the river seldom exceed 60°F and are suitable for adult immigration and holding.

WATER QUALITY

The only point source pollution that has been identified and may potentially affect this reach of the river is the Iron Mountain Mine described in Section 2.3.7.3. Non-point source pollution sources include both urban and agricultural runoff.

FLOW CONDITIONS

Flow conditions in the upper Sacramento River are not likely to adversely affect the upstream adult immigration period for winter-run Chinook salmon.

2.3.7.2 SPAWNING

Spawning escapements of winter-run Chinook salmon in the Sacramento River have declined from near 100,000 in the late 1960s to less than 200 in the early 1990s (Good *et al.* 2005). The CDFG estimated that 191 winter-run Chinook salmon returned in 1991 and that 189 returned in 1994 (Arkush *et al.* 1997). Runs increased to 1,361 in 1995 and 1,296 in 1996 (Arkush *et al.* 1997). Escapements increased to 8,120, 7,360 and 8,133 in 2001, 2002 and 2003 respectively (CDFG 2004c). It should be noted that, some proportion of the escapement is made up of winter-run Chinook salmon propagated at the LSNFH. In 2005, over 18 percent of the run was composed of fish from LSNFH (Lindley *et al*. 2007).

In the Sacramento River, winter-run Chinook salmon spawn from late-April through mid-August with peak spawning activity in May and June (NMFS 1997). See Section 2.2.2 for a more complete description of the biological requirements and description of this life stage. Factors that may adversely affect winter-run Chinook salmon spawning are similar in both river reaches described below although the magnitude of the effects may differ.

Spawning in this reach of the Sacramento River may be affected by adverse flow conditions, physical habitat alteration, recreational sportfishing and poaching, and poor water quality (water temperature). Each of these potential effects is described below.

Although lower water temperatures in this reach of the Sacramento River make spawning habitat more suitable, the adverse effects of changing flow regimes, physical habitat alteration, sportfishing harvest and poaching are likely magnified in this reach due to higher densities of winter-run Chinook salmon spawning.

PASSAGE IMPEDIMENTS/BARRIERS

Keswick Dam presents an impassable barrier to upstream salmonid migration and, therefore, marks the upstream extent of currently accessable spawning habitat in this reach of the Sacramento River.

HARVEST/ANGLING IMPACTS

Sport fishing regulations in the Sacramento River are designed to minimize the legal take of winter-run Chinook salmon. However, because the taking of salmon is permitted after August 1, some late spawning winter-run Chinook salmon may be taken. Additionally, the Sacramento River is a popular year-round fishery and some salmon may be inadvertently caught or incorrectly identified by anglers fishing for rainbow trout.

WATER TEMPERATURE

Because of suitable water temperatures in this reach of the river and only marginal water temperature conditions downstream of the RBDD, almost all spawning activity occurs in the upper Sacramento River. Other factors affecting winter-run Chinook salmon spawning in the upper Sacramento River are similar to those affecting spawning in the middle Sacramento River described above. Water temperatures in this reach of the river are slightly lower than those found in the middle Sacramento reach making spawning habitat more suitable.

Generally, successful spawning for Chinook salmon occurs at water temperatures below 60°F (NMFS 1997). The NMFS OCAP BO requires water temperatures to be maintained below 56°F. The 56°F temperature criterion is measured as the average daily water temperature and as such, the criteria may allow water temperatures to exceed 56°F for some periods during a day. However, water temperatures are not likely to exceed 56°F for more than a few hours. Prior to 1997, during some years, water temperatures began exceeding 60°F in May and during July and August, water temperatures were frequently above 60°F (NMFS 1997). In 1997, a TCD was installed at Shasta Dam allowing better management of water temperatures in the Sacramento River. CDFG (2004c) reports that the TCD is working well and that very low egg loss occurred due to adverse water temperatures in 2002 and 2003. Currently the 56°F compliance point is at Bend Bridge near the town of Red Bluff. Downstream of this point, water temperatures likely increase rather quickly during the summer months because of the warm weather and warmwater agricultural return flows.

WATER QUALITY

Water quality in the upper Sacramento River is similar to that described in the idle reach described above. Because of the proximity of the Iron Mountain Mine, point source pollutants may be more concentrated in this reach of the river but effects on spawning are likely negligible.

FLOW CONDITIONS

Large flow fluctuations are the main concern regarding adverse flow conditions in the middle and upper Sacramento River. The largest and most frequent flow reductions have occurred in the late summer and early fall when flashboards at the ACID Dam require adjustment. However, because the largest flow reductions normally occur after spawning has taken place, it is not likely that adverse flow conditions in this reach of the river have a significant negative effect on winter-run Chinook salmon spawning.

SPAWNING HABITAT AVAILABILITY

It is generally thought that available spawning habitat in the upper Sacramento River is sufficient to support the winter-run Chinook salmon population at its currently low level (NMFS 1997). However, as the population recovers, spawning gravel availability could become a limiting factor (NMFS 1997).

PHYSICAL HABITAT ALTERATION

Chinook salmon require clean loose gravel from 0.75 to 4.0 inches in diameter for successful spawning (NMFS 1997). The construction of dams in the upper Sacramento River has eliminated the major source of suitable gravel recruitment to reaches of the river below Keswick Dam. Gravel sources from the banks of the river and floodplain have also been substantially reduced by levee and bank protection measures.

HATCHERY EFFECTS

Hatchery effects that are not specific to a particular life stage are discussed above in Section 2.3.2.1. Potential negative effects specific to spawning are discussed below.

The first release of hatchery-raised winter-run Chinook salmon fry from the CNFH occurred in 1990. Use of the CNFH for the propagation program was unsuccessful primarily because fish imprinted on Battle Creek and adults returned to Battle Creek where instream conditions are too warm to allow successful spawning and embryo incubation. Additionally, genetic analyses showed that some spring-run Chinook salmon were misidentified as winter-run and used for hatchery propagation in 1993, 1994 and 1995 (NMFS 1997). Subsequently, hybrids were released in 1993 and 1994.

The LSNFH has been producing and releasing winter-run Chinook salmon since 1998. The fish are marked with CWTs, adipose fin clipped and released as pre-smolts each winter in late-January or early-February.

Broodstock for the winter-run conservation program is collected from fish traps at Keswick Dam throughout the migration period. The collection target for winter Chinook salmon broodstock is 15% of the estimated run size, up to a maximum of 120 natural-origin adults. The overall strategy of the program is to increase the abundance of the natural population and bring it closer to recovery status. The greatest potential effect on spawning may be dominance of hatchery influence on the natural population. High survival is afforded to hatchery juveniles. Artificial propagation of winter-run preferentially spawns natural adults, but with the limitations of current collection methods, there may be skewing of genetic representation of the population not par with natural selection. Preferential survival of hatchery fish over time may disrupt gene complexes of the natural population with those inherited through artificial selection. Taylor (1991) reports that because hatchery fish are adapted to the hatchery environment, natural spawning with wild fish reduces the fitness of the natural population. Recently, NMFS (2007a) reported that the rising proportion of hatchery fish among returning adults threatens to shift the population from a low to moderate risk of extinction. Additionally, Lindley *et al.* (2007) recommend that in order to maintain a low risk of genetic introgression with hatchery fish, no more than five percent of the naturally spawning population should be composed of hatchery fish.

Since 2001, hatchery-origin winter-run Chinook salmon have made up more than five percent of the run and in 2005, the contribution of hatchery fish exceeded 18 percent (Lindley *et al.* 2007).

2.3.7.3 EMBRYO INCUBATION

In the Sacramento River, winter-run Chinook salmon spawning occurs from late-April through mid-August. Fry emergence occurs from mid-June through mid-October (NMFS 1997). Therefore, embryo incubation is believed to occur from mid-April through mid-October. Nearly all spawning of winter-run Chinook salmon occurs in the upper Sacramento River upstream of the RBDD. In 2002, one redd was observed downstream of RBDD, while in 2003, three redds were observed below this point (CDFG 2004). Embryo incubation is defined as the time span from fertilized egg deposition until fry emergence from the gravel. Within the appropriate water temperature range, eggs normally hatch in 40 to 60 days. Newly hatched fish (alevins) normally remain in the gravel for an additional four to six weeks until the yolk sac has been absorbed (NMFS 1997). See Section 2.2.3 for a more complete description of the biological requirements and description of this life stage. Factors that may affect winter-run Chinook salmon embryo incubation are similar in both river reaches and are described below; however, the magnitude of the effects may differ.

Factors affecting winter-run Chinook salmon embryo incubation in the upper Sacramento River are similar to those affecting embryo incubation in the middle Sacramento River described above. Water temperatures in this reach of the river are lower than those found in the middle Sacramento River reach making embryo incubation habitat more suitable and warm water temperatures are seldom a problem for developing embryos in this reach of the river.

The adverse effects of fluctuating flow regimes and water pollution from both point and non-point sources are likely magnified in this reach of the river because of the higher densities of embryo development.

HARVEST/ANGLING IMPACTS

Because recreational fishing in the Sacramento River is permitted year-round, it is possible that incubating embryos in redds could be disturbed by wading anglers.

WATER TEMPERATURE

The embryo incubation life stage of winter-run Chinook salmon is the most sensitive to elevated water temperatures. Preferred water temperatures for Chinook salmon egg incubation and embryo development range from 46°F to 56°F (NMFS 1997). Sacramento River water temperatures are managed to provide 56°F or cooler conditions from Keswick Dam downstream to the Balls Ferry to Bend Bridge reach throughout the summer. A significant reduction in egg viability occurs at water temperatures above 57.5°F and total mortality may occur at 62°F (NMFS 1997). Additionally, several diseases that can adversely affect developing embryos become more virulent as water temperatures increase. For example, Saprolegnia is a common fungal disease, which spreads rapidly and suffocates developing eggs in a redd. The rate of fungal growth rises exponentially as water temperatures increase from the mid-50s to the low-60s (NMFS 1997). Historically, water temperatures in the middle Sacramento River typically exceeded 60°F from July through September and in drier years may have exceeded 66°F (NMFS 1997). Winter-run Chinook salmon that spawned downstream of the RBDD normally did not produce viable offspring because of lethal water temperatures (Hallock and Fisher 1985). However, with implementation of the TCD at Shasta Dam in 1997 suitable water temperatures for embryo incubation may extend downstream of Bend Bridge. Currently, river water temperatures just below the RBDD only marginally exceed the incipient lethal level for incubating eggs during June through September, by reaching 57°F to 58°F. These water temperatures are in the range that would typically cause mortality for 10 to 20 percent of eggs (Cramer *et al.* 2003).

WATER QUALITY

Water quality issues that may produce adverse effects on winter-run Chinook salmon include both point source and non-point source pollution. Non-point source pollution consists of sediments from storm events, stormwater runoff in urban and developing areas and agricultural runoff. Sediments constitute nearly half of the material introduced to the river from non-point sources (NMFS 1997). Excess silt and other suspended solids are mobilized during storm events from plowed fields, construction and logging sites and mines. High sediment loading can interfere with eggs developing in redds by reducing the ability of oxygenated water to percolate down to eggs in the gravel. Stormwater runoff in urban areas can transport oil, trash, heavy metals and toxic organics all of which are potentially harmful to incubating eggs. Agricultural runoff can contain excess nutrients, pesticides and trace metals.

The inactive Iron Mountain Mine in the Spring Creek watershed near Keswick Dam creates the largest point source discharge of toxic material into the Sacramento River. The three metals of particular concern are copper, cadmium and zinc. The early life stages of salmon are the most sensitive to these metals (NMFS 1997). The acid mine drainage from Iron Mountain Mine is among the most acidic and metal laden anywhere in the world (NMFS 1997). Historically, discharge from the mine has produced massive fish kills.

In 1983, the Iron Mountain Mine site was declared a superfund site. Since that time various mitigation measures have been implemented including a neutralization plant that has improved the ability to control metal loadings to the river. (NMFS 1997) reported that although significant improvements have been made, basin plan objectives were not yet achieved by 1997. Since that time, other mitigation measures have been implemented resulting in a 95 percent reduction in historic copper, cadmium and zinc discharges (EPA 2006). At present, acid mine waste still escapes untreated from waste piles and seepage on the north side of Iron Mountain and flows into Boulder Creek, which eventually flows into the Sacramento River (EPA 2006). However, there were no significant exceedances of dissolved metal concentrations in the Sacramento River in 2002 and 2003 (CDFG 2004c). Another point source of pollution in the upper Sacramento River is the Simpson Mill near Redding, which discharges PCBs into the river (NMFS 1997).

FLOW CONDITIONS

Flow fluctuations are a serious concern related to potential adverse effects on the embryo incubation life stage of winter-run Chinook salmon. For example, if spawning salmon construct redds during periods of high flow, those redds could become dewatered during subsequent periods of low flow. Historically, the largest and most rapid flow reductions have occurred during the irrigation season when adjustments are required at the ACID Dam. To accommodate these adjustments, Sacramento River flows at times have been decreased by one-half or greater, over the course of a few hours (NMFS 1997). Flow fluctuations adversely affecting winter-run Chinook salmon embryo and pre-emergent fry incubation occur every year and could only be controlled by significant changes in dam operations. Specifically, releases from Keswick Dam typically drop from summer high flows of 13,000 to 15,000 cfs to fall flows of 3,250 to 5,500 cfs in September, prior to the emergence of fry from the tail end of the winter-run spawning distribution. Dropping flows from 13,000 cfs to 5,500 cfs would result in dewatering 20.7% of winter-run redds (USFWS 2006). Adherence to NMFS ramping criteria and the use of CVPIA B2 water serve to reduce the adverse effects of flow fluctuation.

2.3.7.4 JUVENILE REARING AND OUTMIGRATION

Winter-run Chinook salmon juveniles rearing in the upper Sacramento River exhibit peak abundance during September, with outmigration past the RBDD occurring from July through March (Reclamation 1992; Vogel and Marine 1991). NMFS (1997) reports juvenile rearing and outmigration extending from June through April. Outmigration of juveniles past Knights Landing, approximately 155 river miles downstream of the RBDD, reportedly occurs between November and March peaking in December (Snider and Titus 2000). See Section 2.2.4 for a more complete description of the biological requirements and description of this life stage. Factors that may adversely affect winter-run Chinook salmon juvenile rearing and outmigration are similar in each of the three river reaches described below although the magnitude of the effects may differ.

Factors that may adversely affect juvenile winter-run Chinook salmon in the upper Sacramento River are similar to those described above in the middle Sacramento River and include passage impediments, physical habitat alteration, water quality, predation, and entrainment. In addition to those factors described above, adverse flow conditions in this reach of the river likely have a greater impact on juveniles as described below.

WATER TEMPERATURE

Following the installation of the TCD at Shasta Dam in 1997, water temperatures in much of this reach of river seldom exceed 60°F and are generally suitable for juvenile salmon rearing year-round.

WATER QUALITY

Point source pollution may occur from both the Iron Mountain Mine and the Simpson Mill as described above. Iron Mountain Mine was once the largest source of surface water pollution in the U.S.; after clean up operations lead by the EPA in the 1990s and 2000s, there has been a 95 percent reduction in the discharge of acidity, copper, cadmium, and zinc. Because the juvenile life stage of Chinook salmon is the most susceptible to adverse effects from pollution and the proximity of these two potential sources of pollution, potential adverse effects are likely more profound in the upper Sacramento River compared to the lower reaches. Effects of non-point source pollution from urban runoff and agricultural drainage are similar to those described above for the middle Sacramento River. However, pollution associated with urban runoff is likely higher due to the proximity of the cities of Redding and Red Bluff.

FLOW CONDITIONS

Almost all spawning and embryo incubation of winter-run Chinook salmon occurs in the upper Sacramento River upstream of the RBDD. Therefore, there is a high density of newly emerged fry in this section of the river. The emergence of fry from the gravel coincides with the irrigation season when flashboard adjustments at the ACID Dam are required and cause reductions in flow. Winter-run Chinook salmon fry prefer shallow nearshore areas with slow current and cover during the late summer and fall. Sudden flow reductions associated with flashboard adjustments at the ACID Dam may strand fry in shallow pools or sidechannels where they may be dewatered or subjected to high water temperatures.

Keswick Dam at RM 302 presents an impassable barrier to upstream migrating adult Chinook salmon, and hence represents the upstream extent of winter-run Chinook salmon habitat. The ACID Dam, located about three miles below Keswick Dam, represents the furthest upstream impediment, due to injury, to juvenile outmigration. The dam is only in place during the irrigation season which typically extends from April through November. During the rest of the year neither upstream adult migration nor downstream juvenile outmigration is hindered. However, peak juvenile outmigration occurs in September and October while the dam is in place. Juveniles migrate past the dam by either dropping as much as ten feet over the dam to the river below or moving through the bypass facility. In either case, juveniles may become disoriented and more susceptible to predation.

The RBDD, at the downstream extent of the upper Sacramento River, creates the final passage impediment to downstream outmigration in this reach of the river. The dam is described in

Section 2.3.7.1. When the dam gates are lowered, Lake Red Bluff is formed slowing flows and delaying juvenile outmigration allowing more opportunities for predation as described below under Predation. Historically there was a high level of mortality associated with fish using an ineffective juvenile fish bypass facility at the dam. A "Downstream Migrant Fish Facility" was installed in 1992, which appears to have reduced mortality associated with use of the bypass facility.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Physical habitat alteration in the upper Sacramento River is similar to that described above for the middle Sacramento River. However, the adverse effects of loss of riparian habitat on juvenile Chinook salmon rearing in the upper Sacramento River may be more profound because of the higher densities of juveniles in this river reach. Whereas the lower reaches of the river serve more as a migration corridor, the upper Sacramento River is where initial juvenile rearing occurs.

Levee building, bank protection measures and the disconnection of the river from its historic floodplain have all had negative effects on riparian habitat. Woody debris and SRA habitat provide important escape cover for juvenile salmon. Aquatic and terrestrial insects, a major component of juvenile salmon diet, are dependent on riparian habitat. Aquatic invertebrates are dependent on the organic material provided by a healthy riparian habitat and many terrestrial invertebrates also depend on this habitat. Studies by the CDFG as reported in NMFS (NMFS 1997) demonstrated that a significant portion of juvenile Chinook salmon diet is composed of terrestrial insects, particularly aphids, which are dependent on riparian habitat.

ENTRAINMENT

Adverse effects due to entrainment of outmigrating juvenile winter-run Chinook salmon at unscreened diversions are similar to those described above for the middle Sacramento River. The new downstream migrant fish facility at the RBDD may have reduced entrainment problems at the RBDD.

PREDATION

Significant predators of juvenile winter-run Chinook salmon in the upper Sacramento River include Sacramento pikeminnow and both hatchery and wild steelhead. Striped bass, a significant predator in lower reaches of the river typically do not utilize the upper Sacramento River; however, they are present immediately below the RBDD.

The most serious adverse effect due to predation occurs in the vicinity of the RBDD. Passage through Lake Red Bluff can delay outmigrating juvenile winter-run Chinook salmon and increases the opportunities for predation by both fish and birds (Vogel and Smith 1986 as citied *in* NMFS 1997). Winter-run Chinook salmon juveniles passing under the gates at the RBDD are heavily preyed upon by both striped bass and Sacramento pikeminnow (NMFS 1997). Large concentrations of Sacramento pikeminnow have been observed accumulating immediately below the RBDD when juvenile winter-run Chinook salmon begin outmigration in late summer and early fall (Garcia 1989 in NMFS 1997).

The extent of predation on juvenile Chinook salmon by hatchery reared steelhead is not known. However, steelhead releases by the CNFH may have a high potential for inducing high levels of predation on naturally produced Chinook salmon (CALFED 2000b). The CNFH has a current production target of releasing approximately 600,000 steelhead in January at a size of four fish per pound, approximately 195 mm (USFWS 2001). There is also evidence of residualization of CNFH steelhead in the upper Sacramento River, which would compound the effects of annual CNFH steelhead releases.

HATCHERY EFFECTS

The extent of predation on juvenile Chinook salmon by hatchery-reared steelhead is not known. However, steelhead releases by the CNFH may have a high potential for inducing high levels of predation on naturally produced Chinook salmon (CALFED 2000c). The CNFH has a current production target of releasing approximately 600,000 steelhead in January and February at sizes of 125 to 275 mm (CALFED 2000c).

LSNFH releases up to 250,000 pre-smolt winter-run at 85 to 90 mm FL, a larger size than their wild counterparts. LSNFH winter-run appear to leave the upper Sacramento River enmass, and may precipitate the outmigration of remaining wild winter-run they encounter through a "pied-piper effect." The net effect of this phenomenon is two-fold: a smaller wild fish may leave before its development triggers an outmigration response and compete poorly for refugia and prey, but it may be afforded some protection by traveling amid a large number of fish.

2.3.8 SUB-ADULT AND ADULT OCEAN RESIDENCE

2.3.8.1 HARVEST

The recent increase in abundance of winter-run Chinook salmon is attributed to the harvest management measures developed by the PFMC in accordance with the NMFS 1996 and 1997 supplemental BOs on the FMP restricting recreational and commercial fisheries south of Point Arena, California (NMFS 2000). The harvest index (CVI) ranged from 0.55 to about 0.80 from 1970 to 1995, when harvest rates were restricted to protect winter-run Chinook salmon. In 2001, the CVI fell to 0.27.

The recent release of a significant number of adipose fin-clipped juvenile winter-run Chinook salmon has provided new information on the harvest rates of winter-run Chinook salmon in coastal recreational and troll fisheries. The PFMC's Sacramento River Winter and Spring Chinook Salmon Workgroup performed a cohort reconstruction of the 1998 brood year (NMFS 2003). Winter-run Chinook salmon are mainly vulnerable to ocean fisheries at age 3. The workgroup estimated that the ocean fishery impact rate on 3-year olds was 0.23, and the in-river sportfishery impact rate was 0.24. These impacts combine to reduce escapement by 59 percent of what it would have been in the absence of fisheries mortalities, assuming no natural mortality during the fishing season. The high estimated rate of harvest from the in-river sportfishery is a consequence of the recovery of eight coded-wire tags, and was not anticipated due to fishery closures from January 15 to July 31 to reduce impacts on winter-run Chinook salmon. Currently (2007), the in-river sportfishery is closed from December 31 through July 16 to avoid harvest of winter-run Chinook salmon during the tail end of the late-fall Chinook salmon run.

While ocean sport fishing regulations prevent the retention of winter-run Chinook salmon, there are mortalities associated with the capture and subsequent release of fish. The hook-and-release mortality rate for Chinook salmon of all sizes released from recreational ocean fisheries was estimated to be 14 percent by the Salmon Technical Team (PFMC 2000). In addition, the Salmon Technical Team recommended using a *drop-off-mortality-rate* (i.e., the proportion of fish encountered by fishing gear that are killed without being brought into the vessel) of 5 percent.

Pacific coast salmon management is based largely on the analysis of CWT recoveries from hatchery fish. The CWT contains information on the fish's origin, brood year, year of release and other information. The recent recoveries of CWT fish in the ocean and river have provided data to re-examine the impact of ocean harvest on winter-run Chinook salmon. The CWT data indicate that the harvest fraction on winter-run Chinook salmon was 0.54 for the brood year 1992 (NMFS 1996c). The NMFS Biological Assessment indicates that this harvest fraction was estimated based on relatively limited data due to the small size of juveniles tagged. However, the recovery of tagged winter-run Chinook salmon verifies the incidence of harvest and provides a rough approximation of present ocean impacts.

It was determined that the 0.54 harvest rate was acceptable because it was below levels sustained by other Chinook salmon stocks. However, the winter-run Chinook salmon population has shown low spawning abundances and therefore, it may be that a harvest fraction of 0.50 is too high to sustain the winter-run Chinook salmon population.

A biological opinion on the winter-run Chinook salmon ocean harvest suggests that for brood years 1998, 1999, and 2000, the spawner reduction rates associated with winter-run ocean harvest were 0.26, 0.23, and 0.24, respectively. The spawner reduction rate is the observed fishery mortality in terms of adult-equivalents (fish that are expected to survive natural mortality and spawn) divided by the predicted number of spawners that would survive natural mortality in the absence of fishery mortality (NMFS 2004b).

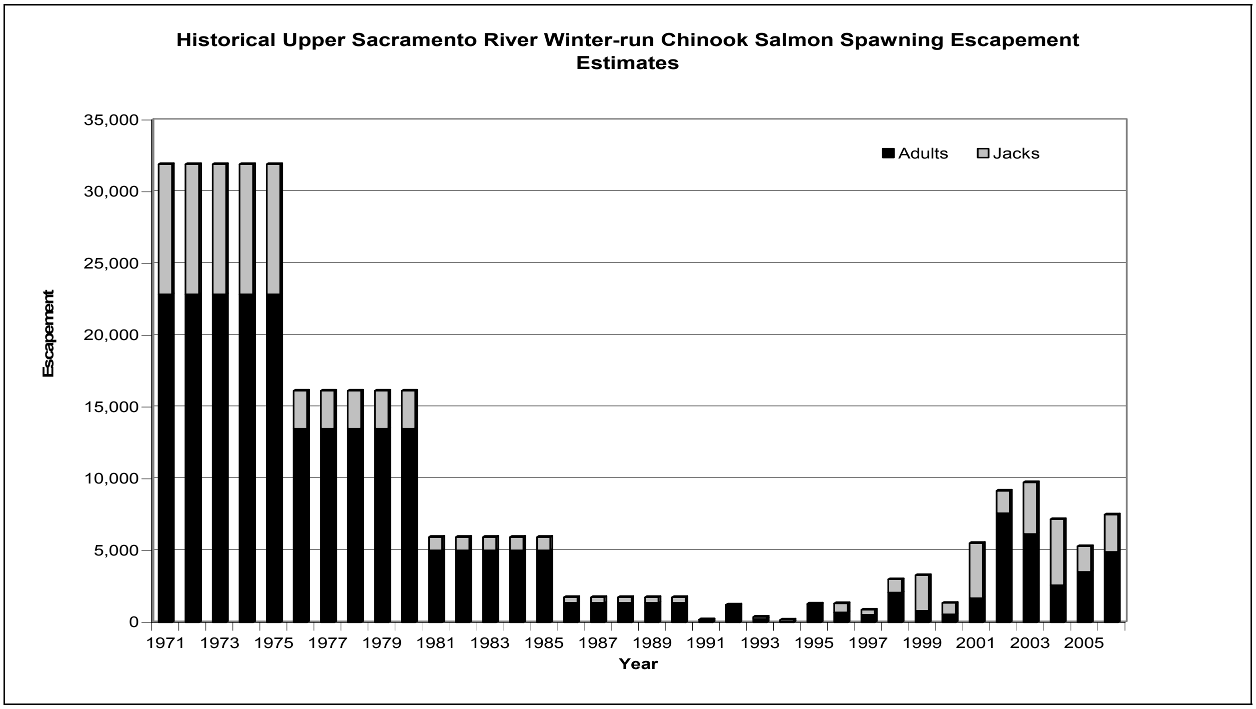

Figure 2-6. Historical Upper Sacramento River Winter-run Chinook Salmon Spawning Escapement Estimates

2.3.8.2 OCEAN CONDITIONS

In recent years scientific evidence supports hypotheses about the direct and indirect effects of climate change on the ocean production of salmon. Most of this research has focused on the effects of oceanic climate change on the growth and abundance of salmonids (Hollowed *et al.* 2001; Kruse 1998; Myers *et al.* 2000; Pearcy 1997). Two of the most researched phenomena are the El Niño-Southern-Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). ENSO is a short-term (8 to 15 months) climate change event that occurs at irregular intervals (approximately every 3 to 7 years) and alternates between two phases, the El Niño (warm) and the La Nina (cool).

The PDO is a multi-decadal (20 to 30 year) ENSO-like pattern of North Pacific climate change. The PDO seems to be associated with an inverse relationship between salmon abundance in the Alaska and the U.S. Pacific Coast regions. During a positive PDO phase, the abundance of Alaska salmon is high, and the abundance of U.S. West Coast salmon is low.

ENSO has been shown to produce dramatic effects on marine communities. Alterations in the physical oceanographic properties of the marine environment can be observed as far north as Alaska. Less known is the phenomenon of La Nina, the cool phase of ENSO events that follows El Niño. During the 1982-1983 El Niño event there were observable alternations in oceanic plankton distributions, fish community structure, and reduced ocean catches off the coastal waters of southern California. Along central California coast, the 1992-1993 El Niño corresponded to delayed phytoplankton blooms, changes in the abundance and distribution of invertebrates, an increase in the productivity of southern fish species; however there was a dramatic decline in the northerly rockfish species. More recently, the largest decline in macrozooplankton abundance off central southern California occurred during the 1997-1998 El Niño (Brodeur and Pearcy 1992a).

Brodeur *et al.* (1992b) found that juvenile Chinook and coho salmon have the potential to easily exhaust prey resources during years when ocean productivity is low (e.g., El Niño), but during most years they consume less than 1 percent of the total prey production.

2.4 STRESSOR PRIORITIZATION

2.4.1 STRESSOR MATRIX DEVELOPMENT

2.4.1.1 STRESSOR MATRIX OVERVIEW

A stressor matrix[7], in the form of a single Microsoft Excel worksheet, was developed to structure the winter-run Chinook salmon population, life stage, and stressor information into hierarchically related tiers so that stressors to the ESU could be prioritized. The individual tiers within the matrix, from highest to lowest, are: (1) population; (2) life stage; (3) primary stressor category; and (4) specific stressor. These individual tiers were related hierarchically so that each variable within a tier had several associated variables at the next lower tier, except at the lowest (i.e. fourth) tier.

The general steps required to develop and utilize the winter-run stressor matrix are described as follows:

1. Each life stage within the population was weighted so that all life stage weights in the population summed to one;
2. Each primary stressor category within a life stage was weighted so that all primary stressor category weights in a life stage summed to one;
3. Each specific stressor within a primary stressor category was weighted so that all specific stressor weights in a primary stressor category summed to one;
4. A composite weight for each specific stressor was obtained by multiplying the product of the population weight, the life stage weight, the primary stressor weight, and the specific stressor weight by 100;
5. A normalized weight for each specific stressor was obtained by multiplying the composite weight by the number of specific stressors within a particular primary stressor group; and
6. The stressor matrix was sorted by the normalized weight of the specific stressors in descending order.

The completed stressor matrix sorted by normalized weight is a prioritized list of the life stage-specific stressors affecting the ESU. Specific information explaining the individual steps taken to generate this prioritized list is provided in the following sections.

[7] For winter-run Chinook salmon, a single stressor matrix was developed corresponding to the mainstem upper Sacramento River population, whereas for spring-run Chinook salmon and steelhead, multiple individual stressor matrices were developed corresponding to each of the extant populations for these species.

2.4.1.2 POPULATION IDENTIFICATION AND RANKING

The winter-run Chinook salmon threats assessment was limited to the Sacramento River population, which represents the only extant[8] population in the ESU. Thus, this population received a weight of one in the stressor matrix.

2.4.1.3 LIFE STAGE IDENTIFICATION AND RANKING

For the purpose of developing the stressor matrices, the freshwater life cycle for winter-run Chinook salmon was broken up into four commonly acknowledged life stages: (1) adult immigration and holding; (2) spawning; (3) embryo incubation; and (4) juvenile rearing and outmigration. When weighting stressors in the juvenile rearing and outmigration life stage, the temporal and spatial distribution of post-emergent fry, young-of-year, and yearling/smolts was considered along with the factors affecting each of these juvenile age/size classes.

The individual life stages of winter-run Chinook salmon were weighted in relative importance according to: (1) the relative importance of each life stage in establishing initial year class strength; and (2) relative vulnerability of each life stage to current stressors. It is recognized that each life stage is important to the production the subsequent year class and, as such, life stages were ranked unequally only when differences were clearly warranted. For example, for winter-run Chinook salmon, the adult immigration and staging life stage was given a lower (i.e., 0.1) ranking relative to the three other life stages because flows are generally high and water temperatures are generally cool during this life stage making the life stage relatively less vulnerable to current stressors. The other three winter-run Chinook salmon life stages were ranked relatively equal (i.e., 0.25-0.35) to one another. The life stage weightings for each spring-run Chinook salmon and steelhead population are presented in Appendices B and C, respectively.

2.4.1.4 STRESSOR IDENTIFICATION AND RANKING

The primary stressors affecting winter-run Chinook salmon throughout its life cycle were identified by: (1) conducting three public workshops; (2) reviewing published literature, including the proposed Sacramento winter-run Chinook salmon recovery plan published in 1997 (NMFS 1997), Chinook salmon status review documents (Myers *et al.* 1998), and numerous other technical sources related to Central Valley salmon; and (3) utilizing the technical expertise of several Central Valley salmonid biologists. The threats lists generated from the public workshops were used as a starting point for identifying and categorizing threats. The following is a list of the primary stressor categories ultimately considered for the stressor matrix development.

1. Passage Impediments/Barriers
2. Harvest/Angling Impacts
3. Water Temperature
4. Water Quality
5. Flow Conditions
6. Loss of Riparian Habitat and Instream Cover
7. Loss of Natural River Morphology and Function

[8] Historically, winter-run Chinook salmon inhabited the Little Sacramento River, Pit-Fall-Hat Creeks, the McCloud River, and Battle Creek.

8. Loss of Floodplain Habitat
9. Loss of Tidal Marsh Habitat
10. Spawning Habitat Availability
12. Physical Habitat Alteration (e.g., lack of instream gravel supply, watershed disturbance)
13. Invasive Species/Food Web Changes
14. Entrainment
15. Predation
17. Hatchery Effects

The primary stressor categories presented were not necessarily considered to be an exhaustive list of stressors. However, the list contains the major threats and stressors to the Sacramento River population that can potentially be alleviated through recovery actions. Threats to the Sacramento River winter-run Chinook salmon population not on this list include low abundance as well as changes in ocean conditions that may adversely affect the ocean food web (i.e., altered ocean currents that limit upwelling). The threat of low abundance should be reduced if the primary stressors considered in the stressor matrix are minimized or eliminated. The threat of an altered oceanic food distribution adversely affecting the population is an impossible threat to alleviate through recovery actions.

Some of the primary stressor categories are self explanatory, while others require some elucidation to fully understand their context and how they were considered in the stressor matrix. "Passage Impediments/Barriers" were considered to be threats affecting both the adult immigration and staging, and the spawning life stages, because the impediments/barriers may physically block access to historic staging and spawning habitats. As a consequence, they also eliminate the spatial segregation of spawning habitat that historically existed for spring-run and fall-run Chinook salmon. "Harvest/Angling Impacts" include recreational and commercial harvest in the ocean[9], Bay-Delta, and river systems, as well as incidental impacts of anglers physically disturbing incubating embryos while wading through the river.

"Flow Conditions" includes flow dependent habitat availability in-river systems and the anthropogenically altered hydrology in the Delta. For example, the CVP and SWP have resulted in changing the Delta from a tidally driven saline-estuarine-freshwater system to one that is primarily fresh water. Additionally, the C.W. Jones (formerly Tracy) and the Harvey O. Banks pumping plants affect Delta flow conditions in several ways including: (1) by creating reverse flow conditions in Old and Middle Rivers; (2) by effectively pulling Sacramento River water down into the central Delta.

"Loss of Natural River Morphology and Function" is the result of river channelization and confinement, which leads to a decrease in riverine habitat complexity, and thus, a decrease in the quantity and quality of juvenile rearing habitat. Additionally, this primary stressor category includes the effect that dams have on the aquatic invertebrate species composition and distribution, which may have an effect on the quality and quantity of food resources available to juvenile salmonids. For example, in a natural river system without one or more large dams, there is an upstream source of lotic aquatic invertebrate species available to juvenile salmonids,

[9] For ease of application to the stressor matrix, the impact of ocean harvest was considered in the adult immigration and holding/staging life stage.

whereas on a river with a large terminal dam, the upstream drift of food resources to juvenile salmonids is drastically altered.

The “Spawning Habitat Availability” category was considered to include the quantity and quality of spawning habitat currently accessible to the fish, whereas, as previously mentioned, the loss of access to historic spawning habitat was considered in the “Passage Impediments/Barriers” category. The “Invasive Species/Food Web Changes” category included the potential effects of native (i.e., microsystis) and non-native (e.g., Asian clam, *A. aspera*) species on the quantity and quality of food available to juvenile salmonids in the Bay-Delta system. The “Hatchery Effects” primary stressor category was considered a threat to the spawning and the juvenile rearing and outmigration life stages. The spawning life stage is affected due to the potential for hatchery-origin salmon to compete with naturally-origin for spawning habitat, and due to the potential for reduced genetic integrity when hatchery-origin salmon spawn with natural-origin salmon. The juvenile rearing and outmigration life stage is affected due to competition between hatchery- and natural-origin for habitat and food, and due to predation by yearling-sized or larger steelhead released from hatcheries on young-of-year Chinook salmon.

Specific stressors are the individual physical structures or locations at which the primary stressor category is affecting the species. As shown in **Table 2-2**, four river sections of the Sacramento River system (i.e., the Delta, and the lower, middle, and upper Sacramento River) are identified as specific stressors within the water temperature primary stressor category.

Table 2-2. Excerpt from the Winter-run Chinook Salmon Stressor Matrix

Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	Number of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Juvenile Rearing and Outmigration	0.325	Water Temperature	0.050	Delta	0.200	0.325	4	1.30	**M**
Juvenile Rearing and Outmigration	0.325	Water Temperature	0.050	Lower Sacramento River	0.300	0.488	4	1.95	**H**
Juvenile Rearing and Outmigration	0.325	Water Temperature	0.050	Middle Sacramento River	0.400	0.650	4	2.60	**H**
Juvenile Rearing and Outmigration	0.325	Water Temperature	0.050	Upper Sacramento River	0.100	0.163	4	0.65	**L**

The criteria considered when evaluating and weighting primary stressor categories and specific stressors were adapted from the Interim Endangered and Threatened Species Recovery Planning Guidance (NMFS 2006):

- Scope – The geographic scope of the threat to the species. Impacts can be widespread or localized.

- Severity – A measure of the level of damage to the species or system that can reasonably be expected within 10 years under current circumstances. Ranges from total destruction, serious or moderate degradation or slight impairment.
- Magnitude – The severity plus scope.
- Frequency – A temporal measure of the threat.
- Immediacy – There are varying degrees of immediacy, including , a species is intrinsically vulnerable to threats, or identifiable threats can be "mapped" and seen as increasing or decreasing, or the threats are reasonably predictable.
- Persistence – To identify a persistent threat, the active and historical sources of the stress are evaluated.

In order to account for variation in the number of specific stressors within primary stressor categories, it was necessary to normalize the composite weight. Without this normalization, a given set of specific stressors that have an equal affect on the species may inappropriately receive an unequal weighting if some specific stressors in the set are within a primary stressor category containing only a few specific stressors while the other specific stressors in the set are within a primary stressor category containing several specific stressors. Normalizing the composite weight was accomplished by multiplying the composite weight by the number of specific stressors within a particular primary stressor group.

After all of the variables in the matrix were identified and weighted, and all of the normalized weights were calculated, the matrix was sorted by normalized weight in descending order. This sort put the highest weighted stressors – those with the largest biological impact – at the top of the matrix and the lowest weighted stressors at the bottom. After this initial sort, the matrix was reviewed for stressors that appeared to be inappropriately weighted, slight adjustments were then made until the sorted matrix reasonably represented a prioritized list of stressors.

It is important to discuss and understand the application of the stressor matrix results. Although the matrix provides a pseudo-quantitative means of comparatively ranking individual stressors, we want to avoid attributing unwarranted specificity to the prioritized stressor list. As such, the prioritized stressor list was distributed into four separate quartiles which represent four tiers of stressor importance. The stressors in the quartile with the highest normalized weights were identified as having "Very High" importance. The stressors in the other three quartiles were identified as having either a "High", "Medium", or "Low" importance depending on the magnitude and distribution of the normalized weights. For example, a population with 100 individual stressors with distinct (i.e., unequal) normalized weights would have 25 stressors that were considered of "Very High" importance, 25 with "High" importance, 25 with "Medium" importance, and 25 with "Low" importance. However, if the calculated normalized weight of some of the stressors were equal, then the distribution could be altered such that not all importance categories received the same number of stressors. Staying with this example, if the 25th and 26th ranked stressors in the sorted list of 100 stressors were equal, then the "Very High" importance stressor category would contain 26 stressors. The "High" importance category would receive 25 or more stressors depending on whether the normalized weights for the stressors at the quartile cutoff were equal or not, and so on.

2.4.2 STRESSOR MATRIX RESULTS

Each life stage of winter-run Chinook salmon is affected by stressors of "Very High" importance. These stressors include:

- The barriers of Keswick and Shasta dams, which block access to historic staging and spawning habitat;
- Ocean harvest;
- Flow fluctuations, water pollution, water temperatures in the upper Sacramento River during embryo incubation;
- Loss of juvenile rearing habitat in the form of lost natural river morphology and function, and lost riparian habitat and instream cover;
- Predation during juvenile rearing and outmigration; and
- Changes in Delta hydrology, diversion into the central Delta, and entrainment of juveniles at the C.W. Jones and Harvey O. Banks pumping plants.

The complete prioritized list of life stage-specific stressors to the Sacramento River winter-run Chinook salmon ESU is presented in Attachment A.

3.0 CENTRAL VALLEY SPRING-RUN CHINOOK SALMON

3.1 BACKGROUND

3.1.1 LISTING HISTORY

Central Valley spring-run Chinook salmon was proposed as "endangered" by NMFS on March 9, 1998 (63 FR 11482 (March 9, 1998)). NMFS concluded that the Central Valley spring-run Chinook salmon ESU was in danger of extinction because native spring-run Chinook salmon have been extirpated from all tributaries in the San Joaquin River Basin, which represented a large portion of the historic range and abundance of the ESU as a whole. Moreover, the only streams considered to have wild spring-run Chinook salmon at that time were Mill and Deer Creeks, and possibly Butte Creek (tributaries to the Sacramento River). These populations were considered relatively small with sharply declining trends. Hence, demographic and genetic risks due to small population sizes were considered to be high. NMFS also determined that habitat problems were the most important source of ongoing risk to this ESU. Spring-run Chinook salmon cannot access most of their historical spawning and rearing habitat in the Sacramento and San Joaquin River basins (which is now above impassable dams), and current spawning is restricted to the mainstem and a few river tributaries in the Sacramento River (63 FR 11482 (March 9, 1998)). NMFS reported that the remaining spawning habitat accessible to fish is severely degraded. Important juvenile rearing habitat and migration corridor also were degraded. General degradation conditions to rearing and migrating habitat included elevated water temperatures, agricultural and municipal diversions and returns, restricted and regulated flows, entrainment of migrating fish into unscreened or poorly screened diversions, and the poor quality and quantity of remaining habitat. In addition, serious concern existed for threats to genetic integrity posed by hatchery programs in the Central Valley. Most of the spring-run Chinook salmon production in the Central Valley is of hatchery-origin, and naturally spawning populations could be interbreeding with both fall/late fall- and spring-run hatchery fish. NMFS reported that this problem was exacerbated by the increasing production of spring-run Chinook salmon from the Feather River Hatchery. Hatchery strays also were considered to be an increasing problem due to the management practice of releasing a larger proportion of fish off station (into the Delta and San Francisco Bay) (NMFS 2007b).

On September 16, 1999, NMFS listed the Central Valley ESU of spring-run Chinook salmon as a "threatened" species (64 FR 50394 (September 16, 1999)). Although in the original Chinook salmon status review and proposed listing it was concluded that the Central Valley spring-run Chinook salmon ESU was in danger of extinction (Myers *et al.* 1998), in the status review update, the BRT majority shifted to the view that this ESU was not in danger of extinction, but was likely to become endangered in the foreseeable future. A major reason for this shift was data indicating that a large run of spring-run Chinook salmon on Butte Creek in 1998 was naturally produced, rather than strays from Feather River Hatchery (NMFS 2007b).

On March 11, 2002, pursuant to a January 9, 2002 rule issued by NMFS under Section 4(d) of the ESA (15 USC § 1533(d)), the take restrictions that apply statutorily to endangered species began to apply to the Central Valley ESU of spring-run Chinook salmon (67 FR 1116 (January 9, 2002)).

On June 14 2004, NMFS proposed that the Central Valley spring-run Chinook salmon remain a "threatened" species based on the BRT strong majority opinion that the Central Valley spring-run Chinook ESU is ''*likely to become endangered within the foreseeable future*.'' The BRT based its conclusions on the greatly reduced distribution of Central Valley spring Chinook ESU and hatchery influences on natural population. In addition, the BRT noted moderately high risk for the abundance, spatial structure, and diversity Viable Salmonid Population criteria, and a lower risk for the productivity criterion reflecting positive trends. On June 28, 2005, NMFS reaffirmed the threatened status of the Central Valley spring-run Chinook salmon ESU (70 FR 37160 (June 28, 2005)). All naturally spawned populations of spring-run Chinook salmon in the Sacramento River and its tributaries in California, and the Feather River Hatchery spring-run Chinook salmon population are included as part of the Central Valley spring-run Chinook salmon ESU.

3.1.2 CRITICAL HABITAT DESIGNATION

On March 9, 1998, NMFS designated critical habitat for Central Valley spring-run Chinook salmon to include all river reaches accessible to Chinook salmon in the Sacramento River and its tributaries in California. Also included were river reaches and estuarine areas of the Delta, all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait, all waters of San Pablo Bay westward of the Carquinez Bridge, and all waters of San Francisco Bay (north of the San Francisco/Oakland Bay Bridge) from San Pablo Bay to the Golden Gate Bridge.

In response to litigation brought by National Association of Homebuilders (NAHB) on the grounds that the agency did not adequately consider economic impacts of the critical habitat designations (NAHB v. Evans, 2002 WL 1205743 No. 00–Central Valley–2799 (D.D.C.)), NMFS sought judicial approval of a consent decree withdrawing critical habitat designations for 19 Pacific salmon and *O. mykiss* ESUs. The District Court in Washington DC approved the consent decree and vacated the critical habitat designations by Court order on April 30, 2002 (NAHB v. Evans, 2002 WL 1205743 (D.D.C. 2002)).

NMFS proposed new critical habitat for Central Valley spring-run Chinook salmon on December 10, 2004, and published a final rule designating critical habitat for this species on September 2, 2005. The critical habitat encompasses 1,158 miles of stream habitat in the Sacramento River Basin and 254 square miles of estuary habitat in the San Francisco-San Pablo-Suisun Bay complex (70 FR 52488 (September 2, 2005)). For a list of designated critical habitat units, see the September 2, 2005 Federal Register Notice (70 FR 52488 (September 2, 2005)).

3.1.3 UNIQUE SPECIES CHARACTERISTICS

Spring-run Chinook salmon enter rivers as immature fish in spring and early summer and exhibit a classic stream type life history pattern, although the stay of some juveniles in fresh water may be less than a year (Moyle 2002). Spring-run Chinook salmon require freshwater streams with cold temperatures over the summer and suitable gravel for reproduction (CALFED 2000a).

Adult Central Valley spring-run Chinook salmon leave the ocean to begin their upstream migration in late January and early February (CDFG 1998) and enter the Sacramento River between mid February and September, primarily in May and June (Yoshiyama *et al.* 1998, Moyle 2002). While maturing, adults typically hold in large, deep (usually > 2 meters) and cold pools, typically with bedrock bottoms and moderate velocities. These fish can reach higher elevations before the onset of elevated water temperatures and low flows that inhibit access to these areas in the fall (Myers *et al.* 1998).

Central Valley spring-run Chinook salmon spawn on the mainstem Sacramento River between RBDD and Keswick Dam and in tributaries such as Mill, Deer, and Butte Creeks. Spawning occurs at the tails of holding pools between late-August and early-October, peaking in September (Moyle 2002; NMFS 2007b). Redd sites are apparently chosen in part by the presence of subsurface flow. Chinook salmon usually seek a mixture of gravel and small cobbles with low silt content to build their redds. Females deposit their eggs in nests in gravel-bottom areas of relatively swift water. Each female produces 2,000 to 7,000 eggs (Moyle 2002).

Adult Pacific Chinook salmon usually die after spawning (Allen and Hassler 1986; Moyle 2002). However, mature 1-year-old males that have never gone to sea are assumed to spawn by sneaking into the nest of large adults, and may actually survive to spawn a second time. These precocious yearlings have enormous testes – about 21 percent of the body weight. In addition, behavior includes the presence of small jack males that also spawn as streakers. The combination of regular and irregular males endures a high degree of fertilization of eggs – more than 90 percent (Moyle 2002).

The length of time for eggs to develop depends largely on water temperatures. In Butte and Big Chico creeks, emergence occurs from November through January and in the colder waters of Mill and Deer creeks, emergence typically occurs from January through as late as May (Moyle 2002). For maximum embryo survival, water temperatures reportedly must be between 41ºF and 55.4ºF and oxygen levels must be close to saturation (Moyle 2002). Under those conditions, embryos hatch in 40 to 60 days and remain in the gravel as alevins for another 4 to 6 weeks, usually after the yolk sac is fully absorbed. After emerging, Chinook salmon fry tend to seek shallow, nearshore habitat with slow water velocities and move to progressively deeper, faster water as they grow. However, fry may disperse downstream, especially if high-flow events correspond with emergence (Moyle 2002). Movement occurs mostly at night and tends to cease after a couple of weeks, when fry settle down into rearing habitat in streams or estuaries.

Emigration timing is highly variable, as they may migrate downstream as young-of-the year, juveniles, or yearling juveniles. The average size of fry migrants (approximately 40 mm between December and April in Mill, Butte, and Deer Creeks) reflects a prolonged emergence of fry from the gravel (Lindley *et al.* 2004). Studies in Butte Creek (Ward *et al.* 2003a; Ward and McReynolds 2001) found the majority of Central Valley spring-run Chinook salmon migrants to be fry moving downstream primarily during December, January and February; and that these movements appeared to be influenced by flow. Small numbers of Central Valley spring-run Chinook salmon remained in Butte Creek to rear and migrated as yearlings later in the spring. Juvenile emigration patterns in Mill and Deer Creeks are very similar to patterns observed in

Butte Creek, with the exception that Mill and Deer Creek juveniles typically exhibit a later young-of-the year migration and an earlier yearling migration (Lindley *et al.* 2004).

Spring-run Chinook salmon juveniles may reside in freshwater habitat for 12 to 16 months, but many juveniles migrate to the ocean as young-of-the-year in the winter or spring within eight months after hatching (CALFED 2000a). The social behavior of juveniles varies from schooling to territoriality. Spring-run Chinook salmon emigration tends to peak in the Sacramento River during winter (January and February) and spring (April) (Moyle 2002).

Central Valley spring-run Chinook salmon migration corridors begin downstream of the spawning area and extend through the lower Sacramento River and the Delta. Spring-run Chinook salmon in Butte Creek move out as both fry and smolts. Downstream movements of juveniles of all runs serve not only to disperse and move them toward the ocean, but also to provide access to temporary habitats in which slightly warmer water temperatures and abundant food may encourage rapid growth. The tendency of juveniles in rivers to move toward shallow edges, especially during the day, puts them in heavy cover or among emergent vegetation, where invertebrates are abundant and where many predators have a hard time finding them.

Riverine and estuarine habitats of the Bay-Delta are important rearing areas for these migrants. Maslin *et al.* (1999) also have found that substantial numbers of spring-run juveniles use tributaries for non-natal rearing. While small tributaries generally have insufficient flow for spawning adults, juveniles can move upstream to rear, depending on the size, gradient, and quality of the tributary. In the Delta, terrestrial insects are by far the most important food, but crustaceans are also eaten. Juvenile Chinook salmon feed mostly during the day, with peak feeding occurring at dawn and during the afternoon.

Chinook salmon spend two to four years maturing in the ocean before returning to their natal streams to spawn. In the ocean, juvenile Chinook salmon become voracious predators on small fish and crustaceans.

Recovery of CWT Chinook salmon from the Feather River Hatchery in the ocean recreational and commercial fisheries (PSMFC RMIS Database) indicates that Central Valley spring-run Chinook salmon adults are broadly distributed along the Pacific Coast from Northern Oregon to Monterey. Like other stream-type Chinook salmon, Central Valley spring-run Chinook salmon are found far from the coast in the central North Pacific (Healey 1983; Myers *et al.* 1984).

Central Valley spring-run Chinook salmon remain in the ocean for two to four years and then home to their natal region over great distances (NMFS 2007). Once they reach the region of the stream mouth, many "landmarks" are available to guide them further, including geomagnetic anomalies, visual cues and distinctive odors of their home stream. Upstream migration takes place mainly during the day, with fish apparently tracking stream odors on which they imprinted when small. Some Chinook salmon stray to other streams. Straying is presumably also an adaptive mechanism, allowing Chinook salmon to colonize newly opened areas and to mix genetically with other runs, especially those in other streams close to the natal streams (Moyle 2002).

3.1.4 STATUS OF SPRING-RUN CHINOOK SALMON

Historically, spring-run Chinook salmon were predominant throughout the Central Valley occupying the upper and middle reaches (1,000 to 6,000 feet) of the San Joaquin, American, Yuba, Feather, Sacramento, McCloud and Pit rivers, with smaller populations in most tributaries with sufficient habitat for adult salmon holding over the summer months (Stone 1874, Rutter 1904, Clark 1929 *in* NMFS 2007). Clark (1929) estimated that there were historically 6,000 stream miles of salmonid habitat in the Sacramento-San Joaquin River Basin, but only 510 miles remained by 1928. Completion of Friant Dam extirpated the native population from the San Joaquin River and its tributaries (NMFS 2007b).

Central Valley spring-run Chinook salmon were once the most abundant run of salmon in the Central Valley (Campbell and Moyle 1992). The Central Valley drainage as a whole is estimated to have supported spring-run Chinook salmon runs as large as 600,000 fish between the late 1880s and 1940s (CDFG 1998). More than 500,000 Central Valley spring-run Chinook salmon were caught in the Sacramento-San Joaquin commercial fishery in 1883 (CDFG 1998; Yoshiyama *et al.* 1998). Before construction of Friant Dam, nearly 50,000 adults were counted in the San Joaquin River (Fry 1961). The San Joaquin populations essentially were extirpated by the 1940s, with only small remnants of the run persisting through the 1950s in the Merced River (Yoshiyama *et al.* 1998). Populations in the upper Sacramento, Feather, and Yuba rivers were virtually eliminated with the construction of major dams during the 1950s and 1960s (NMFS 2007b). On the American River, the completion of Nimbus Dam in 1955 extirpated the spring-run Chinook salmon population, which was already greatly diminished by the effects of smaller dams (e.g., Old Folsom Dam and the North Fork Ditch Company Dam) and mining activities (Yoshiyama et al. 1996).

The Central Valley spring-run Chinook salmon ESU has displayed broad fluctuations in adult abundance between 1967 and 2006 (**Figure 3-1**). Sacramento River tributary populations in Mill, Deer, and Butte Creeks are probably the best trend indicators for the Central Valley spring-run Chinook ESU as a whole because these streams contain the primary independent populations with the ESU. Generally, these streams have shown a positive escapement trend since 1992, which is when consistent escapement methodologies started being used on tributary spring-run surveys, making data comparable between years (**Figure 3-2**). Escapement numbers are dominated by Butte Creek returns, which have averaged over 7,000 fish since 1995 (NMFS 2007b).

During this period (1992-2006), there have been significant habitat improvements (including the removal of several small dams and increases in summer flows) in these watersheds, as well as reduced ocean fisheries and a favorable terrestrial and marine climate (NMFS 2007b).

On the Feather River, significant numbers of spring-run Chinook salmon, as identified by run timing, return to the Feather River Hatchery. Coded-wire tag, information from these hatchery returns, however, indicates that substantial introgression has occurred between fall-run and spring-run Chinook salmon populations within the Feather River system due to hatchery practices. This introgression has compromised the genetic integrity of the spring-run Chinook salmon stock. In addition, the Central Valley hatchery practice of trucking fall-run production for out-of-basin release, and the use of large numbers of hatchery fall-run juveniles for monitoring studies, has resulted in high straying rates of returning adults, and threatening the genetic integrity of all extant spring-run populations as well as natural fall-run populations (Williamson and May 2003).

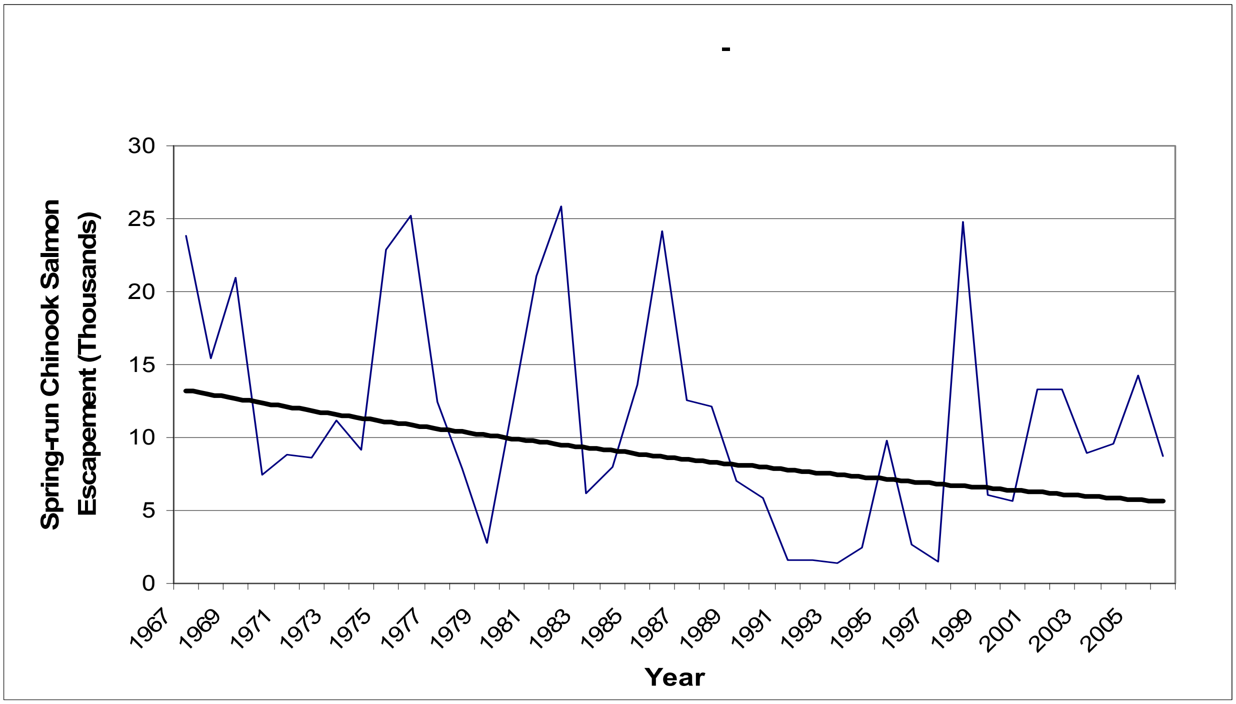

Figure 3-1. Annual Estimated Central Valley Spring-run Chinook Salmon Escapement from 1967 to 2006
Source: (CDFG 2007)

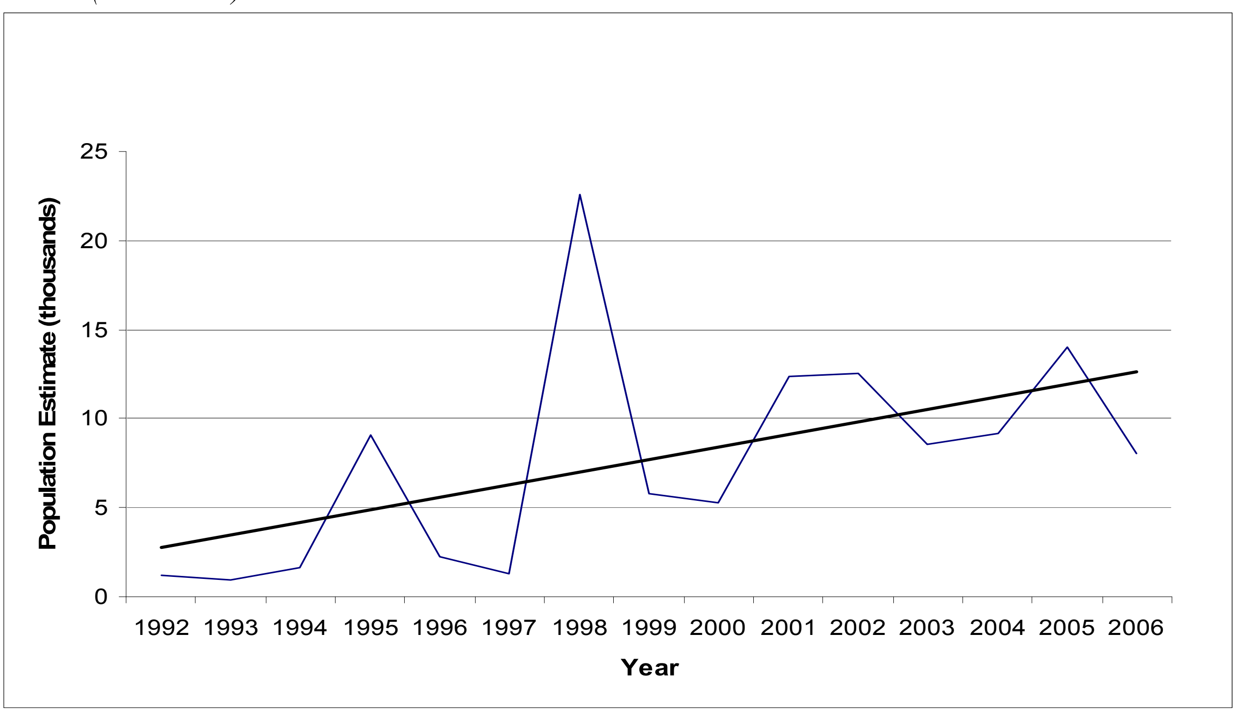

Figure 3-2. Spring-run Chinook Salmon Combined Population Estimates for Mill, Deer and Butte Creeks from 1992 to 2006
Source: (CDFG 2007)

Although recent Central Valley spring-run Chinook salmon population trends are positive, annual abundance estimates display a high level of fluctuation, and the overall number of Central Valley spring-run Chinook salmon remains well below estimates of historic abundance.

The viability of the Central Valley spring-run Chinook salmon, essentially represented by three populations located within the same ecoregion is vulnerable to changes in the environment through a lack of spatial geographic diversity. The current geographic distribution of viable populations makes the Central Valley spring-run Chinook salmon ESU vulnerable to catastrophic disturbance (Lindley *et al.* 2007). Such potential catastrophes include volcanic eruption of Lassen Peak, prolonged drought conditions reducing coldwater pool adult holding habitat, and a large wildfire (approximately 30 kilometer maximum diameter) encompassing the Deer, Mill and Butte creek watersheds. Because the Central Valley spring-run Chinook salmon ESU is spatially confined to relatively few remaining streams, continues to display broad fluctuations in abundance, and a large proportion of the population (i.e., in Butte Creek) faces the risk of high mortality rates due to elevated water temperatures during the adult holding period, the population remains at a moderate to high risk of extinction (NMFS 2007b).

3.2 LIFE HISTORY AND BIOLOGICAL REQUIREMENTS

3.2.1 ADULT IMMIGRATION AND HOLDING

3.2.1.1 GEOGRAPHIC AND TEMPORAL DISTRIBUTION

Adult Central Valley spring-run Chinook salmon leave the ocean to begin their upstream migration in late-January and early February (CDFG 1998), and enter the Sacramento River between mid February and September, primarily in May and June (Moyle 2002; Yoshiyama *et al.* 1998). Figures **3-3, 3-4, and 3-5** show the timings of this life stage by diversity group.

3.2.1.2 BIOLOGICAL REQUIREMENTS

Similar to the winter-run, spring-run Chinook salmon generally enter rivers as sexually immature fish and must hold in freshwater for up to several months before spawning (Moyle 2002). Spring-run Chinook salmon spawn in areas with water velocities ranging from 0.06 to 3.80 ft/sec (USFWS 2003b). Spawning depths can range from as little as 0.3 feet to 3.3 feet (USFWS 2003b). Preferred water depths (defined as a suitability greater than 0.5) range from 0.5 to 3.0 feet (USFWS 2003b). Substrate is an important component of Chinook salmon spawning habitat, and generally includes a mixture of gravel and small cobbles (Moyle 2002). USFWS (2003b) reports that preferred spring-run Chinook salmon spawning substrate (defined as a suitability greater than 0.5) is composed mostly of large gravel and small cobbles from 1-3 inches to 3-5 inches in diameter.

3.2.2 ADULT SPAWNING

3.2.2.1 GEOGRAPHIC AND TEMPORAL DISTRIBUTION

Spawning of Central Valley spring-run Chinook salmon generally takes place from about mid-August through October but may vary somewhat among individual streams within each diversity group as shown in Figures 3-3, 3-4 and 3-5.

3.2.2.2 BIOLOGICAL REQUIREMENTS

Spawning of Central Valley spring-run Chinook salmon normally occurs between mid-August and early October, peaking in September (Moyle 2002). Habitat requirements to support the biological needs of spring-run Chinook salmon spawning are similar to those for winter-run described above in Section 2.2.3.2.

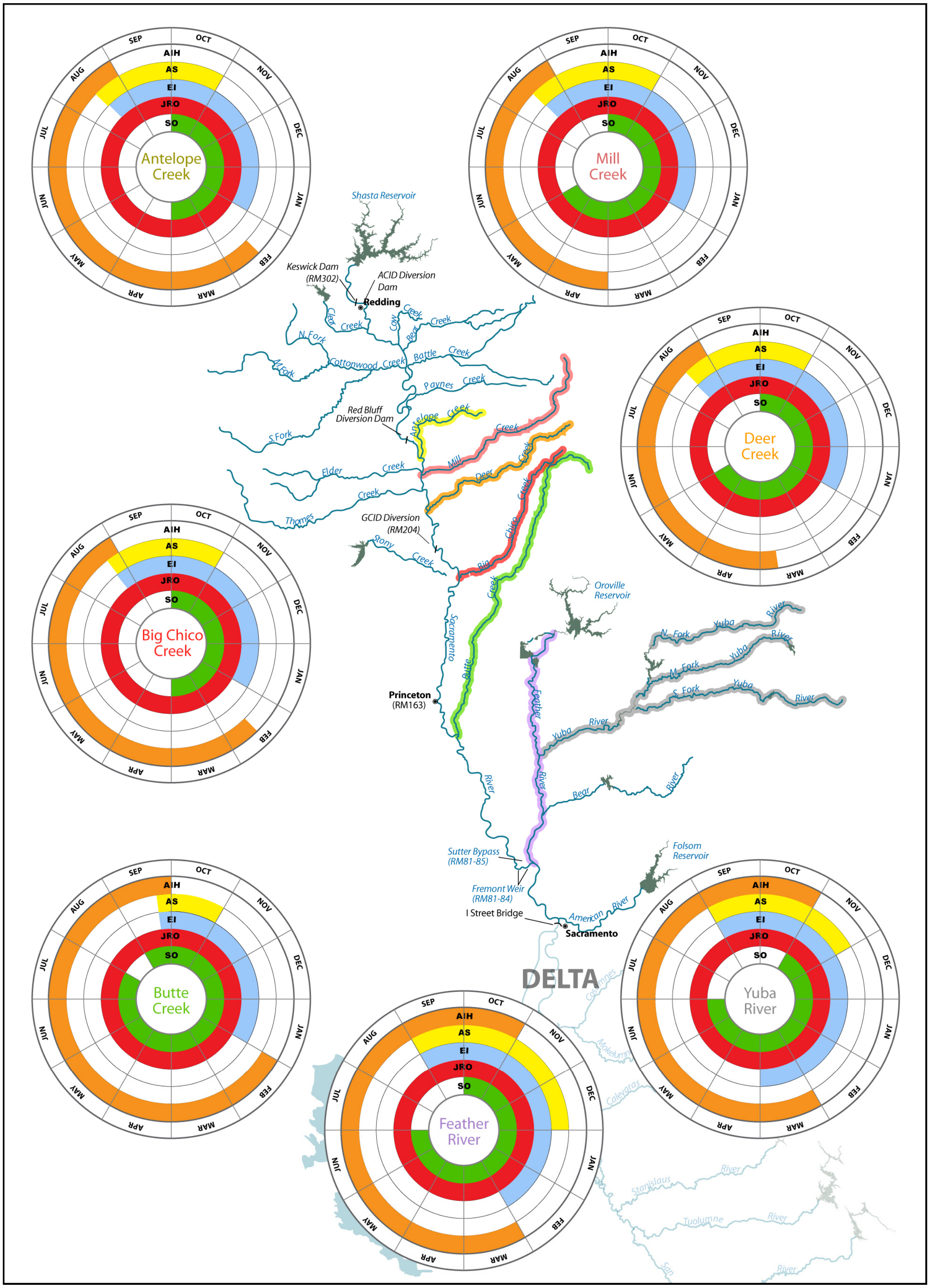

Figure 3-3. Life Stage Timing for Spring-run Chinook Salmon Populations in the Northern Sierra Nevada Diversity Group. AIH: Adult immigration and holding; AS: Adult spawning; EI: Embryo incubation; JRO: Juvenile rearing and outmigration; SO: Smolt outmigration

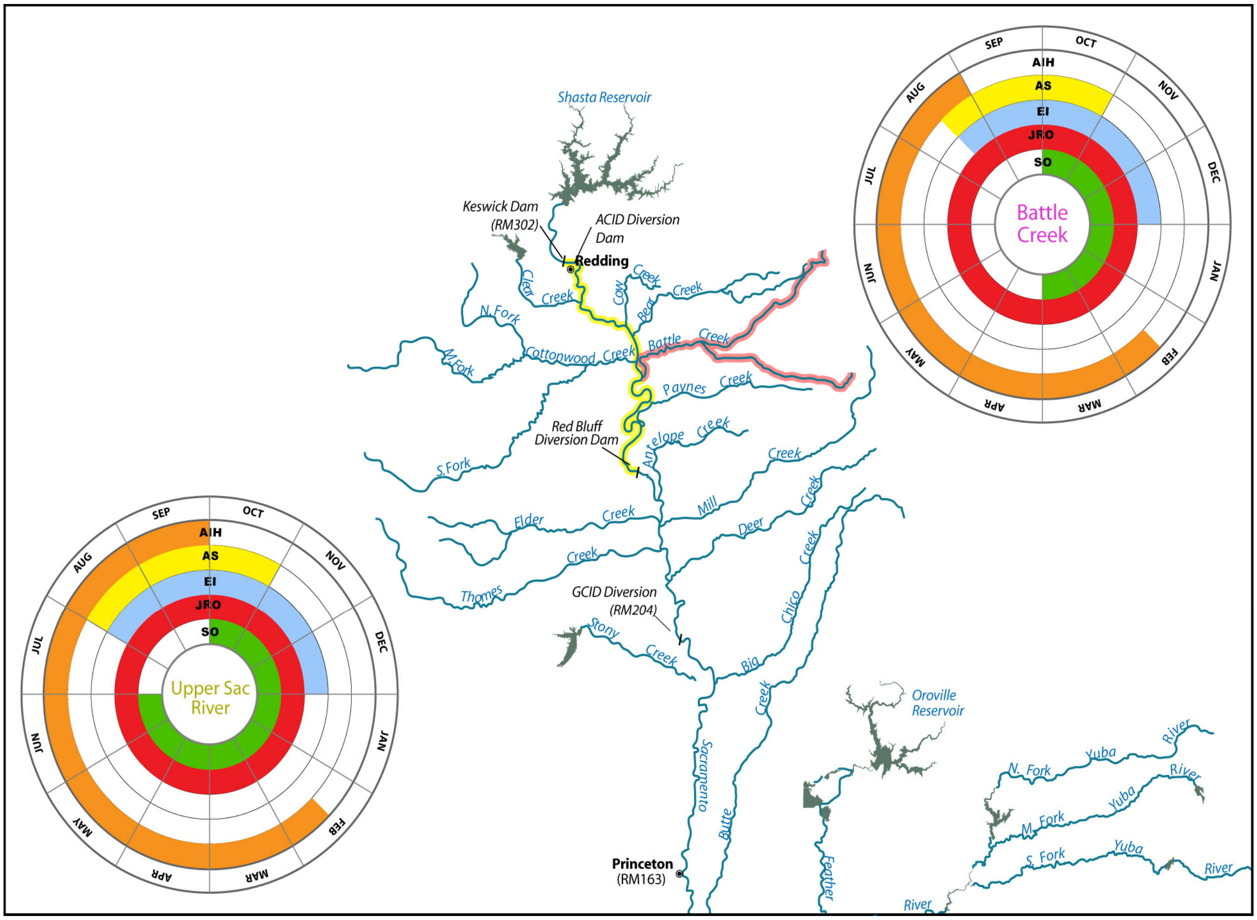

Figure 3-4. Life Stage Timing for Spring-run Chinook Salmon Populations in the Basalt and Porous Lava Diversity Group. AIH: Adult immigration and holding; AS: Adult spawning; EI: Embryo incubation; JRO: Juvenile rearing and outmigration; SO: Smolt outmigration

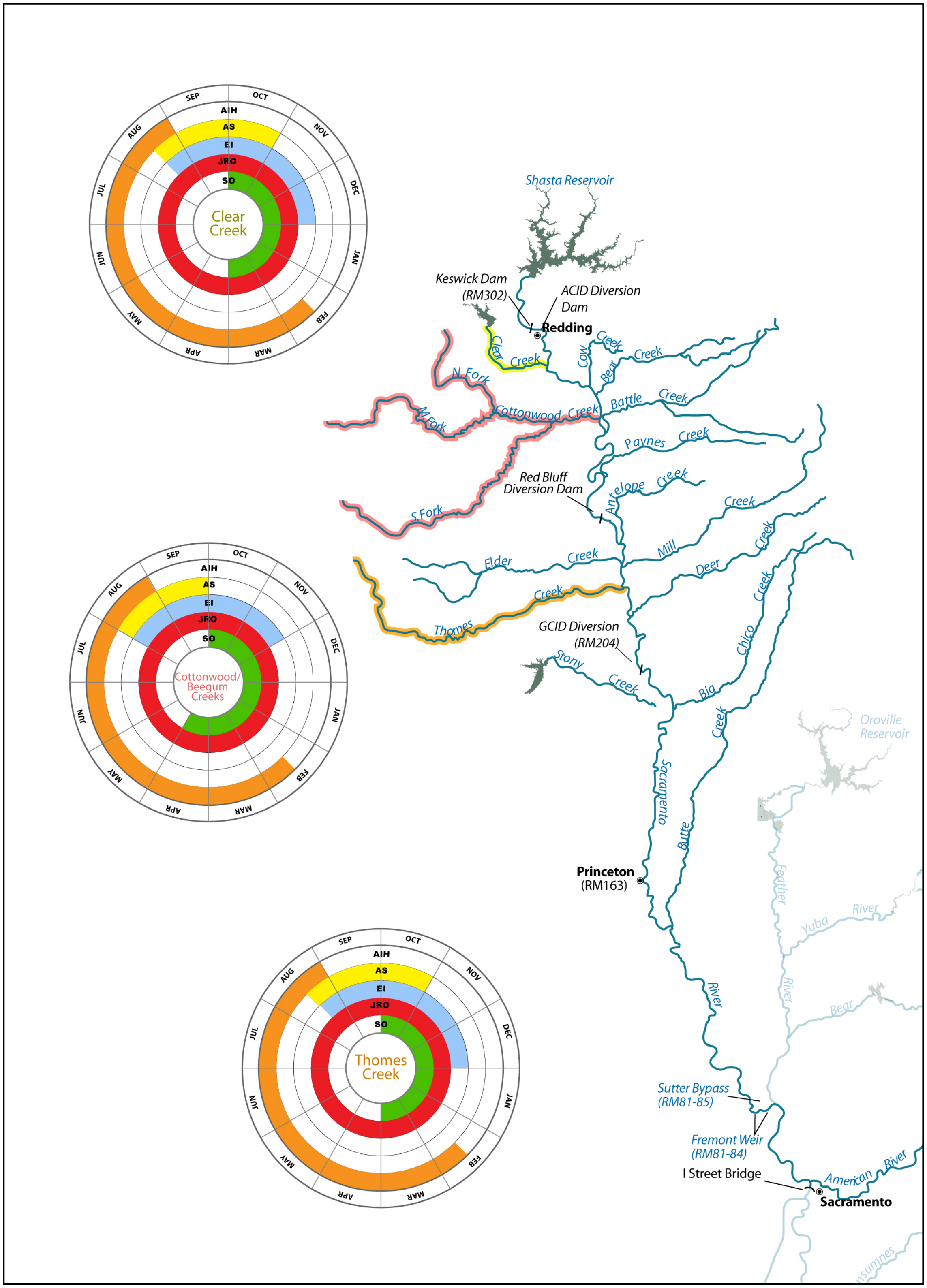

Figure 3-5. Life Stage Timing for Spring-run Chinook Salmon Populations in the Northwestern California Diversity Group. AIH: Adult immigration and holding; AS: Adult spawning; EI: Embryo incubation; JRO: Juvenile rearing and outmigration; SO: Smolt outmigration

3.2.3 EMBRYO INCUBATION

3.2.3.1 GEOGRAPHIC AND TEMPORAL DISTRIBUTION

In the Sacramento River, putative spring-run Chinook salmon spawning occurs from August through October. Embryo incubation is defined as the time span from fertilized egg deposition until fry emergence from the gravel. Within the appropriate water temperature range, eggs normally hatch in 40 to 60 days. Newly hatched fish (alevins) normally remain in the gravel for an additional four to six weeks until the yolk sac has been absorbed (NMFS 1997). Therefore; embryo incubation is expected to last from August potentially through January as shown in Figures 3-3, 3-4 and 3-5.

3.2.3.2 BIOLOGICAL REQUIREMENTS

The length of time required for embryo incubation and emergence from the gravel is dependant on water temperature. For maximum embryo survival, water temperatures reportedly must be between 41°F and 55.4°F and oxygen saturation levels must be close to maximum (Moyle 2002). Under those conditions, embryos hatch in 40 to 60 days and remain in the gravel as alevins (the life stage between hatching and egg sack absorption) for another 4 to 6 weeks before emerging as fry (Moyle 2002). Spring-run Chinook salmon fry emerge from the gravel from November to March (Moyle 2002). Habitat requirements to support the biological needs of spring-run Chinook salmon embryo incubation are similar to those for winter-run Chinook salmon described above in Section 2.2.3.2.

3.2.4 JUVENILE REARING AND OUTMIGRATION

3.2.4.1 GEOGRAPHIC AND TEMPORAL DISTRIBUTION

Juvenile rearing and outmigration varies by stream within each diversity group as shown in Figures 3-3, 3-4 and 3-5.

3.2.4.2 BIOLOGICAL REQUIREMENTS

Upon emergence from the gravel, juvenile spring-run Chinook salmon may reside in freshwater for 12 to 16 months, but some migrate to the ocean as young-of-the-year in the winter or spring months within eight months of hatching (CALFED 2000e). The average size of fry migrants (approximately 40 mm between December and April in Mill, Butte and Deer creeks) reflects a prolonged emergence of fry from the gravel (Lindley *et al.* 2004). Studies in Butte Creek (Ward *et al.* 2003a) found the majority of spring-run migrants to be fry moving downstream primarily during December, January and February; and that these movements appeared to be influenced by flow. Small numbers of spring-run juveniles remained in Butte Creek to rear and migrate as yearlings later in the spring. Juvenile emigration patterns in Mill and Deer creeks are very similar to patterns observed in Butte Creek, with the exception that Mill and Deer creek juveniles typically exhibit a later young-of-the-year migration and an earlier yearling migration (Lindley *et al.* 2004). In contrast, data collected on the Feather River suggests that the bulk of juvenile emigration occurs during November and December (DWR and Reclamation 1999; Painter *et al.* 1977). Seesholtz *et al.* (2003) speculate that because juvenile rearing habitat in the Low Flow Channel of the Feather River is limited, juveniles may be forced to emigrate from the area early due to competition for resources. Other habitat requirements to support the biological needs of spring-run Chinook salmon juvenile rearing and outmigration are similar to those for winter-run described above in Section 2.2.4.2.

3.2.5 SMOLT OUTMIGRATION

3.2.5.1 GEOGRAPHIC AND TEMPORAL DISTRIBUTION

Generally smolt outmigration occurs from late fall through early spring. However, the timing of smolt outmigration may differ by stream of origin within each diversity group as shown in figures 3-3, 3-4 and 3-5.

3.2.5.2 BIOLOGICAL REQUIREMENTS

After emigration from natal tributaries, little is known about residence time of spring-run Chinook salmon in the main stem Sacramento River. Additionally, little is known about estuarine residence time of spring-run Chinook salmon. MacFarlane and Norton (2002) concluded that unlike populations in the Pacific Northwest, Central Valley Chinook salmon show little estuarine dependence and may benefit from expedited ocean entry. Spring-run Chinook salmon yearlings are larger in size than the other runs of Chinook salmon and are ready to smolt upon entering the Delta; therefore, they probably spend little time rearing in the Delta.

3.2.6 SUB-ADULT AND ADULT OCEAN RESIDENCE

3.2.6.1 GEOGRAPHIC AND TEMPORAL DISTRIBUTION

Central Valley spring-run Chinook salmon generally spend from one to four years in the ocean before returning to spawn in their natal streams. Fisher (1994) reports that 87 percent of returning spring-run Chinook salmon are three year olds as determined by catches at the Red Bluff Diversion Dam. Adults normally leave the ocean and enter the Sacramento River between mid February and July as immature fish and hold in cool water pools until sexually mature.

3.2.6.2 BIOLOGICAL REQUIREMENTS

Habitat requirements to support the biological needs of spring-run Chinook salmon sub-adult and ocean residence are similar to those for winter-run described above in Section 2.2.5.2.

3.3 THREATS AND STRESSORS

3.3.1 SUMMARY OF ESA LISTING FACTORS

Threats to Central Valley spring-run Chinook salmon generally fall into three broad categories: loss of most historical spawning habitat, degradation of remaining habitat, and genetic threats from the Feather River Hatchery spring-run Chinook salmon program.

Native spring-run Chinook salmon have been extirpated from all tributaries in the San Joaquin River Basin, which represents a large portion of the historic range and abundance of the ESU. Yoshiyama *et al*. (2001) estimated that 72 percent of salmon spawning and rearing habitat has been lost in the Central Valley. This figure is for fall- as well as spring-run Chinook salmon; hence NMFS (2005) reported that the amount of spring-run Chinook salmon habitat lost is presumably higher because spring-run Chinook salmon spawn and rear in higher elevations, areas more likely to be behind impassable dams. Naturally-spawning populations of Central Valley spring-run Chinook salmon currently are restricted to accessible reaches of the upper Sacramento River, Antelope Creek, Battle Creek, Beegum Creek, Big Chico Creek, Butte Creek, Clear Creek, Deer Creek, Feather River, Mill Creek, and Yuba River (CDFG 1998). These populations are likely relatively small. The Feather River population is supplemented by the Feather River Hatchery production, and may be hybridized with fall-run Chinook salmon. Little is known about the status of the spring-run Chinook salmon population on the Yuba River, other than that it appears to be small. The upper Sacramento River supports a small spring-run Chinook salmon population, but population status is poorly documented, and the degree of hybridization with fall-run Chinook salmon is unknown (CDFG 1998).

Habitat problems are one of the most important sources of ongoing risk to the Central Valley spring-run Chinook salmon (NMFS 1998). Like most spring-run Chinook salmon, Central Valley spring-run Chinook salmon require cool freshwater while they mature over the summer. In the Central Valley, summer water temperatures are reportedly suitable for Chinook salmon only above 150 to 500-meter elevations, and most such habitat is now upstream of impassable dams (NMFS 2005). Current spawning is restricted to the mainstem and a few river tributaries in the Sacramento River, where the habitat in most of those rivers and creeks is severely degraded (NMFS 1998).

General degradation of rearing and migrating habitat includes elevated water temperatures, agricultural and municipal diversions and returns, restricted and regulated flows, entrainment of migrating fish into unscreened or poorly screened diversions, predation by nonnative species, and the poor quality and quantity of remaining habitat (NMFS 1998). Hydropower dams and water diversions in some years have greatly reduced or eliminated instream flows during spring-run migration periods (NMFS 1998).

In addition, hatchery programs in the Central Valley may pose threats to spring-run Chinook salmon stock genetic integrity (NMFS 1998). Most of the Central Valley spring-run Chinook salmon production is of hatchery-origin, and naturally spawning populations may be interbreeding with both fall/late fall- and spring-run Chinook salmon hatchery fish. This problem has been exacerbated by the continued production of spring-run Chinook salmon from the Feather River Hatchery, especially in light of reports suggesting a high degree of introgression between spring- and fall/late fall-run broodstock in the hatcheries. In the 1940s, trapping of adult Chinook salmon that originated from areas above Keswick and Shasta dams may have resulted in stock mixing, and further mixing with fall-run Chinook salmon apparently occurred with fish transferred to the CNFH. Deer Creek, one of the locations generally believed most likely to retain essentially native spring-run Chinook salmon, was a target of adult outplants from the 1940s trapping operation, but the success of those transplants is uncertain (NMFS 2005).

Hatchery strays are considered to be an increasing problem due to the management practice of releasing a larger proportion of fish off-site (NMFS 1998). Any activity involving the release of hatchery fish away from their natal stream source will result in the straying of some component of the release, with a direct correlation between distance from stream source and rate of straying (CDFG *et al.* 2001). Since 1967, artificial production has focused on the program at the Feather

River Hatchery. The Feather River Hatchery began trucking and releasing half its spring-run Chinook salmon production into San Pablo Bay, causing high rates of straying (CDFG 2001a). Cramer and Demko (1996) assumed that half of the hatchery-reared spring-run Chinook salmon returning to the Feather River did not return to the hatchery. This assumption was made based on previous data reported in Meyer (1982) as cited in Cramer and Demko (1996), which showed that for one cohort, only about 40 percent of the run entered the hatchery. The number of FRFH spring-run which stray into other Central Valley streams is largely unknown due to the current lack of adequate monitoring. CWT recoveries from Butte Creek do not indicate that FRFH spring-run Chinook salmon are straying into Butte Creek at significant levels. Given the large number of juveniles released off station, the potential contribution of straying adults to rivers throughout the Central Valley is considerable (NMFS 2005).

Protective efforts aimed at the Central Valley spring-run Chinook salmon include: (1) the CVPIA; (2) CALFED Bay-Delta ERP; (3), CDFG's Salmonid Restoration Program for coastal watersheds; (4) NMFS and state-funded multi-county conservation planning efforts in California; (5) the ongoing ESA Section 7 and habitat conservation planning efforts within the range of currently listed species; (6) the state listing of Sacramento River (Central Valley) spring-run Chinook salmon as a threatened species under the CESA; (7) the joint effort of NMFS, DWR and CDFG to address hatchery concerns; incorporating conservation elements into the FRFH spring-run hatchery program; (8) state-implemented freshwater harvest management conservation measures; and (9) increased monitoring and evaluation efforts in support of conservation of this ESU. Specifically, in the Sacramento River Basin, significant efforts are underway to restore habitat in the Battle Creek drainage in the upper Sacramento River. NMFS, USFWS, and CDFG reached agreement with the Pacific Gas and Electric Company (PG&E) to restore access to nearly 42 miles of high quality spawning and rearing habitat. Significant habitat restoration efforts also were conducted in Butte, Deer, Mill and Clear Creeks to remove barriers, improve streamflows, and improve riparian habitat conditions. Major new fish screen projects also were initiated or completed. Additional habitat restoration efforts were funded in the Delta region, which should benefit anadromous salmonids in the Central Valley, San Joaquin River, and the Delta.

Unfortunately, existing protective efforts have proved inadequate to ensure that the Central Valley spring-run Chinook salmon ESU is no longer at risk of becoming endangered. Risks persist to the spatial structure and diversity of the ESU. Only three extant independent populations exist (i.e., Mill, Deer, and Butte creeks), and they are especially vulnerable to disease or catastrophic events because they are in close proximity. In addition, until there are means to identify and spatially separate the spring-run and fall-run populations in the lower basin of the Feather River and mainstem Sacramento River, some level of genetic introgression of the races is expected to continue.

3.3.1.1 Destruction, Modification, or Curtailment of Habitat or Range

Habitat degradation is the most important source of ongoing risk to spring-run Chinook salmon. The distribution of spring-run Chinook salmon is limited by access to historical spawning habitat above impassable dams and degraded habitat in the Sacramento. Current spawning habitat is restricted to the mainstem and a few tributaries to the Sacramento River. The remaining accessible habitat for spawning or juvenile rearing is severely degraded by elevated water temperatures, agricultural and municipal diversions and returns, restricted and regulated flows, and entrainment of migrating fish into unscreened or poorly screened diversions. Dams and water diversions for agriculture, flood control, domestic and hydropower purposes have greatly reduced or eliminated historically accessible habitat, and degraded remaining habitat.

3.3.1.2 Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Overutilization for commercial, recreational, scientific or educational purposes does not appear to have a significant impact on spring-run Chinook salmon populations but warrants continued assessment. Commercial fishing for salmon is managed by the PFMC and is constrained by time and area to meet the Central Valley spring-run Chinook salmon ESA consultation standard, and includes restrictions requiring minimum size limits and use of circle hooks for anglers. Ocean harvest restrictions since 1995 have led to reduced ocean harvest of spring-run Chinook salmon (i.e., Central Valley Chinook salmon ocean harvest index, or CVI, ranged from 0.55 to nearly 0.80 from 1970 to 1995, and was reduced to 0.27 in 2001.

The permits NMFS issues for scientific or educational purposes stipulate specific conditions to minimize take of spring-run Chinook salmon individuals during permitted activities. There are currently five active permits in the Central Valley that may affect spring-run Chinook salmon. These permitted studies provide information about spring-run Chinook salmon that is useful to the management and conservation of the ESU.

3.3.1.3 Disease or Predation

Chinook salmon are exposed to bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, hatcheries, migratory routes, and the marine environment. Naturally spawned fish tend to be less susceptible to pathogens than hatchery-reared fish, which are more susceptible to disease such as IHNV outbreaks that are common in hatcheries.

Predation is a threat to spring-run Chinook salmon, especially in the Delta where there are high densities of non-native fish (e.g., small and large mouth bass, striped bass, catfish, sculpin) that prey on outmigrating salmon. Currently, studies are proposed to evaluated predation rates of juvenile salmonids in riprapped banks in the mainstem Sacramento River and at the oxbow channel near the GCID fish screen. In the ocean environment, salmon are common prey for harbor seals and sea lions.

3.3.1.4 Inadequacy of Existing Regulatory Mechanisms

Federal Efforts

There have been several federal actions to try to reduce threats to the spring-run Chinook salmon ESU. Actions undertaken pursuant to Section 7 BOs have helped to increase the abundance of spring-run Chinook salmon. Actions taken under the BOs for the CVP and SWP have led to increased freshwater survival, and the BOs for ocean harvest have led to increased ocean survival and adult escapement. There have also been several habitat restoration efforts implemented under CVPIA and CALFED programs that have led to several projects involving fish passage improvements, fish screens, floodplain management, habitat restoration, watershed planning, and other projects that have led to improved fish habitats and increased abundance of spring-run Chinook salmon. There are several important projects that have been initiated or implemented in the Central Valley, such as restoring salmonid habitat in the Battle Creek drainage, improving fish passage, riparian habitat, and streamflows in Butte, Deer, Mill and Clear creek tributaries in the upper Sacramento River, and installing major new fish screens at large diversions in the Sacramento River.

However, despite federal actions to reduce threats to the spring-run Chinook salmon ESU, the existing protective efforts are inadequate to ensure the ESU is no longer at risk of becoming endangered. There remain risks to the spatial structure and diversity of the ESU. There are only three extant independent populations, and they are especially vulnerable to disease or catastrophic events because they are in close proximity.

NON-FEDERAL EFFORTS

A wide range of restoration and conservation actions have been implemented or are in the planning states of development to help the spring-run Chinook salmon ESU. Most of these actions are pursuant to implementation of conservation and restoration actions in the CALFED Bay-Delta Program, which is composed of 25 state and federal agencies, and has contributed to increased abundance and productivity of the spring-run Chinook salmon ESU. The state of California listed spring-run Chinook salmon as threatened in 1998 under CESA. The state's NCCP involves long-term planning with several stakeholders. CDFG has established specific in-river fishing regulations to protect spring-run Chinook salmon. CDFG and DWR have started a marking/tagging and recovery program to evaluate the contribution of hatchery and natural production in naturally spawning populations in the Feather River, as well as to review and modify hatchery operating criteria to help ensure natural stock integrity. CDFG's 1994 Fish Screen Policy requires screening of all diversions located with the essential habitat of a CESA-listed species. Several spring-run Chinook salmon tributaries have been identified and assigned a high priority for implementing corrective actions and receive restoration funding. Grassroots organizations, such as the Battle Creek Watershed Conservancy, Butte Creek Conservancy, Sutter Bypass water users, Butte Sink Duck Clubs, Mill Creek Conservancy, and Deer Creek Watershed Conservancy, are engaged in the development and implementation of conservation and recovery measures to improve conditions for spring-run Chinook salmon.

However, despite federal and non-federal efforts and joint partnerships, some of the ongoing protective efforts are very recent and few address salmon conservation at a scale that is adequate to protect and conserve the entire ESU.

3.3.1.5 OTHER NATURAL AND MANMADE FACTORS AFFECTING THE SPECIES' CONTINUED EXISTENCE

In the last two decades, the abundance of spring-run Chinook salmon has shown a positive trend, but the increase in fish numbers does not address the concern for lack of spatial structure and diversity within the ESU. The hatchery stock of spring-run Chinook salmon in the Feather River contributes to the ESU in terms of abundance. In the past three years, CDFG has been restoring and enhancing the spring-run genotype at the Feather River Hatchery, in an effort to isolate fish arriving at the hatchery early in the season from those arriving late. If efforts to isolate the spring-run phenotype in the Feather River are successful, the risks to the ESU's spatial structure and diversity would be reduced. Reproductive isolation between spring- and fall-run Chinook salmon also is needed on the mainstem Sacramento River.

Changes in climatic events and global climate, such as El Niño ocean conditions and prolonged drought conditions, may be a significant factor in the decline of salmon as unstable Chinook salmon populations reach particularly low levels. The ESU is highly vulnerable to drought conditions. With the three independent populations located in such close proximity (Deer, Mill and Butte creeks), any regional catastrophic event may have severe impacts to the remaining independent populations.

Unscreened water diversions entrain outmigrating juvenile salmon and fry. Unscreened water diversions and CVP and SWP pumping plants entrain juvenile salmon, leading to fish mortality. The cumulative effect of entrainment at these diversions and delays in outmigration of smolts caused by reduced flow may affect spring-run Chinook salmon fitness.

3.3.2 NON-LIFE STAGE-SPECIFIC THREATS AND STRESSORS FOR THE ESU

Potential threats to the California Central Valley spring-run Chinook salmon population that are not specific to a particular life stage include the potential negative impacts of the current artificial propagation program utilizing the FRFH; the small wild population size; the genetic integrity of the population due to both hatchery influence and small wild population size; and the potential effects of long-term climate change. Each of these potential threats is discussed in the following sections.

3.3.2.1 FEATHER RIVER HATCHERY ARTIFICIAL PROPAGATION PROGRAM

The FRFH is the only hatchery in the Central Valley that currently produces spring-run Chinook salmon. The FRFH was constructed in 1967 to compensate for anadromous salmonid spawning habitat lost with construction of the Oroville Dam. The FRFH has a goal of releasing 2,000,000 spring-run Chinook salmon smolts annually (DWR 2004a). Adverse effects of artificial propagation programs are described in Section 2.3.2.1 for winter-run Chinook salmon produced at the Livingston Stone National Hatchery and many of these potential adverse effects would also apply to the FRFH's production of spring-run. Other effects unique to the FRFH and spring-run Chinook salmon are described below.

Prior to 2004, FRFH hatchery staff differentiated spring-run Chinook salmon from fall-run Chinook salmon by opening the ladder to the hatchery on September 1. Those fish ascending the ladder from September 1 through September 15 were assumed to be spring-run Chinook salmon while those ascending the ladder after September 15 were assumed to be fall-run (Kastner 2003). This practice led to considerable hybridization between spring- and fall-run Chinook salmon (DWR 2004a). Since 2004, the FRFH fish ladder remains open during the spring months, closing on June 30, and those fish ascending the ladder are marked with an external floy tag and returned to the river. This practice allows FRFH staff to identify those previously marked fish as spring-run when they re-enter the ladder in September (DWR 2004a). Only floy-tagged fish are spawned with floy-tagged fish in the month of September. No other fish are spawned during this time as part of an effort to prevent hybridization with fall-run, and introduce a temporal separation between stocks in the hatchery. During the FRFH spring-run spawning season, all heads from adipose fin-clipped fish will be taken and sent to CDFG's laboratory in Santa Rosa for tag extraction and decoding. The tag information will be used to test the hypothesis that early spring-run spawners will produce progeny that maintain that run fidelity.

The FRFH also releases a significant portion of its spring-run production into San Pablo Bay. This practice increases the chances that these fish will stray into other Central Valley streams when they return as adults to spawn. This straying has the potential to transfer genetic material from hatchery fish to wild naturally spawning fish and is generally viewed as an adverse hatchery impact. Of particular concern would be the straying of hatchery fish into Deer, Mill or Butte creeks, affecting the genetic integrity of the only significantly distinct spring-run Chinook salmon populations in the Central Valley (DWR 2004a).

3.3.2.2 Small Population Size Composed of Only Three Extant Natural Populations

Streams that currently support wild, persistent populations of spring-run Chinook salmon in the Central Valley include Mill, Deer and Butte creeks (CDFG 1998). Population index counts for these three creeks for the 1995 to 2007 time period are shown in Figure 3-6.

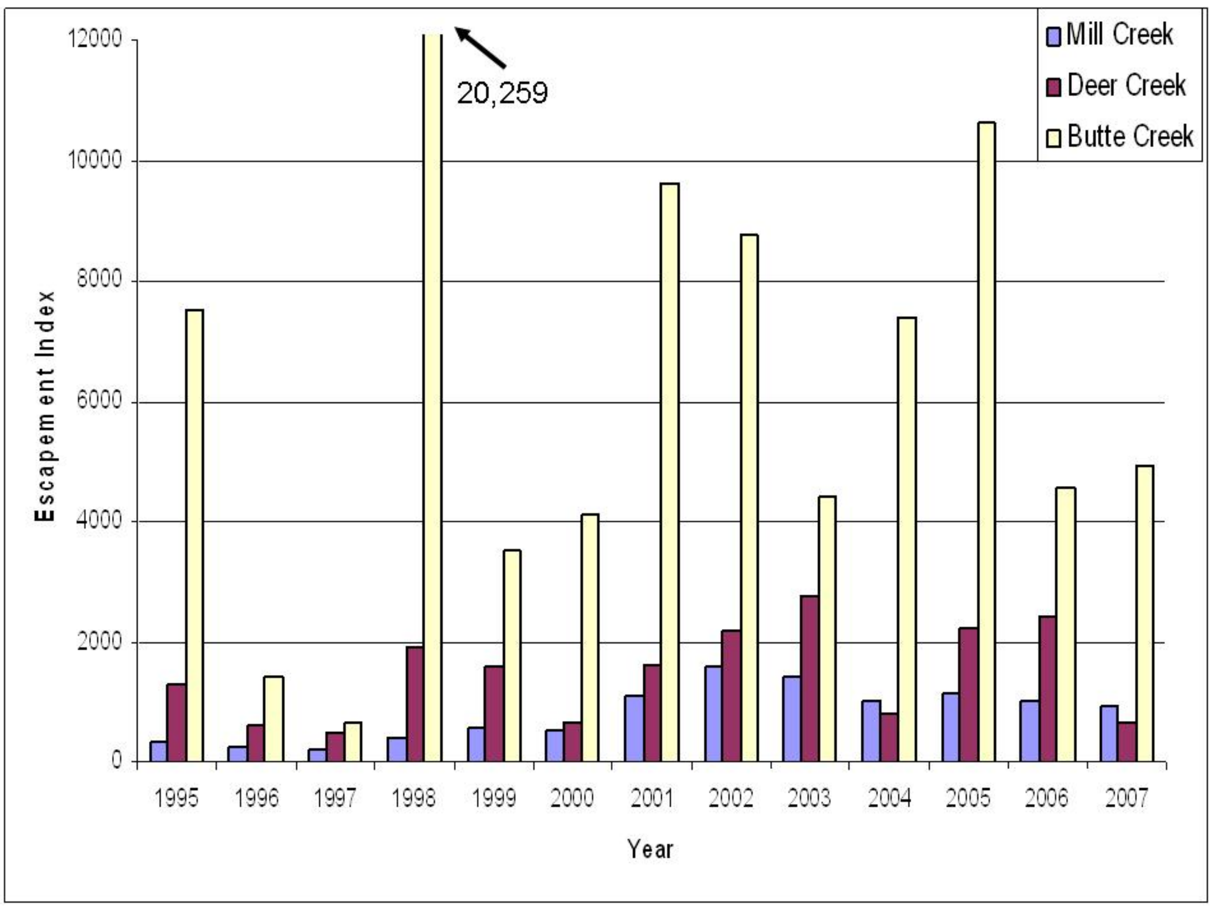

Figure 3-6 . Adult Spring-run Chinook Salmon Population Index for Mill, Deer and Butte Creeks.

Each of these three populations is small and isolated. Additionally, these populations are genetically distinct from other populations classified as spring-run Chinook salmon in the Central Valley (e.g., Feather River) (DWR 2004a). Banks *et al.* (2000) suggest that the spring-run phenotype in the Central Valley is actually shown by two genetically distinct subpopulations- 1) Butte Creek and 2) Deer and Mill creeks spring-run Chinook salmon. Lindley *et al.* (2007) report that the current distribution of viable populations makes the Central Valley spring-run Chinook salmon ESU vulnerable to catastrophic disturbance. All three extant independent populations are in basins whose headwaters lie within the debris and pyroclastic flow radii of Lassen Peak, an active volcano that USGS views as highly dangerous. Additionally, a fire with a maximum diameter of 30 km, big enough to burn the headwaters of Mill, Deer and Butte creeks simultaneously, has roughly a 10 percent chance of occurring somewhere in the Central Valley each year. Fire-caused loss of overstory vegetation is associated with higher summer water temperatures (Dunham *et al*. 2007), and streams in severely burned basins often have reduced channel stability and complexity, and higher sediment loads.

CDFG (1998) reports that there may be other streams supporting spring-run Chinook salmon including Battle, Antelope, Clear, Cottonwood, and Big Chico creeks, and the mainstem Sacramento, Yuba, and Feather rivers. These populations may be hybridized to some degree with both fall-run due to the lack of spatial separation of spawning habitat and with FRFH spring-run. Other potential problems associated with a small population are similar to those associated with the winter-run Chinook salmon population and are further described in Section 2.3.2.2.

3.3.2.3 GENETIC INTEGRITY

Issues concerning the genetic integrity of spring-run Chinook salmon are similar to those described for winter-run Chinook salmon in Section 2.3.2.3 above. Other issues that may be unique to spring-run Chinook salmon in the Central Valley are described below.

Historically, spring-run Chinook salmon acquired and maintained genetic integrity through spatiotemporal isolation with other Central Valley Chinook salmon runs. Spring-run Chinook salmon were temporally isolated from winter-run, and largely isolated in both time and space from the fall-run. With the construction of dams presenting impassable barriers to upstream tributaries of the Sacramento River much of this historical spatiotemporal integrity has been eliminated.

Several sources suggest that putative spawning by spring-run Chinook salmon in the mainstem Sacramento River may actually be by spring-run/fall-run hybrids or early fall-run. For example, in the NMFS OCAP BO, reports that due to the overlap of ESUs and resultant hybridization since the construction of Shasta Dam, Chinook salmon that spawn in the mainstem Sacramento River during September are more likely to be early fall-run rather than spring-run. In the CVP and SWP OCAP BA (Reclamation 2003), it is reported that the increasing overlap in spring-run and fall-run Chinook salmon spawning periods is evidence that genetic introgression is occurring.

3.3.2.4 LONG-TERM CLIMATE CHANGE

The potential effects of long-term climate change on Central Valley spring-run Chinook salmon would be similar to those described above in Section 2.3.2.4 for winter-run Chinook salmon.

However, because spring-run Chinook salmon normally spend a longer time in freshwater as juveniles than other Chinook salmon races, and pre-spawning adults typically hold in the river during the warmest summer months, any negative effects of climate change may be more profound on this race of Chinook salmon.

3.3.3 San Francisco, San Pablo, and Suisun Bays

3.3.3.1 Adult Immigration and Holding

Adult spring-run Chinook salmon immigration and holding in California's Central Valley Basin occurs from mid-February through July, and peaks during April and May (CDFG 1998; DWR and Reclamation 1999; Lindley *et al.* 2004). Threats to spring-run Chinook salmon adult immigration and holding that potentially occur in the Bays are similar to those described above in Section 2.3.3.1 for winter-run Chinook salmon.

3.3.3.2 Juvenile Rearing and Outmigration

Threats to spring-run Chinook salmon juvenile rearing and outmigration that potentially occur in San Francisco, San Pablo, and Suisun Bay are similar to those described above in Section 2.3.3.2 for winter-run Chinook salmon.

3.3.4 Sacramento-San Joaquin Delta

3.3.4.1 Adult Immigration and Holding

Threats to spring-run Chinook salmon adult immigration and holding that potentially occur in the Delta are similar to those described above in Section 2.3.4.1 for winter-run Chinook salmon. Because water temperatures in the Delta are normally too warm for this life stage during June and July, it is likely that most spring-run have passed through the Delta into the mainstem Sacramento River and beyond by this time. Water temperatures in the Delta would not be suitable for holding after the end of May.

3.3.4.2 Juvenile Rearing and Outmigration

Factors creating threats to the juvenile rearing and outmigration life stage of spring-run Chinook salmon would be similar to those described above in Section 2.3.4.2 for winter-run Chinook salmon. Water temperatures in the Delta begin rising in April and are likely unsuitable after May. Recent recoveries of CWT Butte Creek spring-run Chinook salmon in Delta salvage and trawl data indicate that these fish are present during March, April, and May.

3.3.5 Lower Sacramento River (Princeton [RM 163] to the Delta)

3.3.5.1 Adult Immigration and Holding

Adult spring-run Chinook salmon immigration into the Delta and the lower Sacramento River occurs from mid-February through July, and peaks during April-May (Moyle 2002). See Section 3.2.1 for a more complete description of the biological requirements and description of this life stage. Factors that may adversely affect spring-run Chinook salmon adult immigration and holding in the lower Sacramento River include passage impediments, adverse flow conditions, harvest in the sportfishery, poaching, and potential water quality problems, particularly adverse water temperatures.

PASSAGE IMPEDIMENTS/BARRIERS

In the lower portions of the Sacramento River, flows are diverted into the SDWSC. Adult salmon have been caught close to the locks at the upstream end of the channel and have also been observed to be blocked from migrating upstream by the locks (NMFS 1997).

HARVEST/ANGLING IMPACTS

There is no commercial fishery for salmon in the Sacramento River and the in-river sportfishery only allows the taking of salmon from the beginning of August through December 31. Therefore, based on the run timing of spring-run Chinook salmon there is likely no legal harvest in this section of the river.

The extent of poaching of spring-run Chinook salmon in this reach of the river is unknown. There are no man-made structures that would unnaturally increase densities allowing for easy poaching however, some level of poaching likely occurs due to snagging by anglers or inadvertent misidentification of caught fish.

WATER TEMPERATURE

Suitable water temperatures for adult spring-run Chinook salmon migrating upstream to spawning grounds range from 57°F to 67°F (NMFS 1997). However, spring-run Chinook salmon are immature when upstream migration begins and need to hold in suitable habitat for several months prior to spawning. The maximum suitable water temperature for holding is 59°F to 60°F (NMFS 1997). Because water temperatures in this reach of the lower Sacramento River generally begin exceeding 60°F in April, it is likely that little if any suitable holding habitat exists in this reach and that it is only used by adults as a migration corridor. However, it should be noted that daily average water temperatures exceed 60°F during the holding period in the Central Valley's most productive spring-run Chinook salmon creeks (i.e., Mill, Deer, and Butte creeks).

NMFS (1997) reports that recent research has indicated that water temperatures in the lower Sacramento River may have risen by as much as 4 to 7°F since the late 1970s. Potentially the cumulative losses of shade along the river may have influenced water temperatures in this reach. The loss of shaded habitat and potential effects are described below in Section 3.3.5.2.

WATER QUALITY

Water quality in the lower Sacramento River is not likely to adversely affect adult immigrating spring-run Chinook salmon.

FLOW CONDITIONS

During high flow or flood events, water is diverted into the Sutter and Yolo bypasses upstream of the City of Sacramento. Adult spring-run Chinook salmon migrating upstream may enter these bypasses, where their migration may be delayed or blocked by control structures, particularly during early spring months. To date, there have not been any measures implemented to protect adult spring-run Chinook salmon from entrainment into the flood control bypasses (NMFS 1997).

3.3.5.2 JUVENILE REARING AND OUTMIGRATION

The timing of juvenile spring-run Chinook salmon emigration from the spawning and rearing grounds varies among the tributaries of origin, and can occur during the period extending from October through April (Vogel and Marine 1991). In Mill Creek, spring-run Chinook salmon emigration extends through June.

WATER TEMPERATURE

Optimal water temperatures for juvenile Chinook salmon range from 53.6°F to 57.2°F (NMFS 1997). A daily average water temperature of 60°F is considered the upper temperature limit for juvenile Chinook salmon growth and rearing (NMFS 1997). Spring-run Chinook salmon juveniles are most abundant in the lower Sacramento River during winter months when average water temperatures are normally less than 60°F. However, because some spring-run Chinook salmon juveniles may be in this reach of the river at any time during the year it is possible that juveniles are exposed to water temperatures above 60°F. Additionally, outmigrating spring-run Chinook salmon may be exposed to warmwater releases from the Colusa Drain at Knights Landing. Warm water is released from the drain to the river mainly from April through June. Releases from the drain can exceed 2,000 cfs and 80°F.

WATER QUALITY

The major point source threat of pollution in the Sacramento River is the Iron Mountain Mine as described for winter-run Chinook salmon above. However, because the Iron Mountain Mine is so far north of the lower Sacramento River, most heavy metal contaminants from the mine have likely either settled out or have been diluted to acceptable EPA standards by the time water reaches this reach of the river. Within the lower Sacramento River and Bay-Delta there are three large municipal water treatment plants which can be an important point source of pollution: the West Sacramento Wastewater Treatment Plant (WWTP), the Sacramento Regional WWTP, and the Stockton Sewage Treatment Plant. Pre-treatment, primary treatment and secondary treatments in place since the 1950s have all reduced pollutant loading to the system however, heavy metal loadings and toxic organic pollutants remain a major concern (NMFS 1997).

The main non-point sources of pollution in the lower Sacramento River are urban runoff and agricultural drainage. Stormwater runoff from the city of Sacramento has been shown to be acutely toxic to aquatic invertebrates (NMFS 1997). Significant urban runoff also occurs during the dry season and is created from domestic/commercial landscape irrigation, groundwater infiltration, pumped groundwater discharges and construction projects (NMFS 1997). The Colusa Basin Drain is the largest source of agricultural return flow in the Sacramento River. It drains agricultural areas serviced by the Tehama-Colusa and Glenn-Colusa Irrigation districts and discharges to the Sacramento River below Knights Landing. The drain has been identified as a major source of warm water, pesticides, turbidity, suspended sediments, dissolved solids, nutrients and trace metals (NMFS 1997).

FLOW CONDITIONS

Flood control structures in the lower Sacramento River are designed to divert water from the river during a major flood event into the Butte Creek Basin and the Sutter and Yolo bypasses. The diversions can be significant. For example, the flood control system can divert as much as four to five times more flow down the bypasses than remains in the river (NMFS 1997). Juvenile spring-run Chinook salmon migrating down the river may enter the diversions during storm events. Studies conducted on the Sutter Bypass show that the highest proportion of flows are diverted from December through March with a peak occurring in February (NMFS 1997). Juveniles diverted into the bypasses may experience migration delays, potential stranding as flood flows recede and increased rates of predation. However, the Sutter and Yolo bypasses also provide important rearing habitat to juvenile salmonids. Therefore, stranding likely occurs only during very high flow events followed by a rapid cessation of flow.

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Stream bank stabilization in the lower Sacramento River has primarily involved riprapping. Riprapping the river bank involves removing vegetation along the bank and upper levees which removes most instream and overhead cover in nearshore areas. Overhanging vegetation is referred to as SRA habitat. Woody debris and overhanging vegetation within SRA habitat provide escape cover for juvenile salmonids from predators. Aquatic and terrestrial insects are an important component of juvenile salmon diet. These insects are dependent on a healthy riparian habitat. SRA habitat also can provide some degree of local temperature modification and refugia during summer months due to the shading it provides to nearshore habitats (USFWS 1980). The importance of SRA habitat to Chinook salmon was demonstrated in studies conducted by the USFWS (DeHaven 1989). In early summer, juvenile Chinook salmon were found exclusively in areas of SRA habitat, and none were found in nearby riprapped areas (DeHaven 1989).

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Flood control measures, regulated flow regimes and river bank protection measures have all had a profound effect on riparian and instream habitat in the lower Sacramento River. Levees constructed in this reach are built close to the river in order to increase streamflow, channelize the river to prevent natural meandering, and maximize the sediment carrying capacity of the river (NMFS 1997). Channelization of the river requires bank protection measures such as riprapping to reduce the effects of streambank erosion. Additionally, nearshore aquatic areas are deepened and sloped to a uniform gradient, such that variations in water depth, velocity and direction of flow are replaced by consistent moderate to high velocities.

LOSS OF FLOODPLAIN HABITAT

The process of channelizing the lower Sacramento River and the construction of levees for flood control has resulted in a loss of connectivity with the floodplain which serves as an important source of woody debris and gravels that aid in establishing a diverse riverine habitat. In addition, floodplains in the Central Valley have been shown to provide quality rearing habitat for salmonids (Sommer *et al*. 2001a).

ENTRAINMENT

Entrainment is defined as the redirection of fish from their natural migratory pathway into areas or pathways not normally used. Entrainment also includes the take, or removal, of juvenile fish from their habitat through the operation of water diversion devices and structures such as siphons, pumps and gravity diversions (NMFS 1997). A primary source of entrainment is unscreened or inadequately screened diversions. A survey by CDFG identified 350 unscreened diversions along the Sacramento River downstream of Hamilton City.

Entrainment of juvenile winter-run Chinook salmon has been identified as one of the most significant causes of mortality in the Sacramento River and Delta (NMFS 1997) and is likely also true for spring-run. In addition, a program to flood rice field stubble during the winter has been implemented extending the period for potential entrainment (NMFS 1997).
Outmigrating juvenile spring-run Chinook salmon may also be diverted into the Yolo or Sutter bypasses during high flow or flood events and stranded as flood waters recede. The entrance to the Yolo Bypass is the Fremont Weir upstream of Sacramento near the confluence with the Feather River. During high flows weir gates are open and because the weir is not screened, juveniles enter the Yolo Bypass, where they may rear and eventually leave through the lower end upstream of Chipps Island in the Delta, or be trapped in isolated ponds as waters recede. Additionally, Sacramento River water is diverted into the SDWSC, and outmigrating juvenile Chinook salmon may enter the channel where water quality, flow levels and rearing conditions are extremely poor (NMFS 1997).

PREDATION

Only limited information on predation of spring-run Chinook salmon juveniles is available. Native species that are known to prey on juvenile salmon include Sacramento Pikeminnow and steelhead. Predation by pikeminnow can be significant when juvenile salmon occur in high densities such as below dams or near diversions. Although Sacramento pikeminnow are a native species and predation on juvenile spring-run Chinook salmon is a natural phenomenon, loss of SRA habitat and artificial instream structures tend to favor predators and may change the natural predator-prey dynamics in the system favoring predatory species (CALFED 2000c). Hatchery reared steelhead may also prey on juvenile salmon. Non-native striped bass may also be a significant predator on juvenile salmon. Although no recent studies of striped bass predation on juvenile salmon have been completed, Thomas (1967 *in* NMFS 1997) found that in the lower Sacramento River, salmon accounted for 22 percent of striped bass diet.

HATCHERY EFFECTS

In the lower Sacramento River, hatchery steelhead from the FRFH are planted in the Feather River below Yuba City at a large enough size and at a time when they could intercept outmigrating spring-run Chinook salmon juveniles (NMFS 1997).

3.3.6 MIDDLE SACRAMENTO RIVER (RED BLUFF DIVERSION DAM [RM 243] TO PRINCETON [RM 163])

3.3.6.1 ADULT IMMIGRATION AND HOLDING

In this reach of the river, the potential threats to the adult immigration and holding life stage of spring-run Chinook salmon arise from a potential passage impediment at the GCID HCPP, potential water quality problems, particularly adverse water temperatures, harvest in the sportfishery and poaching.

PASSAGE IMPEDIMENTS/BARRIERS

Although the GCID HCPP (~RM 205) and associated water diversions present problems for emigrating juvenile salmonids, adults are likely not affected.

HARVEST/ANGLING IMPACTS

Current sportfishing regulations in the Sacramento River allow for the taking of salmon after August 1. It is possible that some spring-run Chinook salmon could be holding in the mainstem river below the RBDD prior to spawning in mid-August to October. The magnitude of the harvest of spring-run Chinook salmon is not known.

The extent of poaching of spring-run Chinook salmon in this reach of the river is unknown. Some level of poaching likely occurs due to snagging by anglers or inadvertent misidentification of caught fish. Additionally, when passage at the RBDD is hindered there may be unusually high densities of salmon downstream of the dam that present poaching opportunities.

WATER TEMPERATURE

Water Temperatures in this reach of the river are similar to those occurring in the lower Sacramento River. However, some holding of adult spring-run Chinook salmon may occur downstream of the RBDD in deep coldwater pools. With the installation of the TCD at Shasta Dam in 1997, water temperatures have cooled slightly and suitable water temperatures for adult holding likely extend downstream of the RBDD for a short distance.

WATER QUALITY

Water quality in the middle Sacramento River is not likely to adversely affect adult immigrating spring-run Chinook salmon.

3.3.6.2 JUVENILE REARING AND OUTMIGRATION

Factors that may adversely affect juvenile spring-run Chinook salmon in the middle Sacramento River are similar to those that occur in the lower river as described above. However, in addition to those factors there is a potential downstream passage impediment at the GCID HCPP at RM 205.

PASSAGE IMPEDIMENTS

Historically, the GCID HCPP at RM 205 created downstream migration problems for spring-run juvenile Chinook salmon. The GCID pumping plant may divert up to 20 percent of the Sacramento River flow. Rotary drum fish screens were installed in 1972 to help protect juvenile salmon but they were largely ineffective and never met NMFS or CDFG screen design criteria. Flat plate screens were installed in front of the rotary screens in 1993 to help alleviate the problem until a more permanent solution could be found. Juvenile spring-run Chinook salmon are exposed to the GCID pumping plant facilities as early as mid-July extending into late-November when the diversion season ends.

The interim flat-plate screens were an improvement over the rotary drum screens but were still likely to subject juvenile salmon to impingement due to high approach velocities along the screens, inadequate sweeping to approach velocities, and long exposure time at the screen (USFWS 1995 *in* NMFS 1997). Construction of a new screening facility was completed in 2001 and the testing and monitoring program for the facility are now underway (Reclamation 2007). The testing and monitoring of the new facility is scheduled to be completed in 2007 (Reclamation 2007).

WATER TEMPERATURE

Water temperatures normally exceed 60°F from July through September and in dry years can often exceed 66°F (NMFS 1997). Therefore, the middle Sacramento River likely provides little habitat suitable for juvenile Chinook salmon rearing.

WATER QUALITY

Water quality issues in the middle Sacramento River are similar to those described above in the lower Sacramento River. The only point source pollution that has been identified and may potentially affect this reach of the river is the Iron Mountain Mine described for winter-run Chinook salmon above. Non-point source pollution sources include both urban and agricultural runoff similar to that described above for the lower Sacramento River. Urban runoff is likely not as great in this reach of the river as that occurring in the lower Sacramento River but agricultural runoff is likely similar or greater.

FLOW CONDITIONS

Flow conditions, under current regulated flow regimes, in the middle Sacramento River likely have little effect on outmigrating juvenile spring-run Chinook salmon.

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Loss of riparian habitat that has occurred in the middle Sacramento River is similar to that described above for the lower Sacramento River.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Physical habitat alteration that has occurred in the middle Sacramento River is similar to that described above for the lower Sacramento River. The river is not quite as confined in this reach as levees are constructed further from the channel than those occurring in the lower river.

LOSS OF FLOODPLAIN HABITAT

Although the river is not quite as confined in this reach as levees are constructed further from the channel than those occurring in the lower river, the river is disconnected from its historic floodplain by flood control measures including regulated flows and levees.

ENTRAINMENT

Entrainment is defined for winter-run Chinook salmon above. The exact number of unscreened diversions in this reach of the river is not known. A study by the California Advisory Committee on Salmon and Steelhead Trout completed in 1987 reported that over 300 unscreened irrigation, industrial, and municipal water supply diversions occur on the Sacramento River between Redding and Sacramento (NMFS 1997). Although most of these diversions are small, cumulatively they likely entrain a large number of outmigrating juvenile salmonids.

Studies are currently underway to determine the effectiveness of new fish screens at the GCID HCPP to determine the effectiveness of new fish screen installed in 2001 (Reclamation 2007). However, juvenile emigration data suggest that peak spring-run movement past the GCID facility occurs in fall and winter months, when pumping volume is low or has ceased for the season (CUWA and SWC 2004).

PREDATION

Predation on juvenile spring-run Chinook salmon in the middle Sacramento River is likely occurring from native Sacramento pikeminnow, native and hatchery-reared steelhead and striped bass. Although the extent of predation is unknown, predation from Sacramento pikeminnow and striped bass is likely similar to that occurring in the lower Sacramento River as described above. Predation from hatchery steelhead is likely somewhat less than that occurring in the lower Sacramento River because the Feather River hatchery fish enter the Sacramento River downstream of this reach. Additionally, steelhead released from the CNFH are likely more evenly distributed throughout the river by the time they reach this section.

Opportunities for high predation rates also may be present at the GCID HCPP. The plant is described below as a passage impediment. Studies have indicated that Sacramento pikeminnow are the primary predator at the pumping plant, although striped bass were also found with Chinook salmon in their stomachs (CALFED 2000c). Vogel and Marine (1995) report that predation is likely in the vicinity of the fish screens associated with the diversion.

HATCHERY EFFECTS

Direct adverse effects of hatchery operations are likely minimal in the middle reach of the Sacramento River primarily because steelhead released from the Feather River Hatchery enter the river downstream and steelhead released by the CNFH are likely more evenly distributed throughout the system by the time they reach the middle reach.

3.3.7 UPPER SACRAMENTO RIVER (KESWICK DAM TO RED BLUFF DIVERSION DAM)

3.3.7.1 ADULT IMMIGRATION AND HOLDING

In this reach of the river, the potential threats to the adult immigration and holding life stage of spring-run Chinook salmon arise from potential passage impediments at the RBDD, harvest in the sportfishery and poaching. Keswick Dam, at the upstream terminus of this reach of the river, presents an impassable barrier to upstream migration.

PASSAGE IMPEDIMENTS/BARRIERS

Keswick Dam (~RM 302) presents an impassable barrier to all upstream migration of spring-run Chinook salmon and represents the upstream extent of anadromous salmonid habitat in the mainstem Sacramento River. The ACID Dam (RM 298.5) was constructed in 1917 about three river miles downstream of the current Keswick Dam site. Originally the dam was a barrier to upstream fish migration until 1927, when a poorly designed fish ladder was installed (NMFS 1997). The dam is a 450-foot long flashboard structure which has the capability of raising the backwater level 10 feet. The dam is only installed during the irrigation season which typically runs from early April to October or early November. As mentioned above, the fish ladder that provides passage around the dam was poorly designed and although spring-run Chinook salmon were able to negotiate the ladder, it did present a partial impediment to upstream migration. In 2001 a new fish ladder was installed. Post-project monitoring indicates that the new fish ladder is operating effectively (Killam 2006). Another potential problem associated with the facility is that high volume releases from the ACID's canal downstream of the dam may create false attraction flows for migrating adult salmon and encourage them to enter the canal where they could be stranded (NMFS 1997).

The reach from the ACID to Keswick Dam is three miles; representing only a small portion of the potential spawning area. Winter-run carcass surveys from 2001 through 2006 (post ladder improvements) indicate that an average of 42.13% of the winter-run spawn above the ACID Dam (Killam 2006) and the same is likely true for spring-run.

HARVEST/ANGLING IMPACTS

Harvest of spring-run Chinook salmon in this reach of the river is likely similar to that in the middle reach. High densities of salmon near Keswick Dam could create poaching opportunities.

WATER TEMPERATURE

Following the installation of the TCD at Shasta Dam in 1997, water temperatures in this reach of the river seldom exceed 60°F and are suitable for spring-run Chinook salmon adult immigration and holding.

WATER QUALITY

Water quality in this reach of the Sacramento River is not at a level to cause adverse effects on immigrating adult salmonids.

FLOW CONDITIONS

Large flow fluctuations are the main concern regarding adverse flow conditions in the middle and upper Sacramento River. Historically, the largest and most frequent flow reductions have occurred in the late summer and early fall when flashboards at the ACID required adjustment. In years of full water deliveries by the CVP, flows had been reduced from levels of 10,000 to 14,000 cfs to a level of 5,000 cfs (NMFS 1997). Flow reduction rates are divided into several intervals to prevent rapid reductions potentially stranding adults. Although these flow reductions may adversely affect other life stages, adult immigration and holding is likely not affected.

3.3.7.2 SPAWNING

The amount of spawning of spring-run Chinook salmon in the mainstem Sacramento River is not certain. CDFG (2004b) reports that they cannot make reliable carcass survey estimates of returning adult spring-run Chinook salmon in the mainstem Sacramento River because of the overlap in spawn timing with fall-run Chinook salmon. In 2002, an estimated 608 salmon displaying spring-run characteristics passed RBDD. Of these, 125 were estimated to have entered Beegum Creek, a tributary to Cottonwood Creek. The remaining fish (485) may have spawned in the mainstem Sacramento River or entered other upstream tributaries such as Clear Creek or Battle Creek. Aerial redd surveys showed no redds downstream from RBDD. In 2003, an estimated 145 salmon displaying spring-run characteristics passed RBDD. However, because a greater number than this were estimated to enter Beegum Creek, Clear Creek and Battle Creek, no spring-run Chinook salmon were estimated to have spawned in the mainstem Sacramento River in 2003.

Similarly, Reclamation (2003) reports that redd counts conducted in the Sacramento River during the typical spring-run spawning period (late August and September) have shown low numbers of new redds relative to new redds counted during winter-run spawning timing and fall-run spawning timing. Peaks in redd count numbers are evident during winter-run spawning and fall-run spawning but not during spring-run spawning. During redd surveys the number of new redds has diminished through July and then increased at the end of September before large increase that typically occurs after October 1 when they become classified as fall-run. This suggests that the number of spring-run Chinook salmon spawning in the Sacramento River is low (average of 26 redds counted) relative to the average spring-run escapement estimate of 908 between 1990 and 2001 in the mainstem Sacramento River. The additional fish have not been accounted for in tributaries upstream of the RBDD.

Any spawning of spring-run Chinook salmon that may occur in this reach of the river may be adversely affected by poor water quality (water temperature), adverse flow conditions, physical habitat alteration, hybridization with hatchery stock, and recreational sportfishing and poaching. Each of these potential effects is described below.

Passage Impediments/Barriers

Keswick Dam marks the upstream extent of currently accessable anadromous salmonid habitat in the Sacramento River. If any spawning of spring-run Chinook salmon occurs in the upper Sacramento River it would likely be upstream of the RBDD

Harvest/Angling Impacts

Sportfishing regulations in the Sacramento River allow for the taking of salmon after August 1 to the end of December. During August, late spawning winter-run and Chinook salmon exhibiting spring-run behavior are present in this reach of the river. Therefore, some take is likely. Beginning in August, early spawning fall-run Chinook salmon begin to arrive and they likely make up the majority of the harvest through the end of the year.

The affect of poaching on spring-run Chinook salmon in this reach of the river is not known but deliberate poaching activity is not likely heavy until later in the year when fall-run have arrived. However, this section of the river is a popular year-round sportfishery and some spring-run may be misidentified by anglers and taken prior to August 1.

Water Temperature

Generally, successful spawning for Chinook salmon occurs at water temperatures below 56°F (USFWS 1999a). Since 1993 managing water temperatures for winter-run Chinook salmon from May through August have exhausted the cold water pool by September. As a result, water temperatures routinely exceed 56°F in the upper Sacramento River durng September and October when spring-run Chinook salmon are spawning.

Water Quality

Water quality in this reach of the Sacramento River is generally not at a level to cause direct adverse effects on spawning adult salmonids.

Flow Conditions

Large flow fluctuations are the main concern regarding adverse flow conditions in the middle and upper Sacramento River. Historically, the largest and most frequent flow reductions have occurred in the late summer and early fall when flashboards at the ACID Dam required adjustment. In years of full water deliveries by the CVP, flows had been reduced from levels of 10,000 to 14,000 cfs to a level of 5,000 cfs (NMFS 1997). Currently, under the CVP/SWP BO, flow reductions are conducted in intervals to prevent the stranding of juveniles and spawning adults likely are not affected by changes in flow. However, eggs in redds and developing embryos may be affected as described below under embryo incubation.

SPAWNING HABITAT AVAILABILITY

Spring-run Chinook salmon are the earliest spawning of anadromous salmonids in the Sacramento River Basin, therefore the few spring-run that may spawn in the mainstem Sacramento River would have first access to available habitat. However, later spawning fall-run Chinook salmon are quite numerous in the upper Sacramento River and may superimpose their redds on existing spring-run redds thus eliminating any advantage to spring-run early spawning.

PHYSICAL HABITAT ALTERATION

Chinook salmon require clean loose gravel from 0.75 to 4.0 inches in diameter for successful spawning (NMFS 1997). The construction of dams in the upper Sacramento River has eliminated the major source of suitable gravel recruitment to reaches of the river below Keswick Dam. Gravel sources from the banks of the river and floodplain have also been substantially reduced by levee and bank protection measures. Because very little spawning occurs in this portion of the river, it is not likely that a lack of suitable spawning gravel in this reach of the river has a significant negative effect on spring-run Chinook salmon spawning.

HATCHERY EFFECTS

The FRFH is the only hatchery in the Central Valley producing spring-run Chinook salmon. Prior to 2004, FRFH hatchery staff differentiated spring-run from fall-run by applying a cut-off date to fish entering the hatchery. Those fish ascending the ladder from September 1 through September 15 were assumed to be spring-run Chinook salmon while those ascending the ladder after September 15 were assumed to be fall-run (Kastner 2003). This practice led to considerable hybridization between spring- and fall-run Chinook salmon (DWR 2004a). Since 2004, the fish ladder remains open during the spring months, closing on June 30, and those fish ascending the ladder are marked with an external tag and returned to the river. This practice allows FRFH staff to identify those previously marked fish as spring-run when they re-enter the ladder in September, reducing potential hybridization with the fall-run (DWR 2004a). There are no observable genetic differences between the FRFH spring and fall runs, however the spring run enters the river in April, May and June as bright (green) fish.

In order to reduce mortality associated with downstream migration subsequent to hatchery releases, fish are often trucked to and released in San Pablo Bay. These practices likely increase straying rates increasing the potential for Feather River Hatchery produced spring-run Chinook salmon to hybridize with naturally spawning Chinook salmon throughout the Central Valley (Williams 2006).

3.3.7.3 EMBRYO INCUBATION

HARVEST/ANGLING IMPACTS
The Sacramento River supports a popular year-round recreational fishery. It is possible that anglers could disturb developing embryos in redds while wading.

WATER TEMPERATURE
The embryo incubation life stage of Chinook salmon is the most sensitive to elevated water temperatures. Preferred water temperatures for Chinook salmon egg incubation and embryo development range from 46°F to 56°F (NMFS 1997). A significant reduction in egg viability occurs at water temperatures above 57.5°F and total mortality may occur at 62°F (NMFS 1997).

WATER QUALITY
Water quality issues that may produce adverse effects on spring-run Chinook salmon include both point source and non-point source pollution. The inactive Iron Mountain Mine in the Spring Creek watershed near Keswick Dam creates the largest discharge of toxic material into the Sacramento River. There are three metals of particular concern: copper, cadmium and zinc. The early life stages of salmon are the most sensitive to these metals (NMFS 1997). The acid mine drainage from Iron Mountain Mine is among the most acidic and metal laden anywhere in the world (NMFS 1997). Historically, discharge from the mine has produced massive fish kills.

In 1983 the Iron Mountain Mine site was declared a superfund site by the EPA. Since that time various mitigation measures have been implemented including a neutralization plant that has improved the ability to control metal loadings to the river. NMFS (1997) reported that although significant improvements have been made, basin plan objectives had not yet been achieved in 1997. Since that time, other mitigation measures have been implemented resulting in a 95 percent reduction in historic copper, cadmium and zinc discharges (EPA 2006). At present, acid mine waste still escapes untreated from waste pile and seepage on the north side of Iron Mountain and flows into Boulder Creek, which eventually flows into the Sacramento River (EPA 2006). However, there were no significant exceedances of dissolved metal concentrations in the Sacramento River in 2002 and 2003 (CDFG 2004c). Another point source of pollution in the upper Sacramento River identified in NMFS (1997) is the Simpson Mill near Redding which discharges PCBs into the river.

Non-point source pollution consists of sediments from storm events, stormwater runoff in urban and developing areas and agricultural runoff. Sediments constitute nearly half of the material introduced to the river from non-point sources (NMFS 1997). Excess silt and other suspended solids are mobilized during storm events from plowed fields, construction and logging sites and mines. High sediment loading can interfere with eggs developing in redds by reducing the ability of oxygenated water to percolate down to eggs in the gravel. Stormwater runoff in urban areas can transport oil, trash, heavy metals and toxic organics all of which are potentially harmful to incubating eggs. Agricultural runoff can contain excess nutrients, pesticides and trace metals.

FLOW CONDITIONS
Flow fluctuations are the primary concern related to potential adverse effects on the embryo incubation life stage of spring-run Chinook salmon. For example, if spawning salmon construct

redds during periods of high flow, those redds could become dewatered during subsequent periods of low flow. Historically, the largest and most rapid flow reductions have occurred during the irrigation season (normally, early April through October) when adjustments are required at the ACID Dam. To accommodate these adjustments, Sacramento River flows at times have been decreased by one-half or greater, over the course of a few hours (NMFS 1997). Currently, under the CVP/SWP BO, flow reductions are divided into several intervals to prevent the stranding of juveniles. However, reducing the rates of flow reduction does not protect existing redds from becoming dewatered.

3.3.7.4 Juvenile Rearing and Outmigration

Passage Impediments

Keswick Dam at RM 302 presents an impassable barrier to upstream migrating adult Chinook salmon hence it represents the upstream extent of spring-run Chinook salmon habitat on the mainstem Sacramento River. The ACID Dam, located about three miles below Keswick Dam, represents the furthest upstream impediment, by potentially causing injury, to juvenile outmigration. The dam is only in place during the irrigation season which typically extends from April through November. During the rest of the year neither upstream adult migration nor downstream juvenile outmigration is hindered. Juveniles outmigrate past the dam by either dropping as much as ten feet over the dam to the river below or moving through the bypass facility.

The RBDD, at the downstream extent of the upper Sacramento River, creates the final passage impediment to downstream outmigration in this reach of the river. When the dam gates are lowered (currently mid-May through mid-September), Lake Red Bluff is formed slowing flows and delaying juvenile outmigration allowing more opportunities for predation. Historically there was both direct and indirect mortality associated with fish using an ineffective juvenile fish bypass facility at the dam. A “Downstream Migrant Fish Facility” was installed as part of the Headworks system in 1990 which appears to have reduced mortality associated with use of the bypass facility.

Water Temperature

Following the installation of the TCD at Shasta Dam in 1997 water temperatures in this reach of the river seldom exceed 60°F and are suitable for juvenile salmon rearing year-round.

Water Quality

Point source pollution may occur from both the Iron Mountain Mine and the Simpson Mill as described above. Because the juvenile life stage of Chinook salmon is the most susceptible to adverse effects from pollution and the proximity of these two potential sources of pollution, potential adverse effects are likely more profound in the upper Sacramento River compared to the lower reaches. Effects of non-point source pollution from urban runoff and agricultural drainage are similar to those described above for the middle Sacramento River. However, pollution associated with urban runoff is likely higher due to the proximity of the cities of Redding and Red Bluff.

Flow Conditions

There is likely very little rearing of juvenile spring-run Chinook salmon that occurs in the upper Sacramento River. Additionally, any spring-run juvenile Chinook salmon juveniles in this reach are likely only there during winter months when flows are not affected by agricultural diversions.

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

In certain sections of the Sacramento River from Keswick Dam to Red Bluff Diversion, less than 20 percent of the river bank is built as a levee or used bank protection measures to protect the City of Redding and Red Bluff as well as nearby agricultural land from flooding. The rest of the river has been channelized due to the geological formation and controlled flow regimes in the upper Sacramento River downstream from Keswick Dam and Red Bluff Diversion resulting in channelization and disconnection of the river from its historic floodplain. This has negative effects on riparian habitat due to the river's inability to naturally recruit riparian species seedlings as well as woody debris to deposit elsewhere. Woody debris and SRA habitat provide important escape cover for juvenile salmon. Aquatic and terrestrial insects, a major component of juvenile salmon diet, are dependent on riparian habitat. Aquatic invertebrates are dependent on the organic material provided be a healthy riparian habitat and many terrestrial invertebrates also depend on this habitat. Studies by the CDFG as reported in NMFS (NMFS 1997) demonstrated that a significant portion of juvenile Chinook salmon diet is composed of terrestrial insects, particularly aphids which are dependent on riparian habitat.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Controlled flow regimes and channelization of the upper Sacramento River have resulted in a loss of natural river morphology and function.

LOSS OF FLOODPLAIN HABITAT

Controlled flow regimes and channelization of the upper Sacramento River have resulted in a disconnection of the river with its historic floodplain.

ENTRAINMENT

Adverse effects due to entrainment of outmigrating juvenile spring-run Chinook salmon at unscreened diversions are similar to those described above for the middle Sacramento River. The new downstream migrant fish facility at the RBDD appears to have alleviated entrainment problems at the RBDD.

PREDATION

Significant predators of juvenile spring-run Chinook salmon in the upper Sacramento River include Sacramento pikeminnow and both hatchery and wild steelhead. Striped bass, a significant predator in lower reaches of the river, typically do not utilize the upper Sacramento River; however, they are present immediately below the RBDD.

The most serious adverse effect due to predation occurs in the vicinity of the RBDD. Passage through Lake Red Bluff can delay outmigrating juvenile spring-run Chinook salmon and increases the opportunities for predation by both fish and birds (Vogel and Smith 1986 as citied *in* NMFS 1997). Chinook salmon juveniles passing under the gates at the RBDD are heavily preyed upon by both striped bass and Sacramento pikeminnow (NMFS 1997). Large concentrations of Sacramento pikeminnow have been observed accumulating immediately below the RBDD when juvenile Chinook salmon are present (Garcia 1989 *in* NMFS 1997).

HATCHERY EFFECTS

The extent of predation on juvenile Chinook salmon by hatchery-reared steelhead is not known. However, steelhead releases by the CNFH may have a high potential for inducing high levels of predation on naturally produced Chinook salmon (CALFED 2000c). The CNFH has a current production target of releasing approximately 600,000 steelhead in January and February at sizes of 125 to 275 mm (CALFED 2000c).

3.3.8 NORTHERN SIERRA NEVADA DIVERSITY GROUP

The northern Sierra Nevada spring-run Chinook salmon Diversity Group historically was comprised of populations in the Mokelumne, American, Yuba, and Feather rivers and Butte, Big Chico, Deer, Mill, and Antelope creeks (**Figure 3-7**). Currently, spawning populations of Chinook salmon exhibiting spring-run characteristics occur in each of these rivers/creeks except for the Mokelumne and American rivers.

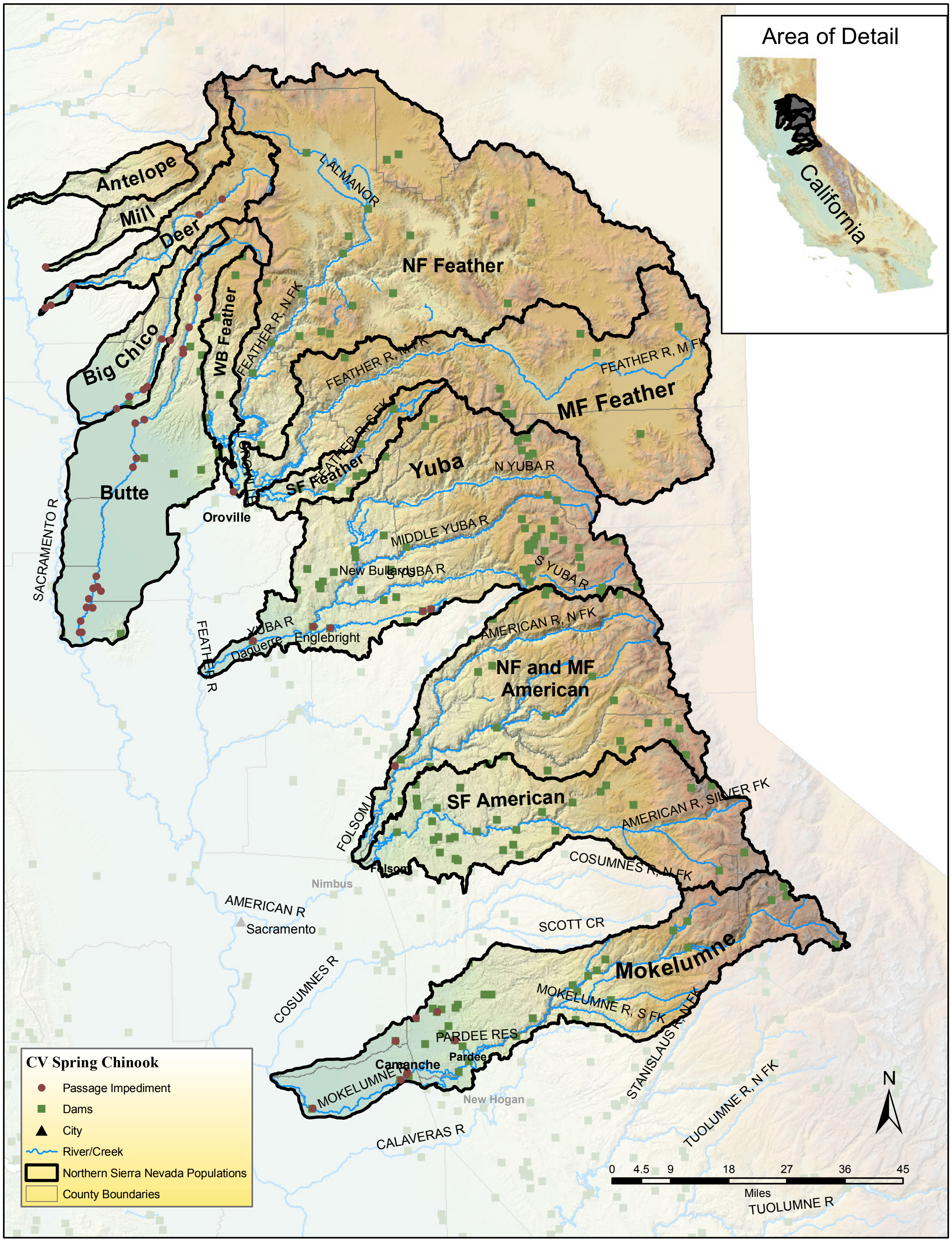

Figure 3-7. Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group

3.3.8.1 FEATHER RIVER

The Feather River watershed is located at the north end of the Sierra Nevada. The watershed is bounded by the volcanic Cascade Range to the north, the Great Basin on the east, the Sacramento Valley on the west, and higher elevation portions of the Sierra Nevada on the south. The Feather River watershed upstream of Oroville Dam is approximately 3,600 square miles and comprises approximately 68 percent of the Feather River Basin. Downstream of Oroville Dam, the basin extends south and includes the drainage of the Yuba and Bear Rivers. The Yuba River joins the Feather River near the City of Marysville, 39 river miles downstream of the City of Oroville, and the confluence of the Bear River and the Feather River is 55 river miles downstream of the City of Oroville. Approximately 67 miles downstream of the City of Oroville, the Feather River flows into the Sacramento River, near the town of Verona, about 21 river miles upstream of Sacramento. The Feather River watershed, upstream of the confluence of the Sacramento and Feather rivers, has an area of about 5,900 square miles.

The Feather River supports runs of both spring- and fall-run Chinook salmon. Historically, spring-run Chinook salmon immigrated to the upper tributaries of the Feather River in the spring and early summer where they would hold and eventually spawn in late summer or early fall. Fall-run Chinook salmon would immigrate to the lower Feather River in the fall and spawn immediately upon arrival. The construction of Oroville Dam presented an impassable migration barrier to upstream migration and today spawning is confined to the lower Feather River, primarily in the eight-mile reach extending from the Fish Barrier Dam downstream to the Thermalito Afterbay Outlet. Currently, the genetic distinctness of the two runs is not clear. DWR (2004a) reports that the FRFH-produced spring-run Chinook salmon as well as naturally spawning spring-run Chinook salmon in the Feather River were more closely related to fall-run than the documented spring-run populations in Butte, Mill and Deer creeks. Given that both spring-run and fall-run Chinook salmon spawn in the same reach of the Feather River and at about the same time, in high densities, it is likely that the population is hybridized. Nevertheless, fish exhibiting the typical life history of the spring-run are found holding at the Thermalito Afterbay Outlet and the Fish Barrier Dam as early as March (DWR 2004a). Annually, 30,000 to 170,000 Chinook salmon spawn in the lower Feather River, however, the proportion of putative spring-run to fall-run is unknown.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

The construction of Oroville Dam presented an impassable migration barrier to upstream migration and today spawning is confined to the lower Feather River, primarily in the eight-mile reach extending from the Fish Barrier Dam downstream to the Thermalito Afterbay Outlet. Sunset pumps may impede salmon at low flows.

HARVEST/ANGLING IMPACTS

The sportfishery in the lower Feather River currently allows the taking of salmon from January 1 through September 30. From about mid-August through September; only Chinook salmon exhibiting spring-run timing would likely be in the river. Additionally, unusually high densities of fish in the lower Feather River likely create favorable poaching opportunities.

WATER TEMPERATURE

Suitable water temperatures for adult spring-run Chinook salmon migrating upstream to spawning grounds reportedly range from 57°F to 67°F (NMFS 1997). However, spring-run Chinook salmon are immature when upstream migration begins and need to hold in suitable habitat for several months prior to spawning. The maximum suitable water temperature for holding is reported to be about 59°F to 60°F (NMFS 1997). Under a 1983 agreement between CDFG and DWR, water temperatures are generally maintained below 60°F year-round above the Thermalito Afterbay Outlet (DWR 1983), but can exceed 65°F downstream during the summer months.

WATER QUALITY

Water quality in the lower Feather River is not likely to adversely affect immigrating adult anadromous salmonids. However, water quality may affect more sensitive life stages as discussed below under embryo incubation.

FLOW CONDITIONS

Except during flood events, flows in the reach of the lower Feather River extending downstream to the Thermalito Afterbay Outlet (Low Flow Channel) are maintained at a constant 600 cfs. Under the new Settlement Agreement, as part of the FERC relicensing for the Oroville Facilities, flows in the Low Flow Channel will be increased to a constant 800 cfs (FERC 2007). The instream flow requirements below the Thermalito Afterbay Outlet are 1,700 cfs from October through March and 1,000 cfs from April through September.

SPAWNING

The Feather River supports one of the largest runs of Chinook salmon in the Central Valley (Sommer *et al.* 2001b). Approximately 75 percent of the natural spawning for Chinook salmon occurs between the Fish Barrier Dam at RM 67 and the Thermalito Afterbay Outlet at RM 59, with the remainder occurring in the reach downstream of the Thermalito Afterbay Outlet to Honcut Creek at RM 44 (Sommer *et al.* 2001b).

PASSAGE IMPEDIMENTS/BARRIERS

The construction of Oroville Dam and subsequent blocking of upstream migration has eliminated the spatial separation between spawning fall-run and spring-run Chinook salmon. Reportedly, spring-run Chinook salmon migrated to the upper Feather River and its tributaries from mid-March through the end of July (CDFG 1998). Fall-run Chinook salmon reportedly migrated later and spawned in lower reaches of the Feather River than spring-run Chinook salmon (Yoshiyama *et al.* 2001). Restricted access to historic spawning grounds currently causes spring-run Chinook salmon to spawn in the same lowland reaches that fall-run Chinook salmon use as spawning habitat. The overlap in spawning site locations, combined with an overlap in spawning timing (Moyle 2002) with temporally adjacent runs, may be responsible for inbreeding between spring-run and fall-run Chinook salmon in the lower Feather River (Hedgecock *et al.* 2001).

In the Feather River, spring-run Chinook salmon spawning may occur a few weeks earlier than fall-run spawning, but currently there is no clear distinction between the two, because of the disruption of spatial segregation by Oroville Dam. Thus spawning of spring-run Chinook salmon occurs during the same months as fall-run. This presents difficulties from a management perspective in determining the proportional contribution of total spawning escapement by the spring- and fall-runs. Because of unnaturally high densities of spawning in the Low Flow Channel, spawning habitat is likely a limiting factor. Intuitively it could be inferred that the slightly earlier spawning Chinook salmon displaying spring-run behavior would have better access to the limited spawning habitat, however, early spawning likely leads to a higher rate of redd superimposition. Redd superimposition occurs when spawning Chinook salmon dig redds on top of existing redds dug by other Chinook salmon. The rate of superimposition is a function of spawning densities and typically occurs in systems where spawning habitat is limited (Fukushima *et al.* 1998). Redd superimposition may disproportionately affect early spawners, and therefore potentially affect Chinook salmon exhibiting spring-run life history characteristics. As part of the Settlement Agreement for FERC relicensing of the Oroville Facilities, one or more weirs will be installed in the upper section of the river to aid in spatially segregating the spring- and fall runs (FERC 2007).

HARVEST/ANGLING IMPACTS

Regulations allow taking of salmon from January 1 through September 30. During this time period, Chinook salmon displaying spring-run behavior likely make up the majority of the spawning population. Unusually high densities of Chinook salmon in the lower Feather River likely create favorable poaching opportunities.

WATER TEMPERATURE

Releases are made from the coldwater pool in Lake Oroville Reservoir and this cold water generally provides suitable water temperatures in the Low Flow Channel (i.e., reach of the river extending from the Fish Barrier Dam downstream to the Thermalito Afterbay Outlet) (DWR 2001). However, downstream of the Thermalito Afterbay Outlet, water temperatures can reach 74°F in the summer (DWR 2001).

WATER QUALITY

Water quality in the lower Feather River is not likely to adversely affect spawning adult salmon. However, water quality may affect more sensitive life stages as discussed below under embryo incubation.

FLOW CONDITIONS

Flows in the Low Flow Channel are regulated to 600 cfs, except during flood events when flows have reached as high as 150,000 cfs (DWR 1983). The instream flow requirements below the Thermalito Afterbay Outlet are 1,700 cfs from October through March and 1,000 cfs from April through September. PHABSIM indicates that at flows of 600 cfs in the Low Flow Channel, approximately 91 percent of potential spawning habitat is available. In the High Flow Channel, approximately 86 percent of the potential spawning habitat is available at 1,000 cfs (DWR 2004e).

SPAWNING HABITAT AVAILABILITY

Spawning habitat for Chinook salmon below Oroville Dam has been affected by changes to the geomorphic processes caused by several factors, including hydraulic mining, land use practices, construction of flood management levees, regulated flow regimes, and operation of Oroville Dam. The dam blocks sediment recruitment from the upstream areas of the watershed. In the lower reaches of the river, levees and bank armoring prevent gravel recruitment. Periodic flows of sufficient magnitude to mobilize smaller sized gravel from spawning riffles result in armoring of the remaining substrate. DWR (DWR 1996) evaluated the quality of spawning gravels in the lower Feather River based on bulk gravel samples and Wolman surface samples obtained during spring 1996. The study concluded that the worst scoured areas had an armored surface layer too coarse for spawning salmonids. Additionally, much of the streambed substrate in the reach from the Fish Barrier Dam to the Thermalito Afterbay Outlet is composed of large gravel and cobble, which is too large for construction of spawning redds for Chinook salmon. This reach of the lower Feather River is by far the most intensively used spawning habitat of the river for salmon. The settlement agreement as part of the Oroville FERC relicensing process provides provisions for a gravel supplementation and monitoring program (FERC 2007).

Physical Habitat Alteration

Regulation of the lower Feather River by the Oroville facilities has changed both streamflow and sediment discharge. Attenuation of peak flows, decreased winter flows, increased summer flows, and changes to flow frequencies have led to a general decrease in channel complexity downstream of Oroville Dam. Because several species and races of fish occur in the lower Feather River, a diversity of habitat types is required. Decreases in channel diversity lead to a decrease in habitat diversity and quality.

Hatchery Effects

The FRFH is the only hatchery in the Central Valley producing spring-run Chinook salmon. Prior to 2004, FRFH staff differentiated spring-run from fall-run by applying a cut-off date to fish ascending the fish ladder. Those fish ascending the ladder from September 1 through September 15 were assumed to be spring-run Chinook salmon while those ascending the ladder after September 15 were assumed to be fall-run (Kastner 2003). This practice led to considerable hybridization between spring- and fall-run Chinook salmon (DWR 2004a). Since 2004, the fish ladder remains open during the spring months and those fish ascending the ladder are marked with an external tag and returned to the river. This practice allows FRFH staff to identify those previously marked fish as spring-run when they re-enter the ladder in September (DWR 2004a). While this practice reduces the potential for hybridization with the fall-run in the hatchery, it is likely that many hatchery produced spring-run hybridize with the fall-run because of the lack of temporal and spatial isolation in the Feather River Low Flow Channel as mentioned above.

Embryo Incubation

Redd superimposition is likely the most serious factor affecting embryo incubation of spring-run Chinook salmon in the Feather River. Chinook salmon spawning escapements to the lower Feather River are much higher than available spawning habitat can support leading to high rates of redd superimposition. Spring-run Chinook salmon redds would be more affected than fall-run because spring-run spawn earlier in the year. The Settlement Agreement under the FERC relicensing for the Oroville Facilities calls for the installation of one or more weirs in the Low Flow Channel of the Feather River to aid in the spatial segregation of fall and spring-run Chinook salmon which should reduce the adverse effects of redd superimposition on spring-run Chinook salmon redds (FERC 2007).

Harvest/Angling Impacts

The lower Feather River supports a popular year-round fishery. It is possible that redds could be disturbed by wading anglers.

WATER TEMPERATURE

Spring-run Chinook salmon embryos incubating in the Low Flow Channel are likely not adversely affected by high water temperatures as water temperatures seldom exceed 60°F. However, embryos from early spawning spring-run Chinook salmon that may have constructed redds downstream of the Thermalito Afterbay Outlet may experience water temperatures lethal to embryos. However, under the Settlement Agreement as part of the FERC relicensing process for the Oroville Facilities, increases in flow through the Low Flow Channel will likely lead to a slight reduction in water temperatures downstream of the Thermalito Afterbay Outlet.

WATER QUALITY

As part of the FERC relicensing process for the Oroville Facilities, six of the relicensing studies specifically address metals contamination in the lower Feather River. As part of these studies, water quality samples were collected at 17 locations within the lower Feather River. Samples exceeding aquatic life water quality criteria occurred for four constituents: total aluminum, iron, copper, and lead. In the reach of the Feather River extending from the Fish Barrier Dam downstream to the Thermalito Afterbay Outlet, 19 percent of the water quality samples exceeded aquatic life water quality criteria. Samples taken from the reach of the Feather River extending from the Thermalito Afterbay Outlet downstream to the confluence with the Sacramento River were variable, but all were higher than the upstream reach and 3 exceeded aquatic life water quality criteria 100 percent of the time. Copper exceeded aquatic life water quality criteria in 5 of 276 samples; two of these occurrences were in the reach of the Feather River extending from the Fish Barrier Dam downstream to the Thermalito Afterbay Outlet. Iron only exceeded aquatic life water quality criteria at three sampling locations; all locations were downstream of the lower Feather River confluence with Honcut Creek. Lead exceeded aquatic life water criteria only once at several stations, but three or four times at the two most downstream stations on the Feather River. Heavy metal contamination could affect embryo survival.

FLOW CONDITIONS

Adverse effects on developing embryos could occur if a flow fluctuation caused redds to become dewatered while eggs were incubating.

Oroville Facilities releases are regulated and subject to regulatory flow criteria. Under an agreement with CDFG, flows in the Low Flow Channel are regulated to 600 cfs, except during flood events when flows have reached as high as 150,000 cfs (DWR 1983). The instream flow requirements below the Thermalito Afterbay Outlet are 1,700 cfs from October through March and 1,000 cfs from April through September.

Results from the PHABSIM indicate that at flows of 600 cfs in the Low Flow Channel, approximately 91 percent of potential spawning habitat is available, and in the reach extending downstream from the Thermalito Afterbay Outlet approximately 86 percent of the potential spawning habitat is available at 1,000 cfs (DWR 2004e).

JUVENILE REARING AND OUTMIGRATION

Juvenile Chinook salmon in the lower Feather River have been reported to emigrate from approximately mid-November through June, with peak emigration occurring from January through March (Cavallo Unpublished Work; DWR 2002a; Painter *et al.* 1977). From 1999 to 2003 DWR conducted snorkel, seine and electrofishing surveys in the lower Feather River. Age-0 Chinook salmon were very abundant in the spring but were nearly absent from summer surveys, suggesting behavior consistent with fall-run (DWR 2004b).

WATER TEMPERATURE

Water temperatures in the Low Flow Channel normally remain below 62°F year-round and are suitable for juvenile Chinook salmon rearing. During the January through March time period, when approximately 96 percent of juvenile Chinook salmon emigrate (DWR 2002a), water temperatures generally remain suitable for emigration throughout the lower Feather River (DWR 2003).

WATER QUALITY

At times, heavy metal concentrations in the lower Feather river are known to exceed EPA guidelines as discussed above under embryo incubation. Exposure of juveniles for extended periods of time could lead to decreased survival.

FLOW CONDITIONS

Flows in the Low Flow Channel of the Feather River, where most juvenile rearing of salmonids occurs, is maintained at a constant 600 cfs year-round except during flood events. Some flow fluctuations may occur downstream of the Thermalito Afterbay Outlet that have the potential to strand juvenile rearing or outmigrating salmonids. Since 2001, DWR has been conducting a juvenile stranding study on Chinook salmon and steelhead in the lower Feather River. Empirical observations and aerial surveys identified over 30 areas that have the potential to strand juveniles with flow decreases. However, sampling of isolated areas indicated relatively little juvenile salmonid stranding. Furthermore the proportion of stranded salmonids represented a very small percentage (<<1 percent) of the estimated number of emigrants (DWR 2004c).

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Fixed flows in the lower Feather River have resulted in fewer channel forming or re-shaping events leading to a lack of habitat diversity. This lack of diversity results in unnatural riparian conditions and a lack of recruitment of riparian vegetation.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Channel complexity refers to the diversity of geomorphic features in a particular river reach. Features such as undercut banks, meanders, point bars side channels and backwaters all provide habitat for juvenile salmonids. Regulation of the lower Feather River by the Oroville facilities has changed both streamflow and sediment discharge. Attenuation of peak flows, decreased winter flows, increased summer flows, and changes to flow frequencies have led to a general decrease in channel complexity downstream of Oroville Dam. Because several species and races of fish occur in the lower Feather River, a diversity of habitat types is required. Decreases in channel diversity lead to a decrease in habitat diversity and quality.

The high concentration of spawning salmonids in the Low Flow Channel results in a high concentration of juveniles in the Low Flow Channel. Seesholtz *et al.* (2003) found that most out-migration of juvenile Chinook salmon occurs between January and April and that these fish are relatively small. Based on historic accounts of juvenile salmonid emigration, the current peak in the emigration period is somewhat earlier than pre-dam conditions (Painter *et al.* 1977; Warner 1954). Seesholtz *et al.* (2003) further report that substantial numbers of juveniles remain in the Low Flow Channel through the end of June. Seesholtz *et al.* (2003) speculate that this early emigration may be caused by competition with other juvenile salmonids, including Chinook salmon and steelhead, for rearing habitat.

LOSS OF FLOODPLAIN HABITAT

Regular intermediate flood flushing flows to maintain geomorphic function of the river and replenish fish and riparian habitats are generally rare in the lower Feather River because of flow regulation by the Oroville Facilities. Lack of frequent high flow/flood events has led to a lack of floodplain renewal and connectivity to the channel.

ENTRAINMENT

The main diversion on the lower Feather River downstream of the Thermalito Afterbay occurs at Sunset Pumps at RM 38.6. The pumps divert 65,500 acre-feet of water annually. Although the diversion is screened, the mesh size does not meet NOAA or CDFG criteria, and some entrainment of juvenile salmonids likely occurs.

PREDATION

Known predators of Chinook salmon, including steelhead and pikeminnow, occur throughout the Low Flow Channel, although counts of these predators are reported to be low (Seesholtz *et al.* 2003). There are also a variety of predatory birds within this stretch of the Feather River, which may feed on salmon.

Significant numbers of predators do reportedly exist in the High Flow Channel below the Thermalito Afterbay Outlet. Analysis of CWT recovery data indicates that predation on hatchery-reared Feather River Chinook salmon released in the Feather River is high, however further analysis reveals that most of this predation takes place in the Sacramento River downstream of the Feather River confluence (DWR 2004d).

One aspect of the Oroville Project operations and facilities that may enhance predation in the High Flow Channel is that the high density of juveniles in the Low Flow Channel may cause early emigration of juvenile salmonids. Because juvenile rearing habitat in the Low Flow Channel is limited, juveniles may be forced to emigrate from the area due to competition for resources. Relatively small juvenile salmonids may be less capable of avoiding predators than those that rear to a larger size in the Low Flow Channel prior to beginning their seaward migration.

There is some evidence that the Sunset Pumps weir may create habitat favorable to predators. Screens are installed annually on the pumps by the CDFW dive team and some dives have noted a high number of non-native predatory fish (i.e., striped bass and black bass) above and below the rock weir.

<u>HATCHERY EFFECTS</u>

The FRFH raises and releases both spring- and fall-run Chinook salmon. It is likely that these hatchery-reared fish compete for limited resources with naturally spawned fish in the lower Feather River. There is speculation that the early outmigration of Chinook salmon observed in the Feather River is because of competition for limited resources. Additionally, the FRFH produces and releases yearling steelhead into the lower Feather River. These fish are large enough to prey on juvenile Chinook salmon.

3.3.8.2 YUBA RIVER

The lower Yuba River consists of the approximately 24-mile stretch of river extending from Englebright Dam, the first impassible fish barrier along the river, downstream to the confluence with the Feather River near Marysville.

<u>ADULT IMMIGRATION AND HOLDING</u>

Adult spring-run Chinook salmon immigration and holding has previously been reported to primarily occur in the Yuba River from March through October (Vogel and Marine 1991), with upstream migration generally peaking in May (SWRI 2002).

<u>PASSAGE IMPEDIMENTS/BARRIERS</u>

Englebright Dam presents an impassable barrier to upstream migration for anadromous salmonids and marks the upstream extent of currently accessable Chinook salmon habitat. Daguerre Point Dam may also provide a partial barrier to upstream migration. The design of Daguerre Point Dam fish ladders, as currently operated by the U.S. Army Corps of Engineers (USACE), are suboptimal. For example, during high flows across the spillway, the fish ladder is obscured making it difficult for salmonids migrating upstream to find the entrances to the fish ladders. Fall-run Chinook salmon have been observed attempting to leap over the dam, indicating that these fish were unable to navigate the fish ladders (CALFED and YCWA 2005). Both ladders also tend to become loaded with organic material and sediment, which can directly inhibit passage and/or reduce attraction flows at the ladder entrances. The fish ladder exits are close to the spillway, which can result in fish being swept back over the dam while attempting to exit the ladder.

Daguerre Point Dam can delay or prevent upstream migration of adult spring-run Chinook salmon in the lower Yuba River (NMFS 2007c). Daguerre Point Dam includes suboptimal fish ladder design and sheet flow across the dam spillway that reportedly may interfere with attraction to ladder entrances, particularly during high flow periods (January through March) (NMFS 2007c). The location of the ladder entrances also makes it difficult for immigrating adults to find the entrances (NMFS 2007c). Since 2001, wooden flash boards have been periodically affixed to the crest of the dam during low flow periods to aid in directing the flows towards the fish ladder entrances. Fish passage monitoring data from 2006 indicates that the installation of the flash boards resulted in an immediate and dramatic increase in the passage of salmon up the ladders, and is thought to have improved the ability of salmon to locate and enter the ladders (NMFS 2007c). Both ladders, particularly the north ladder, reportedly tend to clog with woody debris during high flow events, however, a log boom was installed at the north ladder in 2003 to reduce woody debris accumulation and an updated inspection and maintenance plan has allowed for more frequent inspection and cleaning of the ladders. Additionally, gravel buildup at the top of both ladders reportedly can block passage or reduce attraction flows at ladders, however, since 2003 the Corps has implemented a program to reduce gravel accumulation in front of the ladders (NMFS 2007c). Options to improve fish passage at Daguerre Point Dam where identified by the USFWS' Anadromous Fish Restoration Program (AFRP). The Project Modification Report recently completed by the USACE included engineering surveys, hydraulic evaluation, and a preliminary environmental assessment. There is no anticipated date for the implementation or completion of improvements to Daguerre Point Dam.

HARVEST/ANGLING IMPACTS

Poaching of adult Chinook salmon at the Daguerre Point Dam fish ladders has been well documented by CDFG, and is considered a chronic problem. Poaching is exacerbated when fish congregate below Daguerre Point Dam during low and high flows when the ladders are not open. In addition, poachers have tampered with the fish ladders to prevent adult salmon passage and thus increasing the concentration of individual fish below the dam.

Fishing for Chinook salmon on the lower Yuba River is regulated by CDFG. CDFG angling regulations permit fishing for Chinook salmon from the mouth of the Yuba River to Daguerre Point Dam year-round. Harvest of Chinook salmon downstream of Daguerre Point Dam is permitted from January 1 through February 28 and from August 1 through October 15. It is illegal to harvest salmon upstream of Daguerre Point Dam at any time. Additionally, regulations were crafted on the Feather River, downstream of the Yuba River confluence, to exclude spring-run salmon from recreational fishery harvest impacts.

WATER TEMPERATURE

Water temperatures in the Yuba River remain fairly cool year-round due to cool water releases from Engle bright Dam. Additionally, deep coldwater pools are available providing summer holding habitat downstream of the Narrows I and Narrows II powerhouses, or further downstream in the Narrows Reach (YCWA *et al.* 2007), where water depths can exceed 40 feet.

WATER QUALITY

Water quality continues to be an item of question due to inflow from Deer Creek, which includes effluent from the Lake Wildwood Wastewater Treatment Facility (LWWTF). The LWWTF continues to exceed State Water Quality Control Board standards for treated effluent discharged to a stream. Additionally, the effects of flows exiting the Yuba Goldfields have not been studied.

FLOW CONDITIONS

The natural hydrograph of the Yuba River is generally characterized by rapid increases and decreases in flows in the late-fall through winter (i.e., November through March) associated with seasonal precipitation events. During the spring months (i.e., April through June) flows exhibit more gradual, sustained increases and decreases. During the summer (i.e., July through October) flows remain relatively stable). Therefore, flow conditions during the spring-run Chinook salmon immigration period are generally relatively stable.

SPAWNING

PASSAGE IMPEDIMENTS/BARRIERS

From Daguerre Point Dam upstream to Englebright Dam there are no barriers to upstream adult immigration.

Harvest/Angling Impacts

Angling impacts on spawning spring-run Chinook salmon are likely minimal because harvest is prohibited above Daguerre Point Dam where most spawning occurs.

Water Temperature

Average daily water temperatures recorded at Daguerre Point Dam from 1997 to 2001 ranged from 57.7ºF in September to 56.0ºF in October.

Water Quality

Water quality in the lower Yuba River is adequate to support Chinook salmon adult spawning.

Flow Conditions

Flows during the time that spring-run Chinook salmon would be spawning are relatively stable.

Spawning Habitat Availability

Most spawning habitat in the lower Yuba River is upstream of Daguerre Point Dam. Although water temperatures below the dam are likely suitable for Chinook salmon spawning, gravel downstream of the dam is embedded with silt (YCWA 2000). Spawning habitat above Daguerre Point Dam is ample with the exception of the Englebright Dam Reach, where it is limited.

Physical Habitat Alteration

The most extensive habitat alterations in the lower Yuba River have occurred as a result of gold mining operations. The Yuba Goldfields are located along the lower Yuba River near Daguerre Point Dam, approximately 10 miles north of Marysville. The area of the Goldfields is approximately 8,000 acres. The Goldfields have been used for gold mining for about 100 years. As a result thousands of acres of continuous mounds of cobble and rock terrain have been left behind. As a result of the permeability of the substrates composing the Goldfields, several interconnected channels and ponds have formed throughout the area. Surface water in the ponds and canals of the Goldfields are hydraulically connected to the Yuba River. A proportion of flow entering the Goldfields is eventually returned to the Yuba River downstream of Daguerre Point Dam via an outlet canal. Prior to 2003, a fraction of the lower Yuba River Chinook salmon population (e.g., spring-run, fall-run, and late-fall-run) and, presumably, steelhead routinely migrated from the mainstem of the Yuba River into the Yuba Goldfields via the outlet canal. In 2003, a fish barrier was constructed at the outlet canal to prevent fish from entering the Yuba Goldfields. However, fish were still observed passing the barrier during flood or high flow events.

Hatchery Effects

Hatchery reared spring-run Chinook salmon were planted in the Yuba River during the 1970s. Additionally, adipose fin-clipped Chinook salmon have been observed in the Yuba River during recent carcass surveys indicating that some level of straying into the Yuba watershed is occurring. Monitoring efforts in the Yuba River have confirmed FRFH spring-run occur there (M. Tucker, NMFS, pers. comm.). Hybridization of the FRFH spring-run with the native spring-run population would result in compromising the genetic integrity and lowering the fitness of the latter. The hatchery stock would compete with native spring-run over available holding and spawning habitat, and possibly transfer the Feather River strain of IHNV to the local population.

EMBRYO INCUBATION

HARVEST/ANGLING IMPACTS

Because the lower Yuba River supports a year-round recreational fishery, it is possible that some level of redd disturbance by wading anglers occurs.

WATER TEMPERATURE

Spring-run Chinook embryo incubation primarily occurs in the lower Yuba River from September through March (YCWA *et al.* 2007). The intragravel residence times of incubating eggs and alevins (yolk-sac fry) are highly dependent upon water temperatures. Maximum Chinook salmon embryo survival reportedly occurs in water temperatures ranging from 41°F to 56°F (USFWS 1995c). The average water temperature in the Yuba River at Daguerre Point Dam ranges from approximately 47ºF in January and February to approximately 57ºF in September.

WATER QUALITY

Water quality in the lower Yuba River is generally good. There is a concern that a substantial amount of mercury may be in the Yuba Goldfields that could be mobilized by flood events but this would likely be downstream of developing embryos.

FLOW CONDITIONS

Flow reductions from normal maintenance and emergency operations of the Narrows I and II powerhouses below Englebright dam has been associated with cases of redd dewatering. Since 1991, maintenance activities have been scheduled at such times that potential redd dewatering would be minimized. Currently, flows are kept fairly constant during the time period when spring-run Chinook salmon embryos would be developing. Additionally, releases from Englebright Dam are coordinated with the River Management Team, which tries to avoid redd dewatering events.

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

The average daily mean water temperature downstream of Daguerre Point Dam from May through September ranges between 57.9ºF in May to 61.6ºF in September at Marysville (SWRI 2002). These temperatures are within the suitable range for juvenile spring-run Chinook salmon rearing and outmigration.

WATER QUALITY

Water quality in the lower Yuba River is generally good. There is a concern that a substantial amount of mercury may be in the Yuba Goldfields that could be mobilized by flood events.

FLOW CONDITIONS

Field observations on the lower Yuba River indicate that both natural and controlled flow reductions can cause some degree of fish stranding (YCWA 1998; YCWA 1999). The magnitude of stranding is site-specific and associated with the specific developmental stage of the fry prior to the onset of flow reductions, channel morphology, and aquatic habitat characteristics.

There are two types of stranding that are associated with flow reductions:

- Stranding associated with the rate of flow reductions (i.e., ramping rates), which determines if the juvenile fish can react quickly enough to avoid being stranded from exposed substrates in side channels and channel margins as flows decrease.
- Stranding associated with the magnitude of flow reductions, regardless of ramping rate, which determines the extent of stranding within off channel habitats as flows decrease.

The SWRCB requires that YCWA, in consultation with the CDFG, NMFS, and USFWS verify that salmon fry are being protected from dewatering events during controlled flow reductions on the lower Yuba River. However, some level of mortality associated with controlled flow reductions is unavoidable, and therefore should be considered as a factor when assessing threats to juvenile salmonids in the lower Yuba River (YCWA 1999).

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

The reduction of peak flows in the late winter and spring have resulted in a reduction of riparian vegetation. There is a wide variation throughout the growing season of willow regeneration because each species of willow requires flows at specific periods for reproduction and growth. Cottonwood regeneration is also more prominent under natural flow regimes (YCWA 2000).

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Attenuated peak flows and controlled flow regimes have altered the area's geomorphology and have affected the natural meandering of the river downstream of Englebright Dam.

LOSS OF FLOODPLAIN HABITAT

Controlled flows and decreases in peak flows has reduced the frequency of floodplain inundation resulting in a separation of the river channel from its natural floodplain.

ENTRAINMENT

As juvenile salmonids pass Daguerre Point Dam, physical injury may occur as they pass over the dam or through its fish ladders (SWRI 2002). Water diversions in the lower Yuba River generally begin in the early spring and extend through the fall. As a result, potential threats to juvenile steelhead occur at the Hallwood-Cordua and South Yuba Brophy diversions.

Fish screens recently installed at the Hallwood-Cordua diversion are considered to be an improvement over those previously present but, the current pipe design may not allow sufficient flow to completely eliminate juvenile salmonid losses at the diversion.

The South Yuba-Brophy system diverts water through an excavated channel from the south bank of the lower Yuba River to Daguerre Point Dam. The water is then subsequently diverted through a porous rock dike that is intended to exclude fish. The current design of this rock structure does not meet NMFS or CDFG juvenile fish screen criteria (SWRI 2002).

There are also three major screeded diversions on the lower Yuba River located upstream of Daguerre Point Dam: (1) the Browns Valley Pumpline Diversion Facility; (2) the South-Yuba/Brophy Water District Canal; and (3) the Hallwood-Cordua Canal. In addition, there are 16 unscreened water diversion facilities downstream of Daguerre Point Dam (SWRI 2002) which could potentially entrain juvenile salmonids in the lower Yuba River.

PREDATION

The extent of predation on juvenile Chinook salmon in the Yuba River is not well documented, however, several non-native introduced known predators of juvenile salmonids are found in the Yuba River including striped bass, American shad and black bass species. Sacramento pikeminnow, a native predatory species is also found in the lower Yuba River. Manmade alterations to the lower Yuba River channel (i.e., Daguerre Point Dam) may provide more predation opportunities for pikeminnow than would occur under natural conditions.

HATCHERY EFFECTS

The extent of potential hatchery effects on juvenile Chinook salmon in the lower Yuba River is unknown. It is possible that some hatchery-reared Chinook salmon from the FRFH may move into the lower Yuba River in search of rearing habitat. Some competition for resources with naturally spawned Chinook salmon could occur as a result. Additionally, hatchery-reared steelhead from the FRFH could likewise move into the Yuba River in search of rearing habitat and may prey on juvenile Chinook salmon.

3.3.8.3 BUTTE CREEK

Butte Creek originates in the Jonesville Basin, Lassen National Forest, on the western slope of the Sierra Nevada Mountains, and drains about 150 square miles in the northeast portion of Butte County. Butte Creek enters the Sacramento Valley southeast of Chico and meanders in a southwesterly direction to the initial point of entry into the Sacramento River at Butte Slough. A second point of entry into the Sacramento River is through the Sutter Bypass and Sacramento Slough.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

Butte Creek is a highly developed watershed system with multiple diversions as well as water imports from foreign sources. Fish passage through Butte Creek is affected by about 22 major structures and an estimated 60 to 80 minor structures (e.g., pump diversions). Currently, it is estimated that salmonids have access to approximately 53 miles of Butte Creek (DWR 2005a).

There are several fish passage impediments and barriers on Butte Creek upstream of Highway 99, including the Quartz Bowl Falls (natural impediment) and the Centerville Diversion Dam (manmade barrier). CDFG reported that salmon and steelhead are unable to migrate upstream of the Quartz Bowl Falls on an annual basis (DWR 2005a). CDFG biologist report observing salmon in the reach between Quartz Bowl Falls and the Centerville Head Dam on only three occasions in the past 25 years when spring flows were in excess of 2,000 cfs (e.g., 1998 and 2003).

HARVEST/ANGLING IMPACTS

Recreational fishing in Butte Creek is limited to catch-and-release of trout and salmon from November 15 through February 15 with gear restrictions (i.e., artificial lures and barbless hooks only). These restrictions apply to the reach of Butte Creek extending from the Oro-Chico Road Bridge upstream to the Centerville Head Dam. Downstream of this point, recreational fishing is allowed year-round only for species other than trout and salmon.

WATER TEMPERATURE

Water temperatures were monitored from June through October from Cable Bridge (downstream) to Quartz Bowl (upstream) within the spring-run Chinook salmon holding and spawning reach of Butte Creek in 2002. **Table 3-1** depicts water temperature exceedances of critical values as measured at different locations in Butte Creek during 2002 from June through October.

Table 3-1. Water Temperature Exceedances in Butte Creek in 2002

Location	Number of Days Equal to or Exceeding		
	15.0ºC (59°F)	17.5ºC (63.5°F)	20.0ºC (68°F)
Quartz Bowl Pool	105	57	8
Chimney Rock	113	68	18
Pool 4	121	81	41
Centerville Estates	122	81	44
Cable Bridge	127	99	54

Pre-spawning mortality surveys were conducted in 2002 from the Parrot-Phelan Diversion to the Centerville Head Dam. There were 1,699 pre-spawning mortalities observed from June 26, 2002 to September 19, 2002. Higher than normal water temperatures in conjunction with a large number of adult returns resulted in an outbreak of Columnaris (*Flavobacterium columnare*). Pre-spawning mortalities in Butte Creek prior to this had been reported, however, they have been sporadically recorded, but have never been systematically assessed (CDFG 2000).

There were approximately 17,294 adult spring-run Chinook salmon that migrated to Butte Creek during 2003, of those an estimated 11,231 pre-spawning mortalities occurred. According to CDFG pathologists, the primary cause of these mortalities was an outbreak of two diseases, *Flovobacterium columnare* (Columnaris) and the protozoan *Ichthyophthirius multiphilis* (Ich).

WATER QUALITY

Currently, water quality conditions in Butte Creek meet all EPA water quality constituent requirements.

FLOW CONDITIONS

The present PG&E hydropower facilities divert water from the West Branch of the Feather River at the Hendricks Head Dam near Stirling City, which is then combined with Butte Creek water diverted at the Butte Head Dam. Power is generated at two sites − the DeSabla Powerhouse located above spring-run Chinook salmon holding and spawning areas, and the Centerville Powerhouse located in the middle of the approximately 11-mile holding and spawning reach. Annual diversion from the West Branch of the Feather River average approximately 47,000 acre-feet, and provides approximately 40 percent of the flows in Butte Creek during the months of July through September.

Diversions at the PG&E Centerville Head Dam supply water to the Centerville Powerhouse and reduce flows in Butte Creek to a minimum of 40 cfs from June 1 through September 14. The reach of Butte Creek between the Centerville Head Dam and the Centerville Powerhouse is approximately 5.5 miles long and is considered to be the highest quality and quantity of summer holding habitat in Butte Creek.

Diversions at the Centerville Head Dam which supply water to the Centerville Powerhouse, significantly reduce water temperatures in the reach immediately below the powerhouse due to reduced transit time and shading along the diversion canal. This reduction in water temperatures provides additional summer holding habitat that would potentially not exist.

SPAWNING

Spring-run Chinook salmon in Butte Creek primarily spawn in stream reaches between the Parrot-Phelan Diversion Dam and the Centerville Head Dam (USFWS 2003a).

PASSAGE IMPEDIMENTS/BARRIERS

Historically, dams, inefficient fish ladders, and the dewatering of portions of Butte Creek as a result of water diversions created impediments to upstream passage for spawning adult spring-run Chinook salmon. Since the early 1990s, restoration actions in Butte Creek have focused on improving instream flow during the spring critical immigration period, thereby increasing the likelihood that fish will succeed in reaching the upstream holding and spawning areas, even in dry years. Currently, the minimum flow for allowing upstream passage is estimated at 80 cfs (CALFED 2006).

HARVEST/ANGLING IMPACTS

Butte Creek, from the confluence with the Sacramento River upstream to the Oro-Chico Road Bridge crossing south of Chico, is closed to trout and salmon fishing year-round. From the Oro-Chico Road Bridge crossing upstream to the Centerville Head Dam, catch and release fishing for trout and salmon is allowed from November 15 through February 15. However, Butte Creek is open to fishing for other species all year and some inadvertent catch of spring-run Chinook salmon may occur.

WATER TEMPERATURE

Water temperatures between Parrot-Phelan Diversion Dam and the Centerville Head Dam in Butte Creek frequently exceed the reported optimums for spring-run Chinook spawning. Water temperatures frequently exceed 59ºF from July through September. In recent years, as escapement in Butte Creek has increased, mortality of pre-spawning adults has also increased due to a combination of high water temperatures and the bacterial disease Columnaris, leading to speculation that the adult carrying capacity of Butte Creek has been reached (Stillwater Sciences Website 2007). An estimated 17,294 adult spring-run Chinook salmon migrated to Butte Creek during 2003, of which an estimated 11,231 died prior to spawning (Ward *et al.* 2003b). Pre-spawn mortalities were primarily due to high water temperatures, overcrowding of fish in limited holding pools, and disease (e.g., Columnaris and Ich) (Ward *et al.* 2003b).

Subsequent to the 1991 FERC requirement that PG&E maintain a minimum release of 40 cfs from June through September below the Centerville Head Dam, Ward *et al*. (2003b) report that the flow and temperature regime appears to have maximized survival and spawning success.

WATER QUALITY

Available data indicate that overall water quality in Butte Creek ranges from good to excellent in the upper watershed and degrades in quality lower in the system (Butte Creek Watershed Website 2004). Both pH and dissolved oxygen concentrations appear to be below Central Valley Regional Water Quality Control Board (RWQCB) criteria all of the time. Turbidity, mineral concentrations, nutrient loads and heavy metal concentrations (e.g., lead) have at times exceeded Central Valley RWQCB criteria for short periods of time (Butte Creek Watershed Website 2004).

FLOW CONDITIONS

PG&E's minimum instream flow requirement at the Lower Centerville Diversion Dam is 40 cfs from June 1 to September 14. Average monthly flows from June through September (1998-2002) were between 49 cfs and 46 cfs. During the onset of the spawning period in mid-September of 2004, PG&E in consultation with CDFG and NMFS, increased flows to 60 cfs (PG&E 2005).

SPAWNING HABITAT AVAILABILITY

Based upon estimates of spawning habitat, the reach of Butte Creek upstream of the Centerville Powerhouse could support 152 to 1,316 spawners at 40 cfs and 270 to 2,352 spawners at 130 cfs. The reach downstream of the powerhouse could support 1,262 to 10,976 spawners at 130 cfs.

Within the 11-mile spring-run Chinook salmon holding and spawning reach, the area with the most deep holding pools is within the upper three miles of the reach while the majority of suitable spawning gravel substrate is within the lower five miles of the reach (Ward *et al.* 2003b).

PHYSICAL HABITAT ALTERATION

Hydropower generation has altered flows in Butte Creek since about 1908. During the key June to September holding period, diversions from the West Branch of the Feather River have increased natural flows in the creek and have generally provided cooler temperatures (Ward *et al.* 2003b).

The reach of Butte Creek from the Centerville Powerhouse downstream to the Parrott-Phelan Dam has undergone and continues to undergo residential development. Channel modification projects designed to repair or prevent flood-related damage to roads and houses have degraded natural processes which serve to recruit gravel, provide instream cover and forage, and provide summer holding pools (Butte Creek Watershed Website 2004).

HATCHERY EFFECTS

The trucking of FRFH spring-run, and their release into San Pablo Bay, facilitates the straying of adult spring-run hatchery returns and threatens the Butte Creek spring-run population. Genetic integrity of the Butte Creek spring-run may be compromised, and their fitness and productivity lowered. The hatchery stock would compete with native spring-run over available holding and spawning habitat, and possibly transfer the Feather River strain of IHNV to the local population. The BRT considers the FRFH spring-run Chinook salmon program to be a major threat to the genetic integrity of wild spring-run Chinook salmon populations in the Central Valley (NMFS 2003).

EMBRYO INCUBATION

HARVEST/ANGLING IMPACTS

Because Butte Creek is open to angling year-round, there may be some inadvertent negative impacts to embryo incubation from anglers wading through redds or otherwise disturbing substrates containing redds.

WATER TEMPERATURE

The thermal criteria used to evaluate the suitability of spring-run Chinook salmon water temperatures suggests that water temperatures between 57.2ºF and 60.8ºF for a duration of approximately 20 days could potentially result embryo mortality rates of up to 25 percent from September 15 to September 30 (Armour 1991; CDFG 1998). However, it has been suggested that given that Butte Creek spring-run Chinook salmon are genetically distinct from the Mill Creek and Deer Creek populations (Lindley *et al.* 2004), it is likely that they have adapted to the warmer environs of the Butte Creek watershed. It could be possible that Butte Creek spring -run Chinook salmon can tolerate water temperatures exceeding 60ºF which can occur during the first month of embryo incubation. However, there also may be higher embryo mortality rate for eggs deposited during first month (September) of the spawning period, relative to those deposited later during October when water temperatures decrease below approximately 55ºF (**Figure 3-8**).

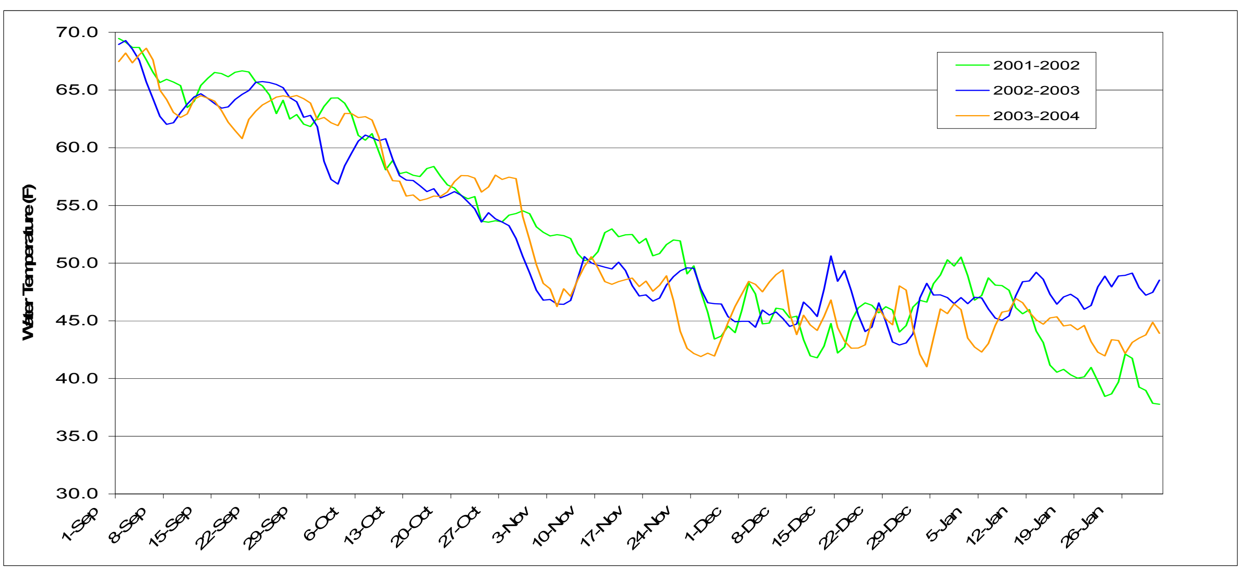

Figure 3-8. Water Temperatures Recorded in Butte Creek Near Chico During the Spring-run Chinook Salmon Embryo Incubation Period (September through January)
(USGS Gage: 39.7260°N 121.7090°W)

WATER QUALITY

Available data indicate that overall water quality in Butte Creek ranges from good to excellent in the upper watershed and degrades in quality lower in the system (Butte Creek Watershed Website 2004). Both pH and dissolved oxygen concentrations appear to be below Central Valley RWQCB criteria all of the time. Turbidity, mineral concentrations, nutrient loads and heavy metal concentrations (e.g., lead) have at times exceeded Central Valley RWQCB criteria for short periods of time (Butte Creek Watershed Website 2004).

The upper reaches of Butte Creek reportedly have relatively high dissolved oxygen concentrations. Monitoring conducted by DWR between December 1990 and October 1992, recorded dissolved oxygen levels ranging from 9.1 mg/l to 13.1 mg/l. These levels exceed minimum EPA requirements (PG&E 2005).

Flow Conditions

PG&E's minimum instream flow requirement at the Lower Centerville Diversion Dam is 40 cfs from June 1 to September 14. Average monthly flows from June through September (1998-2002) were between 49 cfs and 46 cfs. During the onset of the spawning period in mid-September of 2004, PG&E in consultation with CDFG and NMFS, increased flows to 60 cfs (PG&E 2005).

Juvenile Rearing and Outmigration

Water Temperature

Water temperatures during the period when flows are managed and when juvenile Chinook salmon are present (e.g., October 15 through January), are likely near optimal ranges. However, water temperatures could be a concern during the late spring especially in the lower reaches of Butte Creek. During the 2002-2003 juvenile migration study period in Butte Creek, the majority of Butte Creek juvenile spring-run Chinook salmon emigrated as fry from December through January. As observed during previous study years, some young-of-the-year remained in Butte Creek above the Parrot-Phelan Diversion Dam prior to emigrating in the spring (Ward *et al.* 2004).

Water Quality

Available data indicate that overall water quality in Butte Creek ranges from good to excellent in the upper watershed and degrades in quality lower in the system (Butte Creek Watershed Website 2004). Both pH and dissolved oxygen concentrations appear to be below Central Valley RWQCB criteria all of the time. Turbidity, mineral concentrations, nutrient loads and heavy metal concentrations (e.g., lead) have at times exceeded Central Valley RWQCB criteria for short periods of time (Butte Creek Watershed Website 2004).

Flow Conditions

Butte Creek is primarily a free-flowing stream lacking large storage dams to control or buffer flows (CDFG 1999a). Flows are highly variable with the majority of out migration of juveniles occurring during high flow events (CDFG 1999a).

Loss of Riparian Habitat and Instream Cover

The distribution of riparian habitat, particularly in the lower reaches of Butte Creek, has been reduced by anthropogenic changes for flood control, agriculture and urbanization (Butte Creek Watershed Website 2004).

Loss of Natural River Morphology and Function

The reach of Butte Creek from the Centerville Powerhouse downstream to the Parrott-Phelan Dam has undergone, and continues to undergo, residential development. Channel modification projects designed to repair or prevent flood-related damage to roads and houses have degraded natural processes which serve to recruit gravel, provide instream cover and forage, and provide summer holding pools (Butte Creek Watershed Website 2004).

Loss of Floodplain Habitat

Although Butte Creek is bordered by levees in some areas, it also passes through Butte Slough and the Sutter Bypass where connectivity to the floodplain still exists to some extent (Butte Creek Watershed Website 2004).

Entrainment

In Butte Creek most water diversion facilities have been screened or modified to prevent juvenile fish entrainment (PG&E 2005). In addition, as part of PG&E's FERC relicensing project, PG&E has proposed to undertake a project assessing potential juvenile entrainment at its project facilities including the Hendricks Canal, Toadtown Canal and Powerhouse, Butte Canal, DeSabla Forebay and Powerhouse, Lower Centerville Canal, and Centerville Powerhouse (PG&E 2005).

Predation

Introduced fish species that are known predators in the Butte Creek system include largemouth and smallmouth bass, black and white crappie, channel catfish and potentially, striped bass and American shad. The native Sacramento pikeminnow is also a major predator on juvenile salmonids particularly near manmade structures (Butte Creek Watershed Website 2004).

Hatchery Effects

Juvenile Chinook salmon in Butte Creek are not likely directly affected by hatchery operations. There is some potential for outmigrating juveniles to be preyed upon by hatchery steelhead as they enter either the Sacramento or Feather rivers.

3.3.8.4 Big Chico Creek

Big Chico Creek originates on Colby Mountain, located in Tehama County, California. The creek flows 45 miles to its confluence with the Sacramento River in Butte County. The creek's elevation ranges from 120 feet at the Sacramento River to 6000 feet at Colby Mountain. A portion of Big Chico Creek flows through the city of Chico, California's Bidwell Park and California State University, Chico. Big Chico Creek currently supports a remnant, non-sustaining population of spring-run Chinook salmon.

Adult Immigration and Holding

Passage Impediments/Barriers

Big Chico Creek has no major reservoirs, but has two small dams and three natural barriers that could impede anadromous fish migration.

Five Mile Dam was built by the USACE for the purpose of flood control in 1963. The dam effectively spilt the Big Chico Creek flows into three separate channels−Big Chico Creek, Sycamore Channel, and Lindo Channel. The design of the flood control structure creates a ponding effect upstream during flood events. This causes gravels to drop out of suspended load upstream of the diversion which creates a gravel bar that blocks the flow to Lindo Channel unless it the gravel bar is mechanically removed. As a result, Lindo Channel frequently lacks sufficient flows to allow upstream migrants to pass, and has the potential to trap adults within the channel during immigration to spawning areas upstream (DWR 2005b).

The Iron Canyon fish ladder was built in the late 1950s to facilitate fish passage through Bidwell Park. This structure has been damaged, and frequently impedes adult salmonid upstream migration. Currently, a project is in planning phase to repair the fish ladder to allow fish passage to an additional 9 miles of spawning habitat over a wider range of flows (CDFG Website 2005). In addition, fish passage through the narrow canyon walls of Bear Hole, located downstream of the Iron Canyon fish ladder, impedes fish passage during low flows. Under high flow conditions, fish have been observed passing major barriers (Iron Canyon). However, under normal and low-flow conditions fish passage is more problematic (DWR 2005b).

HARVEST/ANGLING IMPACTS

Recreational catch-and-release fishing in Big Chico Creek is permitted: (1) one mile downstream of Bidwell Park, is limited to June 16 through October 15 with gear restrictions (i.e., artificial lures and barbless hooks only); and (2) from Bear Hole to the Big Chico Creek Ecological Reserve from November 1 through April 30. Fishing upstream of Big Chico Creek Ecological Reserve is prohibited year-round.

WATER TEMPERATURE

During low flows in the summer, water flows continuously through Big Chico Creek, however, in Lindo Channel, flows become intermittent. It has been suggested that water temperatures from Iron Canyon to Higgins Hole, which may contain holding adult spring-run Chinook salmon, can potentially reach critical levels during the late summer, particularly during dry water years (DWR 2005b).

Higgins Hole is the upstream limit to spring-run Chinook salmon immigration and is reportedly the best summer holding habitat available in Big Chico Creek. However, mean daily water temperatures during the summer months reportedly generally range from 64ºF to 68ºF (**Figure 3-9**).

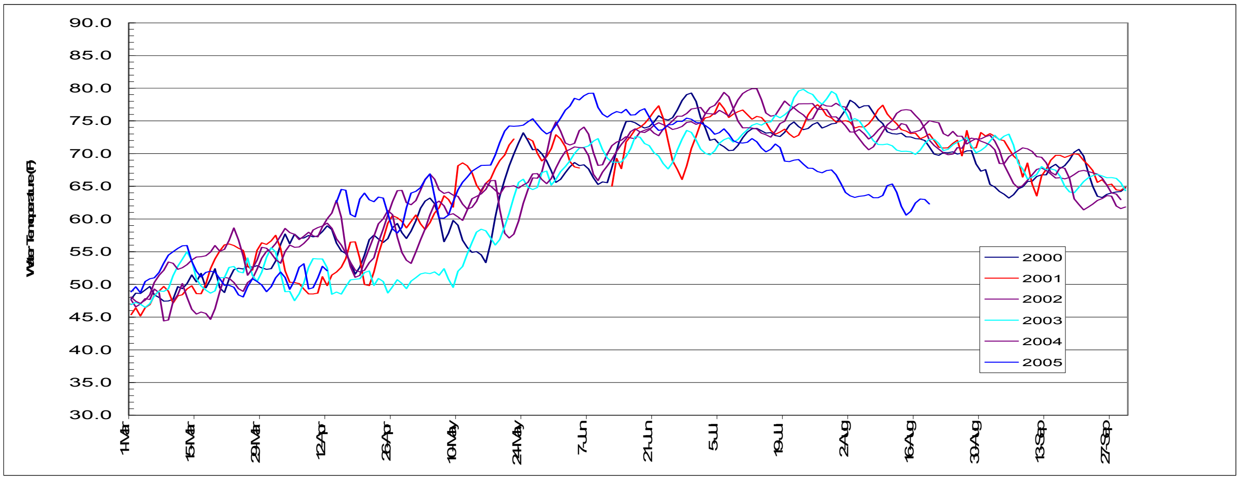

Figure 3-9. Average Daily Water Temperatures in Big Chico Creek Near Chico During the Spring-run Chinook Salmon Adult Immigration and Holding Period March through September (2000-2005)
Source: CDEC

WATER QUALITY

Water quality in Big Chico Creek and Lindo Channel has been degraded by cadmium, mercury, and other metals associated with gold mining in the upper watershed. The California State University, Chico reported significant concentrations of fecal coliform bacteria during the summer months due to Sycamore pool, which is heavily used as a swimming hole. However, Big Chico Creek currently meets EPA water quality constituent standards. There is also potential for increased suspended sediment loads during the cleaning of Sycamore Pool which is formed by One-Mile Dam. However, a project was completed in 1997 which constructed a bypass waterway that isolates the cleaning area from the flowing creek. The bypass channel consists of a concrete box culvert installed below the surface of the pool bottom. The channel extends the entire length of the pool exiting beyond the fish ladder. A flash board dam will be installed at the entrance to the pool to provide for the diversion of clean water from the channel during cleaning operations.

FLOW CONDITIONS

Mean monthly flows in Big Chico Creek from 1930 to 1986 during the spring-run Chinook salmon immigration and holding period (i.e., February through August) range from approximately 400 cfs to approximately 40 cfs.

Big Chico Creek flows through the Chico alluvial fan at the Five-Mile Recreation Area. Flows at Five-Mile are regulated for flood control by diversion of high flows from a single stilling basin in Big Chico Creek and two flood bypass channels (Lindo Channel and Sycamore Channel). The invert elevations of Big Chico Creek and the Lindo Channel diversion are similar, thus flows are sustained in both channels during the summer low flow period. However, due to a gravel bar formation below the stilling basin, flows in Lindo Channel become intermittent from May through November each year.

SPAWNING

Spring-run Chinook salmon in Big Chico Creek primarily spawn in stream reaches between the Higgins Hole and Iron Canyon (CDFG 2004a).

Passage Impediments/Barriers

The first barrier to upstream migration on Big Chico Creek occurs in Iron Canyon where a jumble of boulders has accumulated in the Creek. These boulders present an impassable barrier at normal flows but allow passage at high flows (Big Chico Creek Watershed Alliance Website 2007). The Iron Canyon fish ladder was built in the late 1950s to facilitate fish passage. This structure has been damaged, and frequently impedes adult salmonid upstream migration. Currently, a project is underway to repair the fish ladder to allow fish passage to an additional nine miles of spawning habitat over a wider range of flows (CDFG Website 2005). The waterfall at Higgins Hole is currently thought to be the uppermost barrier to anadromous fish migrations (CDFG 2001a).

Harvest/Angling Impacts

Currently, Big Chico Creek is open to catch and release fishing from the confluence with the Sacramento River to Bear Hole located approximately one mile downstream of Bidwell Park during the June 16 to February 15 time period, however, from October 15 through February 15 only barbless artificial lures may be used. Big Chico Creek, from Bear Hole to the upper boundary of the Big Chico Creek Ecological Reserve is open to catch and release fishing, with barbless artificial lures, from November 1 through April 30. From the upper boundary of the ecological reserve to Higgins Hole Falls, Big Chico Creek is closed to fishing at all times of the year.

Water Temperatures

Summer water temperatures in Big Chico Creek are marginal for holding spring-run Chinook salmon and are seldom suitable for spawning until mid-October (Big Chico Creek Watershed Alliance Website 2007). **Figure 3-10** depicts stream water temperatures recorded in Big Chico Creek near Chico during the normal spring-run Chinook salmon spawning period of September through October. It should be noted that water temperatures at the Chico gage are not representative of the thermal conditions experienced by spring-run Chinook salmon in Big Chico Creek because the fish hold and spawn further upstream.

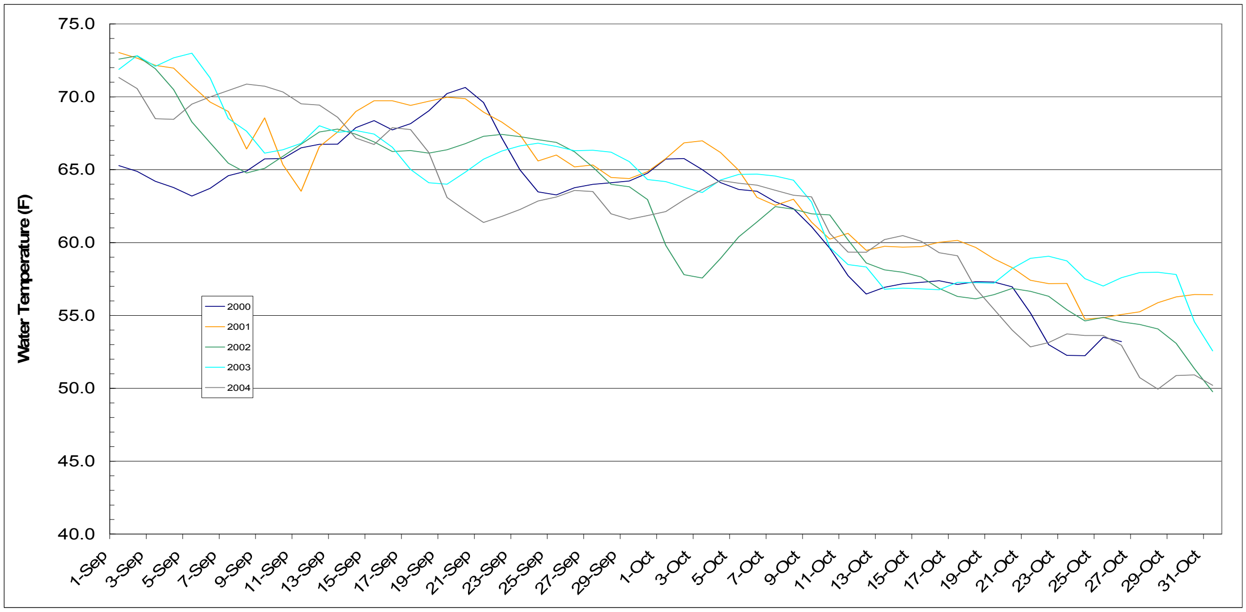

Figure 3-10. Average Daily Water Temperature in Big Chico Creek Near Chico During Adult Spring-run Chinook Salmon Spawning Period September through October (2000-2004)

WATER QUALITY

A number of issues and concerns have been raised regarding the water quality in the Big Chico Creek watershed, primarily, increased sediment loads and turbidity, fecal coliform contamination, urban stormwater runoff, groundwater contamination, agricultural runoff, siltation-, pollutant-, and garbage-related contamination from the Minnehaha Mine, sediment-, erosion-, and septic-related contamination from the Boy Scout Camp at Chico Meadows, and the potential threat of petroleum contamination from Highway 32 (CDFG 2001a).

FLOW CONDITIONS

Adult spring-run Chinook salmon enter Big Chico Creek between March and June, although, late arriving individuals often have difficulty in upstream migrations because of low-flow conditions. Early arriving individuals are normally blocked by waterfalls. Spring-run Chinook salmon normally spend summer months in deep pools from Iron Canyon to Higgins Hole and spawn in adjacent riffles when water temperatures become suitable in the fall (Big Chico Creek Watershed Alliance Website 2007).

SPAWNING HABITAT AVAILABILITY

A survey of spawning gravels was conducted by DWR in 1997 to determine the gravel size distribution at various spawning sites in Big Chico Creek. The sites were located along Big Chico Creek at Highway 32; below the Five-Mile Area flood control structure; and at Rose Avenue. These sites are primarily utilized by fall-run Chinook salmon. The gravel sizes ranged from 20 mm to 100 mm (approximately 1 to 4 inches) in mean diameter. Gravels within these ranges are considered to be suitable for salmonid spawning (Big Chico Creek Watershed Alliance Website 2007).

Gravel recruitment downstream of the Five-Mile Flood Diversion Complex is reduced and gravel also becomes trapped in the One-Mile Pond from which it is customarily removed rather than transported downstream (Big Chico Creek Watershed Alliance Website 2007). Additionally, the practice of removing large woody debris from urban and floodway stream reaches has reduced habitat and increased streambed scouring (Big Chico Creek Watershed Alliance Website 2007).

Physical Habitat Alteration

The presence of dams on Big Chico Creek limits the composition and volume of sediments transported which reduces the supply of spawning gravels downstream of the dams. Large volumes of suspended sediment in the bedload are deposited within the stilling pond above the Five-Mile area. As a result, coarse sediments are not transported downstream below the Five-Mile area. At Chico's One-Mile Recreation Area, the flow is again reduced and additional volumes of sediment are deposited on the upstream side of the dam. Low-flow silt transport in the Big Chico Creek has been increased by swimming pool clean out and summer water activities by humans, dogs and horses. Unlike high-flow conditions in which silt only deposits where flow velocity is reduced in backwater and overflow sites, silt carried during low flows settle out in riffles and pools where it degrades habitat for spawning (Big Chico Creek Watershed Alliance Website 2007).

Hatchery Effects

The trucking of FRFH spring-run, and their release into San Pablo Bay, facilitates the straying of adult spring-run hatchery returns and threatens the Big Chico Creek spring-run population. Genetic integrity of the Big Chico Creek spring-run may be compromised, and their fitness and productivity lowered. The hatchery stock would compete with native spring-run over available holding and spawning habitat, and possibly transfer the Feather River strain of IHNV to the local population.

Embryo Incubation

Harvest/Angling Impacts

Because Big Chico Creek is open to angling during the spring-run Chinook salmon embryo incubation period, there may be some inadvertent negative impacts to embryo incubation from anglers wading through redds or otherwise disturbing substrates containing redds.

Water Temperature

The thermal criteria used to evaluate the suitability of spring-run Chinook salmon water temperatures suggests that water temperatures between 57.2ºF and 60.8ºF for approximately 20 days could potentially result in embryo mortality rates of up to 25 percent from September 15 to September 30 (USFWS 1996; Armour 1991; and CDFG 1998). However, it is hypothesized that Big Chico Creek spring-run Chinook salmon may be more tolerant of high water temperatures then those in nearby streams (e.g., Mill, Deer and Butte creeks) (Lindley *et al.* 2004). There would likely be higher embryo mortality rate for eggs deposited during the first month (September) of the spawning period, relative to those deposited later during October of some water years when temperatures decrease below approximately 55ºF (**Figure 3-11**). The water temperatures experienced by spring-run Chinook salmon spawners and eggs in Big Chico Creek are likely cooler than those depicted in Figure 3-11, because spawning takes place further upstream than the Chico gage.

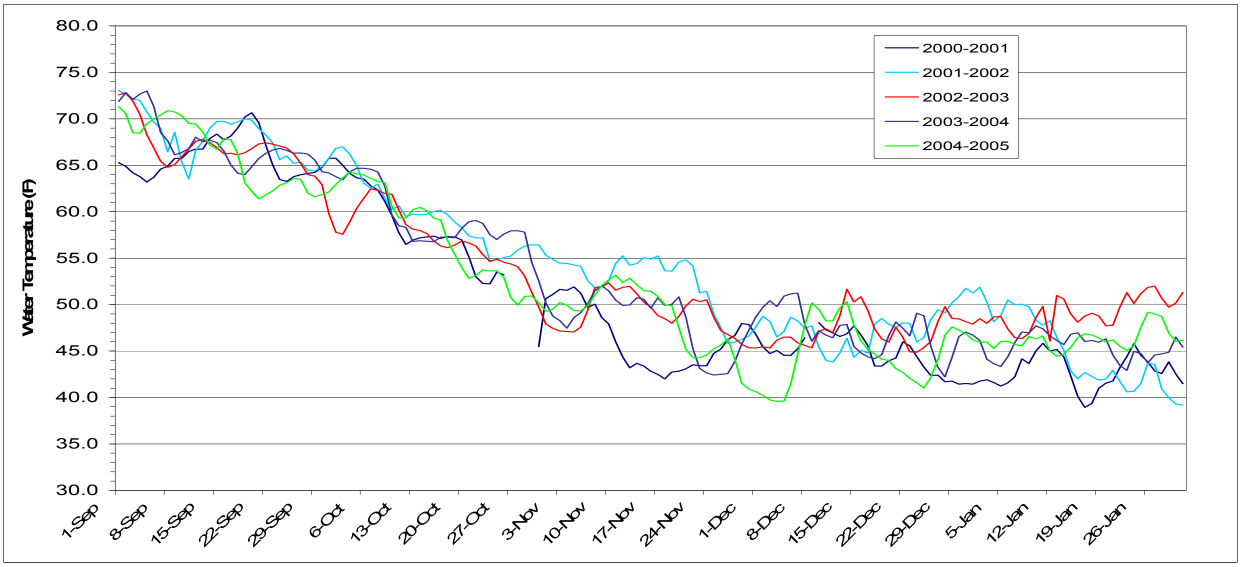

Figure 3-11. Water Temperatures Recorded in Big Chico Creek Near Chico During the Spring-run Chinook Salmon Embryo Incubation Period (September through January)
(39.7680°N 121.7770°W)

WATER QUALITY

A number of issues and concerns have been raised regarding the water quality in the Big Chico Creek watershed, primarily, increased sediment loads and turbidity, fecal coliform contamination, urban stormwater runoff, groundwater contamination, agricultural runoff, siltation-, pollutant-, and garbage-related contamination from the Minnehaha Mine, sediment-, erosion-, and septic-related contamination from the Boy Scout Camp at Chico Meadows, and the potential threat of petroleum contamination from Highway 32 (CDFG 2001a).

FLOW CONDITIONS

Due to flood control management structures (e.g., Lindo Channel and the Sycamore Creek Bypass Channel) Big Chico Creek lacks the flows necessary to maintain the optimal substrate size distributions for the successful incubation of spring-run Chinook salmon embryos. Substrates are often dominated by small gravel, sand, and fine sediments which reduce the interstitial spaces between substrates. Such reductions can result in decreased water flow through redds, leading to low dissolved oxygen concentrations, and poor removal of metabolic wastes. These conditions could reduce embryo growth rates, fitness, and survival.
Fluctuation in flows during the embryo incubation period that could potentially cause redd dewatering events in Big Chico Creek have not been reported to date.

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

Water temperatures in Big Chico Creek, downstream of Iron Canyon, are not suitable for salmonids during the summer months. Most juvenile rearing of spring-run Chinook salmon occurs in the foothill reaches (Big Chico Creek Watershed Alliance Website 2007).

WATER QUALITY

A number of issues and concerns have been raised regarding the water quality in the Big Chico Creek watershed, primarily, increased sediment loads and turbidity, fecal coliform contamination, urban stormwater runoff, groundwater contamination, agricultural runoff, siltation-, pollutant-, and garbage-related contamination from the Minnehaha Mine, sediment-, erosion-, and septic-related contamination from the Boy Scout Camp at Chico Meadows, and the potential threat of petroleum contamination from Highway 32 (CDFG 2001a).

FLOW CONDITIONS

Flows in Big Chico creek begin to decline in the late-spring and are continuous only in the main channel by summer. The Lindo Channel and Mud Creek channels have only intermittent flow during most years during the summer months (DWR 2005a). As a result of these receding flows there is a potential that juvenile fish emigrating later in the spring may be exposed to sub-optimal water temperatures and stranding due to receding flows in Big Chico Creek and its flood control channels (CDFG 2001a).

Lindo Channel often ceases to flow, sometimes trapping downstream migrants several times during a single season (Ward *et al.* 2004). However, a habitat evaluation of Big Chico Creek, Lindo Channel, and Mud Creek conducted by CDFG in 2001 determined that these waterways provided juvenile Chinook salmon with a variety of habitats with suitable cover, substrates, and water temperatures during the winter and early spring (CDFG 2001a).

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Anthropogenic changes in the Big Chico Creek watershed have reduced or degraded riparian habitat. However, some programs are underway to improve riparian habitat by various groups in the area. For example, there has been marked improvement in riparian habitat in Lindo Channel between Manzanita Avenue and Mangrove Avenue (Big Chico Creek Watershed Alliance Website 2007).

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Some of the valley reaches in Lindo Channel, Mud and Rock creeks that are maintained for flood control, lack sufficient vegetation to maintain stream structure (Big Chico Creek Watershed Alliance Website 2007).

LOSS OF FLOODPLAIN HABITAT

Flows in Big Chico Creek, as it emerges onto the Chico Fan at the Five-Mile Recreation Area are regulated for flood control by diversion of flows into two bypass channels: Lindo Channel and the Sycamore Creek Bypass Channel. This has resulted in a disconnection of the river to its normal floodplain and likely results in less habitat diversity in the lower reaches of Big Chico Creek (Big Chico Creek Watershed Alliance Website 2007).

ENTRAINMENT

In addition to providing water supply to agricultural operations in the area, CDFG and USFWS also hold rights to use water to flood wetlands in the Llano Seco Ranch they own and operate. CDFG and USFWS do not use their water rights because of potential impacts to salmon. Relocation of the pumping station would allow them to exercise their legal rights and also reduce fish entrainment along Big Chico Creek.

Entrainment and/or impingement of juvenile fish at the various flood control structures and diversions in Big Chico Creek could potentially cause physical harm to rearing and emigrating juveniles during high flows in the winter and early spring. However, each of the Big Chico Creek diversions have fish screens.

PREDATION

Smallmouth bass are abundant in the valley zone of Big Chico Creek. Smallmouth bass are particularly abundant in dry years while in wet years, high flows typically scour the fish from streams. Therefore, during dry years, smallmouth bass likely present a predation problem for juvenile salmonids in Big Chico Creek (Big Chico Creek Watershed Alliance Website 2007). Big Chico Creek also supports a population of brown trout which are a known piscivorous species (Big Chico Creek Watershed Alliance Website 2007).

HATCHERY EFFECTS

From 1987 to 1992, spring-run Chinook salmon fry were planted in Big Chico Creek during the spring. The plants did not appear to be successful in that very few, if any, of the planted fish returned to spawn (Big Chico Creek Watershed Alliance Website 2007).

3.3.8.5 DEER CREEK

Deer Creek is part of the lower Cascade Mountain Range and drains an area of approximately 229 square miles. Deer Creek meets the Sacramento River near the town of Vina at RM 230. Deer Creek currently supports a small self-sustaining population of spring-run Chinook salmon. The viability of the population in Deer Creek is dependent on the maintenance and protection of what is currently considered to be excellent habitat. Unlike many Central Valley watersheds, headwater stream habitat in the drainages adjacent to Mount Lassen remains relatively undisturbed. Deer Creek has approximately 25 miles of accessible anadromous fish habitat within the Lassen National Forest.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

The first natural barrier in Deer Creek is a fall about nine miles upstream of Polk Springs and approximately 40 miles from the mouth. This fall is about 16 feet high, and salmon had never been known to pass beyond it until a fish ladder was constructed in 1943. There is a second fall on Deer Creek about ten miles upstream of the falls near Polk Springs. This fall contains a sheer drop of about 20 feet. A fish ladder also was constructed at this barrier in early 1950s, but is not operated to allow spring-run Chinook salmon to move upstream because the upstream areas are thought to lack holding habitat (Deer Creek Conservancy Website 2007).

Deer Creek has three potential manmade physical impediments to fish passage in the lower watershed; (1) Stanford-Vina Ranch Diversion Dam, which is equipped with marginally functioning fish ladders; (2) Cone-Kimball Diversion Dam; and (3) Deer Creek Irrigation Company Dam (a collapsible structure that is not a permanent impediment to fish passage). Historically, these water diversions caused instream flows to decrease to levels which blocked access for late-summer upstream fish migration (DWR 2005a). However, the Stanford Vina Ranch Irrigation Company (SVRIC) has responded to CDFG requests for voluntary system shut downs to provide "transport windows" for migrating anadromous salmonids (Deer Creek Conservancy Website 2007). Deer Creek Irrigation District also is implementing a grant funded program with CDFW and DWR to provide bypass flows in exchange for groundwater. In the absence of water exchange agreements, these water diversions may cause low instream flows that block access for later arriving spring-run Chinook salmon.

The SVRIC has also made fish ladder improvements. The negative impacts of water diversions from Deer Creek may be mitigated by a proposed water exchange project, which would provide replacement water in lieu of water from water diversions during biologically critical periods. Replacement water may be from groundwater wells or other sources. Development of this replacement water requires some funding. All of the diversion structures would contain CDFG-designed and operated fish ladders and screens (Deer Creek Conservancy Website 2007).

HARVEST/ANGLING IMPACTS

The entire Deer Creek fishery is limited to catch and release of spring-run Chinook salmon, which occurs from below upper Deer Creek Falls and fishway downstream to the USGS gaging station from the last Saturday in April to November 15 with gear restrictions (i.e., artificial lures and barbless hooks only), and from the USGS gaging station to the mouth of Deer Creek from June 16 through September 30.

WATER TEMPERATURE

The following water temperature information was obtained from the Deer Creek Watershed Conservancy (Deer Creek Conservancy Website 2007).

DWR maintains a water temperature data logger at the Highway 99 Bridge. Data records exist in a computerized database for the period of July 1993 to present. This station is part of the DWR Water Quantity and Quality Measurement Program for collecting long-term basic data at various stations. Since May of 1997, DWR also has maintained continuous water temperature recorders at eight stations in Deer Creek (i.e., at the mouth, Highway 99, upper diversion dam, Ponderosa Way, A Line Road, the Meadows, Upper Falls, and Apperson Camp). However, permanent funding is needed for these gaging stations to negotiate pulse flows with irrigation districts, as the stations are not currently funded after 2009.

A review of the data from July 1993 to the present for the Highway 99 Bridge station indicates that, during the period of mid-May through mid-September, water temperatures exceeded 80°F on numerous occasions.

The CDFG previously monitored water temperatures via data loggers on Deer Creek at Stanford-Vina Dam, A Line Road Crossing, and Ponderosa Way. Data exist for portions of the years from 1992 to 1996. These units were displaced in the floods of January 1997. The purpose for temperature monitoring was to evaluate spring-run salmon life history patterns (e.g., adult/juvenile migration patterns). CDFG has particular concerns about temperatures greater than 80°F below Stanford-Vina Dam.

Reviews of the CDFG data indicate that maximum water temperatures observed at Stanford-Vina Dam for April, May, and June of 1994 were 77.2°F, 81.1°F, and 86.0°F, respectively. There is only one year of record for this station. At the next station upstream (Ponderosa Way), the maximum 1992 water temperature occurred on July 17 (76.1°F). Records for Ponderosa Way during 1993, 1994, and 1996 are incomplete. The maximum water temperature for 1995 was 67.6°F on July 18. The uppermost station at A Line Road Crossing had an observed maximum water temperature in 1992 of 69.6°F (July 17). In 1993, the maximum water temperature at this station was 66°F, which occurred on August 2. The maximum observed water temperatures during 1994 and 1995 were 69.8°F (July 20) and 62.2°F (August 5), respectively. No records exist for the summer and fall during 1996 at A Line Road Crossing.

WATER QUALITY

Water quality monitoring in Deer Creek has shown levels of coliform bacteria, minerals and nutrients to be low and not restrictive to beneficial use (Deer Creek Conservancy Website 2007; DWR 2005a). Concentrations of aluminum have at times exceeded the California Toxic Rule and the EPA chronic criteria for the protection of freshwater organisms (Deer Creek Conservancy Website 2007; DWR 2005a). Deer Creek currently meets EPA water quality standards.

FLOW CONDITIONS

Water diversions reduce streamflow in Deer Creek which may impede migration of adult spring-run Chinook salmon. There is a proposed water exchange project that may allow adequate flows during periods of fish migration. However, an instream flow assessment is necessary to determine appropriate flow levels in Deer Creek (Deer Creek Conservancy Website 2007).

SPAWNING

The Upper Canyon Reach of Deer Creek extends from the lowermost Highway 32 Bridge crossing downstream approximately 14 miles. The known range for adult spring-run Chinook salmon spawning extends from the Upper Falls downstream to the mouth of the canyon (DWR 2005a). Deer Creek is reported to have excellent spawning and holding habitat throughout the Lower Canyon Reach upstream to the Upper Deer Creek Falls near Highway 32.

PASSAGE IMPEDIMENTS/BARRIERS

Deer Creek has five potential manmade physical impediments to fish passage in the lower watershed; (1) Stanford-Vina Ranch Diversion Dam, which is equipped with marginally functioning fish ladders; (2) Cone-Kimball Diversion Dam; (3) North Main Diversion Canal; (4) Deer Creek Irrigation Company Dam (a collapsible structure that is not a permanent impediment to fish passage – but can be during dry springs when irrigation begins early in the year); and (5) an unnamed canal. Historically, these water diversions caused instream flows to decrease to levels which blocked access for late-summer upstream fish migration (DWR 2005a). However, the SVRIC has responded to CDFG requests for voluntary system shut downs to provide "transport windows" for migrating anadromous salmonids (Deer Creek Conservancy Website 2007). Deer Creek Irrigation District also has worked with CDFW and DWR in the past to provide instream flows in exchange for groundwater.

HARVEST/ANGLING IMPACTS

Regulations in Deer Creek permit catch and release fishing only. From Deer Creek falls, downstream for 31 miles, catch and release fishing with artificial lures and barbless hooks is permitted from the last Saturday in April through November 15. From the USGS gaging station cable crossing downstream to the mouth of Deer Creek, catch and release fishing is permitted from June 16 through September 30.

Water Temperatures

Maximum daily water temperatures from the Upper Falls to Ponderosa Way from June through October (1995 through 1998) range between 65.5ºF and 72.5ºF (Klamath Resource Information System Website 2007). It is likely that suitable water temperatures for spawning spring-run Chinook salmon do not occur until mid- to late-October.

Water Quality

Water quality monitoring in Deer Creek has shown levels of coliform bacteria, minerals and nutrients to be low and not restrictive to beneficial use (Deer Creek Conservancy Website 2007; DWR 2005a). Concentrations of aluminum have at times exceeded the California Toxic Rule and the EPA chronic criteria for the protection of freshwater organisms (Deer Creek Conservancy Website 2007; DWR 2005a).

Flow Conditions

There has been no salmonid flow habitat relationships developed for salmonids in Deer Creek. Because there are no major storage facilities on Deer Creek, late fall and winter flow patterns in the area where spring-run Chinook salmon spawning occurs, mimic natural patterns.

Spawning Habitat Availability

Spring-run Chinook salmon habitat in the upper watershed is considered to be excellent, with numerous holding areas and an abundance of spawning gravel (DWR 2005a; USFWS 1999). Flood protection, cattle grazing and water diversions have had a negative effect on habitat in the lower watershed. Stream channelization has reduced the opportunities for gravel deposition. Gravels that might have been deposited are likely to be washed downstream during high flow events because of the increased shear stress produced in these straightened reaches (DWR 2005a; USFWS 1999b).

Physical Habitat Alteration

While habitat in the upper watershed is relatively pristine, channelization has occurred in the lower watershed reducing opportunities for natural deposition of spawning gravel. Additionally, water diversions have led to low-flow conditions which can effect habitat availability (DWR 2005a; USFWS 1999b).

Hatchery Effects

The trucking of FRFH spring-run, and their release into San Pablo Bay, facilitates the straying of adult spring-run hatchery returns and threatens the Deer Creek spring-run population. Genetic integrity of the Deer Creek spring-run may be compromised, and their fitness and productivity lowered. The hatchery stock would compete with native spring-run over available holding and spawning habitat, and possibly transfer the Feather River strain of IHNV to the local population.

Embryo Incubation

Embryo incubation in Deer Creek reportedly occurs from mid-August through mid-March (Deer Creek Conservancy Website 2007).

HARVEST/ANGLING IMPACTS

Because Deer Creek is open to angling during most of the spring-run Chinook salmon embryo incubation period, there may be some inadvertent negative impacts to embryo incubation from anglers wading through redds or otherwise disturbing substrates containing redds.

WATER TEMPERATURE

Water temperature monitoring efforts on Deer Creek include data collected from 1993 to the present at the Highway 99 Bridge as part of the DWR Water Quantity and Quality Measurement Program. In addition, since May of 1997, DWR also has maintained continuous water temperature recorders at eight stations in Deer Creek (Deer Creek Conservancy Website 2007): (1) at the mouth of Deer Creek; (2) Highway 99; (3) upper diversion dam; (4) Ponderosa Way; (5) A Line Road; (6) the Meadows; (7) Upper Falls; (8) and Apperson Camp. However, permanent funding is needed for these gaging stations to negotiate pulse flows with irrigation districts, as the stations are not currently funded after 2009. In addition, data collected at these locations is not representative of conditions within primary spring-run Chinook salmon spawning areas located farther upstream (i.e., the Highway 32 Bridge upstream to the Upper Falls).

Based on recent relatively high natural production estimates for Deer Creek, it is likely that water temperatures in the upstream reaches of Deer Creek are suitable for all juvenile spring-run life stages, including embryo incubation.

WATER QUALITY

Water quality monitoring in Deer Creek has shown levels of coliform bacteria, minerals and nutrients to be low and not restrictive to beneficial use (Deer Creek Conservancy Website 2007; DWR 2005a). Concentrations of aluminum have at times exceeded the California Toxic Rule and the EPA chronic criteria for the protection of freshwater organisms (Deer Creek Conservancy Website 2007; DWR 2005a).

FLOW CONDITIONS

There are no significant water diversions in the upstream reaches (i.e., primary spawning habitat) of Deer Creek that could result in unnatural flow fluctuations that could cause redd dewatering events.

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

Deer Creek reportedly provides relatively good habitat for juvenile salmonids (DWR 2005a). Water temperatures recorded in Deer Creek during the 1997-98 brood year (CDFG 1999b) were within the reported optimal ranges for the juvenile rearing and emigration period (January through March).

WATER QUALITY

Water quality monitoring in Deer Creek has shown levels of coliform bacteria, minerals and nutrients to be low and not restrictive to beneficial use (Deer Creek Conservancy Website 2007; DWR 2005a). Concentrations of aluminum have at times exceeded the California Toxic Rule and the EPA chronic criteria for the protection of freshwater organisms (Deer Creek Conservancy Website 2007; DWR 2005a).

FLOW CONDITIONS

Deer Creek flow average about 320 cfs over the course of a year, however, the stream experiences a high snowmelt flow almost every year and high flows resulting from rain on snow events. These high flows have been known to reach over 21,000 cfs breaching the levee system (MacWilliams *et al.* 2004). The downstream migration of juvenile spring-run Chinook salmon occurs concurrently with peak flows from January through March. The extent to which flow fluctuations from water diversions in Deer Creek may cause juvenile stranding is currently unknown.

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Recent studies have concluded that aquatic habitat in Deer Creek is limited by the current flood control project in the valley floor of the watershed. Effects of the flood control project include lack of habitat diversity and riparian vegetation due to channel maintenance and clearing (MacWilliams *et al.* 2004)

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Flood control activities such as stream channelization, levee construction, and clearing have led to a lack of habitat diversity by constraining high flow and flood events between the levees (MacWilliams *et al.* 2004).

LOSS OF FLOODPLAIN HABITAT

The Deer Creek Flood Control Project was completed by the USACE in 1953. About 16 km of levees were built along lower Deer Creek to control flooding and the channel was straightened and cleared. As a result of this work, natural geomorphic processes were disrupted and the riparian zone was limited to a small band within the constructed levees effectively severing the connection between Deer Creek and the floodplain (MacWilliams *et al.* 2004).

ENTRAINMENT

In Deer Creek, fish screens have been in place at all diversions, although some mortality is still reported to occur (Klamath Resource Information System Website 2007).

PREDATION

Green sunfish, largemouth and smallmouth bass, striped bass and American shad are all piscivorous species that have been introduced to the Sacramento watershed. It is likely that sunfish and bass species both occur in Deer Creek and the loss of natural stream function associated with flood control measures likely enhances predation opportunities.

HATCHERY EFFECTS

Juvenile Chinook salmon in Deer Creek are not likely directly affected by hatchery operations. There is some potential for outmigrating juveniles to be preyed upon by hatchery steelhead as they enter either the Sacramento River.

3.3.8.6 MILL CREEK

Mill Creek is an eastside tributary to the Sacramento River that flows in a southwesterly direction for approximately 60 miles and drains 134 square miles. The creek originates near a thermal spring area in Lassen Volcanic National Park at an elevation of approximately 8,200 feet. It initially flows through meadows and dense forests and then descends rapidly through a steep rock canyon into the Sacramento Valley. Upon emerging from the canyon, the creek flows 8 miles across the Sacramento Valley floor, entering the Sacramento River about 1 mile north of the town of Tehama, near Los Molinos, at an elevation of approximately 200 feet.

The Revised Draft Anadromous Fish Restoration Plan identifies Mill Creek as one of the high priority tributaries to the upper Sacramento River, particularly for its populations of spring-run Chinook salmon and steelhead.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

There are no major reservoirs on Mill Creek. However, two diversions, Ward Dam and Upper Diversion Dam, have historically diverted most of the natural flow during the summer months. Clough Dam, a private diversion serving the properties of two local land owners, was partially washed out in the 1997 flood. The remnants of the dam were removed in 2002; a siphon was installed so that water could still be diverted at the site.

HARVEST/ANGLING IMPACTS

Catch and release fishing is allowed in Mill Creek. For purposes of fishing regulations, the creek is divided into two reaches. From the Lassen National Park boundary downstream to the USGS gaging station at the mouth of Mill Creek Canyon, fishing with barbless hooks and artificial lures is allowed from the last Saturday in April through November 15. From that point downstream to the mouth, fishing is allowed from June 16 through September 30.

WATER TEMPERATURE

Average daily mean water temperatures from May through September (i.e., during the adult spring-run Chinook salmon holding period) in upper Mill Creek during 1997 ranged from approximately 50ºF to approximately 70ºF. During this period average daily water temperatures generally remained between 60ºF and 65ºF (Harvey-Arrison 1999).

WATER QUALITY

Water quality in Mill Creek is adequate to support spring-run Chinook salmon adult immigration and holding.

FLOW CONDITIONS

Mill Creek supports three water diversions. During the irrigation season, instream flows may drop low enough to prevent late migrating adults from moving upstream (DWR 2005a). In dry years when natural flows are low and diversions are operating, increased water temperatures occurring from May through June in the lower reaches of Mill Creek can create a thermal barrier, preventing or delaying adult spring-run Chinook salmon upstream migration (DWR 2005a).

SPAWNING

In Mill Creek, spring-run Chinook salmon hold and spawn from approximately the Lassen National Park boundary downstream to the Little Mill Creek confluence (CDFG 1999b).

PASSAGE IMPEDIMENTS/BARRIERS

Prior to 1997, Clough Dam created a partial barrier to upstream migration in Mill Creek and was utilized as a counting station. In 1997, a flood breached Clough Dam allowing unimpaired access to lower Mill Creek (CDFG 1999b).

HARVEST/ANGLING IMPACTS

Catch and release fishing is allowed in Mill Creek. For purposes of fishing regulations, the creek is divided into two reaches. From the Lassen National Park boundary downstream to the USGS gaging station at the mouth of Mill Creek Canyon, fishing with barbless hooks and artificial lures is allowed from the last Saturday in April through November 15. From that point downstream to the mouth, fishing is allowed from June 16 through September 30.

WATER TEMPERATURES

Maximum daily water temperatures in Mill Creek at various locations recorded from April through November ranged from 62.7ºF to 73.0ºF. In most locations in Mill Creek, water temperatures suitable for spawning occur generally in about the beginning of September. Water temperatures near Little Mill Creek are generally not suitable for spawning until about the beginning of October (CDFG 1999b).

WATER QUALITY

Water quality monitoring in Mill Creek has shown levels of coliform bacteria, minerals and nutrients to be low and not restrictive to beneficial use (DWR 2005a). Concentrations of aluminum and copper have at times exceeded the California Toxic Rule and the EPA chronic criteria for the protection of freshwater organisms (DWR 2005a). Erosion from recent volcanic deposits in and near Lassen Volcanic National Park, in the headwaters of Mill Creek, contributes turbidity to the stream nearly year-round (CDFG 1999b). These water quality conditions likely have no adverse effects on immigrating Chinook salmon.

FLOW CONDITIONS

There have been no flow habitat relationships developed for Mill Creek. There are no major water storage facilities on Mill Creek and water diversions are not occurring during the time and in the area where spring-run Chinook salmon are spawning. Therefore, flows during the spring-run Chinook salmon spawning period tend to mimic historic conditions that occurred under natural flow regimes.

SPAWNING HABITAT AVAILABILITY

The upper reaches of Mill Creek located above diversion dams reportedly provide excellent spring-run spawning habitat (DWR 2005a). Approximately 48 miles of currently accessable spawning habitat exists from the confluence of Little Mill Creek upstream to Morgan Hot Springs (Klamath Resources Information Website 2007). Spawning habitat availability in the upper reaches of Mill Creek is reportedly not easily identifiable due to the variable size range of available substrates. However, individuals appear to be capable of accessing suitable size gravels located beneath the armored surfaces of the river bed (Klamath Resource Information System Website 2007).

PHYSICAL HABITAT ALTERATION

The Mill Creek watershed is relatively long and narrow, with steep slopes. Steep slopes adjacent to the main channel have served as barriers to activity and land use allocations have protected these areas such that the mainstem of the stream is essentially undisturbed (CDFG 1999b).

HATCHERY EFFECTS

The trucking of FRFH spring-run, and their release into San Pablo Bay, facilitates the straying of adult spring-run hatchery returns and threatens the Mill Creek spring-run population. Genetic integrity of the Mill Creek spring-run may be compromised, and their fitness and productivity lowered. The hatchery stock would compete with native spring-run over available holding and spawning habitat, and possibly transfer the Feather River strain of IHNV to the local population.

EMBRYO INCUBATION

HARVEST/ANGLING IMPACTS

Catch and release fishing is allowed in Mill Creek during a portion of the embryo incubation period for spring-run Chinook salmon. Therefore, redds may be exposed to inadvertent disturbance by wading anglers.

WATER TEMPERATURE

Spring-run Chinook salmon redds are located in the upstream reaches of Mill Creek which are generally characterized as having favorable water temperatures during the majority of the embryo incubation period (September through January).

WATER QUALITY

Water quality monitoring in Mill Creek has shown levels of coliform bacteria, minerals and nutrients to be low and not restrictive to beneficial use (DWR 2005a). Concentrations of aluminum and copper have at times exceeded the California Toxic Rule and the EPA chronic criteria for the protection of freshwater organisms (DWR 2005a). Erosion from recent volcanic deposits in and near Lassen Volcanic National Park, in the headwaters of Mill Creek, contributes turbidity to the stream nearly year-round (CDFG 1999b). Increased turbidity could adversely affect developing Chinook salmon embryos.

FLOW CONDITIONS

Flow conditions in the upstream reaches of Mill Creek are not affected by water diversions. As a result, any changes in flow that could potentially result in decreased oxygen flow, or redd dewatering events, would be due to natural fluctuations in streamflow.

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

Mill Creek reportedly provides relatively good habitat for juvenile salmonids (DWR 2005a). Water temperatures recorded in Mill Creek during the 1997-1998 brood year (CDFG 1999b) were within the reported optimal ranges for the juvenile rearing and emigration period (January through March).

WATER QUALITY

Water quality monitoring in Mill Creek has shown levels of coliform bacteria, minerals and nutrients to be low and not restrictive to beneficial use (DWR 2005a). Concentrations of aluminum and copper have at times exceeded the California Toxic Rule and the EPA chronic criteria for the protection of freshwater organisms (DWR 2005a). Erosion from recent volcanic deposits in and near Lassen Volcanic National Park, in the headwaters of Mill Creek, contributes turbidity to the stream nearly year-round (CDFG 1999b).

FLOW CONDITIONS

The downstream migration of juvenile spring-run Chinook salmon occurs concurrently with peak flows from January through March. The extent to which flow fluctuations from water diversions in Mill Creek may affect juvenile salmonid habitat availability and cause juvenile stranding is currently unknown.

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

The Mill Creek watershed is relatively long and narrow, with steep slopes. Steep slopes adjacent to the main channel have served as barriers to activity and land use allocations have protected these areas such that the mainstem of the stream is essentially undisturbed (Klamath Resource Information System Website 2007).

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

The Mill Creek watershed is relatively long and narrow with steep slopes. Steep slopes adjacent to the main channel have served as a barrier to human activity and the environment is essentially undisturbed (Klamath Resource Information System Website 2007)

LOSS OF FLOODPLAIN HABITAT

Because Mill Creek is a relatively narrow watershed with steep slopes, there is little natural connection with the floodplain in the upper reaches.

ENTRAINMENT

In Mill Creek, fish screens have been in place at all diversions, although some mortality is still reported to occur (Klamath Resource Information System Website 2007).

PREDATION

Smallmouth bass, brown trout and green sunfish are all non-native predators known to exist in Mill Creek. The extent of predation that occurs on juvenile spring-run Chinook salmon is unknown.

HATCHERY EFFECTS

Juvenile Chinook salmon in Mill Creek are not likely directly affected by hatchery operations. There is some potential for outmigrating juveniles to be preyed upon by hatchery steelhead as they enter the Sacramento River.

3.3.8.7 ANTELOPE CREEK

Antelope Creek flows southwest from the foothills of the Cascade Range entering the Sacramento River nine miles southeast of the town of Red Bluff. The drainage is approximately 123 square miles and the average stream discharge is 107,200 acre-feet per year.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

Though there are diversion structures in the valley sections of Antelope Creek, there are no major impoundments. A fish ladder at Edwards Irrigation Dam was constructed in 2007 and is reported to be adequate for fish passage. Currently, Paynes Crossing (Middle Slab) is a passage impediment during springs when there is low flow (Brenda Olson, USFWS, personal communication). Anadromous fish (spring- and fall-run Chinook salmon and steelhead) have been able to maintain passage to the upper watershed (Klamath Resource Information System Website 2007). During low-flow conditions, the number of adult spring-run Chinook salmon entering upstream habitat can be reduced due to decreases in water velocities and depths.

HARVEST/ANGLING IMPACTS

Catch and release fishing is allowed in Antelope Creek. For purposes of fishing regulations, the creek is divided into two reaches. From the confluence with the north fork downstream to the USGS gaging station at the mouth of Antelope Creek Canyon, fishing with barbless hooks and artificial lures is allowed from the last Saturday in April through November 15. From that point downstream to the mouth, fishing is allowed from June 16 through September 30. Therefore, the recreational fishery is open for most of the spring-run Chinook salmon adult immigration life stage, although harvest is not allowed.

WATER TEMPERATURE

Maximum water temperatures recorded during July and August from 1992 to 1995 ranged from 67ºF to 70ºF. Water temperatures are likely to warm to support Chinook salmon holding unless cool water refugia are found in deep pools.

WATER QUALITY

As reported in the Eastside Watershed Assessment, there are some water quality concerns in the lower section of Antelpe Creek with the agriculture return ditch.

FLOW CONDITIONS

The degree to which water diversions and structures can impact spring-run Chinook salmon in Antelope Creek varies between years. In some years, some or all of the natural streamflow may be diverted by water-rights holders from mid-spring into the fall (Klamath Resource Information System Website 2007).

SPAWNING

Based on reported observations of spring-run Chinook salmon, the range of their distribution is equal to approximately 9 miles, and extends from approximately 1.6 miles downstream of the Paynes Creek crossing upstream to near McClure Place on the North Fork, and to Bucks Flat on the South Fork (Klamath Resource Information System Website 2007).

PASSAGE IMPEDIMENTS/BARRIERS

Local landowners and CDFG are pursuing a partnership with the Service to implement a fish passage improvement program for Antelope Dam. A fish ladder has been operating at the dam since 1981. Floodwaters damaged the ladder, but a new, more technologically advanced ladder was installed, and improvements were made to the face of the dam to promote use of the ladder. Other than occasional low-flow conditions and beaver dams, there are no other manmade impediments to salmonid upstream migration in Antelope Creek (NMFS Website 2007).

HARVEST/ANGLING IMPACTS

Catch and release fishing is allowed in Antelope Creek. For proposes of fishing regulations, the creek is divided into two reaches. From the confluence with the north fork downstream to the USGS gaging station at the mouth of Antelope Creek Canyon, fishing with barbless hooks and artificial lures is allowed from the last Saturday in April through November 15. From that point downstream to the mouth, fishing is allowed from June 16 through September 30.

WATER TEMPERATURE

Maximum daily water temperatures in Antelope Creek at various locations recorded from April through November (1996, 1997, and 1998) ranged from 60.6ºF to 68.9ºF (Klamath Resource Information System Website 2007).

WATER QUALITY

Water quality in Antelope Creek likely does not cause any adverse effects to spring-run Chinook salmon spawning.

FLOW CONDITIONS

Antelope Creek fish habitat is relatively unaltered above the valley floor but lack of adequate migratory attraction flows into the Sacramento River to this habitat prevents optimum use by anadromous fish (DWR Website 2007b). In wettest years, average flows in winter months range from 200 to 1,200 cfs. In the driest years, flows in winter average 50 cfs. In all but the wettest years, summer and early fall flows average from 20 to 50 cfs. The natural flow pattern is altered by diversions in the lower creek from spring through fall. Flows are typically diverted from April 1 through October 31 (County of Butte Website 2007).

SPAWNING HABITAT AVAILABILITY

Vanicek (1993) rated spawning habitat as fair to poor in Antelope Creek. There have been no flow-spawning habitat relationships developed for Antelope Creek. The effects of fine sediment on spawning areas in Antelope Creek are unknown (Klamath Resource Information System Website 2007).

PHYSICAL HABITAT ALTERATION

The Antelope Creek watershed is relatively long and narrow with steep slopes. Steep slopes adjacent to the main channel have served as a barrier to human activity and the environment is essentially undisturbed (Klamath Resource Information System Website 2007).

HATCHERY EFFECTS

The trucking of FRFH spring-run, and their release into San Pablo Bay, facilitates the straying of adult spring-run hatchery returns and may threaten the Antelope Creek spring-run population. Genetic integrity of the Antelope Creek spring-run could be compromised, and their fitness and productivity lowered. The hatchery stock would compete with native spring-run over available holding and spawning habitat, and possibly transfer the Feather River strain of IHNV to the local population.

Harvest/Angling Impacts

Catch and release fishing is allowed in Antelope Creek during a portion of the embryo incubation period for spring-run Chinook salmon. Therefore, redds may be exposed to inadvertent disturbance by wading anglers.

Water Quality

Because Antelope Creek habitat in the upstream watershed is basically undisturbed, water quality in areas where redds are established likely has no adverse effects on developing embryos.

Flow Conditions

Antelope Creek fish habitat is relatively unaltered above the valley floor, however, flow conditions on Antelope Creek during the spring-run Chinook salmon embryo incubation period are not known at this time.

Juvenile Rearing and Outmigration

Water Temperature

Water temperatures during the spring-run Chinook salmon juvenile rearing and outmigration period have not been reported to the public, although real-time water temperature and flow monitoring data recorders were recently installed at various locations in Antelope Creek as part of an AFRP monitoring project.

Water Quality

Although little water quality information on Antelope Creek is available, because Antelope Creek habitat in the upstream watershed is basically undisturbed, it is hypothesized that water quality in the upstream reaches is not likely a problem for juvenile salmonids.

Flow Conditions

The downstream migration of juvenile spring-run Chinook salmon occurs concurrently with peak flows from January through April. The extent to which flow fluctuations from water diversions in Antelope Creek may affect juvenile salmonid habitat availability and cause juvenile stranding is currently unknown. However, there are two diversions in Antelope Creek at the canyon mouth. One is operated by the Edwards Ranch, which has water rights of 50 cfs, and the other by the Los Molinos Water Company which has a water right of 70 cfs. Flows are diverted between April 1 and October 31. The stream is usually dewatered when both diversions operate (Klamath Resource Information System Website 2007). In 2007 and 2008, rescues of spring Chinook salmon juveniles and steelhead have been necessary due to an early irrigation season. Permanent funding is needed for these gaging stations to negotiate pulse flows with irrigation districts (Brenda Olson, USFWS, personal communication).

Loss of Riparian Habitat and Instream Cover

The Antelope Creek watershed is relatively long and narrow with steep slopes. Steep slopes adjacent to the main channel have served as a barrier to human activity and the environment is essentially undisturbed (Klamath Resource Information System Website 2007).

LOSS OF FLOODPLAIN HABITAT

Because Antelope Creek is a relatively narrow watershed with steep slopes, there is little natural connection with the floodplain (Klamath Resource Information System Website 2007).

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

The Antelope Creek watershed is relatively long and narrow with steep slopes. Steep slopes adjacent to the main channel have served as a barrier to human activity and the environment is essentially undisturbed. Therefore, above the valley floor, the creek has essentially retained its natural functions.

ENTRAINMENT

The Antelope Main canal could potentially cause entrainment or impingement of juvenile spring-run Chinook salmon. The diversions associated with this canal are equipped with fish screens, but there are no bypasses. In addition, entrainment has been observed at Paynes Crossing (Brenda Olson, USFWS, personal communication).

PREDATION

Smallmouth bass, brown trout and green sunfish are all non-native predators known to exist in Antelope Creek. The extent of predation that occurs on juvenile Chinook salmon is unknown.

HATCHERY EFFECTS

Juvenile Chinook salmon in Antelope Creek are not likely directly affected by hatchery operations. There is some potential for outmigrating juveniles to be preyed upon by hatchery steelhead as they enter either the Sacramento River.

3.3.9 BASALT AND POROUS LAVA DIVERSITY GROUP

The basalt and porous lava spring-run Chinook salmon Diversity Group historically was comprised of populations in Battle Creek, the upper Sacramento River (upstream of where Keswick and Shasta dams now reside), the McCloud River, and the Pit River (**Figure 3-12**). Currently, within this diversity group, spawning populations of Chinook salmon exhibiting spring-run characteristics occur in Battle Creek and the mainstem Sacramento River immediately downstream of Keswick Dam.

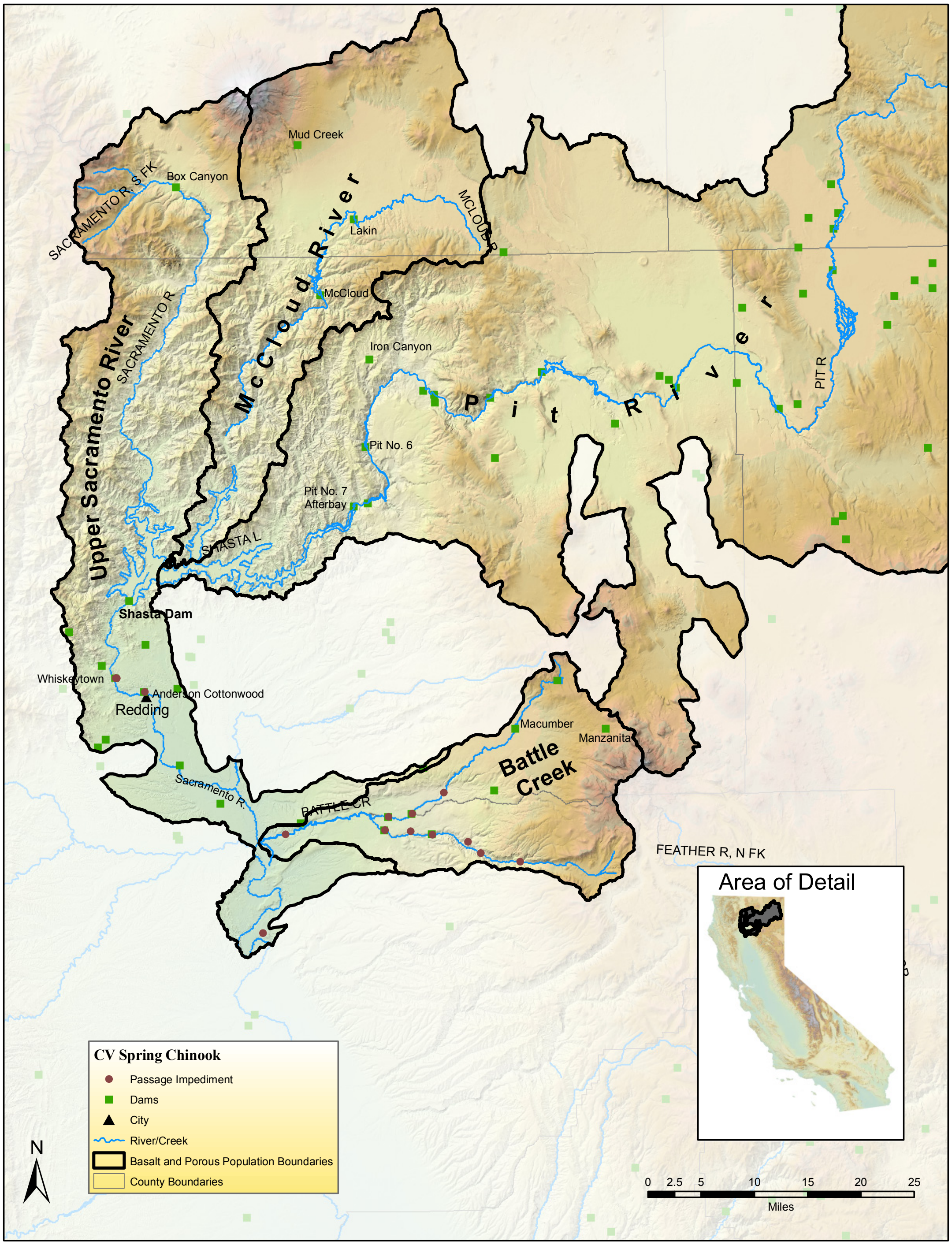

Figure 3-12. Basalt and Porous Lava Spring-run Chinook Salmon Diversity Group

3.3.9.1 BATTLE CREEK

Battle Creek enters the Sacramento River approximately five miles southeast of the Shasta County town of Cottonwood. It flows into the Sacramento Valley from the east, draining a watershed of approximately 360 square miles.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

The main stem of Battle Creek has had three structures that act as potential impediments to adult anadromous fish migration: (1) the CNFH barrier weir that diverts returning hatchery fish into the hatchery for brood stock collection each year from September through early March; (2) the Orwick seasonal gravel diversion dam; and (3) the tailrace from PG&E's Coleman Powerhouse, which had been known to attract anadromous salmonids into an area with little spawning habitat, but has currently been improved by the construction of a fish exclusion weir in 2004.

HARVEST/ANGLING IMPACTS

Battle Creek supports a popular recreational fishery. As a result, some level of poaching likely occurs. Current fishing regulations do not allow any fishing from the mouth of Battle Creek to 250 feet upstream of the weir at the CNFH. Upstream of that point, catch and release fishing with artificial lures and barbless hooks is allowed from the last Saturday in April to November 15.

WATER TEMPERATURE

Battle Creek water temperatures is generally cool because of the many cold springs that feed into it and because it receives significant snowmelt during the spring and summer. However, operation of hydroelectric facilities also influences water temperatures in Battle Creek. Reduced streamflow resulting from diversions may cause the water temperatures in the stream to warm. Shunting water between the power facilities also may cause stream warming if the water flows in open canals for some distance (KRIS Website 2007).

The North Fork Battle Creek contains excellent habitat for spring-run Chinook, even at the lowest (i.e., elevation) sections because cold springs feed the creek. The South Fork is also influenced by springs and would maintain at least acceptable habitat in its lower sections under a restored flow regime. The observed water temperatures in Battle Creek also indicate that the mainstem might provide some acceptable habitat for spring Chinook holding in wet years (USFWS 2008). Average daily water temperatures for various locations in the mainstem and north and south forks of Battle Creek are shown below in **Table 3-2**.

Table 3-2. Average Daily Water Temperatures (°F) in Battle Creek From 1 June through 30 September (Adult Holding Period), 1998 through 2007.

Average Daily Water Temperature (°F) from 1 June through 30 September (adult holding period)										
Location	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Battle Creek at Mouth	—	64.0	67.0	67.7	67.2	65.4	66.3	65.4	64.4	66.8
BC below Confluence of North and South Fork	57.4	60.0	62.9	62.8	64.7	62.0	62.7	61.7	60.4	62.1
BC - South Fork at Coleman Diversion Dam	57.1	59.0	60.7	59.8	60.1	60.1	60.3	59.5	58.9	58.9
BC - North Fork at Wildcat Dam	58.5	58.6	59.9	60.4	60.1	59.5	58.7	59.4	59.6	60.8
BC - North Fork at Eagle Canyon Dam	56.3	57.1	58.7	58.2	58.1	58.2	57.9	59.6	60.4	57.7

Source: (USFWS 2008)

WATER QUALITY

Little information on water quality in Battle Creek is available. However, it is assumed to be quite good as Battle Creek also provides water to the CNFH.

FLOW CONDITIONS

Two studies were conducted to determine the flows necessary to facilitate fish passage within the Battle Creek watershed (Kier Associates 1999). The results of these two studies were used to develop instream flow alternatives for the Battle Creek Salmon and Steelhead Restoration Project (Reclamation and SWRCB 2005). These new recommended minimum instream flows range from 35 to 88 cfs.

SPAWNING

Prime quality spawning, holding, and rearing habitat for steelhead, and winter-run and spring-run Chinook occurs upstream of Wildcat and Coleman dams on the north and south forks of Battle Creek, respectively. The habitat and water temperatures in these upper stream reaches are excellent for all life stages of salmonids. Battle Creek has complex channel features that create relatively good habitat for Central Valley salmonids including, an abundance of coldwater springs, high natural flows, and continuous flows during the summer months. High quality spawning habitat for spring-run Chinook salmon is primarily located upstream of Wildcat and Coleman dams on the north and south forks of Battle Creek (DWR 2005a).

PASSAGE IMPEDIMENTS/BARRIERS

The mainstem of Battle Creek has had three structures that act as potential impediments to adult anadromous fish migration: (1) the CNFH barrier weir that diverts returning hatchery fish into the hatchery for brood stock collection each year from September through early March; (2) the Orwick seasonal gravel diversion dam; and (3) the tailrace from PG&E's Coleman Powerhouse, which had been known to attract adult Chinook salmon and steelhead into an area with little spawning habitat, but has currently been improved by the construction of a fish exclusion weir in 2004 (DWR 2005a).

In the mid-1990s, the fish ladders at Eagle Canyon on North Fork Battle Creek and PG&E's Colman Dam on South Fork Battle Creek were intentionally closed primarily to manage populations of spring-run Chinook salmon. Closing the ladders limited the amount of stream available for spring-run Chinook salmon that passed the CNFH barrier weir. It was assumed that this would increase the rate at which fish encounter each other during the spawning season, and would reduce entrainment by unscreened diversions.

The North Fork Battle Creek has three dams: (1) Wildcat Dam; (2) Eagle Canyon Dam; and (3) North Battle Creek Dam. All of these structures are located downstream of natural barriers to upstream fish migration. These structures divert water for hydroelectric power production.

The South Fork of Battle Creek also has three hydroelectric diversion dams downstream of natural barriers: (1) South Diversion Dam; (2) Inskip Dam; and (3) Coleman Dam.

HARVEST/ANGLING IMPACTS

Battle Creek supports a popular recreational fishery. As a result, some level of poaching likely occurs. Current fishing regulations do not allow any fishing from the mouth of Battle Creek to 250 feet upstream of the weir at the CNFH. Upstream of that point, catch and release fishing with artificial lures and barbless hooks is allowed from the last Saturday in April to November 15.

WATER TEMPERATURE

DWR has 22 water temperature monitoring locations within the Battle Creek watershed. Field parameters such as dissolved oxygen, electrical conductivity, turbidity, and water temperature have been collected since 1998 (DWR 2005a).

Average daily water temperatures in 1988 and 1989 in Battle Creek above the CNFH approached or exceeded lethal water temperatures for holding and spawning spring-run Chinook salmon during summer months. During the period July 1 to September 14, average water temperature exceeded 66.2°F in all four years, indicating that spring-run Chinook salmon adults holding at the site would be unable to successfully spawn.

Water temperatures in Battle Creek warm at lower elevations due to higher air temperatures. The North Fork above its confluence with the South Fork is the warmest location while those reaches upstream are cooler. Water temperatures generally do not rise significantly between Wildcat Diversion Dam and Eagle Canyon Dam because large amounts of cold spring water enter the creek at Eagle Canyon, located between these two locations. High water temperatures that may occur at these locations are partially a result of low flows related to hydropower operation. Water temperatures become cool enough (i.e., < 66ºF) for adult spring-run Chinook holding at Eagle Canyon Diversion Dam and the North Battle Feeder Dam.

During the period July 1 to September 14, 2001, average water temperatures exceeded 66.2°F below the Wildcat Diversion Dam and the Eagle Canyon Diversion Dam, indicating that spring-run Chinook adults at the site would be unable to successfully spawn. During the period September 15 through 30, average water temperatures did not exceed 62°F, indicating that all sites were suitable for spring-run Chinook salmon spawning (Armour 1991), (USFWS 1995d), and (CDFG 1998).

WATER QUALITY

Water quality in Battle Creek is suitable for salmonid spawning.

FLOW CONDITIONS

Monthly average flows in Coleman Canal above the Coleman Forebay (USGS Gage 11376450) from August through October were greater than 250 cfs (1979 to 2001). Results of an IFIM study conducted by the Battle Creek Working Group (Kier Associates 1999), determined that flows necessary to provide 95 percent of the maximum weighted usable area (WUA) for the upper reaches of North Fork Battle Creek would be approximately 60 cfs from August through September. The monthly average flow in North Fork Battle Creek below the diversion to Eagle Canyon power canal (USGS Gage 11376150) from August through November (1995 to 2001) was approximately 30 cfs. The average monthly average flow in North Fork Battle Creek below the diversion to the Wildcat Channel (USGS Gage 11376160) from August through November (1995 to 2001) was approximately 35 cfs.

Results of the IFIM study conducted by the Battle Creek Working Group (Kier Associates 1999), determined that flows necessary to provide flows that would provide 95 percent of the maximum WUA for the upper reaches of South Fork Battle Creek would be approximately 65 cfs from August through September. The monthly average flow in South Fork Battle Creek at the South Powerhouse power canal (USGS Gage 11376410) from August through November (1980 to 2001) were greater than approximately 150 cfs (KRIS Website 2007).

SPAWNING HABITAT AVAILABILITY

Stream channel conditions in Battle Creek are considered suitable for salmonid production (Battle Creek Watershed Conservancy 2004). Reclamation (2003) cited *in* Battle Creek Watershed Conservancy 2004, assumed that key stream habitat conditions were of sufficient quality that the abundance of threatened or endangered salmonid populations could be substantially increased by increasing instream flows and constructing fish passage facilities at the Battle Creek Hydroelectric Project diversion dams.

SPAWNING SUBSTRATE AVAILABILITY

Brown and Kimmerer (2004) report that areas suitable for salmonid spawning, based on substrate particle size, are relatively scarce. However, they also report that in-river conditions are likely not a limiting factor due to the current low population numbers of targeted species.

PHYSICAL HABITAT ALTERATION

Stream channel conditions in Battle Creek during the late 20th century have been considered suitable for salmonid production. Key stream habitat conditions appear to be of sufficient quality such that the abundance of threatened or endangered salmonid populations could be increased by increasing instream flows and constructing fish passage facilities at the Battle Creek Hydroelectric Project diversion dams. Land management activities currently occurring in the watershed appear to have little impact on the potential to restore anadromous salmonids to this watershed (Battle Creek Watershed Conservancy 2004)

HATCHERY EFFECTS

The CNFH is located on lower Battle Creek and operations of the hatchery may have negative effects on habitat in lower Battle Creek. For example: (1) operations of the fish ladder at the CNFH may deny access to upstream habitat for spring-run Chinook salmon; (2) broodstock selection at the CNFH may have led to hybridization of fall- and spring-run stocks; and (3) excess production of fall-run Chinook salmon may be overwhelming the carrying capacity of habitat in lower Battle Creek (Ward and Kier 1999b).

Stakeholders and agencies interested in the restoration of Battle Creek fisheries have been working to modify facilities at the CNFH with the goal of isolating CNFH operations from Battle Creek. For example, an ozone treatment plant was installed to keep pathogens out of the hatchery water supply, preventing the release of diseased fish to the system. Additionally, proposals had been made (Ward and Kier 1999b), and construction since began in 2008, to modify the CNFH barrier dam to keep hatchery produced fish out of the main portion of the Battle Creek watershed.

A technical review panel determined that the probability of hybridization between spring-run and fall-run Chinook salmon is unknown (CALFED Bay-Delta Program 2004). While the probability of hybridization is unknown, the potential loss of genetic information through such occurrences could be extremely counter productive to recovery efforts. The review panel recommended that the potential for hybridization be minimized by abandoning restoration of fall and late-fall-run Chinook salmon in Battle Creek, or to reserve those efforts until spring-run Chinook salmon populations have become fully restored (i.e., removed ESA protection). It was recommended by the review panel that passage of fall and late-fall Chinook salmon above the dam, via ladder or jumping, be prevented or reduced to the lowest possible level during the initial stages of recovery. This could be achieved by closing the fish ladder to block fall and late-fall-run Chinook salmon migration.

In order to protect spring-run Chinook salmon from introgressing with fall-run in upper Battle Creek, CNFH changed the timing for closing the barrier weir from September 1 to August 1, i.e., the barrier is now closed the last day of July. Most, if not all, of the spring-run Chinook salmon are believed to have moved above the weir by this time; any spring-run Chinook holding below the weir at its closing could potentially spawn below the weir or enter CNFH and possibly be utilized as broodstock for the fall-run program.

EMBRYO INCUBATION

HARVEST/ANGLING IMPACTS

Battle Creek supports a popular recreational fishery. As a result, some level of disturbance of redds by wading anglers likely occurs.

WATER TEMPERATURE

Water temperature problems may occur during some years due to the diversion of coldwater springs into canals away from adjacent stream channels on the North Fork and South Fork of Battle Creek. However, it is unknown the degree to which these operations currently affect the spring-run Chinook salmon juvenile rearing and emigration life stage (Reclamation et al. 2004).

WATER QUALITY

Water quality factors in Battle Creek are not expected to have adverse effects on developing Chinook salmon embryos.

FLOW CONDITIONS

The operations of the Battle Creek Hydroelectric Project causes water level changes in some reaches of Battle Creek that are more frequent and rapid then those which occur naturally. The effects of these flow changes have not been the direct focus of any study to date. However, the Battle Creek Working Group has identified potential rates of flow fluctuation of less than 0.10 feet per hour based on previous studies conducted in the Pacific Northwest (Ward and Kier 1999a).

As part of the Battle Creek Salmon and Steelhead Restoration Project, PG&E, in cooperation with the resource agencies, has agreed to adaptively manage instream flows in Battle Creek by adjusting flows at diversion dams to maintain habitat and prevent redd dewatering events (KRIS Website 2007).

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

Water temperature problems may occur during some years due to the diversion of coldwater springs into canals away from adjacent stream channels on the North Fork and South Fork of Battle Creek. However, it is unknown the degree to which these operations currently affect the spring-run Chinook salmon juvenile rearing and emigration life stage (KRIS Website 2007).

WATER QUALITY

Water quality factors in Battle Creek are not likely to adversely affect juvenile Chinook salmon.

FLOW CONDITIONS

Powerhouse operations cause flow fluctuations of up to 200 cfs in some reaches of the Battle Creek watershed which could potentially lead to juvenile stranding events. It has been estimated that powerhouse diversions on the North Fork and South Fork of Battle Creek divert up to 97 percent of the natural unimpaired flow (Reclamation et al. 2004).

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Land management activities currently occurring in the watershed appear to have little impact on the potential to restore anadromous salmonids to this watershed (Battle Creek Watershed Conservancy 2004). Restoration of riparian corridors in lower Battle Creek are currently underway (Battle Creek Working Group 1999).

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Stream channel conditions (e.g., gravel distribution and abundance, sedimentation, channel morphology) in Battle Creek are considered to be suitable for salmonid production (Battle Creek Watershed Conservancy 2004). Similarly, land management activities in the watershed are assumed to have little impact on the potential to restore anadromous salmonids to the system (Battle Creek Watershed Conservancy 2004).

LOSS OF FLOODPLAIN HABITAT

There is little to no flood control capacity in the Battle Creek watershed.

ENTRAINMENT

The high volume of surface water diverted from unscreened agricultural and hydroelectric diversions in Battle Creek constitutes a substantial threat to rearing and emigrating juvenile salmonids. However, it is anticipated the installation of positive fish barrier screens in the near future as part of the proposed water management strategy for the Battle Creek watershed will reduce the amount of juvenile entrainment at water diversions (KRIS Website 2007).

PREDATION

The USFWS has identified predation as one of the ways that juvenile salmonids released from the CNFH may affect natural populations of salmonids (Battle Creek Working Group 1999). However, the actual extent of predation on natural populations by steelhead and Chinook salmon on natural populations is not known (Battle Creek Working Group 1999).

HATCHERY EFFECTS

The USFWS has expressed concern that predation, disease transmission and competition/displacement are ways in which juvenile salmonids released from the CNFH may affect natural salmonid populations (Battle Creek Working Group 1999). The actual extent of these potential impacts is not known, although there is speculation that these factors are minimal or non-existent (Battle Creek Working Group 1999). However, these conclusions were not based on completed investigations. Furthermore, these conclusions that suggest minimal impact were derived during a period when Chinook salmon and steelhead populations were depressed. As restoration of Battle Creek salmonid populations proceed, increased interactions between hatchery operations and natural fish populations are expected, suggesting that more investigations of possible impacts are required (Battle Creek Working Group 1999).

3.3.9.2 UPPER SACRAMENTO RIVER

See Section 3.3.7 for a discussion of potential spring-run Chinook salmon in the upper Sacramento River.

3.3.10 NORTHWESTERN CALIFORNIA DIVERSITY GROUP

The northwestern California spring-run Chinook salmon Diversity Group historically was comprised of populations in Stony, Thomes, Beegum, and Clear creeks (**Figure 3-13**). Spring-run Chinook salmon have likely been extirpated from Stony Creek and only small populations of spring-run Chinook salmon occur in Thomes, Beegum, and Clear creeks.

3.3.10.1 THOMES CREEK

Thomes Creek enters the Sacramento River four miles north of the town of Corning. It flows into the Sacramento Valley from the west, draining a watershed of approximately 188 square miles.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

There are no significant dams on Thomes Creek other than two seasonal diversion dams, one near Paskenta and the other near Henleyville. Several small pump diversions are seasonally operated in the stream (DWR Website 2007b). These dams would be in place during the time when spring-run Chinook salmon would be immigrating to upstream areas and likely present obstacles to upstream immigration. Additionally, gravel mining downstream of the Tehama-Colusa Canal siphon crossing has reportedly resulted in a partial barrier to salmonids returning to Thomes Creek to spawn (Vestra Resources, Inc. 2006).

HARVEST/ANGLING IMPACTS

Legal harvest of salmonids in Thomes Creek is not permitted. Angling is permitted but restricted to barbless hooks and artificial flies and lures only.

WATER TEMPERATURE

During most years, water temperatures during the summer months are likely too warm to support adult spring-run Chinook salmon holding.

WATER QUALITY

The surface water quality of streams draining eastward from the Coast Range is generally poor. These streams generally have very high suspended sediment loads due to the metavolcanic bedrock and schist formations which produce clays that stay in suspension during turbulent flow conditions. Soil disturbance within these watersheds can accelerate erosion and sedimentation processes and lead to increased metal and nutrient concentrations. High concentrations of metals and nutrients are commonly present during both low flow and storm runoff events. These concentrations frequently exceed water quality criteria established for the protection of beneficial use or the maintenance of aquatic life. However, water quality is not likely to cause direct harm to adult salmonids utilizing Thomes Creek as a migration corridor.

FLOW CONDITIONS

Thomes Creek is usually dry or intermittent below the USGS stream gage near Paskenta until the first heavy fall rains occur (DWR Website 2007b). Therefore spring-run Chinook salmon utilization of Thomes Creek would likely only occur during wet years.

Figure 3-13. Northwestern California Spring-run Chinook Salmon Diversity Group

SPAWNING

PASSAGE IMPEDIMENTS/BARRIERS

There are no significant dams on Thomes Creek other than two seasonal diversion dams, one near Paskenta and the other near Henleyville. Several small pump diversions are seasonally operated in the stream (DWR Website 2007b). These dams would be in place during the time when spring-run Chinook salmon would be immigrating to upstream areas and likely present obstacles to upstream immigration.

HARVEST/ANGLING IMPACT

Legal harvest of salmonids in Thomes Creek is not permitted. Angling is permitted but restricted to barbless hooks and artificial flies and lures only.

WATER TEMPERATURE

Water temperatures in Thomes Creek are likely too warm to support spring-run Chinook salmon spawning until at least mid-October.

WATER QUALITY

The surface water quality of streams draining eastward from the Coast Range is generally poor. These streams generally have very high suspended sediment loads due to the metavolcanic bedrock and schist formations which produce clays that stay in suspension during turbulent flow conditions. Soil disturbance within these watersheds can accelerate erosion and sedimentation processes and lead to increased metal and nutrient concentrations. High concentrations of metals and nutrients are commonly present during both low flow and storm runoff events. These concentrations frequently exceed water quality criteria established for the protection of beneficial use or the maintenance of aquatic life. Total phosphorus concentrations are at stimulatory levels for algae (DWR Website 2007b).

FLOW CONDITIONS

Flows in the Thomes Creek watershed fluctuate seasonally. Summer low flows are frequently measured at less than 4 cfs, while winter flows often exceed 4,500 cfs. Flows recorded at Paskenta range from zero in 1977 to 37,800 cfs during December 1964. The December 1964 runoff event was triggered by a major rain-on-snow storm. Periodic large floods like the 1964 event can result in tremendous bedload movement (DWR Website 2007b).

Thomes Creek is usually dry or intermittent below the USGS stream gage near Paskenta until the first heavy fall rains occur (DWR Website 2007b). Therefore, spring-run Chinook salmon spawning in Thomes Creek would likely only occur during wet years.

SPAWNING HABITAT AVAILABILITY

Historically, there was about 30 river miles of potential Chinook salmon habitat available in Thomes Creek, of which only the lower 4 miles are currently available (NMFS Website 2005). A small spring-run Chinook salmon run was known to utilize habitat about 8 miles upstream of the town of Paskenta when streamflow was adequate (NMFS Website 2005).

PHYSICAL HABITAT ALTERATION

Little data on habitat alteration within the Thomes Creek Watershed is available. However, Gauthier and Hoover (2005) report that Thomes Creek is one of the largest sediment producers in the western United States. Excessive sediment loading is likely caused by land use practices and road building in the upper watershed.

HATCHERY EFFECTS

The FRFH produces spring-run Chinook salmon and the current hatchery practice of releasing juveniles into San Pablo Bay increases potential straying rates. Hatchery influence could be an important factor influencing the viability of the spring-run Chinook salmon population in Thomes Creek because so few spring-run Chinook salmon return to spawn there.

EMBRYO INCUBATION

HARVEST/ANGLING IMPACTS

Because angling is permitted in Thomes Creek, it is possible that anglers could disturb redds by wading through the stream.

WATER TEMPERATURE

Water temperatures in anadromous salmonid accessible reaches of Thomes Creek likely are not suitable for Chinook salmon embryo incubation until at least mid-October.

WATER QUALITY

The surface water quality of streams draining eastward from the Coast Range is generally poor. These streams generally have very high suspended sediment loads due to the metavolcanic bedrock and schist formations which produce clays that stay in suspension during turbulent flow conditions. Soil disturbance within these watersheds can accelerate erosion and sedimentation processes and lead to increased metal and nutrient concentrations. High concentrations of metals and nutrients are commonly present during both low flow and storm runoff events. These concentrations frequently exceed water quality criteria established for the protection of beneficial use or the maintenance of aquatic life. Total phosphorus concentrations are at stimulatory levels for algae (DWR Website 2007b). These water quality factors would likely decrease survival of Chinook salmon embryos incubating in Thomes Creek.

FLOW CONDITIONS

Thomes Creek has an unimpaired natural pattern of flashy winter and spring flows and very low summer and fall flows creating an environment of fairly inconsistent habitat (CALFED 2000d). Inconsistent flows, particularly during the fall and early winter months, promote an increased potential for redd dewatering. For example, if salmon construct a redd and spawn in shallow water during a period of high flows, a subsequent period of lower flows could result in the redd becoming exposed to dry conditions.

Juvenile Rearing and Outmigration

Water Temperature

Water temperatures in Thomes Creek likely become unsuitable for rearing Chinook salmon by late spring.

Water Quality

The surface water quality of streams draining eastward from the Coast Range is generally poor. These streams generally have very high suspended sediment loads due to the metavolcanic bedrock and schist formations which produce clays that stay in suspension during turbulent flow conditions. Soil disturbance within these watersheds can accelerate erosion and sedimentation processes and lead to increased metal and nutrient concentrations. High concentrations of metals and nutrients are commonly present during both low flow and storm runoff events. These concentrations frequently exceed water quality criteria established for the protection of beneficial use or the maintenance of aquatic life. Total phosphorus concentrations are at stimulatory levels for algae (DWR Website 2007b).

Flow Conditions

Thomes Creek has an unimpaired natural pattern of flashy winter and spring flows and very low summer and fall flows creating an environment of fairly inconsistent habitat (CALFED 2000d). These conditions are not conducive to supporting a persistent population of Chinook salmon. However, during wet years some Chinook salmon spawning may occur and lower Thomes Creek could be utilized for some juvenile rearing or, during wet years, some non-natal juvenile rearing may occur.

Loss of Riparian Habitat and Instream Cover

The lower reach of Thomes Creek has been significantly altered by the construction of flood control levees and bank protection measures (i.e., riprapping) (CALFED 2000d). These measures have resulted in reduced habitat for juvenile Chinook salmon.

Loss of Natural River Morphology and Function

Channel modification projects designed to prevent flood-related damage (e.g., levee construction and bank riprapping) have degraded natural processes which serve to recruit gravel, provide instream cover and forage, and provide habitat diversity in lower Thomes Creek.

Loss of Floodplain Habitat

The construction of levees and bank riprapping of lower Thomes Creek have disconnected the channel from its historic floodplain, thereby preventing the recruitment of large woody debris and natural processes associated with periodic floodplain inundation.

Entrainment

Agricultural diversions on Thomes Creek are unscreened and any outmigrating salmonids likely are susceptible to entrainment in the diversions.

Predation

Sacramento pikeminnow is likely the most important predator of juvenile salmonids in Thomes Creek. While the pikeminnow is native to these waters, habitat alteration may have changed the predator prey dynamics in the system conferring an advantage to pikeminnow.

HATCHERY EFFECTS

The trucking of FRFH spring-run Chinook salmon, and their release into San Pablo Bay, facilitates the straying of adult spring-run hatchery returns and could potentially threaten any native spring-run in Thomes Creek.

3.3.10.2 COTTONWOOD/BEEGUM CREEK

Cottonwood Creek drains the west side of the Central Valley and enters the Sacramento River a short distance downstream from the Redding-Anderson area. Beegum Creek is a tributary to Cottonwood Creek and supports most spring-run Chinook salmon habitat in the Cottonwood Creek watershed. Cottonwood Creek is likely used only as a migration corridor.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

There are no storage reservoirs or irrigation diversions in Cottonwood creek, however, the ACID siphon goes under the creek and can be a passage impediment during fall and spring flows.

HARVEST/ANGLING IMPACTS

Legal harvest of salmonids in Cottonwood Creek and its tributaries is not permitted. Angling is permitted but restricted to barbless hooks and artificial flies and lures only.

WATER TEMPERATURE

Clark (1929) reported that Cottonwood Creek formerly supported spring-run Chinook salmon. Currently, other than Beegum Creek, spring-run Chinook salmon likely do not utilize Cottonwood Creek except as a migration corridor to Beegum Creek.

High water temperatures in Cottonwood Creek likely present a thermal barrier to migrating spring-run Chinook salmon beginning in May. This population has been observed to arrive earlier than most spring-run due to high water temperatures at the mouth of Cottonwood Creek (CDFG 2004b).

WATER QUALITY

Water quality in Cottonwood Creek does not likely adversely affect immigrating adult salmonids. However, more sensitive life stages may be affected as discussed below.

FLOW CONDITIONS

During spring of drier years, low flows in Cottonwood Creek may impede or prevent the upstream migration of spring-run Chinook salmon to over-summer holding areas (CALFED 2000d).

SPAWNING

PASSAGE IMPEDIMENTS/BARRIERS

Spawning surveys have confirmed that spring-run Chinook salmon are both spatially and temporally isolated from fall-run in Beegum Creek (CDFG 2004b). Spawning of Chinook salmon exhibiting spring-run characteristics in Cottonwood Creek is not known to occur.

HARVEST/ANGLING IMPACT

Legal harvest of salmonids in Cottonwood Creek and its tributaries is not permitted. Angling is permitted but restricted to barbless hooks and artificial flies and lures only.

WATER TEMPERATURE

Spawning in Beegum Creek by spring-run Chinook salmon is delayed until mid- to late-October, which is later than timing observed for other Central Valley spring-run populations. This delay in spawning timing is likely due to high water temperatures extending through September in Beegum Creek (CDFG 2004b).

WATER QUALITY

Water quality in Cottonwood or Beegum Creeks likely has no direct adverse effects on spawning salmonids. However, more sensitive life stages may be affected as discussed below.

FLOW CONDITIONS

Flows in Beegum Creek, where most spring-run Chinook salmon spawning occurs likely mimics historic patterns.

SPAWNING HABITAT AVAILABILITY

Currently, approximately 8 river miles of habitat are available in Beegum Creek for spring-run Chinook salmon (NMFS Website 2005). Recent spawning escapements to Beegum Creek are depicted in **Figure 3-14**.

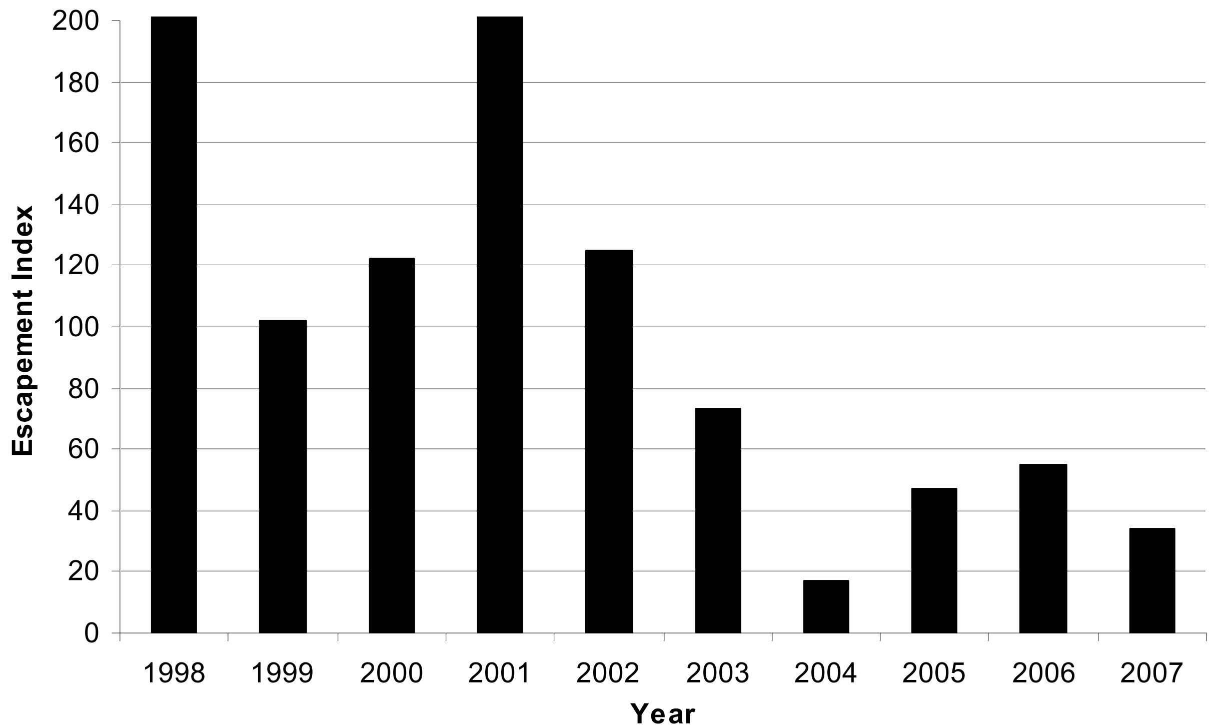

Figure 3-14. Beegum Creek Spawning Escapement Estimates (1993 – 2007)
Source: (CDFG 2009)

SPAWNING SUBSTRATE AVAILABILITY

Coarse sediment supply in Cottonwood Creek is adversely affected by gravel mining. Mining reduces the natural gravel recruitment to potential spawning areas potentially resulting in channel armoring.

PHYSICAL HABITAT ALTERATION

There are no large water development projects or comprehensive flood control measures in the Cottonwood Creek drainage. Habitat alteration has arisen from timber harvest in the upper watershed, grazing in the middle watershed and extensive gravel mining in the lower watershed. There has been a combination of effects that have had a negative effect on fish habitat in the watershed, including grazing (which occurs throughout the watershed), timber harvest, road building, historic gold mining, development, dredging, and instream gravel mining.

HATCHERY EFFECTS

The trucking of FRFH spring-run, and their release into San Pablo Bay, facilitates the straying of adult spring-run hatchery returns and may threaten the Cottonwood/Beegum Creek spring-run population. Genetic integrity of the Cottonwood/Beegum Creek spring-run may be compromised, and their fitness and productivity lowered. The hatchery stock would compete with native spring-run over available holding and spawning habitat, with the possibility of transferring the Feather River strain of IHNV to the local population.

EMBRYO INCUBATION

Harvest/Angling Impacts

Because angling is permitted in Cottonwood Creek and its tributaries, it is possible that anglers could disturb redds by wading through the stream.

Water Temperature

Spawning in Beegum Creek by spring-run Chinook salmon is delayed until mid- to late-October, which is later than timing observed for other Central Valley spring-run populations. This delay in spawning timing is likely due to high water temperatures extending through September in Beegum Creek (CDFG 2004b). Because spawning is delayed, it is likely that water temperatures for embryo incubation are suitable in Beegum Creek.

Water Quality

The surface water quality of streams draining eastward from the Coast Range is generally poor. These streams generally have very high suspended sediment loads due to the metavolcanic bedrock and schist formations which produce clays that stay in suspension during turbulent flow conditions. Soil disturbance within these watersheds can accelerate erosion and sedimentation processes and lead to increased metal and nutrient concentrations. High concentrations of metals and nutrients are commonly present during both low flow and storm runoff events. These concentrations frequently exceed water quality criteria established for the protection of beneficial use or the maintenance of aquatic life. Total phosphorus concentrations are at stimulatory levels for algae (DWR Website 2007b).

Flow Conditions

Flows in Beegum Creek, where Chinook salmon embryos would be incubating are not controlled and mimic historic conditions.

Juvenile Rearing and Outmigration

Water Temperature

Water temperatures in Beegum Creek are likely cool enough to support Chinook salmon juvenile rearing, however, water temperatures downstream in Cottonwood Creek likely become too warm by early summer such that Cottonwood Creek likely only serves as a migration corridor.

Water Quality

Two major instream gravel extraction projects operate in Cottonwood Creek below the Interstate 5 bridge (CALFED 2000d) which likely degrade water quality for a short distance downstream.

Flow Conditions

There are no water development projects on Cottonwood Creek therefore, flows are unregulated. Runoff from the watershed is flashy: high in the rainy season and low in the dry season. The baseflow component of the runoff is small.

Loss of Riparian Habitat and Instream Cover

Extensive gravel mining occurs in lower Cottonwood Creek, which has resulted in a loss of riparian habitat. The remaining portion of the watershed is primarily rural which has helped avoid adverse impacts to the riparian areas.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

There has been little development in the Cottonwood Creek watershed. This has resulted in Cottonwood Creek maintaining most of its historic characteristics and function.

LOSS OF FLOODPLAIN HABITAT

No comprehensive flood control measures have occurred in the Cottonwood Creek drainage resulting in the creek retaining its connection to the floodplain. However, extensive gravel mining occurs in lower Cottonwood Creek, which has resulted in a loss of riparian habitat and floodplain. Non-native weeds such as Arundo and tamarisk are also becoming a problem of increasing concern, which further compromises riparian habitat quality.

ENTRAINMENT

There are irrigation diversions but no storage reservoirs on the Cottonwood Creek. Outmigrating juvenile spring-run Chinook salmon could potentially be entrained at unscreened diversions.

PREDATION

Sacramento pikeminnow is likely the most important predator of juvenile salmonids in Cottonwood/Beegum Creek system. While the pikeminnow is native to these waters, habitat alteration may have changed the predator prey dynamics in the system conferring an advantage to pikeminnow.

HATCHERY EFFECTS

3.3.10.3 CLEAR CREEK

Clear Creek is a westside tributary of the upper Sacramento River and enters the river at RM 289 just south of Redding.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

Whiskeytown Dam at RM 18.1 is an impassable barrier to adult anadromous salmonids and marks the upstream extent of potential Spring-run Chinook salmon habitat. Prior to 2000, the McCormick-Saeltzer Dam presented a barrier to upstream migration for anadromous salmonids. Following removal of the Dam in 2000, access to approximately 12 miles of coldwater habitat upstream to Whiskeytown Dam was restored.

HARVEST/ANGLING IMPACTS

Legal harvest of salmonids in Clear Creek and its tributaries is not permitted. Angling is permitted but restricted to barbless hooks and artificial flies and lures only.

WATER TEMPERATURE

Water temperature targets in Clear Creek are to maintain water temperatures under 60°F during the spring-run Chinook salmon adult immigration and holding life stage period. These water temperatures are maintained by controlling flows from Whiskeytown Dam. However, under the current flow schedule (see below) it may not be possible to maintain water temperatures under 60°F during particularly hot time periods (USFWS 2003b).

Water Quality

The impact of significant accumulations of mercury is an issue in Clear Creek. Mercury contamination is the result of historic gold mining practices in the watershed (CDFG 2004b).

Flow Conditions

Prior to 1999, streamflows below Whiskeytown Dam were reduced annually to approximately 50 cfs during the summer and increased in early October to provide suitable water temperatures for fall-run Chinook salmon spawning. A flow schedule for Clear Creek has been incorporated into the CVPIA AFRP that is designed to maintain flows in Clear Creek that will allow water temperatures conducive to all spring-run Chinook salmon life stages. Currently the release schedule call for maintenance of 200 cfs flows from October 1 to June 1 and 150 cfs, or less, from July through September in order to maintain water temperatures below 60°F (USFWS 2003b). However, a flow experiment in August 1998 demonstrated that during hot periods, flows higher than 150 cfs may be required to meet temperature targets (USFWS 2003b).

Spawning

Passage Impediments/Barriers

Historically, there were approximately 25 river miles of Chinook salmon habitat available for use in Clear Creek of which only 18.1 are currently accessible (NMFS Website 2005). Presumably this allowed for some spatial segregation between the spring and fall runs. Now there is likely some overlap in spawning habitat creating a potential for hybridization between spring-run and early spawning fall-run Chinook salmon.

Since 2003, a temporary picket weir has been installed from approximately mid August to mid November to spatially segregate spring-run from fall-run. Surveys conducted annually since 2003, during the period that the weir is installed has documented a range of 37 to 81 redds upstream of the weir (USFWS).

Harvest/Angling Impact

Legal harvest of salmonids in Clear Creek and its tributaries is not permitted. Angling is permitted but restricted to barbless hooks and artificial flies and lures only.

Water Temperature

Water temperature targets in Clear Creek are to maintain water temperatures under 56°F during the spring-run Chinook salmon spawning life stage period. These water temperatures are maintained by controlling flows from Whiskeytown Dam. However, under the current flow schedule (see below) it may not be possible to maintain water temperatures under 56°F during September to allow for early spawning spring-run Chinook salmon (USFWS 2003b). Currently, the 60°F to 56°F transition date is set at September 15 (USFWS 2003b).

WATER QUALITY

The impact of significant accumulations of mercury is an issue in Clear Creek. Mercury contamination is the result of historic gold mining practices in the watershed (CDFG 2004b)

FLOW CONDITIONS

Prior to 1999, streamflows below Whiskeytown Dam were reduced annually to approximately 50 cfs during the summer and increased in early October to provide suitable water temperatures for fall-run Chinook salmon spawning. A flow schedule for Clear Creek has been incorporated into the CVPIA Anadromous Fisheries Restoration Program Plan that is designed to maintain flows in Clear Creek that will allow water temperatures conducive to all spring-run Chinook salmon life stages. Currently the release schedule call for maintenance of 200 cfs flows from October 1 to June 1 and 150 cfs, or less, from July through September in order to maintain water temperatures below 60°F (USFWS 2003b).

SPAWNING HABITAT AVAILABILITY

Currently, approximately 18.1 river miles are available for Chinook salmon spawning in Clear Creek (NMFS Website 2005). Recent spring-run Chinook salmon escapement estimates are depicted in **Figure 3-15**.

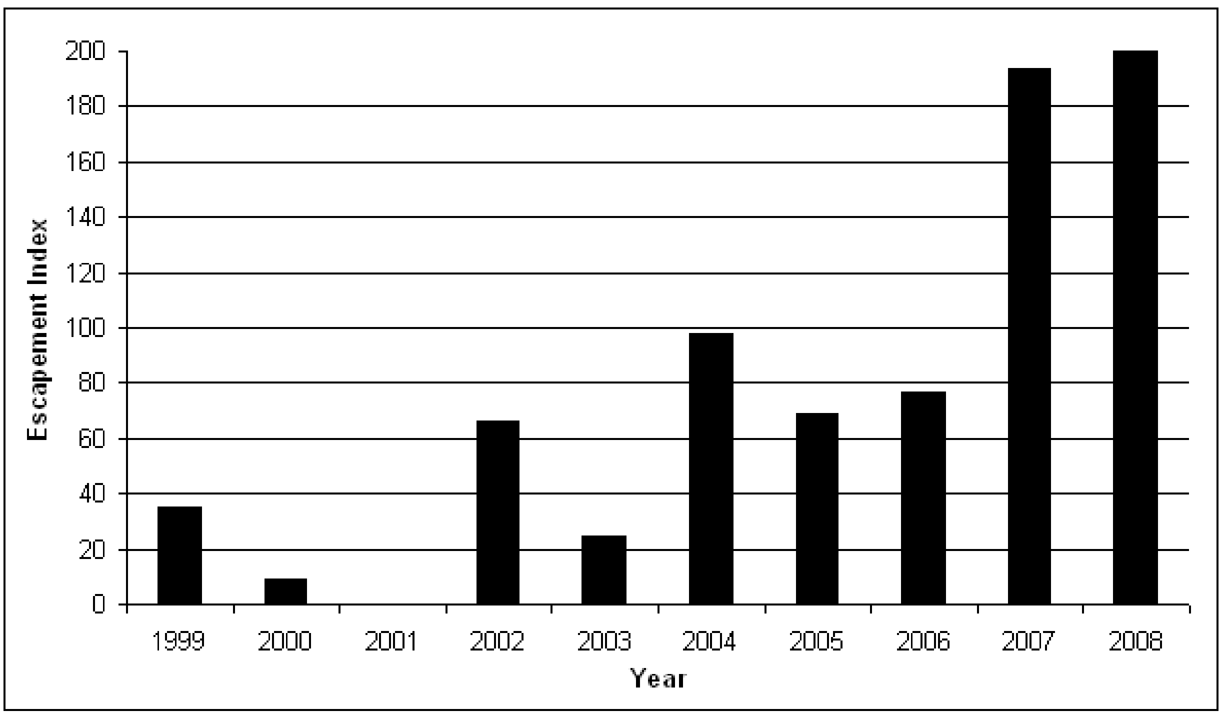

Figure 3-15. Index of Clear Creek Spring-Run Chinook Salmon Escapement (1999 – 2008).
Source: (CDFG 2009)

SPAWNING SUBSTRATE AVAILABILITY

The construction of Whiskeytown Dam, gold mining, and significant gravel mining in the Clear Creek watershed has diminished suitable spawning gravel substrate. Currently, gravel replacement projects are being conducted in the watershed (CDFG 2004b).

PHYSICAL HABITAT ALTERATION

The Clear Creek watershed has undergone extensive modification because of Whiskeytown Dam. Currently, Whiskeytown Dam diverts most of the Clear Creek natural streamflow to Spring Creek. However, extensive rehabilitation efforts are currently underway in the watershed.

HATCHERY EFFECTS

In order to reduce mortality associated with downstream migration subsequent to hatchery releases, Central Valley hatchery production is often trucked to San Pablo Bay for release. This practice likely increases straying rates with the potential for returning hatchery adults to hybridize with naturally spawning Chinook salmon throughout the Central Valley (Williams 2006). Due to the proximity of the Feather River to Clear Creek, there is a potential risk of introgression of Clear Creek spring-run with Feather River Hatchery spring-run and fall-run Chinook salmon escapement.

EMBRYO INCUBATION

HARVEST/ANGLING IMPACTS

Because angling is permitted in Clear Creek and its tributaries, it is possible that anglers could disturb redds by wading through the stream.

WATER TEMPERATURE

Water temperature targets in Clear Creek are to maintain water temperatures under 56°F during the spring-run Chinook salmon embryo incubation life stage period. These water temperatures are maintained by controlling flows from Whiskeytown Dam. However, under the current flow schedule (see below) it may not be possible to maintain water temperatures under 56°F during the first part of September to accommodate early spawners (USFWS 2003b). Currently, the 60°F to 56°F transition date is set at September 15 (USFWS 2003b).

WATER QUALITY

The impact of significant accumulations of mercury is an issue in Clear Creek. Mercury contamination is the result of historic gold mining practices in the watershed (CDFG 2004b). Mercury is particularly detrimental to developing embryos.

FLOW CONDITIONS

Prior to 1999, streamflows below Whiskeytown Dam were reduced annually to approximately 50 cfs during the summer and increased in early October to provide suitable water temperatures for fall-run Chinook salmon spawning. A flow schedule for Clear Creek has been incorporated into the CVPIA AFRP that is designed to maintain flows in Clear Creek that will allow water temperatures conducive to all spring-run Chinook salmon life stages. Currently the release schedule call for maintenance of 200 cfs flows from October 1 to June 1 and 150 cfs, or less, from July through September in order to maintain water temperatures below 60°F (USFWS 2003b).

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

Water temperature targets in Clear Creek are to maintain water temperatures under 60°F during the spring-run Chinook salmon juvenile rearing and downstream movement life stage period. These water temperatures are maintained by controlling flows from Whiskeytown Dam. However, under the current flow schedule (see below) it may not be possible to maintain water temperatures under 60°F during particularly hot time periods (USFWS 2003b).

Water Quality

The impact of significant accumulations of mercury is an issue in Clear Creek. Mercury contamination is the result of historic gold mining practices in the watershed (CDFG 2004b).

Flow Conditions

Prior to 1999, streamflows below Whiskeytown Dam were reduced annually to approximately 50 cfs during the summer and increased in early October to provide suitable water temperatures for fall-run Chinook salmon spawning. A flow schedule for Clear Creek has been incorporated into the CVPIA Anadromous Fisheries Restoration Program Plan that is designed to maintain flows in Clear Creek that will allow water temperatures conducive to all spring-run Chinook salmon life stages. Currently the release schedule call for maintenance of 200 cfs flows from October 1 to June 1 and 150 cfs, or less, from July through September in order to maintain water temperatures below 60°F (USFWS 2003b).

Loss of Riparian Habitat and Instream Cover

Over 30 years of gravel mining in Clear Creek has led to a reduction in riparian habitat along the lower sections (CDFG 2004b). Riparian habitat provides cover for rearing juveniles as well as insect habitat that serves as an important food source.

Loss of Natural River Morphology and Function

Whiskeytown Dam diverts most of the historic flow from Clear Creek into Spring Creek and also regulates flows in Clear Creek such that natural flow regimes no longer occur.

Loss of Floodplain Habitat

Because Clear Creek flows are regulated, the channel has become incised and some connection to the historic flood plain has been lost.

Entrainment

Juvenile entrainment is not a major concern on Clear Creek.

Predation

Sacramento pikeminnow is likely the most important predator of juvenile salmonids in Clear Creek. While the pikeminnow is native to these waters, habitat alteration may have changed the predator prey dynamics in the system conferring an advantage to pikeminnow.

Hatchery Effects

The CNFH on Battle Creek produces and releases both fall-run Chinook salmon and steelhead. Current hatchery production targets are the release of 12 million fall-run Chinook salmon smolts and 500,000 steelhead yearlings annually (DWR 2004a). The fish are released on station. The Chinook release has the potential for creating competition for habitat and food resources for juvenile spring-run Chinook salmon and the steelhead are of sufficient size to be a significant predator on juvenile Chinook salmon once they have moved out into the Sacramento River.

3.3.11 SUB-ADULT AND ADULT OCEAN RESIDENCE

3.3.11.1 HARVEST

The majority of ocean harvest of Central Valley Chinook salmon stocks occur in the recreational and commercial hook-and-line fisheries off the coasts of California and Oregon (Allen and Hassler 1986). Ocean harvest rate of Central Valley spring-run Chinook salmon is a function of the Central Valley Index, which is defined as the ratio of ocean catch of all Central Valley Chinook salmon south of Point Arena, California to the sum of this catch and the escapement of Chinook salmon to Central Valley streams and hatcheries. The CVI ranged from 0.55 to 0.80 from 1970 to 1995. In the mid 1990s harvest restrictions designed to protect winter-run Chinook salmon reduced the CVI. For example, in 2001 the CVI was 0.27.

Direct estimates of spring-run Chinook salmon ocean harvest are available due to a life history investigation that has coded-wire tagged wild Butte Creek spring-run Chinook salmon juveniles for roughly a decade. Analysis using these CWT'd cohorts has provided evidence that ocean harvest of Butte Creek spring-run Chinook salmon has ranged from 36 percent to 59 percent (Grover *et al*. 2004; McReynolds *et al*. 2007). Although CDFG conducts intensive carcass surveys in Butte Creek to recover and examine a high number of carcasses (and that all spring-run Chinook salmon cwt recoveries are expanded for effort), it should be noted that these estimates (on ocean harvest) could be over-estimates if CWT'd fish that survive and return to Butte Creek as adults are not detected. It also should be noted that ocean harvest rates of fall-run Chinook salmon from the Klamath River system, which have an ocean distribution similar to that of Central Valley spring-run Chinook salmon, are considerably lower than the Butte Creek spring-run Chinook salmon rate (pcouncil.org).

Another approach to understanding the ocean harvest rate of Central Valley spring-run Chinook salmon is to look at the ocean harvest of winter-run Chinook salmon. A biological opinion on the winter-run Chinook salmon ocean harvest suggests that for brood years 1998, 1999, and 2000, the spawner reduction rates associated with winter-run ocean harvest were 0.26, 0.23, and 0.24, respectively. The spawner reduction rate is the observed fishery mortality in terms of adult-equivalents (fish that are expected to survive natural mortality and spawn) divided by the predicted number of spawners that would survive natural mortality in the absence of fishery mortality (NMFS 200b).

Spring-run Chinook salmon ocean harvest is expected be similar to that of winter-run Chinook salmon, if not higher. A spring-run Chinook salmon ocean harvest level of at least approximately 25 percent represents a substantial stressor to the ESU.

3.3.11.2 OCEAN CONDITIONS

The general diets of salmonids in coastal waters are fairly well known for all salmon species in much of the continental shelf region off the West Coast and Alaska. Quantitative studies of the diet of juvenile salmonids in the California Current include those by MacFarlane and Norton (2002) for California, which are most relevant to the Central Valley spring-run Chinook salmon

ESU. This study found intra-specific differences in the type and size of prey consumed, with coho salmon, Chinook salmon, and cutthroat trout tending to be mainly piscivorous. However, ontological shifts to larger more evasive occurring during later life-stages (Brodeur *et al.* 2003). In addition, inter-annual and intra-annual differences in prey availability can lead to major differences in the diet composition of salmonids in the marine environment. The studies conducted to date have found that juvenile salmonids are highly opportunistic in their feeding habits and tend to select the most visually obvious prey within the preferred size range.

Brodeur and Pearcy (1992b) found that juvenile Chinook and coho salmon have the potential to easily exhaust prey resources during years when ocean productivity is low (e.g., El Niño), but during most years they consume less than 1 percent of the total prey production.

In recent years scientific evidence supports hypotheses about the direct and indirect effects of climate change on ocean productivity, and thereby its effects on salmon. Most of this research has focused on the effects of oceanic climate change on the growth and abundance of salmonids (Hollowed *et al.* 2001; Kruse 1998; Myers *et al.* 2000; Pearcy 1997). Two of the most researched phenomena are the ENSO and the PDO. ENSO is a short-term (8 to 15 months) climate change event that occurs at irregular intervals (approximately every 3 to 7 years) and alternates between two phases, the El Niño (warm) and the La Nina (cool).

The PDO is a multi-decadal (20 to 30 year) ENSO-like pattern of North Pacific climate change. The PDO seems to be associated with an inverse relationship between salmon abundance in the Alaska and the U.S. Pacific Coast regions. During a positive PDO phase, the abundance of Alaska salmon is high, and the abundance of U.S. West Coast salmon is low. An abrupt change between positive and negative PDO phases is referred to as a *regime shift.*

ENSO has been shown to produce dramatic effects on marine communities. Alterations in the physical oceanographic properties of the marine environment can be observed as far north as Alaska. Less known is the phenomenon of La Nina, the cool phase of ENSO events that follows El Niño. During the 1982-1983 El Niño event, there were observable alternations in oceanic plankton distributions, fish community structure, and reduced ocean catches off the coastal waters of southern California. Along central California coast, the 1992-1993 El Niño corresponded to delayed phytoplankton blooms, changes in the abundance and distribution of invertebrates, and an increase in the productivity of southern fish species. However, there was a dramatic decline in the northerly rockfish species. More recently, the largest decline in macrozooplankton abundance off central southern California occurred during the 1997-1998 El Niño (Pearcy 1997).

Changes in the physiology and behavior of salmonid populations have been recorded during ENSO events. Reduced condition and growth of sockeye salmon in the Gulf of Alaska during the 1997-1998 El Niño event was related to alterations in the primary prey base. Lower survival rates of juvenile coho salmon upon entering the ocean, higher mortality of adult coho, and reduced size in both coho and Chinook salmon occurred off the coast of Oregon during the 1982-1983 El Niño (Pearcy 1997).

In a study conducted by MacFarlane and Norton (2002) during the 1997-1998 El Niño event on juvenile Chinook salmon in the Gulf of the Farallones, an embayment on the central California coast. The Gulf of the Farallones is a large section of the continental shelf extending from Pt. Reyes, north of San Francisco Bay to the Farallon Islands. It receives freshwater outflow from the Sacramento and San Joaquin rivers. It is the point of ocean entry for an estimated 60 million Chinook salmon smolts spawned from four runs; fall, late-fall, winter, and spring in streams and hatcheries of the Central Valley.

Relative growth rates of juvenile Chinook salmon were estimated from daily otolith increment width of individuals captured via trawl at locations in the Gulf of the Farallones. Plankton samples were also collected at 5 meters and 15 to 25 meters below the surface to estimate secondary productivity and zooplankton composition. The mean otolith increment widths were used as an index of somatic growth during the first 100 days after leaving the Bay-Delta. Growth rate indices for juvenile salmonids caught during the 1998 El Niño period were significantly greater ($P<0.0001$) than for fish collected in 1999. Juvenile salmon in the Gulf of the Farallones not only grew faster and had greater lipid concentrations during the El Niño period, their condition (Fulton's K-factor) was better as well. In 1998, mean K increased to approximately 1.42 for gulf salmon from approximately 1.03 at ocean entry, compared with a change from 1.04 at ocean entry to 1.32 in the gulf during 1999.

Primary productivity, indexed by chlorophyll *a* concentrations, was similar between the two years, however, the distribution of phytoplankton differed. In 1998, phytoplankton were distributed within the gulf on the continental shelf to the west. Greater nutrient freshwater influx coupled with higher sea surface temperatures in 1998 may have accounted for the higher productivity in the gulf during the El Niño event. These data indicate that the 1997-1998 El Niño event was not detrimental to juvenile Chinook salmon growth during the earliest stages their life cycle in the marine environment.

A dramatic increasing trend in the abundance of Alaska salmon that began in the late 1970s has been correlated with relatively warmer sea surface temperatures in the North Pacific. Hare and Matura (2001) hypothesized that a sharp negative shift in the PDO climate index in the fall of 1998 may signify a climate change event that will reverse salmon production trends that began in the 1970s. Since the 1990s Western Alaska has observed extremely low Chinook salmon and chum salmon returns, but returns of salmon in the south-central and southeast of Alaska have at times reached historical highs (ADFG 2002). In general, escapement data indicate that salmon returns in many U.S. Pacific Northwest rivers have improved since the late 1990s.

3.4 STRESSOR PRIORITIZATION

3.4.1 STRESSOR MATRIX DEVELOPMENT

3.4.1.1 STRESSOR MATRIX OVERVIEW

Stressor matrices, in the form of Microsoft Excel spreadsheets, were developed to structure the spring-run Chinook salmon diversity group, population, life stage, and stressor information into hierarchically related tiers so that stressors within each diversity group and population in the ESU could be prioritized. The individual tiers within the matrices, from highest to lowest, are:

(1) diversity group; (2) population; (3) life stage; (4) primary stressor category; and (5) specific stressor. These individual tiers were related hierarchically so that each variable within a tier had several associated variables at the next lower tier, except at the lowest tier. The three diversity groups were equally weighted in order to be consistent with the recovery criteria described in this recovery plan, which were, in-part, based on the "representation and redundancy" rule described in Lindley *et al*. (2007). This rule reflects the importance of having multiple diversity groups comprised of multiple independent populations in order to recover the ESU (Lindley *et al.* 2007).

The general steps required to develop and utilize the spring-run stressor matrices are described as follows:

1. Each population within a diversity group was weighted so that all population weights in the diversity group summed to one;
2. Each life stage within the population was weighted so that all life stage weights in the population summed to one;
3. Each primary stressor category within a life stage was weighted so that all primary stressor category weights in a life stage summed to one;
4. Each specific stressor within a primary stressor category was weighted so that all specific stressor weights in a primary stressor category summed to one;
5. A composite weight for each specific stressor was obtained by multiplying the product of the population weight, the life stage weight, the primary stressor weight, and the specific stressor weight by 100;
6. A normalized weight for each specific stressor was obtained by multiplying the composite weight by the number of specific stressors within a particular primary stressor group; and
7. The stressor matrix was sorted by the normalized weight of the specific stressors in descending order.

The completed stressor matrix sorted by normalized weight is a prioritized list of the life stage-specific stressors affecting the ESU. For spring-run Chinook salmon, threats were prioritized within each diversity group as well as within each population. Specific information explaining the individual steps taken to generate these prioritized lists is provided in the following sections.

3.4.1.2 Population Identification and Ranking

The threats assessment for the Central Valley spring-run Chinook salmon ESU included rivers that both historically supported and currently support spring-run Chinook salmon populations. Lindley *et al.* (2004), which describes the population structure of threatened and endangered Chinook salmon ESUs in California's Central Valley Basin was used to identify 12 individual rivers that historically supported and currently support spring-run Chinook salmon populations. These 12 spring-run Chinook salmon populations were categorized into three diversity groups as described by Lindley *et al.* (2007) (**Table 3-3**).

Table 3-3. Central Valley Spring-run Chinook Salmon Populations Included in the Threats Assessment Categorized by Diversity Group

Northern Sierra Nevada Diversity Group	Basalt and Porous Lava Diversity Group	Northwestern California Diversity Group
Feather River	Battle Creek	Thomes Creek
Yuba River	Sacramento River (mainstem)	Cottonwood/Beegum Creek
Butte Creek		Clear Creek
Big Chico Creek		
Deer Creek		
Mill Creek		
Antelope Creek		

Source: (Lindley *et al.* 2007)

Several steps were taken to obtain a population weight. First, for a given population, each of the weighting characteristics listed below received a whole number score of one through four. For example, a population with high abundance and low genetic integrity received a population abundance score of four and a genetic integrity score of one. After scores were identified for the weighting characteristics for each population, the sum of the weighting characteristic scores for one population was divided by the total sum of the scores for all populations within the diversity group. The resultant quotient is the population weight, thus the population weights within a diversity group sum to one. The weighting characteristic scores and population weights for each spring-run Chinook salmon population in each of the three diversity groups are presented in **Tables 3-4, 3-5, and 3-6**.

Within each of the three diversity groups, populations were weighted relative to one another by scoring the weighting characteristics described below.

- Population abundance
  - A population with relatively low returning adult abundance estimates would receive a low score; highly abundant populations would receive a high score

- Genetic integrity
  - A population supported primarily by hatchery-produced fish would receive a low score, whereas a population with little to no influence of hatchery-produced fish would receive a high score

- Population spatial structure
  - A population that is geographically isolated from other populations in the ESU enhances the ESU's spatial structure and would thus receive a high score; populations in close geographic proximity to one another would receive a low score

- The extent to which the current population is genetically and behaviorally representative of the natural historic population
  - A population that was once extirpated and has been re-established would receive a low score
  - A population supported by hatchery production would receive a low score (i.e., 1 or 2 depending on the degree of hatchery influence)
  - A historically dependent population would receive a low score

- o A population characterized by a consistent and relatively stable returning adult population comprised of naturally-produced fish would receive a high score

Table 3-4. Weighting Characteristic Scores and Population Weights for Each Population in the Spring-run Chinook Salmon Northern Sierra Nevada Diversity Group

Northern Sierra Nevada Diversity Group	Deer	Mill	Butte	Yuba	Feather	Antelope	Big Chico
Abundance	3	3	4	3	4	1	2
Genetic Integrity	4	4	4	2	1	3	3
Source/Sink	4	4	4	4	4	2	1
Natural Historic Population	4	4	4	4	4	3	1
Habitat Quantity and Quality	4	4	2	4	2	3	2
Restoration Potential	3	3	2	3	2	3	2
Distinct Spring-run Life History	4	4	3	2	2	4	3
Spatial Consideration	2	2	2	3	3	2	2
Sum	28	28	25	25	22	21	16
Population Weight (Sum to 1)	0.17	0.17	0.15	0.15	0.13	0.13	0.10

Table 3-5. Weighting Characteristic Scores and Population Weights for Each Population in the Spring-run Chinook Salmon Basalt and Porous Lava Diversity Group

Basalt and Porous Lava Diversity Group	Upper Sacramento (Mainstem)	Battle
Abundance	1	4
Genetic Integrity	2	2
Source/Sink	2	4
Natural Historic Population	3	3
Habitat Quantity and Quality	3	2
Restoration Potential	3	4
Distinct Spring-run Life History	2	3
Spatial Consideration	4	4
Sum	20	26
Population Weight (Sum to 1)	0.43	0.57

Table 3-6. Weighting Characteristic Scores and Population Weights for Each Population in the Spring-run Chinook Salmon Northwestern California Diversity Group

Northwestern California Diversity Group	Cottonwood/ Beegum	Clear	Thomes
Abundance	1	2	1
Genetic Integrity	3	2	2
Source/Sink	1	1	1
Natural Historic Population	2	1	1
Habitat Quantity and Quality	2	3	1
Restoration Potential	1	2	1
Distinct Spring-run Life History	4	3	1
Spatial Consideration	4	4	4
Sum	18	18	12
Population Weight (Sum to 1)	0.38	0.38	0.25

- Whether the population primarily functions as a source or sink
  - A population with consistently high abundance may serve as a source of individuals to other populations and would receive a high score
  - Populations primarily dependent on fish straying from other populations would receive a low score

- The general habitat quantity and quality available in the population's natal stream
  - Several variables were considered when evaluating salmonid habitat availability including, but not limited to flow, water temperature, instream cover, riparian habitat, substrate, and the presence of passage impediments/barriers

- The restoration potential of the population's natal stream
  - Populations on rivers/streams that can be relatively easily restored to increase or improve the amount of habitat available to the fish would receive a high score, whereas populations on rivers with limited habitat and large impassable dams would receive a low score

- Whether the population exhibits a distinctive life history
  - Rivers with habitat conditions amenable to a stream-type life history and/or rivers with fish exhibiting a distinctive stream-type life history would receive a high score; populations exhibiting an ocean-type life history would receive a low score

These eight population characteristics were identified to reflect the VSP framework (McElhany *et al.* 2000) in an attempt to best weight populations according to their relative importance to the viability of the diversity group they belong to. Although some redundancy exists in the specific factors considered among the eight population characteristics, each characteristic uniquely reflects the VSP framework.

3.4.1.3 Life Stage Identification and Ranking

The life stage identification and ranking procedures for spring-run Chinook salmon were identical to that of winter-run Chinook salmon. Please see Section 2.4.1.3 for a description of those procedures. The life stage weightings for each spring-run Chinook salmon population are presented in Attachment B.

3.4.1.4 Stressor Identification and Ranking

The stressor identification and ranking procedures for spring-run Chinook salmon were identical to that of winter-run Chinook salmon. Please see Section 2.4.1.4 for a description of those procedures.

3.4.2 Stressor Matrix Results

3.4.2.1 Northern Sierra Nevada Diversity Group

The northern Sierra Nevada spring-run Chinook salmon diversity group is comprised of the Feather and Yuba rivers, and Butte, Big Chico, Deer, Mill, and Antelope creeks. Stressors of very high importance were identified for all populations and life stages in this diversity group including:

- Passage impediments and/or barriers affecting adult immigration in all of the rivers and creeks, except for Butte Creek where most fish passage issues have been addressed;
- High water temperatures during the adult immigration and holding life stage in Butte, Big Chico, Deer, Mill, and Antelope creeks;
- The Fish Barrier Dam and Oroville Dam on the Feather River, and Englebright Dam on the Yuba River as barriers blocking access to historic holding and spawning habitats, a critical factor in the hybridization with fall-run Chinook salmon, and as limiting the instream supply of spawning gravels;
- Entrainment in the Delta, in the lower and middle sections of the Sacramento River, in Antelope Creek, and in the Yuba River;
- Sedimentation impacts on the embryo incubation life stage in Butte, Deer, Mill, and Antelope creeks; and
- Numerous factors affecting the juvenile rearing and outmigration life stage in the Delta and lower Sacramento River such as loss of floodplain habitat, loss of natural river morphology and function, loss of riparian habitat and instream cover, and predation.

Many additional stressors were identified as having a very high importance to the northern Sierra Nevada spring-run Chinook salmon diversity group. The complete prioritized list of life-stage specific stressors to this diversity group is displayed in Attachment B.

3.4.2.2 BASALT AND POROUS LAVA DIVERSITY GROUP

The basalt and porous lava spring-run Chinook salmon diversity group is comprised of the Battle Creek and the mainstem Upper Sacramento River. Stressors of very high importance were identified for both populations and life stages in this diversity group including:

- RBDD on the Sacramento River and the dams on the North and South forks of Battle Creek as passage impediments to the adult immigration and holding life stage;
- Keswick Dam as a barrier blocking access to historic holding and spawning habitats, a critical factor in the hybridization with fall-run Chinook salmon, and as limiting the instream supply of spawning gravels;
- Releases of yearling steelhead produced at CNFH competing with, and more importantly, preying on naturally spawned juvenile Chinook salmon in Battle Creek;
- Low-flow conditions in Battle Creek during the adult immigration and holding life stage;
- Entrainment at individual diversions in the Delta, lower and middle Sacramento River, and in Battle Creek;
- Numerous factors affecting the juvenile rearing and outmigration life stage in the Delta, and lower, middle, and upper Sacramento River such as loss of floodplain habitat, loss of natural river morphology and function, loss of riparian habitat and instream cover, and predation.

Additional stressors were identified as having a very high importance to the basalt and porous lava spring-run Chinook salmon diversity group. The complete prioritized list of life-stage specific stressors to this diversity group is displayed in Attachment B.

3.4.2.3 NORTHWESTERN CALIFORNIA DIVERSITY GROUP

The northwestern California spring-run Chinook salmon diversity group is comprised of the Thomes, Cottonwood/Beegum, and Clear creeks. Stressors of very high importance were identified for all populations and life stages in this diversity group including:

- High water temperatures in Thomes, Cottonwood/Beegum, and Clear creeks during the adult immigration and holding and spawning life stages;
- Agricultural diversion dams and excessive channel braiding impeding adult immigration in Thomes Creek;
- Whiskeytown Dam on Clear Creek as a barrier and as limiting the instream supply of spawning gravels;
- Sedimentation affecting the embryo incubation life stage in Clear and Cottonwood/Beegum creeks;
- Loss of riparian habitat and instream cover in Cottonwood and Clear creeks;
- Loss of natural river morphology and function in Cottonwood/Beegum and Clear creeks; and
- Numerous factors affecting the juvenile rearing and outmigration life stage in the Delta and lower Sacramento River such as loss of floodplain habitat, loss of natural river morphology and function, loss of riparian habitat and instream cover, and predation.

Additional stressors were identified as having a very high importance to the northwestern California spring-run Chinook salmon diversity group. The complete prioritized list of life-stage specific stressors to this diversity group is displayed in Attachment B.

4.0 CENTRAL VALLEY STEELHEAD

4.1 BACKGROUND

4.1.1 LISTING HISTORY

NMFS proposed to list the Central Valley steelhead as endangered on August 9, 1996 (61 FR 41541 (August 1996)). NMFS concluded that the Central Valley steelhead ESU was in danger of extinction because of habitat degradation and destruction, blockage of freshwater habitats, water allocation problems, the pervasive opportunity for genetic introgression resulting from widespread production of hatchery steelhead and the potential ecological interaction between introduced stocks and native stocks. Moreover, NMFS proposed to list steelhead as endangered because steelhead had been extirpated from most of their historical range (61 FR 41541 (August 1996)).

On March 19, 1998, NMFS published a final determination listing the Central Valley steelhead as a threatened species (63 FR 13347 (March 19, 1998)). NMFS concluded that the risks to Central Valley steelhead had diminished since the completion of the 1996 status review based on a review of existing and recently implemented state conservation efforts and federal management programs (e.g., CVPIA AFRP, CALFED) that address key factors for the decline of this species. In addition, NMFS asserted that additional actions benefiting Central Valley steelhead included efforts to enhance fisheries monitoring and conservation actions to address artificial propagation (63 FR 13347 (March 19, 1998)).

On September 8, 2000, pursuant to a July 10, 2000, rule issued by NMFS under Section 4(d) of the ESA (16 USC § 1533(d)), the take restrictions that apply statutorily to endangered species began to apply to Central Valley steelhead (65 FR 42421 (July 10, 2000)).

On January 5, 2006, NMFS departed from their previous practice of applying the ESU policy to steelhead. NMFS concluded that the within a discrete group of steelhead populations, the resident and anadromous life forms of steelhead remain "markedly separated" as a consequence of physical, ecological and behavioral factors, and may therefore warrant delineation as a separate DPS. In addition, on January 5, 2006, NMFS reaffirmed the listing of threatened status of the Central Valley Steelhead DPS (71 FR 834 (January 5, 2006)). NMFS based its conclusion on conservation and protective efforts that, *"mitigate the immediacy of extinction risk facing the Central Valley steelhead DPS."*

This Central Valley Steelhead DPS includes all naturally spawned populations of steelhead in the Sacramento and San Joaquin rivers and their tributaries, excluding steelhead from San Francisco and San Pablo bays and their tributaries (63 FR 13347 *in* NMFS 2007). This decision also included the CNFH and FRFH steelhead populations (NMFS 2007).

4.1.2 CRITICAL HABITAT DESIGNATION

NMFS proposed critical habitat for Central Valley steelhead on February 5, 1999, in compliance with Section 4(a)(3)(A) of the ESA, which requires that, to the maximum extent prudent and determinable, NMFS designates critical habitat concurrently with a determination that a species is endangered or threatened (NMFS 1999). On February 16, 2000, NMFS published a final rule designating critical habitat for Central Valley steelhead which became effective on March 17, 2000. Critical habitat was designated to include all river reaches accessible to listed steelhead in the Sacramento and San Joaquin Rivers and their tributaries in California. Also included were river reaches and estuarine areas of the Delta, all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait, all waters of San Pablo Bay westward of the Carquinez Bridge, and all waters of San Francisco Bay (north of the San Francisco/Oakland Bay Bridge) from San Pablo Bay to the Golden Gate Bridge (NMFS 2000).

In response to litigation brought by NAHB on the grounds that the agency did not adequately consider economic impacts of the critical habitat designations (NAHB v. Evans, 2002 WL 1205743 No. 00–Central Valley–2799 (D.D.C.)), NMFS sought judicial approval of a consent decree withdrawing critical habitat designations for 19 Pacific salmon and *O. mykiss* ESUs. The District Court in Washington DC approved the consent decree and vacated the critical habitat designations by Court order on April 30, 2002 (NAHB v. Evans, 2002 WL 1205743 (D.D.C. 2002)).

NMFS proposed new critical habitat for Central Valley steelhead on December 10, 2004, and published a final rule designating critical habitat for this species on September 2, 2005 which became effective on January 2, 2006. The designated critical habitat encompasses 2,308 miles of stream habitat in the Central Valley and an additional 254 square miles of estuary habitat in the San Francisco-San Pablo-Suisun Bay complex. For a list of designated critical habitat units, see the September 2, 2005 Federal Register Notice (70 FR 52488 (September 2, 2005)).

4.1.3 UNIQUE SPECIES CHARACTERISTICS

4.1.3.1 LIFE HISTORY STRATEGY

Steelhead may exhibit anadromous behavior or remain in fresh water for their entire life. Resident forms are usually referred to as ‘‘rainbow’’ trout, while anadromous life forms are termed ‘‘steelhead.’’ Steelhead typically migrate to marine waters after spending 1 to 3 years in fresh water. They reside in marine waters for typically 1 to 4 years prior to returning to their natal stream to spawn as 2- to 5-year-olds. Unlike Pacific salmon, steelhead are capable of spawning more than once before they die. However, it is rare for steelhead to spawn more than twice before dying; and most that do so are females (Moyle 2002).

Currently, Central Valley steelhead are considered “ocean-maturing” (also known as winter) steelhead, although summer steelhead may have been present prior to construction of large dams (Moyle 2002). Ocean maturing steelhead enter fresh water with well-developed gonads and spawn shortly after river entry. Central Valley steelhead begin entering fresh water in August, with peak in late September through October. They hold until flows are high enough in tributaries to enter for spawning (Moyle 2002). Steelhead adults typically spawn from December through April with peaks from January though March in small streams and tributaries where cool, well-oxygenated water is available year-round (McEwan and Jackson 1996b and Hallock *et al.* 1961). Depending on water temperature, steelhead eggs may incubate in redds for 1.5 to 4 weeks before hatching as alevins. Following yolk sac absorption, alevins emerge from the gravel as young juveniles or fry and begin actively feeding (Moyle 2002).

Regardless of life history strategy, for the first year or two, steelhead are found in cool, clear, fast-flowing permanent streams and rivers where riffles predominate over pools, where ample cover from riparian vegetation or undercut banks, and where invertebrate life is diverse and abundant. In streams, strong shifts in habitat occur with size and season. The smallest fish are most often found in riffles; intermediate size fish in runs; and large size fish in pools. Steelhead are found where daytime water temperatures range from nearly 32ºF in winter to 81ºF in the summer (Moyle 2002).

When water temperatures become stressful in streams, juvenile steelhead are faced with the increased energetic costs of living at high water temperatures. Hence, juvenile steelhead will move into fast riffles to feed because of increased abundance of food, even though there are additional costs associated with maintaining position in fast water. At high water temperatures, steelhead also are more vulnerable to unusual stress, and likely to die as a consequence. When water temperatures are high for steelhead but optimal for a coexisting fish species, interactions may reduce steelhead growth (Moyle 2002).

Predators also have a strong effect on microhabitats selected by steelhead. Small steelhead select places to live based largely on proximity to cover in order to hide from avian predators (Moyle 2002).

Optimal water temperatures for growth of steelhead have been reported around 59ºF to 64.4ºF (Moyle 2002). Many factors affect choice of water temperatures by steelhead, including the availability of food. As steelhead grow, they establish individual feeding territories; juveniles typically rear for one to two years (and up to four years) in streams before emigration as "smolts" (juvenile fish which can survive the transition from fresh water to salt water) (61 FR 41541 (August 1996)). Some may use tidal marsh areas, non-tidal freshwater marshes, and other shallow water areas in the Delta as rearing areas for short periods prior to their final emigration to the sea. In the Sacramento River, juvenile steelhead migrate to the ocean in spring and early summer at 1 to 3 years of age and 10 to 25 cm FL, with peak migration through the Delta in March and April (Reynolds *et al.* 1993). Hallock *et al.* (1961) found that juvenile steelhead in the Sacramento River basin migrate downstream during most months of the year, but the peak emigration period occurred in the spring, with a much smaller peak in the fall.

Growth of steelhead in fresh water is highly variable, but sizes of 10 to 12 cm FL at the end of year one and 16 to 17 cm at the end of year two are fairly typical. An additional spurt of growth may occur in spring, just prior to smolting, giving smolts age one and above an additional size advantage. Steelhead are primarily drift feeders and may forage in open water of estuarine subtidal and riverine tidal wetland habitats. The diet of juvenile steelhead includes emergent aquatic insects, aquatic insect larvae, snails, amphipods, opossum shrimp, and small fish (Moyle 2002).

Steelhead may remain in the ocean from one to four years, growing rapidly as they feed in the highly productive currents along the continental shelf (Barnhart 1986). The age composition of high seas steelhead is dominated by one-year (61.9 percent) and two-year (31.4 percent) ocean fish, with a maximum of six years at sea (Burgner *et al.* 1992). Steelhead experience most of their marine phase mortality soon after they enter the Pacific Ocean (Pearcy 1992). Ocean mortality is poorly understood. Possible causes of juvenile steelhead mortality are predation, starvation, osmotic stress, disease, and advective losses (Wooster 1983; Hunter 1983, both cited in Pearcy 1992). Marine mortality of adult steelhead may occur from unauthorized high seas driftnet fisheries, predation, competition, and environmental conditions in the ocean (Cooper and Johnson 1992). Competition between steelhead and other species for limited food resources in the Pacific Ocean may be a contributing factor to declines in steelhead populations, particularly during years of low productivity (Cooper and Johnson 1992).

Oceanic and climate conditions such as sea surface temperatures, air temperatures, strength of upwelling, El Niño events, salinity, ocean currents, wind speed, and primary and secondary productivity affect all facets of the physical, biological and chemical processes in the marine environment. Some of the conditions associated with El Niño events include warmer water temperatures, weak upwelling, low primary productivity (which leads to decreased zooplankton biomass), decreased southward transport of sub-arctic water, and increased sea levels (Pearcy 1992). For juvenile steelhead, warmer water and weakened upwellings are possibly the most important of the ocean conditions associated with El Niño. Because of the weakened upwelling during an El Niño year, juvenile California steelhead would need to more actively migrate offshore through possibly stressful warm waters with numerous inshore predators. Strong upwelling is probably beneficial because of the greater transport of smolts offshore, beyond major concentrations of inshore predators (Pearcy 1992).

Steelhead have well-developed homing abilities and usually spawn in the same stream and area in which they had lived as fry. These fish also are capable of spawning in tributaries that dry up during summer, because fry emigrate soon after hatching (Moyle 2002). Steelhead usually do not eat when migrating upstream and often lose body weight.

Central Valley steelhead spawn below dams on every major tributary within the Sacramento and San Joaquin River systems. The female steelhead selects a site with good intergravel flow, digs a redd with her tail, usually in the coarse gravel of the tail of a pool or in a riffle, and deposits eggs while an attendant male fertilizes them. Water velocities over redds are typically 20 to 155 cm/sec, and in depths are 10 to 150 cm. Mating behavior between a pair of large adult fish is similar to that of other salmonids but complicated by the presence of other males, which sneak into spawn along with the mated pair (Moyle 2002). The sneaker males can range from small par that have probably never been to sea, to jacks, to slightly smaller subordinate sea-run males, kept at bay by the aggressive attacks of the dominant male (Moyle 2002).

Eggs in the redd are covered with gravel dislodged just upstream by similar redd building actions. The number of eggs laid per female depends on size and origin but ranges from 200 to 12,000 eggs. The eggs hatch in three to four weeks at 50 to 59ºF, and fry emerge from the gravel two to three weeks later (Moyle 2002). However, factors such as redd depth, gravel size, siltation, and water temperature can speed or retard the time to emergence (Shapovalov and Taft 1954). The fry initially live in quiet waters close to shore and exhibit little aggressive behavior for several weeks (Moyle 2002).

4.1.3.2 HISTORIC SPAWNING HABITAT UTILIZATION

Central Valley steelhead historically were well-distributed throughout the Sacramento and San Joaquin rivers prior to dam construction, water development, and watershed perturbations of the 19th and 20th centuries (NMFS 1996, Busby *et al.* 1996 in NMFS 2007). They were found from the upper Sacramento and Pit River systems (now inaccessable due to Shasta and Keswick Dams) south to the Kings and possibly the Kern River systems, and in both east- and west-side Sacramento River tributaries (Yoshiyama *et al.* 1996). Lindley *et al.* (2006) estimated that historically there were at least 81 independant Central Valley steelhead populations distributed primarily throughout the eastern tributaries of the Sacramento and San Joaquin Rivers. Presently, impassable dams block access to 80 percent of historically available habitat, and block access to all historical spawning habitat for about 38 percent of historical populations (Lindley *et al.* 2006). Existing wild steelhead stocks in the Central Valley are mostly confined to the upper Sacramento River and its tributaries, including Antelope, Deer, and Mill creeks and the Yuba River. Populations may exist in Big Chico and Butte Creeks, and a few wild steelhead are produced in the American and Feather rivers (CDFG 1996b).

4.1.4 STATUS OF CENTRAL VALLEY STEELHEAD

4.1.4.1 HISTORIC POPULATION TRENDS

Historic Central Valley steelhead run sizes are difficult to estimate given the paucity of data, but may have approached one to two million adults annually (McEwan 2001). By the early 1960s, the steelhead run size had declined to about 40,000 adults (McEwan 2001). Over the past 30 years, the naturally-spawned steelhead populations in the upper Sacramento River have declined substantially (**Figure 4-1**) (NMFS 2007).

4.1.4.2 CURRENT STATUS

Until recently, Central Valley steelhead were thought to be extirpated from the San Joaquin River system. Recent monitoring has detected small self-sustaining populations of steelhead in the Stanislaus, Mokelumne, and Calaveras rivers, and other streams previously thought to be devoid of steelhead (McEwan 2001). Incidental catches and observations of steelhead juveniles also have occurred on the Tuolumne and Merced rivers during fall-run Chinook salmon monitoring activities, indicating that steelhead are widespread, throughout accessible streams and rivers in the Central Valley (Good *et al.* 2005).

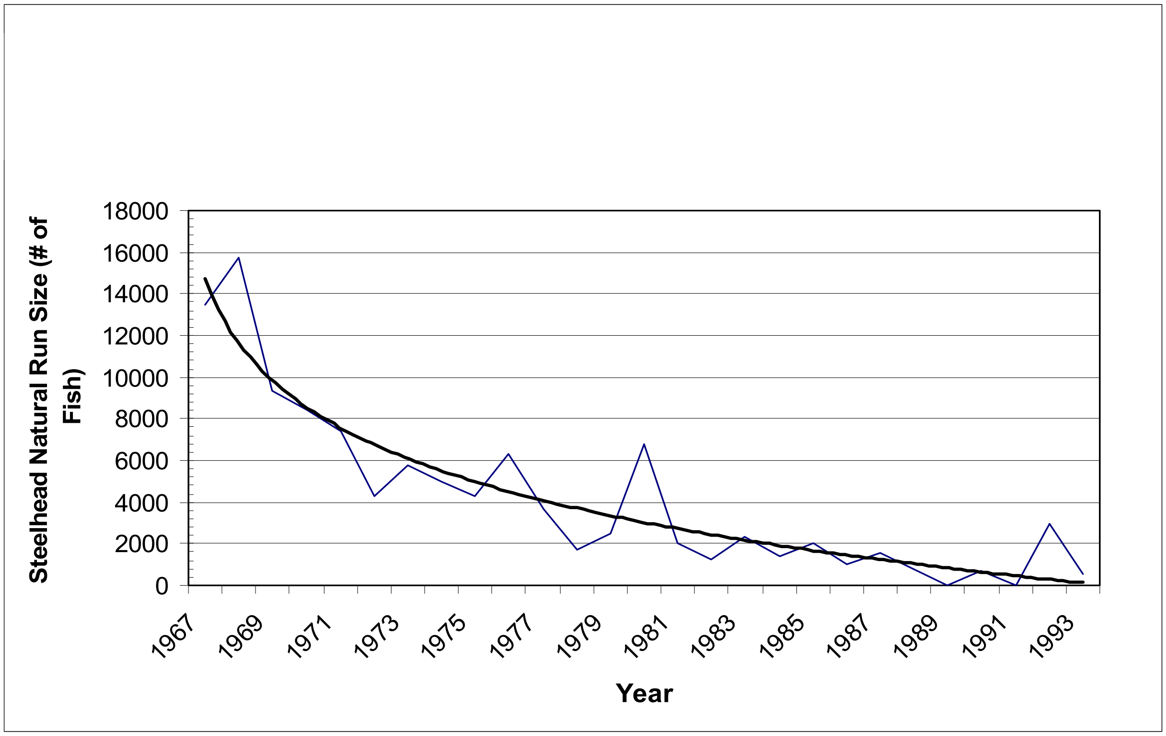

Figure 4-1. Estimated Natural Steelhead Run Size on the Upper Sacramento River, 1967 Through 1993

4.1.4.3 EXTINCTION RISK ASSESSMENT

The majority of BRT votes were for "in danger of extinction," and the remainder was for "likely to become endangered" Abundance, productivity, and spatial structure were of highest concern (4.2–4.4), although diversity considerations were of significant concern (3.6). All categories received a 5 from at least one BRT member. The BRT was highly concerned that what little new information was available indicated that the monotonic decline in total abundance and in the proportion of wild fish in the Central Valley steelhead DPS was continuing. Other major concerns included the loss of the vast majority of historical spawning areas above impassable dams, the lack of any steelheadspecific status monitoring, and the significant production of out-of-DPS steelhead by the Nimbus and Mokelumne river fish hatcheries. The BRT viewed the anadromous life history form as a critical component of diversity within the DPS and did not place much importance on sparse information suggesting widespread and abundant steelhead populations in areas above impassable dams. Dams both reduce the scope for expression of the anadromous life history form, thereby greatly reducing the abundance of anadromous steelhead and prevent exchange of migrants among resident populations, a process presumably mediated by anadromous fish.

As previously discussed, NMFS determined that Central Valley steelhead should not be listed as "endangered" but as threatened because conservation and protective efforts *"mitigate the immediacy of extinction risk facing the Central Valley steelhead DPS."*

4.2 LIFE HISTORY AND BIOLOGICAL REQUIREMENTS

4.2.1 ADULT IMMIGRATION AND HOLDING

4.2.1.1 GEOGRAPHIC AND TEMPORAL DISTRIBUTION

Steelhead are predominantly winter steelhead; therefore, the following information describes the life history of winter steelhead. Adult steelhead generally immigrate from the ocean to the Sacramento River from August through March (McEwan 2001). The general life stage timing for each individual steelhead population is displayed in **Figures 4-2, 4-3, 4-4, and 4-5**.

4.2.1.2 BIOLOGICAL REQUIREMENTS

Adult steelhead immigration into the Delta and the lower Sacramento River occurs from August through March (McEwan 2001; NMFS 2004a), and peaks during January and February (Moyle 2002). Suitable water temperatures for adult steelhead migrating upstream to spawning grounds range from 46°F to 52°F (NMFS 2000; NMFS 2002; SWRCB 2003). Prolonged exposure to water temperatures above 73°F is reported to be lethal to adult steelhead (Moyle 2002).

Adult steelhead hold in deep pools with cool water, normally in the mainstem rivers, until flows are high enough in tributaries to allow entrance for spawning (Moyle 2002). The minimum depth requirement for passage of adults is reported to be 7 inches (Thompson 1972) although the distance fish must travel through shallow water areas is also a critical factor. Additionally, water velocities exceeding 10 to 13 ft/sec likely present barriers to upstream migration (Reiser and Bjornn 1979).

4.2.2 ADULT SPAWNING

4.2.2.1 GEOGRAPHIC AND TEMPORAL DISTRIBUTION

Central Valley adult steelhead generally begin spawning in late December and extend through to March, but also can range from November through April (CDFG 1986). The general life stage timing for each individual steelhead population is displayed in Figures 4-2, 4-3, 4-4 and 4-5.

4.2.2.2 BIOLOGICAL REQUIREMENTS

Steelhead adults typically spawn from December through April with peaks from January though March in small streams and tributaries where cool, well oxygenated water is available year-round (Hallock *et al.* 1961; McEwan 2001). Steelhead spawn in areas with a gravel substrate and water velocities ranging from 1 to 3.6 ft/sec but prefer velocities of about 2 ft/sec (30–110 cm/sec) at depths of 6 to 28 inches (Bovee 1978). Likewise, the USFWS (1995c) reported a water velocity range for steelhead spawning of 0.5–3.6 ft/sec (15.2–109 cm/sec) at similar depths. The preferred range of gravel sizes used by steelhead is 6-100mm (Bjornn and Reiser 1991).

A review of the literature suggests optimal conditions for steelhead spawning occur at water temperatures ≤ 52°F (NMFS 2001; NMFS 2002; Reclamation 1997; SWRCB 2003; USFWS 1995c). The literature also reports high survival and normal development (Kamler and Kato 1983; Redding and Schreck 1979; Rombough 1988) at temperatures below 54°F, however, some evidence suggests that symptoms of thermal stress arise at or near 54.0°F (Humpesch 1985; Timoshina 1972).

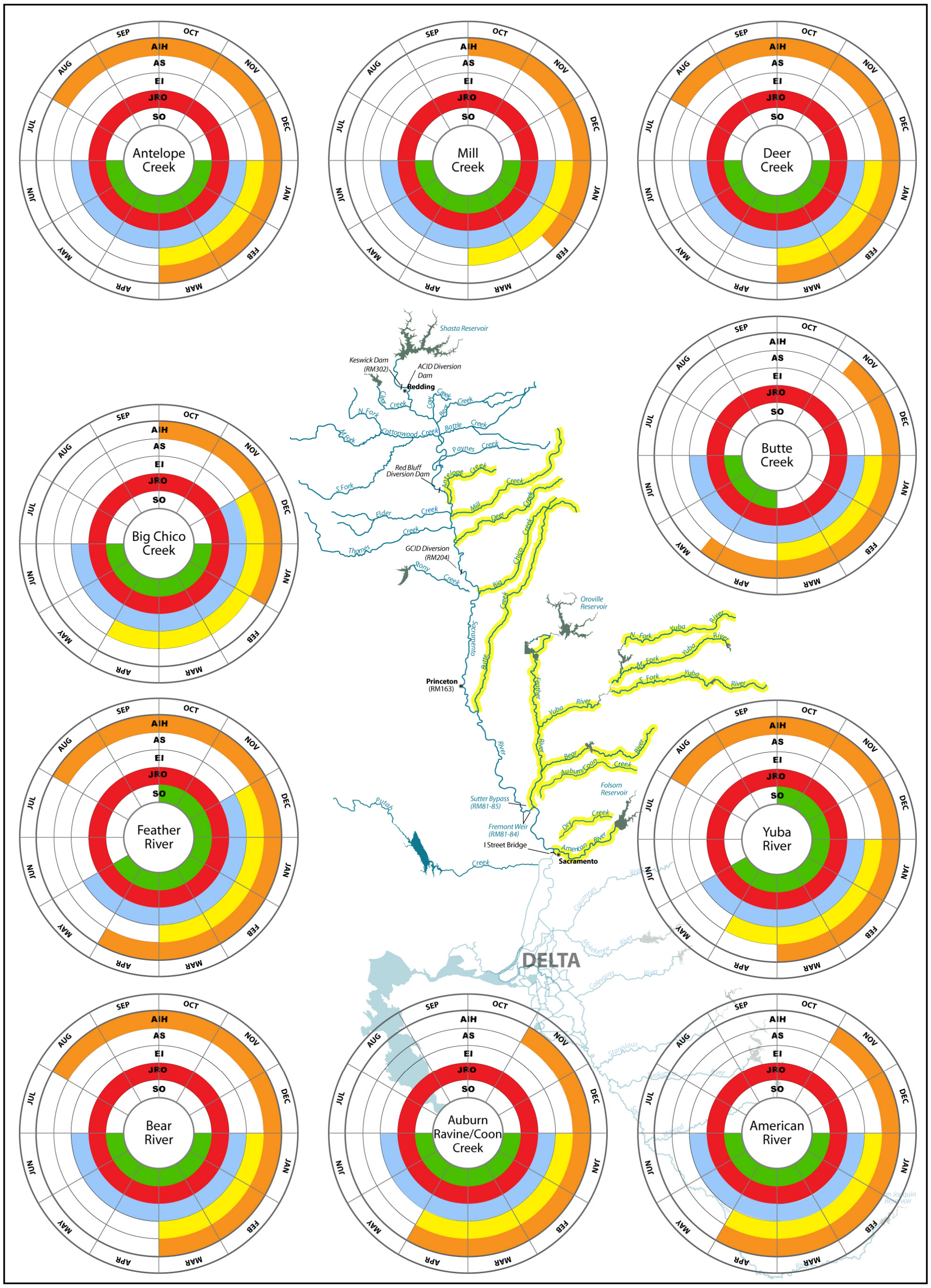

Figure 4-2. Life Stage Timing for Steelhead Populations in the Northern Sierra Nevada Diversity Group

Sources: American River (Water Forum 2001); Auburn/Coon and Dry creeks (assumed to be same as American River); Feather River (CALFED and YCWA 2005; pers. comm., Cavallo 2004); Bear River (Castleberry et al. 1991; CDFG 1986; McEwan 2001); Yuba River (CALFED and YCWA 2005; CDFG 1991b; McEwan 2001); Butte Creek (Shapovalov and Taft 1954; USFWS 2000); Big Chico Creek (Big Chico Creek Watershed Alliance Website 2007; Interagency Ecological Program Steelhead Project Work Team Website 1998); Deer Creek (Castleberry et al. 1991; CDFG 1986; McEwan 2001); Mill Creek (Hallock 1989); Antelope Creek (Castleberry et al. 1991; CDFG 1986; McEwan 2001)

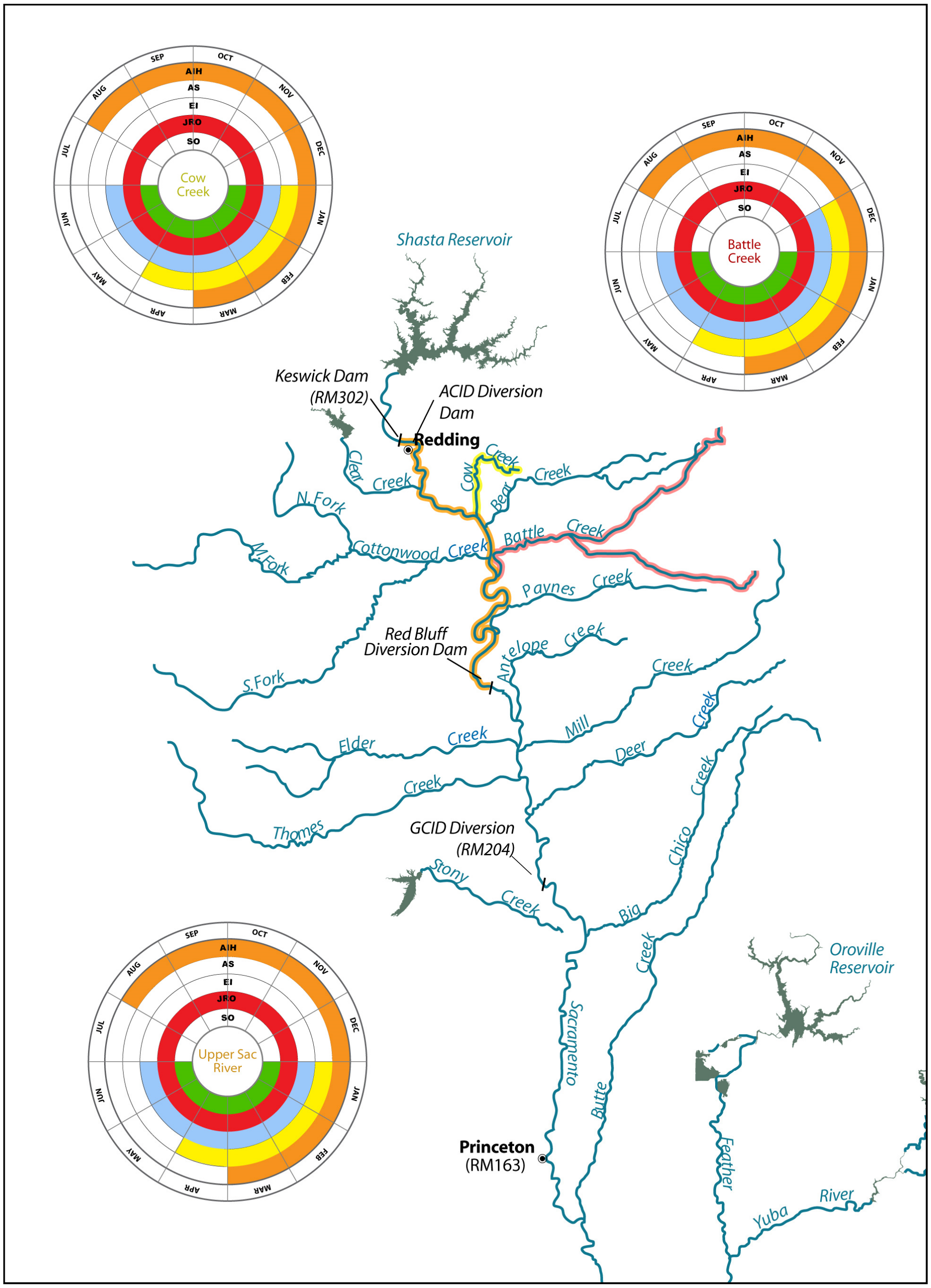

Figure 4-3. Life Stage Timing for Steelhead Populations in the Basalt and Porous Lava Diversity Group

Sources: Battle Creek (Ward and Kier 1999a); Cow Creek (Castleberry et al. 1991; CDFG 1986; McEwan 2001); Upper Sacramento River (Castleberry et al. 1991; CDFG 1986; McEwan 2001)

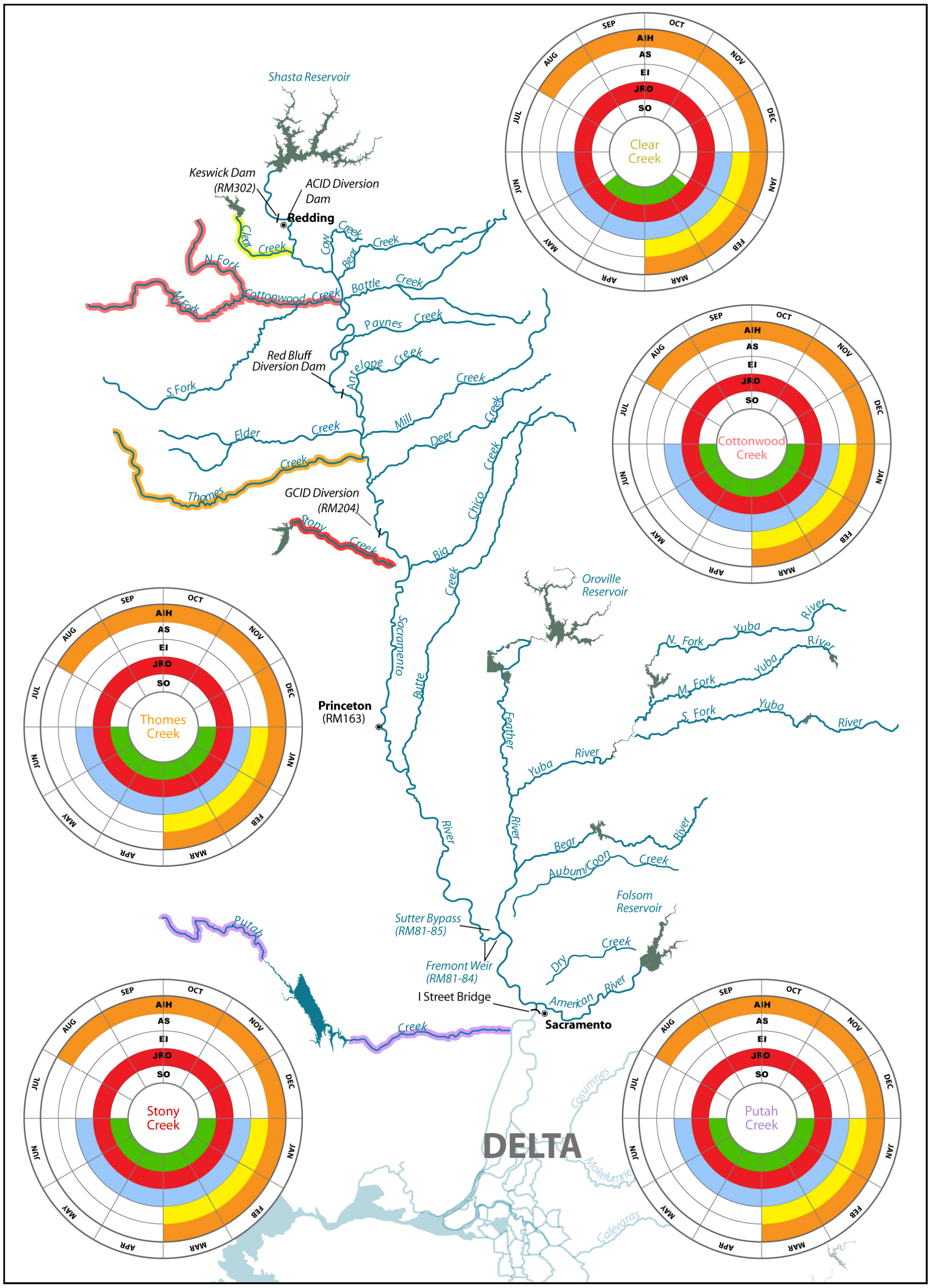

Figure 4-4. Life Stage Timing for Steelhead Populations in the Northwestern California Diversity Group

Sources: Stony Creek (Castleberry et al. 1991; CDFG 1986; McEwan 2001); Thomes Creek (Castleberry et al. 1991; CDFG 1986; McEwan 2001); Cottonwood/Beegum Creek (Castleberry et al. 1991; CDFG 1986; McEwan 2001); Clear Creek (Castleberry et al. 1991; CDFG 1986; McEwan 2001); Putah Creek (Castleberry et al. 1991; CDFG 1986; McEwan 2001)

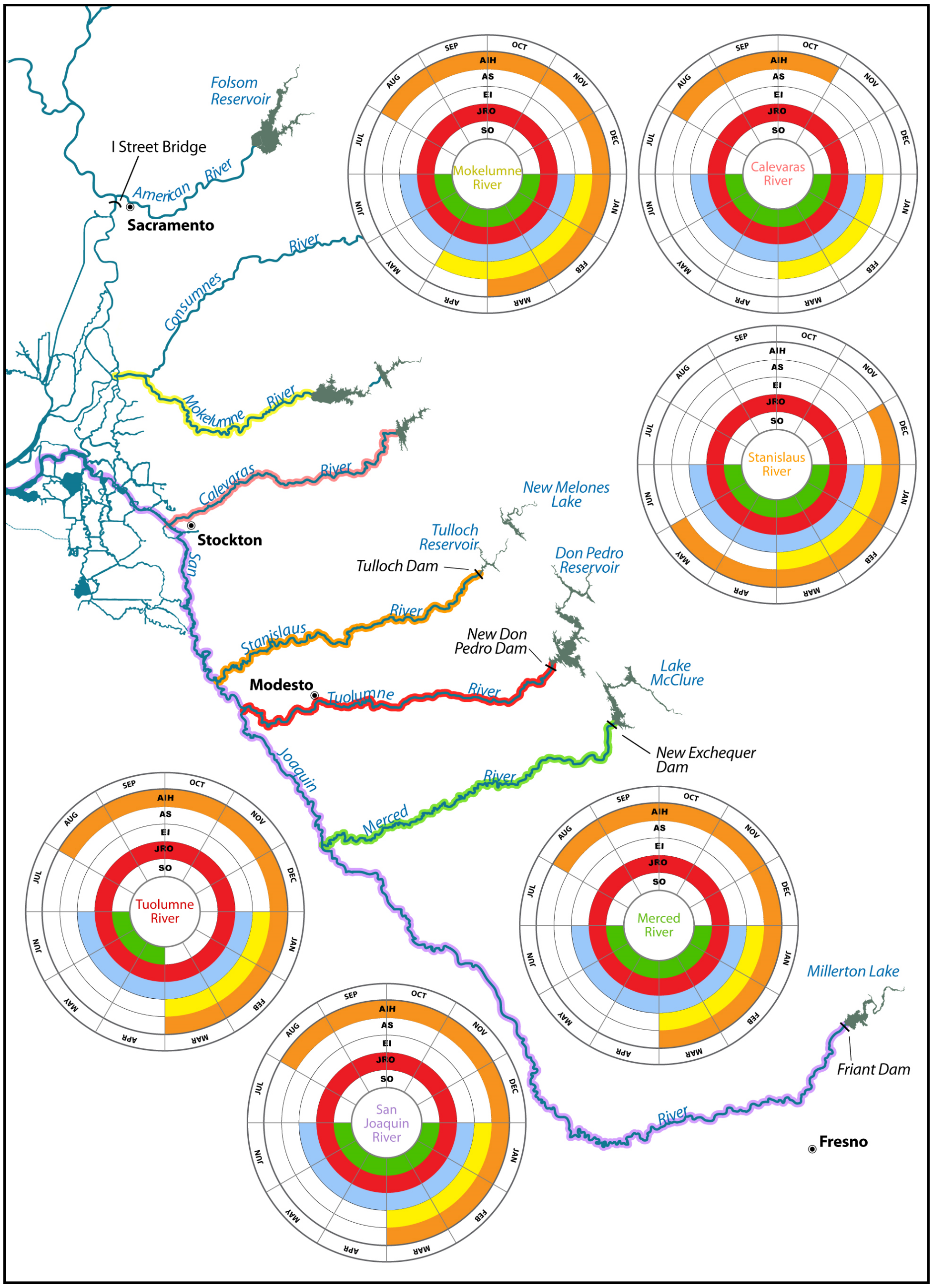

Figure 4-5. Life Stage Timing for Steelhead Populations in the Southern Sierra Nevada Diversity Group

Sources: Mokelumne River (EBMUD Website 2007); Calaveras River (Fishery Foundation of California 2004); Stanislaus River (Castleberry et al. 1991; CDFG 1986; McEwan 2001); Tuolumne River (Castleberry et al. 1991; CDFG 1986; McEwan 2001; Reynolds et al. 1993); Merced River (Castleberry et al. 1991; CDFG 1986; McEwan 2001); San Joaquin River (Castleberry et al. 1991; CDFG 1986; McEwan 2001)

4.2.3 EMBRYO INCUBATION

4.2.3.1 GEOGRAPHIC AND TEMPORAL DISTRIBUTION

California Central Valley adult steelhead eggs incubate within the gravel and hatch from approximately 19 to 80 days at water temperatures ranging from 60°F to 40°F, respectively. After hatching, the young fish (alevins) remain in the gravel for an extra two to six weeks before emerging from the gravel and taking up residence in the shallow margins of the stream. Steelhead generally initiate their embryo incubation period from late-December to June (CDFG 1996b). The general life stage timing for each individual steelhead population is displayed in Figures 4-2, 4-3, 4-4 and 4-5.

4.2.3.2 BIOLOGICAL REQUIREMENTS

Steelhead embryo incubation generally occurs from December through June in the Central Valley. Following deposition of fertilized eggs in the redd, they are covered with loose gravel. Central Valley steelhead eggs can reportedly survive at water temperature ranges of 35.6°F to 59°F (Myrick and Cech 2001). However, steelhead eggs reportedly have the highest survival rates at water temperature ranges of 44.6°F to 50.0°F (Myrick and Cech 2001). The eggs hatch in three to four weeks at 50°F to 59°F, and fry emerge from the gravel four to six weeks later (Shapovalov and Taft 1954).

Steelhead embryo development requires a constant supply of well oxygenated water. This implies a loose gravel substrate allowing high permeability with little silt or sand deposition during the development time period.

4.2.4 JUVENILE REARING AND OUTMIGRATION

4.2.4.1 GEOGRAPHIC AND TEMPORAL DISTRIBUTION

Most juvenile steelhead spend one to three years in fresh water before emigrating to the ocean as smolts (Shapovalov and Taft 1954). The primary period of steelhead smolt outmigration from rivers and creeks to the ocean generally occurs from January to June. The general life stage timing for each individual steelhead population is displayed in Figures 4-2, 4-3, 4-4 and 4-5.

BIOLOGICAL REQUIREMENTS

Regardless of life history strategy, for the first year or two of life rainbow trout and steelhead are found in cool, clear, fast-flowing permanent streams and rivers where riffles predominate over pools, there is ample cover from riparian vegetation or undercut banks, and invertebrate life is diverse and abundant (Moyle 2002). The smallest fish are most often found in riffles; intermediate size fish in runs; and larger fish in pools. Steelhead can be found where daytime water temperatures range from nearly 32°F to 81°F in the summer (Moyle 2002). However, an upper water temperature limit of 65°F is preferred for growth and development of Sacramento River and American River juvenile steelhead (NMFS 2002a).

Studies indicate that the majority of returning adult steelhead in the Central Valley spend two years in freshwater before emigrating to the ocean (McEwan 2001). For juvenile steelhead to survive the winter, they must avoid predation and high flows by finding cover and velocity refuge in the interstitial spaces between cobbles and boulders (Bjornn 1971; Everest *et al.* 1986). Age 0+ steelhead can use shallower habitats and can find interstitial cover in gravel-sized substrates, while age 1+ or 2+ steelhead need a coarser cobble/boulder substrate for cover (Bisson *et al.* 1988).

4.2.5 SMOLT OUTMIGRATION

4.2.5.1 GEOGRAPHIC AND TEMPORAL DISTRIBUTION

In the Sacramento River, juvenile steelhead migrate to the ocean in spring and early summer at 1 to 3 years of age and 10 to 25 cm FL with peak migration through the Delta in March and April (Reynolds et al. 1993). Hallock et al. (1961) found that juvenile steelhead in the Sacramento River basin migrate downstream during most months of the year, but the peak emigration period occurred in the spring, with a much smaller peak in the fall.

4.2.5.2 BIOLOGICAL REQUIREMENTS

Steelhead successfully smolt at water temperatures in the 43.7°F to 52.3°F range (Myrick and Cech 2001). Optimum water temperature range for successful smoltification in young steelhead is 44.0°F to 52.3°F (Rich 1987). Wagner (1974) reported smolting ceased rather abruptly when water temperatures increased to 57°F-64°F.

In the Sacramento River, juvenile steelhead migrate to the ocean in spring and early summer at 1 to 3 years of age and 10 to 25 cm FL, with peak migration through the Delta in March and April (Reynolds *et al.* 1993). Hallock *et al.* (1961) found that juvenile steelhead in the Sacramento River basin migrate downstream during most months of the year, but the peak emigration period occurred in the spring, with a much smaller peak in the fall.

4.2.6 SUB-ADULT AND ADULT OCEAN RESIDENCE

4.2.6.1 GEOGRAPHIC AND TEMPORAL DISTRIBUTION

Steelhead may remain in the ocean from one to four years, growing rapidly as they feed in the highly productive currents along the continental shelf (Barnhart 1986). Compared to Chinook salmon, relatively little is known about the geographic distribution of steelhead in the ocean.

4.2.6.2 BIOLOGICAL REQUIREMENTS

Oceanic and climate conditions such as sea surface temperatures, air temperatures, strength of upwelling, El Niño events, salinity, ocean currents, wind speed, and primary and secondary productivity affect all facets of the physical, biological and chemical processes in the marine environment. Some of the conditions associated with El Niño events include warmer water temperatures, weak upwelling, low primary productivity (which leads to decreased zooplankton biomass), decreased southward transport of sub-arctic water, and increased sea levels (Pearcy 1997). For juvenile steelhead, warmer water and weakened upwellings are possibly the most important of the ocean conditions associated with El Niño. Because of the weakened upwelling during an El Niño year, juvenile California steelhead would need to more actively migrate offshore through possibly stressful warm waters with numerous inshore predators. Strong upwelling is probably beneficial because of the greater transport of smolts offshore, beyond major concentrations of inshore predators (Pearcy 1997).

4.3 THREATS AND STRESSORS

4.3.1 SUMMARY OF ESA LISTING FACTORS

Central Valley steelhead have been extirpated from most of their historical range. At the time of listing, NMFS was concerned with widespread degradation, destruction and blockage of freshwater habitats within this region, and the potential results of continuing habitat destruction and water allocation problems, the pervasive opportunity for genetic introgression resulting from widespread production of hatchery steelhead and the potential ecological interaction between introduced stocks and native stocks.

In 1996, NMFS estimated that Central Valley total run size based on dam counts, hatchery returns, and past spawning surveys was probably less than 10,000 fish. Both natural and hatchery runs have declined since the 1960s. Counts at RBDD averaged 1,400 fish from 1991 to 1996, compared with runs in excess of 10,000 fish in the late 1960s. Run-size estimates for the hatchery produced American River stock averaged less than 1,000 fish, compared to 12,000 to 19,000 in the early 1970s (CDFG 1996b).

Historically, steelhead occurred naturally throughout the Sacramento and San Joaquin River basins; however, stocks have been extirpated from large areas of the Sacramento River Basin and of the San Joaquin River Basin. The California Advisory Committee on Salmon and Steelhead (1988) reported a reduction in Central Valley steelhead habitat from 6,000 miles historically to 300 miles at present. Reynolds *et al.* (1993) reported that 95 percent of salmonid habitat in California's Central Valley has been lost, largely due to mining and water development activities. They also noted that declines in Central Valley steelhead stocks are *"due mostly to water development, inadequate instream flows, rapid flow fluctuations, high summer water temperatures in streams immediately below reservoirs, diversion dams which block access, and entrainment of juveniles into unscreened or poorly screened diversions."* Other problems related to land use practices (agriculture and forestry) and urbanization also have certainly contributed to stock declines.

The major threat to genetic integrity for Central Valley steelhead comes from past and present hatchery practices. Sufficient overlap of spawning hatchery and natural fish within this DPS probably exists for some genetic introgression to occur. Also a substantial problem with straying of hatchery fish exists within this DPS (Hallock 1989). Habitat fragmentation and population declines resulting in small, isolated populations also pose genetic risk from inbreeding, loss of rare alleles, and genetic drift.

In 1998, NMFS continued to identify long-term declines in abundance, small population sizes in the Sacramento River, and the high risk of interbreeding between hatchery and naturally spawned steelhead as major concerns for Central Valley steelhead. The significant loss of historic habitat, degradation of remaining habitat from water diversions, reduction in water quality and other factors, harvest impacts, and the lack of monitoring data on abundance as other important risk factors for this DPS. Nevertheless, NMFS concluded that the risks to Central

Valley steelhead had diminished based on a review of existing and recently implemented state conservation efforts and federal management programs (e.g., CVPIA AFRP, CALFED) that address key factors for the decline of this species. NMFS stated that Central Valley steelhead were benefiting from two major conservation initiatives, being simultaneously implemented: (1) the CVPIA, which was passed by Congress in 1992; and (2) the CALFED Program, a joint state/federal effort implemented in 1995.

The CVPIA is specifically intended to remedy habitat and other problems associated with the construction and operation of the CVP. The CVPIA has two key features related to steelhead. First, it directs the Secretary of the Interior to develop and implement a program that makes all reasonable efforts to double natural production of anadromous fish in Central Valley streams (Section 3406(b)(1)) by the year 2002. The AFRP was initially drafted in 1995 and subsequently revised in 1997. Funding has been appropriated since 1995 to implement restoration projects identified in the AFRP planning process. Second, the CVPIA dedicates up to 800,000 acre-feet of water annually for fish, wildlife, and habitat restoration purposes (Section 3406(b)(2)) and provides for the acquisition of additional water to supplement the 800,000 acre-feet (Section 3406(b)(3)). USFWS, in consultation with other federal and state agencies, has directed the use of this dedicated water yield since 1993.

The CALFED Program, which began in June 1995, was charged with the responsibility of developing a long-term Bay-Delta solution. A major element of the CALFED Program is the ERP, which was intended to provide the foundation for long-term ecosystem and water quality restoration and protection throughout the region. Among the non-flow factors for decline that have been targeted by the Program are unscreened diversions, waste discharges and water pollution prevention, impacts due to poaching, land derived salts, exotic species, fish barriers, channel alterations, loss of riparian wetlands, and other causes of estuarine habitat degradation.

The level of risk faced by the Central Valley steelhead DPS may have diminished since the 1996 listing proposal as a result of habitat restoration and other measures that have recently been implemented through the CALFED and CVPIA programs. Although most restoration measures designed to recover Chinook salmon stocks do benefit steelhead or are benign in that regard, focusing restoration solely on Chinook salmon leads to inadequate measures to restore steelhead because of their different life histories and resource requirements, particularly that of rearing juveniles (McEwan 2001). Additional actions that benefit Central Valley steelhead include efforts to enhance fisheries monitoring, like the Central Valley Steelhead Monitoring Plan, and conservation actions to address artificial propagation.

In 2005 and 2006, NMFS affirmed that risk factors for Central Valley steelhead include extirpation from most of the historical range, a monotonic decline in abundance, declining proportion of wild fish in spawning runs, substantial opportunity for deleterious interactions with hatchery fish (including out-of-basin-origin stocks).

4.3.1.1 Destruction, Modification, or Curtailment of Habitat or Range

The spawning habitat for Central Valley steelhead has been greatly reduced from its historical range. The vast majority of historical spawning habitat for Central Valley steelhead has been eliminated by fish passage impediments associated with water storage, withdrawal, conveyance, and diversions for agriculture, flood control, and domestic and hydropower purposes. Modification of natural flow regimes has resulted in increased water temperatures, changes in fish community structures, depleted flow necessary for migration, spawning, rearing, and flushing of sediments from spawning gravels. These changes in flow regimes may be driving a shift in the frequencies of various life history strategies, especially a decline in the proportion of the population migrating to the ocean. Land use activities, such as those associated with agriculture and urban development, have altered steelhead habitat quantity and quality.

Although many historically harmful practices have been halted, much of the historical damage to habitats limiting steelhead remains to be addressed, and the necessary restoration activities will likely require decades.

4.3.1.2 Overutilization for Commercial, Recreational, Scientific, or Education Purposes

Steelhead have been, and continue to be, an important recreational fishery throughout their range. Although there are no commercial fisheries for steelhead in the ocean, inland steelhead fisheries include tribal and recreational fisheries. In the Central Valley, recreational fishing for steelhead is popular, yet harvest is restricted to only the visibly marked hatchery-origin fish, which reduces the likelihood of retaining naturally spawned wild fish.

The permits NMFS issues for scientific or educational purposes stipulate specific conditions to minimize take of steelhead individuals during permitted activities. There are currently 11 active permits in the Central Valley that may affect steelhead. These permitted studies provide information about Central Valley steelhead that is useful to the management and conservation of the DPS.

4.3.1.3 Disease or Predation

Steelhead are exposed to bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, hatcheries, migratory routes, and the marine environment. Very little current or historical information exists to quantify changes in infection levels and mortality rates attributable to these diseases for steelhead. Naturally spawned fish tend to be less susceptible to pathogens than hatchery-reared fish.

Introduction of non-native species and modification of habitat have resulted in increased predatory populations and salmonid predation in river systems. In general, predation rates on steelhead are considered to be an insignificant contribution to the large declines observed in West Coast steelhead populations. In some local populations, however, predation may significantly influence salmonid abundance when other prey species are not present and habitat conditions lead to the concentration of adults and/or juveniles.

4.3.1.4 Inadequacy of Existing Regulatory Mechanisms

Federal Efforts

There have been several federal actions attempting to reduce threats to the Central Valley steelhead DPS. The BOs for the CVP and SWP and other federal projects involving irrigation and water diversion and fish passage, for example, have improved or minimized adverse impacts to steelhead in the Central Valley. There have also been several habitat restoration efforts implemented under CVPIA and CALFED programs that have led to several projects involving fish passage improvements, fish screens, floodplain management, habitat restoration, watershed planning, and other projects that have contributed to improvement of steelhead habitat.

However, despite federal actions to reduce threats to the Central Valley steelhead DPS, the existing protective efforts are inadequate to ensure the DPS is no longer in need of Federal protection. There remain high risks to the abundance, productivity, diversity, and spatial structure of the steelhead DPS.

NON-FEDERAL EFFORTS

Measures to protect steelhead throughout the State of California have been in place since 1998. The state's Natural Communities Conservation Planning (NCCP) program involves long-term planning with several stakeholders. A wide range of measures have been implemented, including 100 percent marking of all hatchery steelhead, zero bag limits for unmarked steelhead, gear restrictions, closures, and size limits designed to protect smolts. NMFS and CDFG are working to improve inland fishing regulations to better protect both anadromous and resident forms of O. mykiss populations. A proposal to develop a comprehensive status and trends monitoring plan for Central Valley steelhead was submitted for funding consideration to the CALFED ERP in 2005. The proposal, drafted by CDFG and the interagency Central Valley Steelhead Project Work Team, was selected by the ERP Implementing Agency Managers, and is to receive funding as a directed action. Long-term funding for implementation of the monitoring plan, once it is developed, still needs to be secured. There are many sub-watershed groups, landowners, environmental groups, and non-profit organizations that are conducting habitat restoration and planning efforts that may contribute to the conservation of steelhead.

However, despite federal and non-federal efforts to promote the conservation of the Central Valley steelhead DPS, few efforts address conservation needs at scales sufficient to protect the entire steelhead DPS. The lack of status and trend monitoring and research is one of the critical limiting factors to this DPS.

4.3.1.5 OTHER NATURAL AND MANMADE FACTORS AFFECTING ITS CONTINUED EXISTENCE

NMFS and the BRT is concerned that the proportion of naturally produced fish is declining. Two artificial propagation programs for steelhead in the Central Valley – CNFH and FRFH – may decrease risk to the DPS to some degree by contributing increased abundance to the DPS. Potential threats to natural steelhead posed by hatchery programs include: (1) mortality of natural steelhead in fisheries targeting hatchery-origin steelhead; (2) competition for prey and habitat; (3) predation by hatchery-origin fish on younger natural fish; (4) genetic introgression by hatchery-origin fish that spawn naturally and interbreed with local natural populations; and (5) disease transmission.

Changes in climatic events and global climate, such as El Niño ocean conditions and prolonged drought conditions, can threaten the survival of steelhead populations already reduced to low abundance levels as the result of the loss and degradation of freshwater and estuarine habitats.

Floods and persistent drought conditions have reduced already limited spawning, rearing, and migration habitats.

Unscreened water diversions entrain outmigrating juvenile steelhead and fry. Unscreened water diversions and CVP and SWP pumping plants entrain juvenile steelhead, leading to fish mortality.

4.3.2 NON-LIFE STAGE-SPECIFIC THREATS AND STRESSORS FOR THE DPS

Potential threats to the California Central Valley steelhead population that are not specific to a particular life stage include the potential negative impacts of the current artificial propagation program utilizing several hatcheries in the Sacramento-San Joaquin drainage, the small wild population size, the genetic integrity of the population due to both hatchery influence and small population size, and the potential effects of long-term climate change. Each of these potential threats is discussed in the following sections.

4.3.2.1 ARTIFICIAL PROPAGATION PROGRAM

Currently, four hatcheries in the Central Valley produce steelhead to supplement the Central Valley wild steelhead population. The hatcheries and their current production targets are listed in **Table 4-1**.

Table 4-1. Hatcheries Producing Steelhead in the Central Valley

Hatchery	Production Target
Coleman National Fish Hatchery	600,000
Feather River Fish Hatchery	450,000
Nimbus Fish Hatchery	430,000
Mokelumne Fish Hatchery	100,000

Potential adverse effects to wild steelhead populations associated with hatchery production are similar to those described in Section 2.3.2.1 for winter-run Chinook salmon. However, recent research has indicated that approximately 63 to 92 percent of steelhead smolt production is of hatchery-origin (NMFS 2003), which is a higher percentage than winter-run Chinook salmon estimates. More importantly, these data suggest that the relative proportion of wild to hatchery smolt production is decreasing (NMFS 2003). All California hatchery steelhead programs began 100 percent adipose fin-clipping in 1998 to differentiate between hatchery steelhead from natural steelhead.

Propagation of steelhead at the CNFH has been occurring for over 50 years. Hatchery-origin and natural-origin steelhead have been managed as a single stock; mixing of hatchery and natural origin population components occurred through spawning at the hatchery and intermingling of natural spawners in Battle Creek. Niemela *et al*. (2008) used genetic pedigree analysis to evaluate relative reproductive success and fitness among hatchery-origin and natural origin population components based on multilocus DNA microsatellite genotypes. Preliminary results suggest that hatchery origin spawners experienced low relative reproductive success, producing significantly fewer adult offspring in comparison to natural origin spawners. Additionally, repeat spawning was more prevalent in the natural origin component of the population.

4.3.2.2 SMALL POPULATION SIZE

Potential adverse effects of a small population size for steelhead would be similar to those described above in Section 2.3.2.2 for winter-run Chinook salmon. The California Central Valley steelhead DPS mean annual escapement was estimated at 1,952 based on a 5-year period ending in 1993 (Good *et al.* 2005). During that time period a minimum escapement of 1,425 and a maximum escapement of 12,320 were observed (Good *et al.* 2005). A long-term trend analysis indicated that the population was declining (Good *et al.* 2005). In the 2005 Updated Status of Central Valley Steelhead, NMFS suggests that there has been no significant status change since the 1993 data and the population continues to decline (Good *et al.* 2005). The steelhead run in the Feather River has been increasing over the past several years; however, over 99 percent of the run is of direct hatchery-origin (DWR 2002b).

4.3.2.3 GENETIC INTEGRITY

There is still significant local genetic structure to Central Valley steelhead populations, although fish from the San Joaquin and Sacramento basins cannot be distinguished genetically (Nielsen *et al*. 2003). Hatchery effects appear to be localized – for example, Feather River and Feather River Hatchery steelhead are closely related as are American River and Nimbus Hatchery fish (DWR 2002b). Leary *et al.* (1995) report that hatchery straying has increased gene flow among steelhead populations in the Central Valley and that a smaller amount of genetic divergence is observed among Central Valley populations compared to wild British Columbia populations largely uninfluenced by hatcheries. Currently, natural annual production of steelhead smolts in the Central Valley is estimated at 181,000 and hatchery production is 1,340,000 for a ratio of 0.148 (Good *et al.* 2005). Current monitoring by hydroacoustic tracking has revealed that Mokelumne River/Hatchery steelhead (FRFH source stock) are straying into the American River (J. Smith, EBMUD, pers. comm.).

There has also been significant transfer of genetic material among hatcheries within the Central Valley as well as some transfer from systems outside the Central Valley. There have also been transfers of steelhead from the Feather River Hatchery to the Mokelumne Hatchery. For example, eyed eggs from the Nimbus hatchery were transferred to the FRFH several time in the late 1960s and early 1970s (DWR 2002b). Also, Nimbus Hatchery steelhead eggs have often been transferred to the Mokelumne Hatchery. Additionally, an Eel River strain of steelhead was used as the founding broodstock for the Nimbus Hatchery (CDFG 1991c). In the late 1970s, a strain of steelhead was brought in from Washington State for the Feather River Hatchery (DWR 2002b).

4.3.2.4 LONG-TERM CLIMATE CHANGE

The potential effects of long-term climate change on Central Valley steelhead would be similar to those described above in Section 2.3.2.4 for winter-run Chinook salmon. However, because steelhead normally spend a longer time in freshwater as juveniles than other anadromous salmonids, any negative effects of climate change may be more profound on steelhead populations.

4.3.3 SAN FRANCISCO, SAN PABLO AND SUISUN BAYS

4.3.3.1 ADULT IMMIGRATION AND HOLDING

Steelhead adult immigration and holding in California's Central Valley Basin occurs from August through March. Threats to steelhead that potentially may occur in the bays are similar to those described above in Section 2.3.3.1 for winter-run Chinook salmon.

4.3.3.2 JUVENILE REARING AND OUTMIGRATION

Threats to steelhead juvenile rearing and outmigration that potentially occurs in the Bays are similar to those described above in Section 2.3.3.2 for winter-run Chinook salmon.

4.3.4 SACRAMENTO-SAN JOAQUIN DELTA

4.3.4.1 ADULT IMMIGRATION AND HOLDING

Threats to steelhead adult immigration and holding that potentially occur in the Delta are similar to those described above in Section 2.3.4.1 for winter-run Chinook salmon. Because water temperatures in the Delta are normally too warm for this life stage from August through mid-October, it is likely that most steelhead have passed through the Delta into the mainstem Sacramento River and beyond by this time. Water temperatures in the Delta would not be suitable for this life stage during August and September.

4.3.4.2 JUVENILE REARING AND OUTMIGRATION

In the Sacramento River, juvenile steelhead migrate to the ocean in winter and spring, with peak migration through the Delta in March and April (Reynolds et al. 1993). According to juvenile steelhead catch data in the Delta from 1995 to 2006, peak juvenile steelhead catch occurred during March and April at Mossdale, and during January through May at Chipps Island (IEP Website 2007).

Factors creating threats to the juvenile rearing and outmigration life stage of steelhead would be similar to those described above in Section 2.3.4.2 for winter-run Chinook salmon. Water temperatures in the Delta begin rising in April and are likely unsuitable after May.

As discussed in Section 2.3.4.2 predation is considered a major source of fish loss in the Clifton Court Forebay. Past predation studies and fisheries management at Clifton Court Forebay have focused on loss of entrained fish due to predatory fish. Mayfield (2008) suggests that predatory birds may also play a role in predation losses at the forebay and that double-crested cormorants (*Phalacrocorax auritus*) are a likely predator on entrained juvenile steelhead and even more so on other smaller salmonid juveniles.

4.3.5 LOWER SACRAMENTO RIVER (PRINCETON [RM 163] TO THE DELTA)

4.3.5.1 ADULT IMMIGRATION AND HOLDING

Adult steelhead immigration into the Delta and the lower Sacramento River occurs from August through March (McEwan 2001; NMFS 2004a), and peaks during January and February (Moyle 2002). See Section 4.2.1 for a more complete description of the biological requirements and description of this life stage. Factors that may adversely affect steelhead adult immigration and holding in the lower Sacramento River include passage impediments, adverse flow conditions, harvest in the sportfishery, poaching, and potential water quality problems, particularly adverse water temperatures.

PASSAGE IMPEDIMENTS/BARRIERS

In the lower Sacramento River, flows are diverted into the SDWSC. Adult salmon have been caught close to the locks at the upstream end of the channel and have also been observed to be blocked from migrating upstream by the locks (NMFS 1997). It is likely that some steelhead also enter the channel and may be delayed in their upstream migration.

HARVEST/ANGLING IMPACTS

There is no commercial fishery for steelhead in the Sacramento River. The in-river sportfishery generally allows the taking of hatchery steelhead (identified by adipose fin-clip) during the adult immigration and holding period. The Valley district regulations and special regulations prohibit the harvest of any non-clipped rainbow trout/steelhead in anadromous waters above the Deschutes Road Bridge.

The extent of poaching of steelhead in this reach of the river is unknown. There are no man-made structures that would unnaturally increase densities allowing for easy poaching however, some level of poaching likely occurs due to snagging by anglers or inadvertent misidentification of caught fish.

WATER QUALITY

Suitable water temperatures for adult steelhead migrating upstream to spawning grounds range from 46°F to 52°F (CDFG 1991c). Because water temperatures in the lower Sacramento River generally exceed these temperatures, this reach of the river likely serves only as a migration corridor.

Additionally, NMFS (NMFS 1997) reports that recent research has indicated that water temperatures in the lower Sacramento River may have risen by as much as 4°F to 7°F since the late 1970s. Potentially the cumulative losses of shade along the river may have influenced water temperatures in this reach.

FLOW CONDITIONS

During high flow or flood events, water is diverted into the Sutter and Yolo bypasses upstream of the City of Sacramento. Adult steelhead migrating upstream may enter these bypasses, where their migration may be delayed or blocked by control structures. To date, there have not been any measures implemented to protect adult salmonids from entrainment into the flood control bypasses (NMFS 1997).

4.3.5.2 JUVENILE REARING AND OUTMIGRATION

Steelhead juvenile rearing and outmigration on the lower Sacramento River is not well understood. Currently no monitoring takes place from GCID to Knights Landing. The primary period for steelhead smolt emigration occurs from March through June (Castleberry *et al.* 1991).

WATER TEMPERATURE

Water temperature in the lower Sacramento River likely does not adversely affect juvenile steelhead as it is used primarily as a migration corridor. However, outmigrating or rearing juvenile steelhead may also be exposed to warmwater releases from the Colusa Drain at Knights Landing. Warm water is released from the drain to the river mainly from April through June. Releases from the drain can exceed 2,000 cfs and 80°F. Although steelhead would likely show an avoidance reaction to the warmwater, it may present a partial thermal barrier to downstream migration.

WATER QUALITY

The major point source threat of pollution in the Sacramento River is the Iron Mountain Mine as described above for spring-run Chinook salmon. However, because the Iron Mountain Mine is so far north of the lower Sacramento River, most heavy metal contaminants from the mine have likely either settled out or have been diluted to acceptable EPA standards by the time water reaches this reach of the river. Within the lower Sacramento River and Bay-Delta there are three large municipal water treatment plants which can be an important point source of pollution: the West Sacramento WWTP, the Sacramento Regional WWTP, and the Stockton Sewage Treatment Plant. Pre-treatment, primary treatment and secondary treatments in place since the 1950s have all reduced pollutant loading to the system however, heavy metal loadings and toxic organic pollutants remain a major concern (NMFS 1997).

The main non-point sources of pollution in the lower Sacramento River are urban runoff and agricultural drainage. Stormwater runoff from the city of Sacramento has been shown to be acutely toxic to aquatic invertebrates (NMFS 1997). Significant urban runoff also occurs during the dry season and is created from domestic/commercial landscape irrigation, groundwater infiltration, pumped groundwater discharges and construction projects (NMFS 1997). The Colusa Basin Drain is the largest source of agricultural return flow in the Sacramento River. It drains agricultural areas serviced by the Tehama-Colusa and Glenn-Colusa Irrigation districts and discharges to the Sacramento River below Knights Landing. The drain has been identified as a major source of warm water, pesticides, turbidity, suspended sediments, dissolved solids, nutrients and trace metals (NMFS 1997).

FLOW CONDITIONS

Flood control structures in the lower Sacramento River are designed to divert water from the river during a major flood event into the Butte Creek basin and the Sutter and Yolo bypasses. The diversions can be significant. For example, the flood control system can divert as much as four to five times more flow down the bypasses than remains in the river (NMFS 1997). Juvenile steelhead migrating down the river may enter the diversions during storm events. Studies conducted on the Sutter Bypass show that the highest proportion of flows are diverted from December through March with a peak occurring in February (NMFS 1997). Juveniles diverted into the bypasses may experience migration delays, potential stranding as flood flows recede and increased rates of predation.

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Bank stabilization for flood control purposes has resulted in extensive areas of streambank riprapping. Rip-rapping the river bank involves removing vegetation along the bank and upper levees which removes most instream and overhead cover in nearshore areas. Overhanging vegetation is referred to as SRA habitat. Woody debris and overhanging vegetation within SRA habitat provide escape cover for juvenile salmonids from predators. Aquatic and terrestrial insects are an important component of juvenile salmonid diet. These insects are dependent on a healthy riparian habitat.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Flood control measures, regulated flow regimes and river bank protection measures have all had a profound effect on riparian and instream habitat in the lower Sacramento River. Levees constructed in this reach are built close to the river in order to increase streamflow, channelize the river to prevent natural meandering, and maximize the sediment carrying capacity of the river (NMFS 1997). Channelization of the river requires bank protection measures such as riprapping to reduce the effects of streambank erosion. Additionally, nearshore aquatic areas are deepened and sloped to a uniform gradient, such that variations in water depth, velocity and direction of flow are replaced by consistent moderate to high velocities. Juvenile steelhead utilize slow and slack water velocities for rearing and the channelization of the river has removed most of this habitat type.

LOSS OF FLOODPLAIN HABITAT

The process of channelizing the lower Sacramento River has resulted in a loss of connectivity with the floodplain which serves as an important source of woody debris and gravels that aid in establishing a diverse riverine habitat, as well as increasing primary and secondary productivity and exporting nutrients.

ENTRAINMENT

Entrainment is defined as the redirection of fish from their natural migratory pathway into areas or pathways not normally used. Entrainment also includes the take, or removal, of juvenile fish from their habitat through the operation of water diversion devices and structures such as siphons, pumps and gravity diversions (NMFS 1997). A primary source of entrainment is unscreened or inadequately screened diversions. A survey by CDFG identified 350 unscreened diversions along the Sacramento River downstream of Hamilton City.

Entrainment of juvenile winter-run Chinook salmon has been identified as one of the most significant causes of mortality in the Delta (NMFS 1997) and is likely also true for steelhead. In addition, a program to flood rice field stubble during the winter has been implemented extending the period for potential entrainment (NMFS 1997).

Outmigrating juvenile steelhead may also be diverted into the Yolo or Sutter bypasses during high flow or flood events and stranded as flood waters recede. The entrance to the Yolo Bypass is the Fremont Weir upstream of Sacramento near the confluence with the Feather River. During high flows weir gates are open and because the weir is not screened, juveniles enter the Yolo Bypass, where they may rear and eventually leave through the lower end upstream of Chipps Island in the Delta, or be trapped in isolated ponds as waters recede. Additionally, Sacramento River water is diverted into the SDWSC, and outmigrating juvenile steelhead may enter the channel where water quality, flow levels and rearing conditions are extremely poor (NMFS 1997).

PREDATION

Only limited information on predation of steelhead juveniles is available. Native species that are known to prey on juvenile steelhead include Sacramento pikeminnow and potentially other steelhead. Predation by pikeminnow can be significant when juvenile salmonids occur in high densities such as below dams or near diversions. Although Sacramento pikeminnow are a native species and predation on juvenile steelhead is a natural phenomenon, loss of SRA habitat and artificial instream structures tend to favor predators and may change the natural predator-prey dynamics in the system favoring predatory species (CALFED 2000c). Non-native striped bass may also be a significant predator on juvenile steelhead. Although no recent studies of striped bass predation on juvenile salmonids have been completed, Thomas (1967 *in* NMFS 1997) found that in the lower Sacramento River, salmon accounted for 22 percent of striped bass diet.

HATCHERY EFFECTS

Hatchery steelhead may prey on juvenile wild steelhead. In the lower Sacramento River, hatchery steelhead from the FRFH are planted in the Feather River below Yuba City at a large enough size and at a time when they could intercept other rearing wild steelhead.

4.3.6 MIDDLE SACRAMENTO RIVER (RED BLUFF DIVERSION DAM [RM 243] TO PRINCETON [RM 163])

4.3.6.1 ADULT IMMIGRATION AND HOLDING

In this reach of the river, the potential threats to the adult immigration and holding life stage of steelhead arise from a potential passage impediment at the GCID HCPP, potential water quality problems, particularly adverse water temperatures, harvest in the sportfishery and poaching.

PASSAGE IMPEDIMENTS/BARRIERS

Although the GCID HCPP (~RM 205) and associated water diversions present problems for emigrating juvenile salmonids, adults are not likely affected.

HARVEST/ANGLING IMPACTS

Current sportfishing regulations in the Sacramento River allow for the taking of hatchery steelhead during the adult immigration and holding period. The Valley district regulations and special regulations prohibit the harvest of any non-clipped rainbow trout/steelhead in anadromous waters above the Deschutes Road Bridge. It is possible that some wild steelhead could be holding in the mainstem river below the RBDD prior to spawning in late December to March.

The extent of poaching of steelhead in this reach of the river is unknown. Some level of poaching likely occurs due to snagging by anglers or inadvertent misidentification of caught fish. Additionally, when passage at the RBDD is hindered there may be unusually high densities of salmonids downstream of the dam that present poaching opportunities.

WATER TEMPERATURE

Water Temperatures in this reach of the river are similar to those occurring in the lower Sacramento River. However, some holding of adult steelhead may occur downstream of the RBDD in deep coldwater pools. With the installation of the TCD at Shasta Dam in 1997, water temperatures have cooled slightly and suitable water temperatures for adult holding likely extend downstream of the RBDD for a short distance during the winter months.

WATER QUALITY

Water quality in the middle Sacramento River is not likely to adversely affect adult steelhead.

4.3.6.2 JUVENILE REARING AND OUTMIGRATION

Factors that may adversely affect juvenile steelhead in the middle Sacramento River are similar to those that occur in the lower river as described above. However, in addition to those factors there is a potential downstream passage impediment at the GCID's HCPP at RM 205.

WATER TEMPERATURE

Water temperature issues in the middle Sacramento River are similar to those described above in the lower Sacramento River. Water temperatures normally exceed 60°F from July through September and in dry years can often exceed 66°F (NMFS 1997).

WATER QUALITY

The only point source pollution that has been identified and may potentially affect this reach of the river is the Iron Mountain Mine described in Section 3.5.1.2. Non-point source pollution sources include both urban and agricultural runoff similar to that described above for the lower Sacramento River. Urban runoff is likely not as great in this reach of the river as that occurring in the lower Sacramento River but agricultural runoff is likely similar or greater.

FLOW CONDITIONS

Flow conditions, under current regulated flow regimes, in the middle Sacramento River likely have little effect on outmigrating juvenile steelhead.

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Loss of riparian habitat that has occurred in the middle Sacramento River is similar to that described above for the lower Sacramento River.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Physical habitat alteration that has occurred in the middle Sacramento River is similar to that described above for the lower Sacramento River. The river is not quite as confined in this reach as levees are constructed further from the channel than those occurring in the lower river.

LOSS OF FLOODPLAIN HABITAT

Although the river is not quite as confined in this reach as levees are constructed further from the channel than those occurring in the lower river, the river is disconnected from its historic floodplain by flood control measures including regulated flows and levees.

ENTRAINMENT

The exact number of unscreened diversions in this reach of the river is not known. A study by the California Advisory Committee on Salmon and Steelhead Trout completed in 1987 reported that over 300 unscreened irrigation, industrial, and municipal water supply diversions occur on the Sacramento River between Redding and Sacramento (NMFS 1997). Although most of these diversions are small, cumulatively they likely entrain a large number of outmigrating juvenile salmonids.

Studies are currently underway to determine the effectiveness of new fish screens at the GCID HCPP to determine the effectiveness of new fish screens installed in 2001 (Reclamation 2007). However, juvenile emigration data suggest that peak steelhead movement past the GCID facility occurs in spring and early summer months, when pumping volume may be high (CUWA and SWC 2004).

Historically, the GCID HCPP at RM 205 has created downstream migration problems for juvenile salmonids. The GCID pumping plant may divert up to 20 percent of the Sacramento River. Rotary drum fish screens were installed in 1972 to help protect juvenile salmon but they were largely ineffective and never met NMFS or CDFG screen design criteria. Flat plate screens were installed in front of the rotary screens in 1993 to help alleviate the problem until a more permanent solution could be found. Juvenile steelhead are exposed to the GCID pumping plant facilities as early as mid-July extending into late November when the diversion season ends.

The interim flat-plate screens were an improvement over the rotary drum screens but were still likely to subject juvenile salmonids to impingement due to high approach velocities along the screens, inadequate sweeping to approach velocities, and long exposure time at the screen (USFWS 1995 *in* NMFS 1997). Construction of a new screening facility was completed in 2001 and the testing and monitoring program for the facility are now underway (Reclamation 2007). The testing and monitoring of the new facility is scheduled to be completed in 2007 (Reclamation 2007).

PREDATION

Predation on juvenile steelhead in the middle Sacramento River is likely occurring from native Sacramento pikeminnow, native and hatchery-reared steelhead and striped bass. Although the extent of predation is unknown, predation from Sacramento Pikeminnow and striped bass is likely similar to that occurring in the lower Sacramento River as described above. Predation from hatchery steelhead is likely somewhat less than that occurring in the lower Sacramento River because the Feather River hatchery fish enter the Sacramento River downstream of this reach. Additionally, steelhead released from the CNFH are likely more evenly distributed throughout the river by the time they reach this section.

Opportunities for high predation rates also may be present at the GCID HCPP. The plant is described below as a passage impediment. Studies have indicated that Sacramento pikeminnow are the primary predator at the pumping plant, although striped bass were also found with salmonids in their stomachs (CALFED 2000c). Vogel and Marine (1995) report that predation is likely in the vicinity of the fish screens associated with the diversion.

HATCHERY EFFECTS

Direct adverse effects of hatchery operations are likely minimal in the middle reach of the Sacramento River primarily because steelhead released from the FRFH enter the river downstream and steelhead released by the CNFH are likely more evenly distributed throughout the system by the time they reach the middle reach.

4.3.7 UPPER SACRAMENTO RIVER (KESWICK DAM TO RED BLUFF DIVERSION DAM)

4.3.7.1 ADULT IMMIGRATION AND HOLDING

In this reach of the river, the potential threats to the adult immigration and holding life stage of steelhead arise from potential passage impediments at the RBDD, harvest in the sportfishery and poaching. Keswick Dam, at the upstream terminus of this reach of the river presents an impassable barrier to upstream migration.

PASSAGE IMPEDIMENTS/BARRIERS

Keswick Dam (~RM 302) presents an impassable barrier to all upstream migration of steelhead and represents the upstream extent of anadromous salmonid habitat in the mainstem Sacramento River. The ACID Dam (RM 298.5) was constructed in 1917 about three river miles downstream of the current Keswick Dam. Originally the dam was a barrier to upstream fish migration until 1927 when a poorly designed fish ladder was installed (NMFS 1997). The dam is a 450-foot long flashboard structure which has the capability of raising the backwater level 10 feet. The dam is only installed during the irrigation season which typically runs from early April to October or early November. As mentioned above, the fish ladder providing passage around the dam was poorly designed and although steelhead were able to negotiate the ladder, it did present a partial impediment to upstream migration. In 2001, a new fish ladder was installed. Post-project monitoring indicates that the new fish ladder is operating effectively (CDFG 2004c). Another potential problem associated with the facility is that high volume releases from the ACID's canal downstream of the dam may create false attraction flows for migrating adult salmon or steelhead leading them into the canal where they could be stranded (NMFS 1997). Regardless of potential problems associated with the ACID Dam, the facility likely affects only a small portion of the run. The reach from the ACID Dam to Keswick Dam is three miles; representing only a small portion of the potential spawning area.

The RBDD at RM 243 is a concrete structure 52 feet high and 740 feet long. The dam has 11 gates which are raised or lowered to control the level of Lake Red Bluff enabling gravity diversion into the TCC. Permanent fish ladders are located on each abutment of the dam. The fish ladders are inefficient in allowing upstream migration of adult salmonids (NMFS 1997). In several radio tagging studies of adult winter-run Chinook salmon, 43-44 percent of tagged fish were blocked by the dam (Vogel *et al.* 1988, Hallock *et al.* 1982 *in* NMFS 1997). Tagged winter-run Chinook salmon that eventually passed the dam were delayed by an average of 125 hours in one study (Vogel *et al.* 1988 *in* NMFS 1997) and 437 hours in a previous study (Hallock *et al.* 1982 *in* NMFS 1997). At present, the dam gates are kept in the raised position from September 15 through May 14, which should allow for the free passage of immigrating steelhead.

HARVEST/ANGLING IMPACTS

The take of wild trout is allowed from April 1 through the end of August (1 per day) above the Deschutes River Bridge. Wild trout are defined as not having an adipose fin-clip and being less than 16 inches in length. Wild trout greater than 16 inches in length are considered steelhead and take is not allowed. High densities of salmonids near Keswick Dam could create poaching opportunities.

WATER TEMPERATURE
Water temperatures in the upper Sacramento River during the fall and winter months when adult steelhead would be immigrating are suitable for this life stage.

WATER QUALITY
Water quality in the upper Sacramento River likely does not adversely affect adult steelhead.

FLOW CONDITIONS
Flow fluctuations in the upper Sacramento River are not of a magnitude to adversely affect adult steelhead.

4.3.7.2 SPAWNING

Specific information regarding steelhead spawning within the mainstem Sacramento River is limited due to lack of monitoring Currently, the number of steelhead spawning in the Sacramento River is unknown because redds cannot be distinguished from a large resident rainbow trout population that has developed as a result of managing the upper Sacramento River for coldwater species.

Spawning in this reach of the Sacramento River may be affected by adverse flow conditions, physical habitat alteration, recreational sportfishing and poaching, and poor water quality (water temperature). Each of these potential effects is described below.

PASSAGE IMPEDIMENTS/BARRIERS
Keswick Dam presents an impassable barrier to upstream salmonid migration and, therefore, marks the upstream extent of currently accessable spawning habitat in this reach of the Sacramento River.

HARVEST/ANGLING IMPACTS
Harvest of steelhead in this reach of the river is likely similar to that in the middle reach. High densities of salmonids near Keswick Dam could create poaching opportunities.

WATER TEMPERATURE
Because of suitable water temperatures in this reach of the river and only marginal water temperature conditions downstream of the RBDD, almost all spawning activity likely occurs in the upper Sacramento River.

WATER QUALITY
Water quality in the upper Sacramento River is similar to that described in the middle reach described above. Because of the proximity of the Iron Mountain Mine, point source pollutants may be more concentrated in this reach of the river but effects on spawning are likely negligible.

FLOW CONDITIONS
Large flow fluctuations are the main concern regarding adverse flow conditions in the middle and upper Sacramento River. The largest and most frequent flow reductions have occurred in the late summer and early fall when flashboards at the ACID Dam require adjustment. However, because the largest flow reductions normally occur before spawning takes place, it is not likely

that adverse flow conditions in this reach of the river have a significant negative effect on steelhead.

SPAWNING HABITAT AVAILABILITY

As stated above, the level of steelhead spawning in the upper Sacramento River is unknown; however, it is generally thought that available spawning habitat in the upper Sacramento River is sufficient to support the winter-run Chinook salmon population at its currently low level (NMFS 1997). However, as the population recovers, spawning gravel availability could become a limiting factor (NMFS 1997). These same factors likely apply to steelhead.

PHYSICAL HABITAT ALTERATION

The construction of dams in the upper Sacramento River has eliminated the major source of suitable gravel recruitment to reaches of the river below Keswick Dam. Gravel sources from the banks of the river and floodplain have also been substantially reduced by levee and bank protection measures.

HATCHERY EFFECTS

Hatchery influence on spawning steelhead has not been evaluated. However, because a large proportion of steelhead stocks in the Central Valley are of hatchery origin, it is likely that significant inter-breeding between hatchery and wild fish occurs.

4.3.7.3 EMBRYO INCUBATION

HARVEST/ANGLING IMPACTS

The Sacramento River supports a popular year-round recreational fishery. It is possible that anglers could disturb developing embryos in redds while wading.

WATER TEMPERATURE

The embryo incubation life stage of steelhead is the most sensitive to elevated water temperatures. Because embryo incubation of steelhead in the upper Sacramento River generally would occur from January through June, water temperatures are likely suitable for embryo incubation.

WATER QUALITY

Water quality issues that may produce adverse effects on steelhead include both point source and non-point source pollution. The inactive Iron Mountain Mine in the Spring Creek watershed near Keswick Dam creates the largest discharge of toxic material into the Sacramento River. There are three metals of particular concern: copper, cadmium and zinc. The early life stages of salmon are the most sensitive to these metals (NMFS 1997). The acid mine drainage from Iron Mountain Mine is among the most acidic and metal laden anywhere in the world (NMFS 1997). Historically, discharge from the mine has produced massive fish kills.

In 1983 the Iron Mountain Mine site was declared a superfund site by the EPA. Since that time various mitigation measures have been implemented including a neutralization plant that has improved the ability to control metal loadings to the river. NMFS (1997) reported that although significant improvements have been made, basin plan objectives had not yet been achieved in 1997. Since that time, other mitigation measures have been implemented resulting in a 95 percent reduction in historic copper, cadmium and zinc discharges (EPA 2006). At present, acid mine waste still escapes untreated from waste pile and seepage on the north side of Iron Mountain and flows into Boulder Creek, which eventually flows into the Sacramento River (EPA 2006). However, there were no significant exceedances of dissolved metal concentrations in the Sacramento River in 2002 and 2003 (CDFG 2004c). Another point source of pollution in the upper Sacramento River identified in NMFS (1997) is the Simpson Mill near Redding which discharges PCBs into the river.

Non-point source pollution consists of sediments from storm events, stormwater runoff in urban and developing areas and agricultural runoff. Sediments constitute nearly half of the material introduced to the river from non-point sources (NMFS 1997). Excess silt and other suspended solids are mobilized during storm events from plowed fields, construction and logging sites and mines. High sediment loading can interfere with eggs developing in redds by reducing the ability of oxygenated water to percolate down to eggs in the gravel. Stormwater runoff in urban areas can transport oil, trash, heavy metals and toxic organics all of which are potentially harmful to incubating eggs. Agricultural runoff can contain excess nutrients, pesticides and trace metals.

FLOW CONDITIONS

Flow fluctuations are the primary concern related to potential adverse effects on the embryo incubation life stage of steelhead. For example, if spawning steelhead construct redds during periods of high flow, those redds could become dewatered during subsequent periods of low flow. Historically, the largest and most rapid flow reductions have occurred during the irrigation season (normally, early April through October) when adjustments are required at the ACID Dam. To accommodate these adjustments, Sacramento River flows at times have been decreased by one-half or greater, over the course of a few hours (NMFS 1997). Currently, under the CVP/SWP BO, flow reductions are divided into several intervals to prevent the stranding of juveniles. However, reducing the rates of flow reduction does not protect existing redds from becoming dewatered.

4.3.7.4 JUVENILE REARING AND OUTMIGRATION

Factors that may adversely affect juvenile steelhead in the upper Sacramento River are similar to those described above in the middle Sacramento River and include physical habitat alteration, water quality, predation, passage impediments, and entrainment.

PASSAGE IMPEDIMENTS

Keswick Dam at RM 302 presents an impassable barrier to upstream migrating adult steelhead hence it represents the upstream extent of steelhead habitat on the mainstem Sacramento River. The ACID Dam, located about three miles below Keswick Dam, represents the furthest upstream impediment, due to injury, to juvenile outmigration. The dam is only in place during the irrigation season which typically extends from April through November. During the rest of the year neither upstream adult migration nor downstream juvenile outmigration is hindered. Juveniles migrate past the dam by either dropping as much as ten feet over the dam to the river below or moving through the bypass facility. In either case, juveniles may become disoriented and more susceptible to predation.

The RBDD, at the downstream extent of the upper Sacramento River, creates the final passage impediment to downstream outmigration in this reach of the river. The dam is described in Section 3.3.3.1. When the dam gates are lowered, Lake Red Bluff is formed slowing flows and delaying juvenile outmigration, allowing more opportunities for predation as described above in Section 3.6.5.3. Predation is also facilitated below the dam as described in Section 3.6.5.3. Historically, there was both direct and indirect mortality associated with fish using an ineffective juvenile fish bypass facility at the dam. A Downstream Migrant Fish Facility was installed in 1992, which appears to have reduced mortality associated with use of the bypass facility.

WATER TEMPERATURE

Following the installation of the TCD at Shasta Dam in 1997 water temperatures in this reach of the river seldom exceed 60°F and are suitable for juvenile steelhead rearing year-round.

WATER QUALITY

Point source pollution may occur from both the Iron Mountain Mine and the Simpson Mill as described in Section 3.5.1.2. Because the juvenile life stage of steelhead is the most susceptible to adverse effects from pollution and the proximity of these two potential sources of pollution, potential adverse effects are likely more profound in the upper Sacramento River compared to the lower reaches. Effects of non-point source pollution from urban runoff and agricultural drainage are similar to those described above for the middle Sacramento River. However, pollution associated with urban runoff is likely higher due to the proximity of the cities of Redding and Red Bluff.

FLOW CONDITIONS

Although flow fluctuations do occur in the upper Sacramento River for maintenance activities at the ACID or other water project control measures, flow reductions are governed by ramping rates which likely negate adverse effects due to flow fluctuations on juvenile steelhead.

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Levee building, bank protection measures and the disconnection of the river from its historic floodplain have all had negative effects on riparian habitat. Woody debris and SRA habitat provide important escape cover for juvenile salmon. Aquatic and terrestrial insects, a major component of juvenile salmon diet, are dependent on riparian habitat. Aquatic invertebrates are dependent on the organic material provided be a healthy riparian habitat and many terrestrial invertebrates also depend on this habitat. Studies by the CDFG as reported in NMFS (NMFS 1997) demonstrated that a significant portion of juvenile Chinook salmon diet is composed of terrestrial insects, particularly aphids, which are dependent on riparian habitat.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Controlled flow regimes and channelization of the upper Sacramento River have resulted in a loss of natural river morphology and function.

LOSS OF FLOODPLAIN HABITAT

The construction of levees and streambank protection measures have resulted in a disconnection of the river with its historic floodplain.

ENTRAINMENT

Adverse effects due to entrainment of outmigrating juvenile steelhead at unscreened diversions are similar to those described above for the middle Sacramento River. The new downstream migrant fish facility at the RBDD has reduced entrainment problems at the RBDD.

PREDATION

Significant predators of juvenile steelhead in the upper Sacramento River include Sacramento pikeminnow and both hatchery and wild steelhead. Striped bass, a significant predator in lower reaches of the river, typically do not utilize the upper Sacramento River; however, they are present immediately below the RBDD.

The most serious adverse effect due to predation occurs in the vicinity of the RBDD. Passage through Lake Red Bluff can delay outmigrating juvenile steelhead and increases the opportunities for predation by both fish and birds (Vogel and Smith 1986 as citied *in* NMFS 1997). Salmonid juveniles passing under the gates at the RBDD are heavily preyed upon by both striped bass and Sacramento pikeminnow (NMFS 1997). Large concentrations of Sacramento pikeminnow have been observed accumulating immediately below the RBDD when juvenile salmonids are present (Garcia 1989 in NMFS 1997).

HATCHERY EFFECTS

The extent of predation on juvenile wild steelhead by hatchery-reared steelhead is not known. However, steelhead releases by the CNFH may have a high potential for inducing high levels of predation on naturally produced wild salmonids (CALFED 2000c). The CNFH has a current production target of releasing approximately 600,000 steelhead in January and February at sizes of 125 to 275 mm (CALFED 2000c). Juvenile steelhead released by the CNFH may also compete for resources with naturally produced juvenile steelhead.

4.3.8 NORTHERN SIERRA NEVADA DIVERSITY GROUP

4.3.8.1 AMERICAN RIVER

The American River drains a watershed of approximately 1,895 square miles (Reclamation 1996), and is a major tributary to the Sacramento River. The American River has historically provided over 125 miles of riverine habitat to anadromous and resident fishes. Presently, use of the American River by anadromous fish is limited to the 23 miles of river below Nimbus Dam (the lower American River).

The Nimbus Fish Hatchery steelhead program mitigates for steelhead spawning habitat eliminated by construction of Nimbus Dam, with an annual goal of releasing 430,000 yearling steelhead. Specific information on the number and status of indigenous American River steelhead is lacking but early reports suggested that steelhead entered the river during most months of the year and included a spring run. Early Nimbus Fish Hatchery broodstock included naturally produced fish from the American River and stocks from the Mad, Eel, Sacramento and Russian rivers. Based on the ESA listing, the indigenous American River steelhead are presumed to be phenotypically similar to Central Valley steelhead. However, American River steelhead may not have been phenotypically or genotypically similar to the Central Valley stock based on anecdotal run timing information and Nimbus Fish Hatchery records that suggest some American River steelhead were physically larger than typical Sacramento or Feather River winter-run steelhead. The present run of American River winter steelhead are physically larger and demonstrate a freshwater entry timing more similar to winter run Eel River steelhead than the Central Valley stock Lee 2008).

The American River winter steelhead run appears to be a predominately hatchery supported run and since the 2001-2002 trapping season, 97.8% of the steelhead trapped are of hatchery origin. Surveys also suggest that the number of steelhead actually spawning in the river is small. During the last 10 years, most adult steelhead trapped appear to be three years of age and the number of smaller fish (16 in.) during the same period averaged less than two percent (Lee 2008).

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

In 1955, Folsom and Nimbus dams were constructed on the mainstem of the American River approximately 28 and 23 miles, respectively, upstream from the confluence with the Sacramento River. Fish passage facilities were not built at Folsom or Nimbus dams blocking all anadromous salmonid upstream migration at Nimbus Dam. Anadromous salmonids are now restricted to the lower 23 miles of the American River extending from Nimbus Dam downstream to the confluence with the Sacramento River.

HARVEST/ANGLING IMPACTS

Current fishing regulations allow for the harvest of hatchery-reared steelhead (identified by an adipose fin clip) in the American River. The harvesting of wild steelhead is not allowed. However, heavy angling pressure in the river likely leads to some wild steelhead mortality even for those fish that are caught and released. The number of hatchery-reared steelhead harvested in the American River is estimated to have been 116 in 1998 (April through December), 567 in 1999 (January through December), 499 in 2000 (January through December) and 469 in 2001 (January and March through June) (CDFG 1999c, 2000b, 2001d and 2002b).

WATER TEMPERATURE

Water temperatures in the American River during the steelhead adult immigration and holding period (November through April) are generally below 55°F, which is suitable for this life stage (SWRI 2004).

WATER QUALITY

Water quality in the American River is generally good and meets applicable regulatory standards for both aquatic life and human health, with few exceptions. Therefore, water quality conditions in the lower American River are not expected to affect adult steelhead immigration.

FLOW CONDITIONS

Operation of Folsom and Nimbus dams has resulted in higher flows during the fall and summer and significantly lower flows during winter and spring. However, flow standards in the American River are adequate to support steelhead adult immigration.

SPAWNING

Steelhead spawning in the lower American River occurs from December through April. In 2003, 2004 and 2005, between 40 and 48 percent of steelhead redds were found in the upper three miles of the American River (Hannon and Deason 2005). From 2002 through 2005, 95 percent of all steelhead redds in the American River were found upstream of the Watt Avenue Bridge (Hannon and Deason 2005).

Passage Impediments/Barriers

Anadromous salmonids are now restricted to the lower 23 miles of the American River extending from Nimbus Dam downstream to the confluence with the Sacramento River.

Harvest/Angling Impacts

Current fishing regulations allow for the harvest of hatchery-reared steelhead (identified by an adipose fin clip) in the American River. The harvesting of wild steelhead is not allowed.

Water Temperature

In the American River, steelhead spawning generally occurs from January through April. Water temperatures during this time period are generally below 55°F and suitable for steelhead spawning (SWRI 2004).

Water Quality

The Ambient Monitoring Program (AMP) was established under the Sacramento Coordinated Monitoring Program (CMP) to characterize ambient water quality conditions in the Sacramento and American rivers. As reported by the AMP, based on data from 1992 through 1998, monitored ambient water quality constituents meet applicable regulatory standards for both aquatic life and human health, with few exceptions. Therefore, water quality in the lower American River is adequate to support successful steelhead spawning.

Flow Conditions

The construction and operation of Folsom Dam has altered the historic flow regime of the lower American River. Historically, fluctuations during the fall and winter were caused by natural rainfall patterns, but the dry season flows were low and fairly constant. Varying water demands of the CVP have shifted the timing of flow fluctuations to late spring and summer (CDFG 1991c). This shift in the timing of flow fluctuations likely does not affect steelhead spawning. However, flow fluctuations can have an effect on steelhead spawning habitat. For example, reductions from 2,500 cfs to 1,500 cfs would result in a loss of over 60 percent of viable spawning habitat and dewater up to 40 acres of potential spawning habitat (CDFG 2001b).

Spawning Habitat Availability

Observations of lower American River spawning gravel indicate that substrate particle sizes are relatively large compared to those typically used by steelhead in other streams. A lack of suitable spawning gravel may be related to the lack of recruitment of smaller gravel from upstream of Nimbus and Folsom dams (CDFG 1991c).

Physical Habitat Alteration

The lower American River currently provides a diversity of aquatic habitats, including shallow riffles, glides, runs, pools and of channel backwater habitats. From Nimbus Dam downstream to

Goethe Park (approximately nine river miles), the river is relatively unrestricted by levees. From Goethe Park downstream to the confluence with the Sacramento River, the river is constrained by levees which have resulted in a corresponding decrease in habitat diversity (SWRI 2004).

HATCHERY EFFECTS

The source stock of the Nimbus Hatchery steelhead program is from the Eel River, with one-time genetic infusions of CNFH and Warm Springs Hatchery stocks (SWFSC 2003). The run-timing of Nimbus Hatchery steelhead indicates Eel River derivation, and recent genetic analysis (Nielsen *et al.* 2003) links the hatchery stock to the natural spawning population in the American River. The Nimbus Hatchery stock is not part of the Central Valley steelhead DPS, and its impacts to the American River population include genetic introgression, altered life history, and competition over spawning and rearing habitat in the lower American River. Nimbus Hatchery spawns steelhead and re-releases them back into the American River. This may diversify age structure of steelhead in the hatchery stock (advantage) and river (genetic disadvantage), as kelts have higher fecundity and larger eggs. However, as kelts have the potential to spawn again, they compound the effects from annual number of hatchery stock releases. Hatchery returns increase the abundance of the run overall, but dominate or displace natural steelhead numbers.

The steelhead spawning population of the American River ranges between 200 and 400 adults (Reclamation 2005), and includes an unknown percentage of Nimbus Hatchery steelhead. The Hatchery may affect water quality and aquatic life in the American River from its effluent discharge, with unknown implications of disease transmission.

EMBRYO INCUBATION

HARVEST/ANGLING IMPACTS

The lower American River is open to recreational fishing year-round. Therefore, there is a potential for wading anglers to disturb redds.

WATER TEMPERATURE

Embryo incubation of steelhead in the lower American River generally occurs from January through May. During this period, water temperatures are normally below 55°F until about the beginning of May and remain below 60°F for the remainder of May, which is suitable for steelhead embryo incubation (SWRI 2001).

WATER QUALITY

The AMP was established under the Sacramento CMP to characterize ambient water quality conditions in the Sacramento and American rivers. As reported by the AMP, based on data from 1992 through 1998, monitored ambient water quality constituents meet applicable regulatory standards for both aquatic life and human health, with few exceptions. For aquatic life, four metals exceeded the California Toxics Rule for EPA criteria. At Nimbus Dam, lead and zinc exceed applicable criteria less than once every three years, and cadmium, more than once every three years. At Discovery Park, cadmium would exceed applicable criteria more than once every three years, and copper, lead and zinc would exceed applicable criteria less than once every three years (SWRI 2004). Heavy metal concentrations that exceed EPA criteria may adversely affect developing steelhead embryos.

AMP pesticide monitoring conducted on the lower American River has occasionally detected diazinon, diuron, and simazine. The concentrations of diuron and simazine are well below concentrations identified as slightly toxic to fish; diazinon, however, was detected seven times over four years at concentrations above CDFG's recommended maximum values for fish (SWRI 2004). Pesticide concentrations above CDFG recommended values could adversely affect developing steelhead embryos.

FLOW CONDITIONS

CDFG aerial redd surveys conducted in the early 1990s have produced evidence that Chinook salmon redds are dewatered as a result of flow reductions during the fall and winter months. The same is likely true for steelhead (Water Forum 1996). The potential for significant losses to steelhead is greatest when flows are low and redds are concentrated (Water Forum 1996). CDFG conducted a four-year flow fluctuation study during 1997 to 2000. Results of the study indicate that (1) flow fluctuations are regular occurrences in the lower American River; (2) flow fluctuations are more common during the October to June time period and (3) flow fluctuations can significantly change steelhead spawning habitat viability (CDFG 2001c). The need to meet water supply requirements south of the Delta and Delta water quality standards has resulted in fluctuating flow patterns that can dewater spawning areas and associated redds (SWRI 2004).

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

Water temperatures during the summer months can become unsuitable for juvenile steelhead rearing and potentially high water temperatures is believed to be one of the limiting factors for steelhead production (SWRI 2001).

WATER QUALITY

The AMP was established under the Sacramento CMP to characterize ambient water quality conditions in the Sacramento and American rivers. As reported by the AMP, based on data from 1992 through 1998, monitored ambient water quality constituents meet applicable regulatory standards for both aquatic life and human health, with few exceptions. For aquatic life, four metals exceeded the California Toxics Rule for EPA criteria. At Nimbus Dam, lead and zinc exceed applicable criteria less than once every three years, and cadmium, more than once every three years. At Discovery Park, cadmium would exceed applicable criteria more than once every three years, and copper, lead and zinc would exceed applicable criteria less than once every three years (SWRI 2004).

AMP pesticide monitoring conducted on the lower American River has occasionally detected diazinon, diuron, and simazine. The concentrations of diuron and simazine are well below concentrations identified as slightly toxic to fish; diazinon, however, was detected seven times over four years at concentrations above CDFG's recommended maximum values for fish (SWRI 2004).

Flow Conditions

Stranding of juvenile steelhead because of rapid flow fluctuations is frequently observed in the lower American River (SWRI 2001). During a four-year study of isolation events from 1997 to 2000, a total of 22 separate events were observed (CDFG 2001c). Mortality of young salmonids that become stranded is near 100 percent. Sources of mortality in such cases include predation by fish, avian predators and thermal stress (SWRI 2001). Fluctuating flows are believed to result in considerable stranding and loss of steelhead fry in the lower American River (Water Forum 1996).

Loss of Riparian Habitat and Instream Cover

Riparian habitat along the American River is in relatively good condition from Nimbus Dam downstream to the Howe Avenue Bridge, however, revetted banks become common and riparian cover becomes limited downstream from that point (Water Forum 1996).

Loss of Natural River Morphology and Function

The lower American River currently provides a diversity of aquatic habitats, including shallow fast-water riffles, glides, runs, pools, and off-channel backwater habitats. The reach of the river extending from Nimbus Dam (RM 23) downstream to Goethe Park (RM 14), is primarily unrestricted by levees, but is bordered by some developed areas. This reach of the river is contained by natural bluffs and terraces cut into the side of the channel. The river reach from Goethe Park downstream to the confluence with the Sacramento River is bordered by levees. The construction of levees changed the geomorphology and has resulted in a reduction in river meanders and an increase in depth (SWRI 2001).

Loss of Floodplain Habitat

High floodplains produced by the deposition of sandy sediments from upstream hydraulic mining during the Gold Rush are disconnected from the river except during extremely high flow events. Without a regular cycle of floodplain inundation, species favoring infrequent inundation and many non-native species have taken advantage of the altered system and reduced the ecological integrity of the floodplain (USACE *et al.* 2001).

Entrainment

The City of Sacramento's Fairbairn WTP, located about seven miles upstream of the confluence with the Sacramento River, is the only major diversion on the lower American River. Although the diversion is screened, it reportedly does not meet NMFS/CDFG standards. There is a possibility that juvenile salmonids, including steelhead can become entrained (Water Forum 1996).

Predation

American shad, striped bass and species of black bass are all known to inhabit the lower American River and likely prey on juvenile salmonids. Additionally, manmade structures and channel confinement in the lower section of the river may have altered habitat conditions favoring native predators such as Sacramento pikeminnow.

Hatchery Effects

The Nimbus Hatchery raises and releases yearling steelhead into the American River. It is possible that some portion of these fish do not immediately begin a downstream migration and may prey on smaller naturally produced steelhead juveniles in the river.

4.3.8.2 AUBURN/COON CREEK

Auburn Ravine originates north of Auburn in Placer County and drains an area of approximately 70 square miles. Auburn Ravine flows westward out of the Sierra foothills into the East Side Canal, and is hydraulically connected to the Sacramento River via the East Side Canal and the Natomas Cross Canal near the town of Verona.

It is unlikely that Auburn Ravine historically harbored a persistent native population of salmonids. Low elevation streams in the Sierra foothills, such as Auburn Ravine, may have been essentially dry in the summer and fall. Because of their intermittent nature, these streams were not conducive to significant or consistent steelhead populations. However, anecdotal information suggests that adult steelhead have been captured and released by anglers in the Ophir area, approximately 10 miles upstream of the city of Lincoln. Additionally, long-time residents report that steelhead routinely spawned near Auburn (JSA 1999b).

Adult steelhead immigration into the Delta and the lower Sacramento River occurs from August through March (McEwan 2001; NMFS 2004a), and peaks during January and February (Moyle 2002). To reach Auburn Ravine, steelhead would migrate up the Sacramento River and enter the Natomas Cross Canal near the town of Verona. Traveling upstream in the Natomas Cross Canal, fish would then enter the East Canal and migrate slightly over 1 mile upstream to the Auburn Ravine confluence.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

Currently, there are numerous water diversions within Auburn Ravine. Most of these are seasonal agricultural diversions supplied by temporary flashboard dams that are normally in place from April 15 to October 15 having little if any effect on upstream migrating adult steelhead. There are two temporary dams located near the city or Lincoln that may remain in place until as late as mid-November, Lincoln Ranch Duck Club Dam and the Hemphill Dam, both of which are barriers to upstream migration at low to moderate flows and could present obstacles to the early part of the steelhead run (Sierra Business Council 2003).

There are several permanent structures within Auburn Ravine that present obstacles to upstream migration at all but high flows. The first of these structures is the Nevada Irrigation District gaging station located about one-quarter mile downstream of State Route 65 in Lincoln. The structure is a full channel width concrete section forming a broad plume with vertical sides and an upward sloping approach. The structure is likely a significant impediment to adult steelhead upstream migration at all but the highest flows (Sierra Business Council 2003). The next permanent manmade structure in Auburn Ravine is the Nevada Irrigation District Auburn Ravine 1 Dam located off Chili Hill Road near Ophir. This is a gravity arch dam with a crest about 8 feet above the tailwater during normal flows. The dam is an impediment to upstream migration at all but high flows. There is also a natural waterfall just upstream of Ophir that is impassable at low flows.

HARVEST/ANGLING IMPACTS

Catch and release fishing for trout is allowed from the fourth Saturday in May through October 14. This is outside of the time period when steelhead would be expected to be migrating upstream in Auburn Ravine.

WATER TEMPERATURE

Water temperatures in Auburn Ravine typically cool rapidly from mid-October through November and begin warming in March. During this time period, water temperatures generally fall below 60°F in October, and remain below 55°F from November through the beginning of March (Sierra Business Council 2003). These water temperatures should not adversely affect the adult steelhead immigration and holding life stage.

WATER QUALITY

Water quality in Auburn Ravine is generally good. In terms of heavy metal concentrations, copper is the only metal found in Auburn Ravine that occasionally exceeds California's Toxic Rule (Sierra Business Council 2003) and is not likely to adversely affect steelhead adult immigration.

FLOW CONDITIONS

Flow conditions in Auburn Ravine are significantly different under current management practices than those that occur naturally. Jones & Stokes Associates (1999) estimated flows under natural conditions and current management conditions. The results of this comparison are depicted in **Figure 4-6**. These flow conditions are not likely to adversely affect steelhead adult immigration and may provide some benefit when compared to historic conditions.

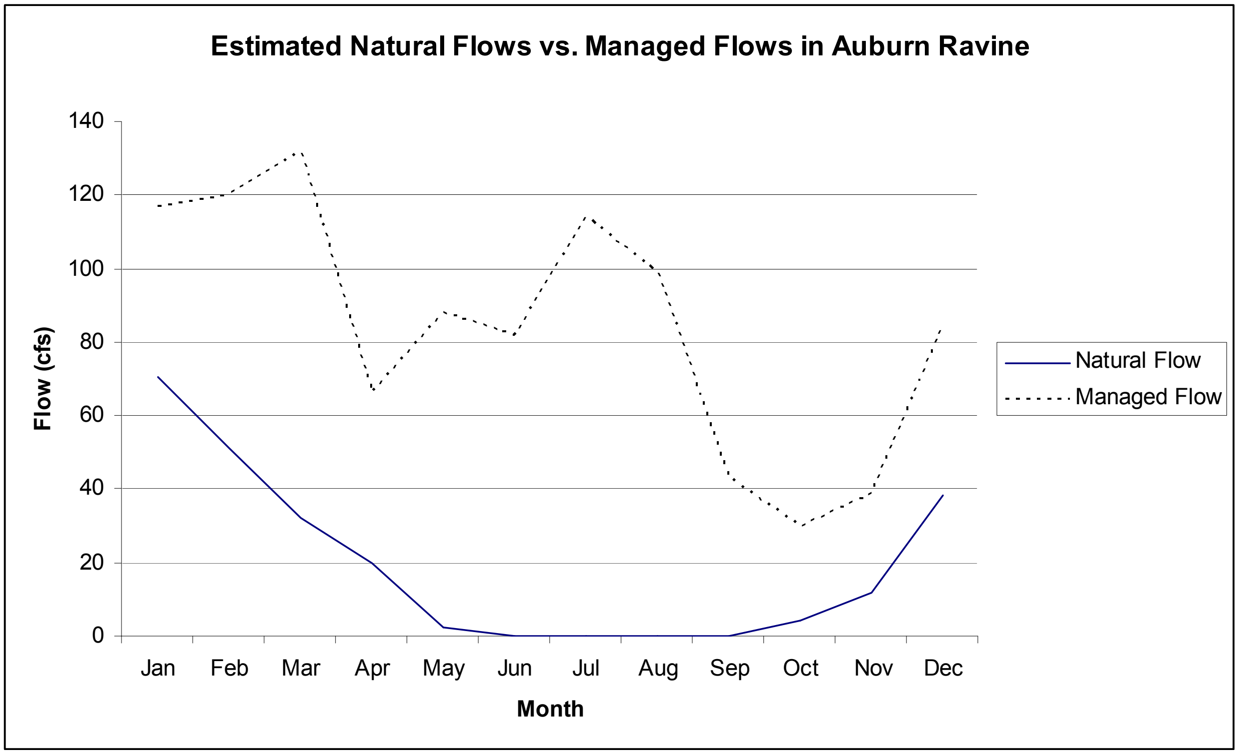

Figure 4-6. Estimated Flows in Auburn Ravine Under Natural and Current Conditions
Source: (JSA 1999b)

SPAWNING

PASSAGE IMPEDIMENTS/BARRIERS

The same passage impediments as described above for adult immigration apply to the spawning life stage.

HARVEST/ANGLING IMPACTS

Catch and release fishing for trout is allowed from the fourth Saturday in May through October 14. This is outside of the time period when steelhead would be expected to be spawning.

WATER TEMPERATURE

Water temperatures in Auburn Ravine typically cool rapidly from mid-October through November and begin warming in March. During this period, water temperatures generally fall below 60°F in October, and remain below 55°F from November through the beginning of March (Sierra Business Council 2003). These water temperatures should not adversely affect the steelhead spawning life stage.

WATER QUALITY

Water quality in Auburn Ravine is fairly good and is not expected to adversely affect steelhead spawning.

Flow Conditions

Currently, winter flows are dominated by discharges from the Lincoln Wastewater Treatment and Reclamation Facility downstream of the town of Lincoln and runoff caused by rainfall events upstream of that point where most spawning is likely to occur.

Spawning Habitat Availability

The results of a stream survey by Jones & Stokes Associates downstream of the Lincoln Wastewater Treatment and Reclamation Facility (RM 10.5) indicated relatively poor spawning habitat in this reach of Auburn Ravine (JSA 1999a). The habitat was found to be of low quality because of the lack of gravel for spawning and a shifting sand substrate that could potentially smother redds.

There appears to be good spawning habitat near Ophir, particularly in the vicinity of the Nevada Irrigation District Auburn Ravine 1 Dam. There is also reportedly good spawning habitat in Dutch Ravine, a tributary of Auburn Ravine near Ophir. However, it is not known if impediments to fish passage in Auburn Ravine prevent utilization of this reach.

Physical Habitat Alteration

Auburn Ravine is a relatively small watercourse, and little of the instream flow is from natural runoff. Most of the instream flow is water imported from the Yuba River, Bear River, and American River watersheds through various means, to meet domestic and agricultural needs in western Placer County and southeastern Sutter County (Sierra Business Council 2003). Related to the distribution of these water supplies, there are approximately 10 small seasonal diversion dams installed throughout Auburn Ravine. Each dam is usually less than 10 feet high and ponds water for diversion into agricultural areas. Larger dams also divert water into major canals.

Hatchery Effects

Stocking records do not indicate that steelhead have been planted in Auburn Ravine. Historically, rainbow trout were planted in Auburn Ravine until 1965, and rainbow trout continue to be planted in water bodies connected to Auburn Ravine (e.g., the Bear River and associated reservoirs).

Embryo Incubation

Harvest/Angling Impacts

Catch and release fishing for trout is allowed from the fourth Saturday in May through October 14. This is outside of the time period when wading anglers may disrupt steelhead embryos developing in redds.

Water Temperature

Discharges from the Lincoln Wastewater Treatment and Reclamation Facility and the Auburn Wastewater Treatment Plant (RM 24.9) increase water temperatures downstream from their respective points of discharge. However, the Basin Plan requires that discharges shall not increase water temperatures more than 5°F above the receiving water temperature (RWQCB 2005). Based on very limited water temperature data collected in 2003 and 2004, water temperatures within and upstream of the area near Ophir provide suitable water temperatures for embryo incubation, however; water temperatures increase rapidly further downstream to the next measurement point, about four miles downstream of Ophir, and are likely not suitable after about mid-March (Sierra Business Council 2003).

WATER QUALITY

Water quality in Auburn Ravine is fairly good. In terms of heavy metal concentrations, copper is the only metal found in Auburn Ravine that occasionally exceeds California's Toxic Rule (Sierra Business Council 2003).

FLOW CONDITIONS

Flow conditions upstream of the Lincoln Wastewater Treatment facilities, where most steelhead embryos would likely be developing, are likely similar to historic conditions in that they are dominated by rainfall events and irrigation diversions are minimal.

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

The lack of shading provided by loss of riparian buffers in the downstream reaches of Auburn Ravine contributes to elevated summer water temperatures. CDFG conducted electrofishing on seven reaches of Auburn Ravine in the fall/winter of 2004 and the spring of 2005 (CDFG unpublished data). The CDFG survey results suggest that Auburn Ravine contains a fairly strong steelhead/rainbow trout population with almost all juvenile rearing occurring upstream of the Lincoln Wastewater Treatment and Reclamation Facility.

Water temperatures in the vicinity of Ophir are generally cool year-round with the warmest temperatures being recorded in September at 61°F. Water temperatures cool quickly to below 55°F by November and remain below 53°F until the following July (City of Auburn 1997).

WATER QUALITY

Water quality in Auburn Ravine is generally good. Occasionally concentrations of copper may exceed California's Toxic Rule (Sierra Business Council 2003), but this is not expected to adversely affect juvenile steelhead.

FLOW CONDITIONS

As described above, flows in Auburn Ravine are significantly different under current management practices compared to natural conditions. Because summer flows are typically higher than would be expected from a Central Valley Sierra foothill stream and winter flows are also higher under existing conditions because of the introduction of water from other sources, flows are likely not a limiting factor in Auburn Ravine. However, there is a two to four week window in late October, when the Wise Powerhouse ceases operations, and prior to the onset of winter rains, which may limit available habitat but likely not more than would have occurred under historic conditions.

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

There has been significant urban development in Auburn Ravine which has resulted in a degraded riparian habitat.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Historically, instream flows in Auburn Ravine were ephemeral (Sierra Business Council 2003). Under natural instream flow conditions, flows gradually declined through the spring, summer, and early fall until the first seasonal storm events occurred. Estimated monthly mean flows in Auburn Ravine under natural conditions range from no flow during mid- to late-summer to approximately 26 cfs during the winter (City of Auburn 1997). Under current management practices, flows in Auburn Ravine are much more consistent from spring through mid-fall. Currently, winter flows are dominated by discharges from wastewater treatment facilities and runoff caused by rainfall events. Summer flows are dominated by irrigation water deliveries. Summer flows have been reported to range from 30 to 175 cfs (Nevada Irrigation District, daily flow in Auburn Ravine below State Route 65, 1976 through 1998). In September and October, flows are substantially decreased as irrigation demands diminish or cease. Flows during this period often are less than three cfs (JSA 1999a). Water management practices in Auburn Ravine have altered the natural temporal variation in instream flows, and as a result, have altered the natural temporal variation in water temperatures.

LOSS OF FLOODPLAIN HABITAT

Regulated flows and flood protection have eliminated much of the connectivity of Auburn Ravine with the historic floodplain.

ENTRAINMENT

During the irrigation season, there are temporary diversion dams throughout Auburn Ravine. All of these diversions are unscreened or poorly screened creating a high risk of entrainment for outmigrating juvenile salmonids. Although most of these dams are not operational during peak juvenile steelhead outmigration, the Sierra Business Council has rated five of them as having a moderate need for screening (Sierra Business Council 2003). Additionally, two permanent diversions, Hemphill Dam and the Nevada Irrigation District Auburn Ravine 1 Dam, are rated as high in priority for screen installations (Sierra Business Council 2003). The Nevada Irrigation District Auburn Ravine 1 Dam is particularly important as spawning and rearing habitat upstream of the dam are rated as excellent (Sierra Business Council 2003).

PREDATION

Several exotic species have been introduced to Auburn Ravine including bluegill and black bullhead, both of which prey on small salmonids. Additionally, black bass species may have been introduced to the area. Manmade structures and alteration of the natural flow regime may have created conditions favoring native predators including Sacramento pikeminnow.

HATCHERY EFFECTS

Most steelhead entering Auburn Ravine are likely of hatchery-origin. It is doubtful that conditions in Auburn Ravine are sufficient to support a self-sustaining population.

4.3.8.3 DRY CREEK

Dry Creek originates in the Sierra Nevada Foothills, drains approximately 101 square miles (ECORP Consulting 2003) and is hydraulically connected to the Sacramento River *via* the Natomas East Main Drainage Canal. Below Elverta Road, Dry Creek diverges into two channels (i.e., the Main Fork and the North Fork). The Main Fork lies to the south and contains flow year-round. The North Fork is several feet higher than the Main Fork and functions as an overflow channel (Foothill Associates 2003). Tributaries to Dry Creek include Secret Ravine, Miners Ravine, Strap Ravine, Antelope Creek, Clover Valley Creek, and Linda Creek.

According to information presented in the *Dry Creek Watershed Coordinated Resource Management Plan* (ECORP Consulting 2003), the mainstem of Dry Creek is not suitable spawning habitat, but is considered only as a migration corridor to upstream areas containing spawning habitat for anadromous salmonids.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS

Potential passage impediments to adult immigration include temporary beaver dams, flashboard dams, pipeline crossings and natural waterfalls. These barriers exist primarily at low flows and likely impede upstream migration of fall-run Chinook salmon and potentially early migrating adult steelhead (Vanicek 1993). As flows increase during winter months, after the irrigation season and the beginning of winter rains, most barriers are likely passable during higher flows. On Miners Ravine, Cottonwood Dam is the largest impediment to upstream migration and is considered a complete barrier to upstream migration (DWR 2002c). Cottonwood Dam blocks several miles of potential steelhead spawning and rearing habitat.

HARVEST/ANGLING IMPACTS

Dry Creek is open for recreational fishing from the fourth Saturday in May through October 15. Regulations call for catch and release fishing for trout. These angling restrictions are protective of steelhead as it is doubtful that adult steelhead would be present during this time period.

WATER TEMPERATURE

Although little water temperature data exists for Dry Creek, during the winter months, water temperatures are likely suitable for steelhead adult immigration.

WATER QUALITY

Sediment toxicity testing in the Dry Creek watershed indicates potential heavy metals toxicity associated with sediment in Secret Ravine (ECORP Consulting 2003). The presence of sediment toxicity would not likely effect steelhead adult immigration.

FLOW CONDITIONS

Instream flows during the rainy season, generally from October through April, consist primarily of groundwater discharge and surface runoff. Maximum monthly mean flows typically occur during February, and range from 165 cfs to 591 cfs (City of Roseville 2003).

SPAWNING

PASSAGE IMPEDIMENTS/BARRIERS

As flows increase during winter months, after the irrigation season and the beginning of winter rains, most barriers are likely passable during higher flows. On Miners Ravine, Cottonwood Dam is the largest impediment to upstream migration and is considered a complete barrier to upstream migration (DWR 2002c). Cottonwood Dam blocks several miles of potential steelhead spawning and rearing habitat.

Harvest/Angling Impacts

Dry Creek is open for recreational fishing from the fourth Saturday in May through October 15. Regulations call for catch and release fishing for trout. These angling restrictions are protective of steelhead as it is doubtful steelhead would be spawning during this time period.

Water Temperature

Although historic water temperature data for Dry Creek is limited, during the winter months, water temperatures are likely suitable for steelhead spawning.

Water Quality

Sediment toxicity in Dry Creek would not directly effect steelhead spawning but, spawning success would likely be negatively impacted.

Flow Conditions

Instream flows during the rainy season, generally from October through April, consist primarily of groundwater discharge and surface runoff. Maximum monthly mean flows typically occur during February, and range from 165 cfs to 591 cfs (City of Roseville 2003).

Spawning Habitat Availability

Several reaches within Miners Ravine have been identified with high sediment loading (DWR 2002c). High sediment loads create embededness (infilling of interstitial spaces). Generally, riffles with greater than 20 percent embededness are considered unsuitable for spawning. A survey of Miners Ravine found that only 17 of 87 riffles had embededness less than 25 percent (DWR 2002c). This survey also found that the most common substrate fractions sand and silt, not cobbles and gravel.

Physical Habitat Alteration

Within the Dry Creek watershed, numerous canals, aqueducts, siphons, reservoirs, ponds, dams, pipelines and other natural and man-made water features have significantly altered the habitat from historic conditions.

Hatchery Effects

The CDFG Native Anadromous Fish and Watershed Branch initiated a reconnaissance level assessment of steelhead distribution and abundance, relative to stream habitat conditions, in 1998 and 1999. At that time, steelhead escapement to the upper Dry Creek watershed was estimated at a few hundred fish, with the most suitable spawning and rearing habitat in Secret Ravine and to a lesser extent, Miners Ravine.

Embryo Incubation

Harvest/Angling Impacts

Dry Creek is open for recreational fishing from the fourth Saturday in May through October 15. Regulations call for catch and release fishing for trout. These angling restrictions are somewhat protective of steelhead embryo incubation as most eggs would have hatched prior to the beginning of the fishing season.

WATER TEMPERATURE

During the winter months, water temperatures are likely suitable for steelhead embryo incubation.

WATER QUALITY

Sediment toxicity testing in the Dry Creek watershed indicates potential heavy metals toxicity associated with sediment in Secret Ravine (ECORP Consulting 2003). The presence of sediment toxicity would affect salmonid eggs and young. A recent risk assessment identified sediment as the primary stressor for Chinook salmon in Secret Ravine (ECORP Consulting 2003).

FLOW CONDITIONS

Instream flows during the rainy season, generally from October through April, consist primarily of groundwater discharge and surface runoff. Maximum monthly mean flows typically occur during February, and range from 165 cfs to 591 cfs (City of Roseville 2003). Although these flow fluctuations could result in some redd dewatering, it is likely that they mimic historic conditions where redds would occur.

JUVENILE REARING AND OUTMIGRATION

PASSAGE IMPEDIMENTS/BARRIERS

Numerous beaver dams occur within both Miners and Secret ravines (Vanicek 1993). Beaver dams are generally beneficial to fish habitat because they contribute to the creation of pool habitat and they detain water and release it slowly, potentially maintaining and stabilizing downstream flows. However, beaver dams can present passage impediments to outmigrating juvenile steelhead, particularly at low flows.

WATER TEMPERATURE

The upper limit for steelhead growth and development is reported to be 65°F. Also, 65°F was found to be within the preferred water temperature range (i.e., 62.6°F to 68.0°F) and supported high growth of Nimbus strain juvenile steelhead (Cech and Myrick 1999). Increasing levels of thermal stress to this life stage may reportedly occur above 65°F. For example, Kaya *et al.* (1977) reported that the upper avoidance water temperature for juvenile rainbow trout was measured at 68°F to 71.6°F.

Water temperatures, as measured in Dry Creek below the confluence of Secret and Miners ravines typically begin exceeding 65°F in early May and by the end of May normally exceed 70°F (Sierra Business Council 2003). Water temperatures remain above 70°F normally until the end of September and fall below 65°F by mid-October (Sierra Business Council 2003).

Based on sampling conducted by CDFG during the 1998 to 2000 time period, Secret Ravine provides good steelhead rearing habitat while Miners Ravine provides less consistent habitat quality in terms of water temperatures (Sierra Business Council 2003).

Water Quality

Sediment toxicity testing in the Dry Creek watershed indicates potential heavy metals toxicity associated with sediment in Secret Ravine (ECORP Consulting 2003). The presence of sediment toxicity would affect salmonid eggs and young. A recent risk assessment identified sediment as the primary stressor for Chinook salmon in Secret Ravine (ECORP Consulting 2003).

Flow Conditions

Instream flows during the rainy season, generally from October through April, consist primarily of groundwater discharge and surface runoff. Maximum monthly mean flows typically occur during February, and range from 165 cfs to 591 cfs (City of Roseville 2003). Reportedly, summer instream flows in lower Dry Creek consist primarily of irrigation return and runoff, groundwater discharge, and treated wastewater effluent from the Dry Creek WWTP (EIP Associates 1993). Recorded monthly mean flows in Dry Creek range from a low of 14.3 cfs in August to 378 cfs in February (ECORP Consulting 2003). Minimum monthly mean flows during July and August typically range from 12 cfs to 17 cfs (City of Roseville 2003).

Juvenile rearing habitat in Miners Ravine is considered marginal. Low-flow conditions during the summer months are considered a constraint to rearing juvenile salmonids in Miners Ravine (ECORP Consulting 2003).

Loss of Riparian Habitat and Instream Cover

Areas within the Dry Creek watershed have experienced significant loss of riparian habitat resulting in increased bank erosion and associated sediment loading. The loss of riparian habitat has also resulted in higher water temperatures in the downstream reach.

Loss of Natural River Morphology and Function

Within the Dry Creek watershed, numerous canals, aqueducts, siphons, reservoirs, ponds, dams, pipelines and other natural and man-made water features significantly influence the local hydrology.

Loss of Floodplain Habitat

The lower Dry Creek watershed has an extensive record of flooding and flood damage, and the most recent flooding occurrences are reported to have occurred in 1986, 1995 and 1997.

Entrainment

During the irrigation season, there are temporary diversion dams throughout Dry Creek. All of these diversions are unscreened or poorly screened creating a high risk of entrainment for outmigrating juvenile salmonids. However, most of these dams are not operational during peak juvenile steelhead outmigration.

Predation

In the mainstem of Dry Creek, downstream of the Miners and Secret ravine confluences, the fish community consists mostly of spotted bass, Sacramento pikeminnow and Sacramento sucker with spotted bass accounting for the largest portion of fish biomass (ECORP Consulting 2003). Spotted bass also occur in the upper watershed including both Miners and Secret ravines. Both spotted bass and Sacramento pikeminnow are known to be important predators of juvenile salmonids.

HATCHERY EFFECTS

It is not likely that Central Valley hatchery operations directly affect juvenile salmonids in the Dry Creek watershed.

4.3.8.4 FEATHER RIVER

The Feather River watershed is located at the north end of the Sierra Nevada. The watershed is bounded by the volcanic Cascade Range to the north, the Great Basin on the east, the Sacramento Valley on the west, and higher elevation portions of the Sierra Nevada on the south. The Feather River watershed upstream of Oroville Dam is approximately 3,600 square miles and comprises approximately 68 percent of the Feather River Basin. Downstream of Oroville Dam, the basin extends south and includes the drainage of the Yuba and Bear Rivers. The Yuba River joins the Feather River near the City of Marysville, 39 river miles downstream of the City of Oroville, and the confluence of the Bear River and the Feather River is 55 river miles downstream of the City of Oroville. Approximately 67 miles downstream of the City of Oroville, the Feather River flows into the Sacramento River, near the town of Verona, about 21 river miles upstream of Sacramento. The Feather River watershed, upstream of the confluence of the Sacramento and Feather Rivers, has an area of about 5,900 square miles.

ADULT IMMIGRATION AND HOLDING

The adult immigration and holding life stage for steelhead in the Feather River occurs from September through April, with peak migration extending from October through November (McEwan 2001; Moyle 2002).

PASSAGE IMPEDIMENTS/BARRIERS

The Fish Barrier Dam at RM 67 presents an impassable barrier to upstream migration for anadromous salmonids. There are no other known passage impediments to upstream migrating adult steelhead in the lower Feather River.

HARVEST/ANGLING IMPACTS

The sportfishery in the lower Feather River currently allows the taking of hatchery trout or steelhead (identified by an adipose fin-clip) year-round. The taking of wild steelhead is not permitted. Unusually high densities of fish during the fall in the lower Feather River likely create favorable poaching opportunities.

WATER TEMPERATURE

Suitable water temperatures for adult steelhead migrating upstream to spawning grounds range from 46.0°F to 52.0°F (NMFS 2000; NMFS 2002; SWRCB 2003). In the lower Feather River, water temperatures are only within the "suitable" range for this life stage during the winter months. Under a 1983 agreement between CDFG and DWR, water temperatures are generally maintained at under 65°F from June 1 through September 30 above the Thermalito Afterbay Outlet (DWR 1983).

WATER QUALITY

Water quality in the lower Feather River likely does not affect steelhead adult immigration.

Flow Conditions

Except during flood events, flows in the reach of the lower Feather River extending downstream to the Thermalito Afterbay Outlet are maintained at a constant 600 cfs. Under the new Settlement Agreement, as part of the FERC relicensing for the Oroville Facilities, flows in the Low Flow Channel will be increased to a constant 800 cfs (FERC 2007).The instream flow requirements below the Thermalito Afterbay Outlet are 1,700 cfs from October through March and 1,000 cfs from April through September. It is likely that flow conditions in the lower Feather River seldom affect this life stage.

Spawning

Passage Impediments/Barriers

There are no known passage impediments to upstream migrating adult steelhead in the lower Feather River downstream of the Fish Barrier Dam.

Harvest/Angling Impacts

The sportfishery in the lower Feather River currently allows the taking of hatchery steelhead (adipose fin-clip) year-round. Wild steelhead may not be taken. Unusually high densities of anadromous salmonids in the lower Feather River likely create favorable poaching opportunities.

Water Temperature

Optimal spawning temperatures for steelhead range from 39°F to 52°F (CDFG 1991c). Water temperatures in the lower Feather River range from 47°F in the winter to as high as 65°F in the summer; however, releases are made from the coldwater pool in Lake Oroville Reservoir and this cold water generally provides suitable water temperatures in the Low Flow Channel (i.e., reach of the river extending from the Fish Barrier Dam downstream to the Thermalito Afterbay Outlet)

Water Quality

Water quality in the lower Feather River likely does not affect steelhead spawning.

Flow Conditions

Except during flood events, flows in the reach of the lower Feather River extending downstream to the Thermalito Afterbay Outlet are maintained at a constant 600 cfs. Under the new Settlement Agreement, as part of the FERC relicensing for the Oroville Facilities, flows in the Low Flow Channel will be increased to a constant 800 cfs (FERC 2007).The instream flow requirements below the Thermalito Afterbay Outlet are 1,700 cfs from October through March and 1,000 cfs from April through September. It is likely that flow conditions in the lower Feather River seldom affect steelhead spawning.

Spawning Habitat Availability

Based on results from PHABSIM, the steelhead spawning habitat index in the upper reach has a very low magnitude and has no distinct optimum over the range of flow between 150 and 1,000 cfs. In the lower reach, there is a maximum in the index apparent at a flow just under 1,000 cfs.

The difference in magnitude and peak can be attributed to the relative scarcity of smaller substrate particle sizes utilized by spawning steelhead (in comparison to adult Chinook salmon) in the Oroville project area of the Feather River (DWR 2004e).

Physical Habitat Alteration

The Oroville Facilities physically block the upstream basin contributions of gravel, sediment, and large woody debris from the lower Feather River, and the upstream passage of anadromous salmonids to historical spawning areas. This has resulted in a gradual depletion of suitable spawning gravels for steelhead.

Hatchery Effects

The FRFH steelhead are part of the Central Valley steelhead DPS, and also appear to compose over 95 percent of the steelhead population in the lower Feather River. As such, the FRFH is maintaining the spatial structure of the DPS and the Feather River steelhead population. The natural population is not self-sustaining in any appreciable number, primarily due to the basin morphology, and relative lack of steelhead habitat in the lower Feather River, and inaccessibility to habitat above Oroville Dam.

FRFH trucks its fall-run production to San Pablo Bay for release. Effects of out-of-basin release include a high degree of straying of adult returns into other streams, with implications to native spring and fall Chinook salmon of competition over habitat and threats to genetic integrity. Straying of fall-run has resulted in the homogeneity of the Central Valley fall-run component of the Central Valley fall-/late fall-run ESU.

Embryo Incubation

Harvest/Angling Impacts

The sportfishery in the lower Feather River currently allows the taking of hatchery steelhead (adipose fin-clip) year-round. It is possible that steelhead redds could be disrupted by wading anglers.

Water Temperature

Water temperatures in the Low Flow Channel are normally below 55°F during the steelhead embryo incubation life stage of December through April and seldom exceed 57°F in May (DWR 2001).

Water Quality

As part of the FERC relicensing process for the Oroville facilities, six of the relicensing studies specifically address metals contamination in the lower Feather River. As part of these studies, water quality samples were collected at 17 locations within the lower Feather River. Samples exceeding aquatic life water quality criteria occurred for four constituents: total aluminum, iron, copper, and lead. In the reach of the Feather River extending from the Fish Barrier Dam downstream to the Thermalito Afterbay Outlet, 19 percent of the water quality samples exceeded aquatic life water quality criteria. Samples taken from the reach of the Feather River extending from the Thermalito Afterbay Outlet downstream to the confluence with the Sacramento River were variable, but all were higher than the upstream reach and 3 exceeded aquatic life water quality criteria 100 percent of the time. Copper exceeded aquatic life water quality criteria in 5 of 276 samples; two of these occurrences were in the reach of the Feather River extending from the Fish Barrier Dam downstream to the Thermalito Afterbay Outlet. Iron only exceeded aquatic life water quality criteria at three sampling locations; all locations were downstream of the lower Feather River confluence with Honcut Creek. Lead exceeded aquatic life water criteria only once at several stations, but three or four times at the two most downstream stations on the Feather River.

Flow Conditions

Adverse affects on developing embryos could occur if a flow fluctuation caused redds to become dewatered while eggs were incubating. Oroville facilities releases are regulated and subject to regulatory flow criteria. Flows in the Low Flow Channel are maintained at a constant 600 cfs where almost all spawning of steelhead occurs. Under the new Settlement Agreement, as part of the FERC relicensing for the Oroville Facilities, flows in the Low Flow Channel will be increased to a constant 800 cfs (FERC 2007).

Juvenile Rearing and Outmigration

Almost 100 percent of juvenile steelhead rearing in the lower Feather River occurs upstream of the Thermalito Afterbay Outlet (DWR and Reclamation 2000). Emigration of juvenile steelhead principally occurs from June through September (DWR and Reclamation 2000).

Water Temperature

Naturally spawned Feather River steelhead have been observed to rear successfully at water temperatures below 65°F (DWR and Reclamation 2000). Water temperatures in the Low Flow Channel normally remain below 62°F year-round and are suitable for juvenile steelhead rearing. Water temperatures downstream of the Thermalito Afterbay Outlet are generally warmer, with the maximum mean daily water temperature at the Thermalito Afterbay Outlet reaching approximately 70°F in the summer (DWR 2001). Because daily summer water temperatures generally exceed 70°F below the Thermalito Afterbay Outlet, it is unlikely that steelhead rear in the lower reach of the river (DWR and Reclamation 2000).

Water Quality

As discussed above under embryo incubation, heavy metal concentrations can occasionally exceed established water quality criteria.

Flow Conditions

Flows in the Low Flow Channel of the Feather River, where most juvenile rearing of salmonids occurs, is maintained at a constant 600 cfs year-round except during flood events. Some flow fluctuations may occur downstream of the Thermalito Afterbay Outlet that have the potential to strand juvenile rearing or outmigrating salmonids. Since 2001, DWR has been conducting a juvenile stranding study on Chinook salmon and steelhead in the lower Feather River. Empirical observations and aerial surveys identified over 30 areas that have the potential to strand juveniles with flow decreases. However, sampling of isolated areas indicated relatively little juvenile salmonid stranding. Furthermore the proportion of stranded salmonids represented a very small percentage (<<1 percent) of the estimated number of emigrants (DWR 2004).

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Fixed flows in the lower Feather River have resulted in fewer channel forming or re-shaping events leading to a lack of habitat diversity. This lack of diversity results in unnatural riparian conditions and a lack of recruitment of riparian vegetation.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Channel complexity refers to the diversity of geomorphic features in a particular river reach. Features such as undercut banks, meanders, point bars side channels and backwaters all provide habitat for juvenile salmonids. Regulation of the lower Feather River by the Oroville facilities has changed both streamflow and sediment discharge. Attenuation of peak flows, decreased winter flows, increased summer flows, and changes to flow frequencies have led to a general decrease in channel complexity downstream of Oroville Dam. Because several species and races of fish occur in the lower Feather River, a diversity of habitat types is required. Decreases in channel diversity lead to a decrease in habitat diversity and quality.

The high concentration of spawning salmonids in the Low Flow Channel results in a high concentration of juveniles in the Low Flow Channel. Based on historic accounts of juvenile salmonid emigration, the current peak in the emigration period is somewhat earlier than pre-dam conditions (Painter *et al.* 1977; Warner 1954). Seesholtz *et al.* (2003) further report that substantial numbers of juveniles remain in the Low Flow Channel through the end of June. Seesholtz *et al.* (2003) speculate that this early emigration may be caused by competition with other juvenile salmonids, including Chinook salmon and hatchery steelhead, for rearing habitat.

LOSS OF FLOODPLAIN HABITAT

Regular intermediate flood flushing flows to maintain geomorphic function of the river and replenish fish and riparian habitats are generally rare in the lower Feather River because of flow regulation by the Oroville facilities. Lack of frequent high flow/flood events has led to a lack of floodplain renewal and connectivity to the channel.

ENTRAINMENT

The main diversion on the lower Feather River downstream of the Thermalito Afterbay occurs at Sunset Pumps at RM 38.6. The pumps divert 65,500 acre-feet of water annually. Although the diversion is screened, the mesh size does not meet NOAA or CDFG criteria, and some entrainment of juvenile salmonids likely occurs.

PREDATION

Counts of known predators on juvenile anadromous salmonids are reported to be very low in the Low Flow Channel (Seesholtz *et al.* 2003). Naturally spawned steelhead are an exception because little is known about their relative abundance. Because water temperatures are relatively low in the Low Flow Channel, it is doubtful that significant predation occurs in this reach by non-salmonid species.

Significant numbers of predators do reportedly exist in the High Flow Channel below the Thermalito Afterbay Outlet. Analysis of CWT recovery data indicates that predation on hatchery-reared Feather River Chinook salmon released in the Feather River is high, however further analysis reveals that most of this predation takes place in the Sacramento River downstream of the Feather River confluence (DWR 2004).

One aspect of the Oroville Project operations and facilities that may enhance predation in the High Flow Channel is that the high density of juveniles in the Low Flow Channel may cause early emigration of juvenile salmonids. Because juvenile rearing habitat in the Low Flow Channel is limited, juveniles may be forced to emigrate from the area due to competition for resources. Relatively small juvenile salmonids may be less capable of avoiding predators than those that rear to a larger size in the Low Flow Channel prior to beginning their seaward migration.

Hatchery Effects

Although most Feather River steelhead are likely of hatchery-origin, the release of yearling steelhead to the Feather River likely creates predation and competition for resources with smaller naturally spawned steelhead

4.3.8.5 Bear River

The Bear River originates on the west side of the Sierra just below Lake Spaulding at the 5,500-foot elevation and flows southwest 65 miles to its confluence with the Feather River at RM 12 of the Feather, draining portions of Nevada, Placer, Sutter and Yuba counties. Anadromous salmonids have access to 15 miles of habitat in the Bear River. The South Sutter Irrigation District Dam (SSIDD) presents an impassable barrier and marks the upstream extent of currently accessable anadromous salmonid habitat. Inadequate streamflow in the Bear River prevents the establishment of a self-sustaining steelhead population (JSA 2004).

Adult Immigration and Holding

Passage Impediments/Barriers

The SSIDD presents an impassable barrier and marks the upstream extent of currently accessable anadromous salmonid habitat.

Harvest/Angling Impacts

Recreational angling is permitted in the Bear River from the last Saturday in April through November 15. Because water temperatures in the Bear Rive likely prevent an early migration of steelhead into the Bear River, very few steelhead would be harvested in the recreational fishery.

Water Temperature

The USFWS's CVPIA *Tributary Production Enhancement Report* of May 1998 identifies high water temperatures as one of the factors limiting steelhead production in the Bear River. However, water temperatures should be cool enough by November to support steelhead adult immigration.

Water Quality

Water quality in the Bear River is generally considered to be good and should be adequate to support steelhead adult immigration.

Flow Conditions

Inadequate streamflow in the Bear River prevents the establishment of a self-sustaining steelhead population (JSA 2004). However, during periods of high flows, steelhead are known to utilize the river for limited spawning (JSA 2004).

Spawning

Passage Impediments/Barriers

The SSIDD presents an impassable barrier and marks the upstream extent of currently accessable anadromous salmonid habitat. During periods of low flows or dry water years, steelhead may not have access to spawning habitat in the Bear River.

Harvest/Angling Impacts

Recreational angling is permitted in the Bear River from the last Saturday in April through November 15. This time period should be protective of any steelhead spawning that may occur in the river.

Water Temperature

During winter months, water temperatures in the Bear River are adequate to support steelhead spawning.

Water Quality

Water quality in the Bear River is generally considered to be good and should not present adverse conditions to steelhead spawning.

Flow Conditions

Inadequate streamflow in the Bear River prevents the establishment of a self-sustaining steelhead population (JSA 2004). However, during periods of high flows, steelhead are known to utilize the river for limited spawning (JSA 2004).

Spawning Habitat Availability

Habitat conditions in the Bear River below Camp Far West Reservoir currently are not favorable for natural production of anadromous fish, including Chinook salmon and steelhead. Salmonid reproduction is severely limited by silted spawning gravels.

Physical Habitat Alteration

The primary modification to habitat in the Bear River stems from water diversions during the irrigation season. Additionally, the Bear River was far more heavily impacted by hydraulic mining (i.e., tons of mining sediment per unit of drainage area) than the Yuba or American Rivers. Closure of Rollins Dam caused a significant reduction in sediment yields and very little sediment remains in the middle Bear today. It is estimated that 125 million cubic meters (160 million cubic yards) of mining sediment is stored in the lower Bear. The high volume of mining sediment, in combination with restricting levees, has caused the lower Bear River to change from wide and shallow to deeply incised.

Hatchery Effects

Because environmental conditions do not support a self-sustaining population of steelhead in the Bear River, those steelhead that do spawn during high flow years have likely originated from the FRFH.

EMBRYO INCUBATION

HARVEST/ANGLING IMPACTS

Recreational angling is permitted in the Bear River from the last Saturday in April through November 15. This time period should prevent the inadvertent disruption of redds by wading anglers.

WATER TEMPERATURE

The USFWS's CVPIA *Tributary Production Enhancement Report* of May 1998 identifies high water temperatures as one of the factors limiting steelhead production in the Bear River. However, steelhead embryos developing during the winter months should not be affected by warm water temperatures.

WATER QUALITY

The Bear River is considered to be an impaired water body by the SWRCB. The pollutant or stressor in the river downstream of Camp Far West Reservoir is diazinon and the pollutant upstream is mercury (JSA 2004). Agricultural runoff is the likely source of diazinon (JSA 2004). These pollutants could adversely impact developing steelhead embryos.

FLOW CONDITIONS

The USFWS's CVPIA *Tributary Production Enhancement Report* identifies instream flows as one of the factors limiting steelhead production in the Bear River. Because steelhead spawning likely only occurs during wet years, flows should be adequate to support embryo incubation.

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

The USFWS's CVPIA *Tributary Production Enhancement Report* identifies high water temperatures as one of the factors limiting steelhead production in the Bear River. Warm water temperatures during the summer months likely preclude steelhead juvenile rearing in the Bear River.

WATER QUALITY

Water quality in the Bear River is generally considered to be good. However, the river is considered to be an impaired water body by the SWRCB. The pollutant or stressor in the river downstream of Camp Far West Reservoir is diazinon and the pollutant upstream is mercury (JSA 2004). Agricultural runoff is the likely source of diazinon (JSA 2004).

FLOW CONDITIONS

During the dry summer months, flows in Bear River sometimes decrease to zero at the USGS gaging site near Wheatland (JSA 2004). The USFWS's CVPIA *Tributary Production*

Enhancement Report identifies instream flows as one of the factors limiting steelhead production in the Bear River.

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Much of the lower Bear River is under private ownership and the condition of riparian habitat has not been investigated. However, it is likely that some riparian habitat has been degraded due to agricultural encroachment into the riparian zone.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

This watershed is one of the most heavily managed in California for water conveyance. Flows are largely controlled by the Nevada Irrigation System and PG&E. The present system of diversions also results in fluctuations that are harder on the riverine habitat and fisheries than the more gradual natural seasonal variations.

LOSS OF FLOODPLAIN HABITAT

The Bear River was far more heavily impacted by hydrologic mining than the Yuba or American rivers and, unlike the Yuba or American rivers, contains a large volume of mining sediment stored in its main channel which is subjected to continual erosion. It is estimated that 125 million cubic meters (160 million cubic yards) of mining sediment is stored in the lower Bear River. The high volume of mining sediment, in combination with restricting levees, has caused the lower Bear River to change from wide and shallow to deeply incised (Sierra Club Website 2007).

ENTRAINMENT

The USFWS's CVPIA *Tributary Production Enhancement Report* identifies unscreened diversions as one of the factors limiting steelhead production in the Bear River.

PREDATION

The same suite of predators (e.g., large and smallmouth bass) as exists in the lower Feather River likely occurs in the Bear River.

HATCHERY EFFECTS

Steelhead released from the Feather River Hatchery may intercept and prey on naturally spawned steelhead emigrating from the Bear River.

4.3.8.6 YUBA RIVER

The Yuba River watershed encompasses 1,339 square miles on the western slopes of the Sierra Nevada Mountain Range, and is located in portions of Sierra, Placer, Yuba, and Nevada counties (Reynolds *et al.* 1993). The primary watercourses of the upper Yuba River watershed are the South, Middle, and North Yuba rivers, which flow into Englebright Reservoir. The lower Yuba River, from Englebright Dam downstream to the confluence with the Feather River, is approximately 24 miles long, and supports a wild Chinook salmon and steelhead fishery.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

Englebright Dam, at RM 24, presents an impassable barrier to anadromous salmonid upstream migration and marks the upstream extent of currently accessable steelhead habitat in the Yuba River. Physical passage impediments on the lower Yuba River are primarily limited to the passability of Daguerre Point Dam fish ladders during certain flow conditions. The design of Daguerre Point Dam fish ladders are suboptimal, as currently operated by the USACE. For example, during high flows across the spillway, the fish ladder is obscured making it difficult for salmonids migrating upstream to find the entrances to the fish ladders. Both ladders tend to become loaded with organic material and sediment, which can directly inhibit passage and/or reduce attraction flows at the ladder entrances. The fish ladder exits are close to the spillway, which can result in fish being swept back over the dam while attempting to exit the ladder. The policy of the USACE is to close the fish ladders when the water surface elevation reaches 130 feet, and remain closed until the water surface elevation drops to an elevation of 127 feet.

Options to improve fish passage at Daguerre Point Dam were identified in the Bulletin 250 Fish Passage Improvement Program (DWR 2005b). The Project Modification Report recently completed by the USACE included engineering surveys, hydraulic evaluation, and a preliminary environmental assessment. There is no anticipated date for the implementation or completion of improvements to Daguerre Point Dam.

HARVEST/ANGLING IMPACTS

Fishing for steelhead on the lower Yuba River is regulated by CDFG. CDFG 2007-2008 angling regulations permit fishing for steelhead from the mouth of the Yuba River to the Highway 20 Bridge with only artificial lures with barbless hooks all year-round. A harvest of one hatchery steelhead (identified by an adipose fin clip) limit is permitted all year from the mouth of the Yuba to the Highway 20 Bridge. From the Highway 20 Bridge to Englebright Dam, fishing for steelhead is permitted from December 1 through August 31 only. During this time, no harvest is permitted. The use of artificial lures with barbless hooks in the lower Yuba River is considered a stressor to immigrating and holding steelhead during August through November.

The extent to which steelhead are targeted for poaching is unknown. However, due to their ESA listing, any level of poaching or angler harvest may constitute a significant limiting factor to the population

WATER TEMPERATURE

Upstream spawning migration of adult steelhead has been reported to cease at temperatures $<$ 39.2°F and $\geq$ 64.4°F. CDFG found in-river water temperatures to be near or above 57°F at the Marysville gage until after mid-October and into November.

WATER QUALITY

Water quality in the lower Yuba River is adequate to support steelhead adult immigration.

FLOW CONDITIONS

The Yuba Goldfields are located along the lower Yuba River near Daguerre Point Dam, approximately 10 miles north of Marysville. The area of the Goldfields is approximately 8,000 acres. The Goldfields have been used for gold mining for about 100 years. As a result thousands of acres of continuous mounds of cobble and rock terrain have been left behind. As a result of the permeability of the substrates composing the Goldfields, several interconnected channels and ponds have formed throughout the area. Surface water and subsurface water in the ponds and canals of the Goldfields are hydraulically connected to the Yuba River downstream of Daguerre Point Dam via an outlet canal.

Prior to 2003, a fraction of the lower Yuba River steelhead population routinely migrated from the mainstem of the Yuba River into the Yuba Goldfields via the outlet canal. In 2003, a fish barrier was constructed at the outlet canal to prevent fish from entering the Yuba Goldfields. High flows during May 2004 breached the barrier structure. However, repairs to the fish barrier have been subsequently made, and the integrity of the barrier is monitored during high flows. Therefore, for the most part, the Yuba Goldfields does not present a direct threat to anadromous salmonids in the lower Yuba River. However, as mentioned above, high flows can create partial barriers to upstream migration at Daguerre Point Dam.

SPAWNING

Steelhead spawn in the lower Yuba River from January through April. Suitable steelhead spawning habitat occurs in the Garcia Pit Gravel Reach and the Daguerre Point Dam Reach. However, only 5 steelhead redds were found below Daguerre Point Dam in 2003, versus 45 redds upstream of Daguerre Point Dam (USFWS 2003c).

PASSAGE IMPEDIMENTS/BARRIERS

From Daguerre Point Dam upstream to Englebright Dam there are no barriers to upstream adult immigration.

HARVEST/ANGLING IMPACTS

Recreational angling impacts to spawning steelhead in the Yuba River are similar to those discussed above for adult immigration.

WATER TEMPERATURE

Average daily water temperatures recorded at Daguerre Point Dam from 1997 to 2001 ranged from 50.3ºF in January to 53.7ºF in April. These temperatures are adequate to support steelhead spawning.

WATER QUALITY

Water quality in the lower Yuba River is adequate to support steelhead spawning.

FLOW CONDITIONS

USFWS (2008) developed steelhead WUA-flow relationships for the lower Yuba River from suitability habitat criteria developed on the lower Yuba River. These relationships indicate that potential spawning habitat is maximized at flows around 1,400 cfs above Daguerre Point Dam. Flows ranging from 700 to 2,700 cfs provide good habitat availability (defined as greater than 80 percent of the maximum habitat) above Daguerre Point Dam. Currently, flow regimes in the lower Yuba River range from 600 to 700 cfs depending on water year type.

SPAWNING HABITAT AVAILABILITY

Most spawning habitat in the lower Yuba River is upstream of Daguerre Point Dam. Although water temperatures below the dam are likely suitable for steelhead spawning, gravel downstream of the dam is embedded with silt (YCWA 2000). Spawning habitat above Daguerre is considered marginal as Englebright Dam blocks recruitment of spawning gravel to the lower Yuba River.

Physical Habitat Alteration

The most extensive habitat alterations in the lower Yuba River have occurred as a result of gold mining operations. The Yuba Goldfields are located along the lower Yuba River near Daguerre Point Dam, approximately 10 miles north of Marysville. The area of the Goldfields is approximately 8,000 acres. The Goldfields have been used for gold mining for about 100 years. As a result thousands of acres of continuous mounds of cobble and rock terrain have been left behind. As a result of the permeability of the substrates composing the Goldfields, several interconnected channels and ponds have formed throughout the area. Surface water in the ponds and canals of the Goldfields are hydraulically connected to the Yuba River. A proportion of flow entering the Goldfields is eventually returned to the Yuba River downstream of Daguerre Point Dam via an outlet canal. Prior to 2003, a fraction of the lower Yuba River Chinook salmon population (e.g., spring-run, fall-run, and late-fall-run) and, presumably, steelhead routinely migrated from the mainstem of the Yuba River into the Yuba Goldfields via the outlet canal. In 2003, a fish barrier was constructed at the outlet canal to prevent fish from entering the Yuba Goldfields. However, fish were still observed passing the barrier during flood or high flow events.

Hatchery Effects

The lower Yuba River is currently thought to support a self-sustaining population of steelhead while the lower Feather River population of steelhead is mostly of hatchery-origin. It is likely that some straying of Feather River steelhead into the lower Yuba River occurs.

Embryo Incubation

Harvest/Angling Impacts

Because the lower Yuba River supports a year-round recreational fishery, it is possible that some level of redd disturbance by wading anglers occurs.

Water Temperature

Steelhead embryo incubation primarily occurs in the lower Yuba River from January through July (CALFED Website 2005). The intragravel residence times of incubating eggs and alevins (yolk-sac fry) are highly dependent upon water temperatures. Maximum steelhead embryo survival reportedly occurs in water temperatures ranging from 41°F to 56°F (USFWS 1995c). The average water temperature in the Yuba River at Daguerre Point Dam is typically around 47ºF in January and February and rises to approximately 56°F in July.

Water Quality

Water quality in the lower Yuba River is generally good. There is a concern that a substantial amount of mercury may be in the Yuba Goldfields that could be mobilized by flood events but this would likely be downstream of developing embryos.

FLOW CONDITIONS

On March 1, 2001, the SWRCB issued a D-1644 which specified flow requirements limiting the magnitude and rate of flow reductions in the lower Yuba River to prevent salmonid redd dewatering and juvenile stranding. The seasonal flow requirements to protect salmonid redds were based on a redd dewatering study conducted by YWCA (SWRCB 2001).

Pursuant to the SWRCB's RD-1644 and agreements between CDFG and YCWA, daily flow fluctuations below Englebright Dam must not be reduced to less than 55 percent of the maximum daily flow release that previously occurred from September 15 to October 31. In addition, during the period from November 1 to March 31 the flow downstream of Englebright Dam cannot be reduced to less than 65 percent of the maximum flow release that occurred during the November through March 31 period, or the minimum instream flow requirement, whichever is greater (SWRI 2002).

FERC issued a License Amendment for the Yuba Project (Project No. 2246) on November 22, 2005, which imposes a more protective set of flow fluctuation and ramping requirements for the Yuba Project. The new criteria govern YCWA's releases of water from the Narrows II Powerhouse and require YCWA to make reasonable efforts to operate New Bullards Bar and Englebright reservoirs to avoid flow fluctuations in the lower Yuba River.

JUVENILE REARING AND OUTMIGRATION

The vast majority of steelhead emigrate as yearlings during October through May, with a relatively small percentage of individuals remaining in the lower Yuba River and emigrating as two or three year olds.

WATER TEMPERATURE

The average daily mean water temperature downstream of Daguerre Point Dam from October through May ranges between 57.5ºF in October to 57.8ºF in May at Marysville (SWRI 2002). These temperatures are within the suitable range for juvenile steelhead rearing and outmigration.

WATER QUALITY

Water quality in the lower Yuba River is generally good. There is a concern that a substantial amount of mercury may be in the Yuba Goldfields that could be mobilized by flood events.

FLOW CONDITIONS

Field observations on the lower Yuba River indicate that both natural and controlled flow reductions can cause some degree of fish stranding (YCWA 1998; YCWA 1999). The magnitude of stranding is site-specific and associated with the specific developmental stage of the fry prior to the onset of flow reductions, channel morphology, and aquatic habitat characteristics.

There are two types of stranding that are associated with flow reductions:

- Stranding associated with the rate of flow reductions (i.e., ramping rates), which determines if the juvenile fish can react quickly enough to avoid being stranded from exposed substrates in side channels and channel margins as flows decrease; and

- Stranding associated with the magnitude of flow reductions, regardless of ramping rate, which determines the extent of stranding within off channel habitats as flows decrease.

The SWRCB requires that YCWA, in consultation with the CDFG, NMFS, and USFWS verify that salmon fry are being protected from dewatering events during controlled flow reductions on the lower Yuba River. However, some level of mortality associated with controlled flow reductions is unavoidable, and therefore should be considered as a factor when assessing threats to juvenile salmonids in the lower Yuba River (YCWA 1999).

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

The reduction of peak flows in the late winter and spring have resulted in a reduction of riparian vegetation. There is a wide variation throughout the growing season f willow regeneration because each species of willow requires flows at specific periods for reproduction and growth. Cottonwood regeneration is also more prominent under natural flow regimes (YCWA 2000).

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Attenuated peak flows and controlled flow regimes have altered the areas geomorphology and have affected the natural meandering of the river downstream of Englebright Dam.

LOSS OF FLOODPLAIN HABITAT

Controlled flows and decreases in peak flows has reduced the frequency of floodplain inundation resulting in a separation of the river channel from its natural floodplain.

ENTRAINMENT

As juvenile steelhead pass Daguerre Point Dam, physical injury may occur as they pass over the dam or through its fish ladders (SWRI 2002). Water diversions in the lower Yuba River generally begin in the early spring and extend through the fall. As a result, potential threats to juvenile steelhead occur at the Hallwood-Cordua and South Yuba Brophy diversions.

Fish screens recently installed at the Hallwood-Cordua diversion are considered to be an improvement over those previously present but, the current pipe design may not allow sufficient flow to completely eliminate juvenile salmonid losses at the diversion.

The South Yuba – Brophy system diverts water through an excavated channel from the south bank of the lower Yuba River to Daguerre Point Dam. The water is then subsequently diverted through a porous rock dike that is intended to exclude fish. The current design of this rock structure does not meet NMFS or CDFG juvenile fish screen criteria (SWRI 2002).

There are also three major screened diversions on the lower Yuba River located upstream of Daguerre Point Dam: (1) the Browns Valley Pumpline Diversion Facility; (2) the South-Yuba/Brophy Water District Canal; and (3) the Hallwood-Cordua Canal. In addition, there are 16 unscreened water diversion facilities downstream of Daguerre Point Dam (SWRI 2002) which could potentially entrain juvenile salmonids in the lower Yuba River.

PREDATION

The extent of predation on juvenile steelhead in the Yuba River is not well documented, however, several non-native introduced known predators of juvenile salmonids are found in the Yuba River including striped bass, American shad and black bass species. Sacramento pikeminnow, a native predatory species is also found in the lower Yuba River. Manmade alterations to the lower Yuba River channel (i.e., Daguerre Point Dam) may provide more predation opportunities for pikeminnow than would occur under natural conditions.

HATCHERY EFFECTS

The extent of potential hatchery effects on juvenile steelhead in the lower Yuba River is unknown. It is possible that some hatchery-reared steelhead from the FRFH may move into the lower Yuba River in search of rearing habitat. Some competition for resources with naturally spawned steelhead could occur as a result.

4.3.8.7 BUTTE CREEK

Butte Creek flows from the western slope of the Sierra Nevada through a steep canyon for approximately 25 miles and meets the valley floor near Chico. The Centerville Diversion Dam, located immediately downstream of the DeSabla Powerhouse is generally considered to be the upper limit of anadromous salmonid habitat.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

Butte Creek is a highly developed watershed system with multiple diversions as well as water imports from foreign sources. Fish passage through Butte Creek is affected by about 22 major structures and an estimated 60 to 80 minor structures (e.g., pump diversions). Currently, it is estimated that salmonids have access to approximately 53 miles of Butte Creek (DWR 2005a).

HARVEST/ANGLING IMPACTS

Recreational harvest of steelhead, as stated in the CDFG 2007-2008 fishing regulations, is limited to catch and release, and occurs from November 15 through February 15 with gear restrictions including artificial lures and barbless hooks only.

WATER TEMPERATURE

Water temperatures during the steelhead adult immigration time period are suitable for this life stage.

WATER QUALITY

Available data indicate that overall water quality in Butte Creek ranges from good to excellent in the upper watershed and degrades in quality lower in the system (Butte Creek Watershed Website 2004). Both pH and dissolved oxygen concentrations appear to be below CVRWQCB criteria all of the time. Turbidity, mineral concentrations, nutrient loads and heavy metal concentrations (e.g., lead) have at times exceeded Central Valley RWQCB criteria for short periods of time (Butte Creek Watershed Website 2004). Although water quality is somewhat degraded, it should be adequate to support steelhead adult immigration.

Flow Conditions

Because there are no large storage facilities on Butte Creek, flow regimes during the winter months when agriculture diversions are not occurring tend to mimic the historic hydrology of the watershed.

Spawning

Steelhead primarily spawn in stream reaches between the Parrot-Phelan Diversion Dam and the Quartz Bowl Falls ith some fish reaching Centerville Diversion Dam.

Passage Impediments/Barriers

There are no significant passage impediments in the reach of Butte Creek where most steelhead spawning would occur during the winter months.

Harvest/Angling Impacts

Potential angling impacts to spawning steelhead are similar to those describe above for the adult immigration life stage.

Water Temperature

Water temperatures during the winter months when steelhead would be spawning are within the suitable range for this life stage.

Water Quality

Water quality in Butte Creek where steelhead spawning is likely to occur is generally considered of high quality.

Flow Conditions

PG&E's minimum instream flow requirement at the Lower Centerville Diversion Dam is 40 cfs from June 1 to September 14. Flows in Butte Creek begin to increase during the steelhead spawning period from November through April. Because there are no large storage facilities on Butte Creek, flow regimes during the winter months when agriculture diversions are not occurring tend to mimic the historic hydrology of the watershed. Butte Creek flow conditions improved when the Parrott-Phelan diversion was moved to the Sacramento River, resulting in 40-45 cfs of water acquisition.

Spawning Habitat Availability

In Butte Creek, the spawning area for steelhead extends from the Centerville Head Dam downstream to the vicinity of the Western Canal Siphon crossing. Steelhead generally spawn upstream of the Parrott-Phelan diversion. Spawning gravel in the reach of the creek from the Centerville Head Dam downstream to the vicinity of Helltown is extremely limited, with the major gravel beds existing below the Centerville Powerhouse (Butte Creek Watershed Website 2004). There is no limitation of gravel recruitment in the area above Centerville Powerhouse, but due to the generally steep gradient and basalt substrate gravel does not hold well.

Physical Habitat Alteration

Hydropower generation has altered flows in Butte Creek since about 1908. The reach of Butte Creek from the Centerville Powerhouse downstream to the Parrott-Phelan Dam has undergone and continues to undergo residential development. Channel modification projects designed to repair or prevent flood-related damage to roads and houses have degraded natural processes which serve to recruit gravel, provide instream cover and forage, and provide holding pools (Butte Creek Watershed Website 2004).

HATCHERY EFFECTS

Steelhead are produced at both the Feather River Hatchery, south of Butte Creek, and the Coleman National Hatchery, north of Butte Creek. It is possible that some hatchery produced steelhead could stray into Butte Creek. The extent to which hatchery steelhead from the Feather River Hatchery or the Coleman National Hatchery steelhead stray into Butte Creek is unknown.

EMBRYO INCUBATION

HARVEST/ANGLING IMPACTS

Because Butte Creek is open to angling year-round, there may be some inadvertent negative impacts to embryo incubation from anglers wading through redds or otherwise disturbing substrates containing redds.

WATER TEMPERATURE

The optimum water temperature range reported for steelhead embryo incubation is between 48ºF and 52ºF (NMFS 2000). Mean monthly water temperatures in Butte Creek near Chico (DWR Gage) generally remain suitable during the embryo incubation period until May, when they reach approximately 56ºF.

WATER QUALITY

Turbidity, mineral concentrations, nutrient loads and heavy metal concentrations (e.g., lead) have at times exceeded Central Valley RWQCB criteria for short periods of time (Butte Creek Watershed Website 2004). Any of these factors could affect developing steelhead embryos, however, most developing embryos would be higher up in the watershed where conditions are better.

FLOW CONDITIONS

Fluctuation in flows during the embryo incubation period which could potentially cause redd dewatering events have not been reported to date.

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

Water temperatures during the period when flows are managed and juvenile steelhead would be present, are likely near optimal ranges. However, water temperatures could be a concern during the late spring and summer for juvenile rearing in the lower reaches of Butte Creek near the Sutter Bypass.

WATER QUALITY

Available data indicate that overall water quality in Butte Creek ranges from good to excellent in the upper watershed and degrades in quality lower in the system (Butte Creek Watershed

Website 2004). Both pH and dissolved oxygen concentrations appear to be below CVRWQCB criteria all of the time. Turbidity, mineral concentrations, nutrient loads and heavy metal concentrations (e.g., lead) have at times exceeded Central Valley RWQCB criteria for short periods of time (Butte Creek Watershed Website 2004).

FLOW CONDITIONS

Butte Creek is primarily a free flowing stream lacking large dams to control or buffer flows (CDFG 1999a). Flows are highly variable with the majority of out migration of juveniles occurring during high flow events (CDFG 1999a). The extent to which flow fluctuations from water diversions in Butte Creek may affect juvenile salmonid habitat availability and cause juvenile stranding is currently unknown.

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

The distribution of riparian habitat, particularly in the lower reaches of Butte Creek has been reduced by anthropogenic changes for flood control, agriculture and urbanization (Butte Creek Watershed Website 2004).

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

The reach of Butte Creek from the Centerville Powerhouse downstream to the Parrott-Phelan Dam has undergone and continues to undergo residential development. Channel modification projects designed to repair or prevent flood-related damage to roads and houses have degraded natural processes which serve to recruit gravel, provide instream cover and forage, and provide summer holding pools (Butte Creek Watershed Website 2004).

LOSS OF FLOODPLAIN HABITAT

Although Butte Creek is bordered by levees in some areas, it also passes through Butte Slough and the Sutter Bypass where connectivity to the floodplain still exists to some extent (Butte Creek Watershed Website 2004)

ENTRAINMENT

In Butte Creek most water diversion facilities have been screened or modified to prevent juvenile fish entrainment (PG&E 2005).

PREDATION

The extent of predation on juvenile steelhead in the Butte Creek is not well documented, however, several known predators of juvenile salmonids are found in the Butte Creek. Striped bass are commonly found in the Sacramento River as well as in Butte Creek. The Sacramento pikeminnow is another well know predator of juvenile salmonids and has been documented as far upstream in the Sacramento River as the RBDD suggesting the presence of pikeminnow in Butte Creek (NMFS 1996b). Increasing flow regulation and associated increasing temperatures, in addition to increased turbulence associated with spillways, may cause increased predator upstream movement, increased predator success, and increased predator survival (NMFS 1996b).

HATCHERY EFFECTS

There are likely no adverse effects due to hatchery production on juveniles in Butte Creek. However, naturally produced steelhead juveniles that utilize portions of the Sutter Bypass for rearing may encounter hatchery produced salmon and steelhead resulting in potential competition for resources.

4.3.8.8 BIG CHICO CREEK

Big Chico Creek originates on Colby Mountain, located in Tehama County, California. The creek flows 45 miles to its confluence with the Sacramento River in Butte County. The creek's elevation ranges from 120 feet at the Sacramento River to 6000 feet at Colby Mountain. A portion of Big Chico Creek flows through the city of Chico, California's Bidwell Park and California State University, Chico.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

Big Chico Creek has no major reservoirs, but has five small dams and three natural barriers that could impede anadromous fish migration. Presently, 24 miles of Big Chico Creek are accessible to steelhead (DWR 2005b).

Five Mile Dam was built by the USACE for the purpose of flood control in 1963. The dam effectively spilt the Big Chico Creek flows into three separate channels, Big Chico Creek, Sycamore Channel, and Lindo Channel. The design of the flood control structure creates a ponding effect upstream during flood events. This causes gravels to drop out of suspended load upstream of the diversion which creates gravel bar that blocks the flow to Lindo Channel unless it is mechanically removed. As a result, Lindo Channel frequently lacks sufficient flows to allow upstream migrants to pass, and has the potential to trap adults within the channel during immigration to spawning areas upstream (DWR 2005b).

The Iron Canyon fish ladder was built in the late 1950s to facilitate fish passage through Bidwell Park. This structure has been damaged, and frequently impedes adult salmonid upstream migration. Currently, a project is underway to repair the fish ladder to allow fish passage to an additional 9 miles of spawning habitat over a wider range of flows (CDFG Website 2005). In addition, fish passage through the narrow canyon walls of Bear Hole, located downstream of the Iron Canyon fish ladder, impedes fish passage during low flows.

HARVEST/ANGLING IMPACTS

Recreational catch and release of trout is allowed from the mouth of Big Chico creek to one mile downstream of Bidwell Park during June 16 through October 15, and from October 16 through February 15 with gear restrictions (i.e., artificial lures and barbless hooks only); and from Bear Hole to the Big Chico Creek Ecological Reserve from November 1 through April 30 with gear restrictions (i.e., artificial lure and barbless hooks only). Fishing between the upper boundaries of Big Chico Creek Ecological Reserve to Higgins Hole Falls is prohibited year-round.

WATER TEMPERATURE

Water temperatures in Big Chico Creek normally fall below 60°F by late October and are under 50°F by the beginning of December, when adult steelhead would be immigrating. These temperatures are suitable for that life stage.

WATER QUALITY

Water quality in Big Chico Creek and Lindo Channel has been degraded by cadmium, mercury, and other metals associated with gold mining in the upper watershed. However, Big Chico Creek currently meets EPA water quality constituent standards and should be adequate to support steelhead adult immigration.

FLOW CONDITIONS

Flow conditions in Big Chico Creek during normal and wet years are adequate to support steelhead adult immigration. During dry years, low flows may create passage impediments or even strand upstream migrating steelhead in Lindo Channel.

SPAWNING

PASSAGE IMPEDIMENTS/BARRIERS

The first barrier to upstream migration on Big Chico Creek occurs in Iron Canyon where a jumble of boulders has accumulated in the Creek. These boulders present an impassable barrier at normal flows but allow passage at high flow (Big Chico Creek Watershed Alliance Website 2007). The Iron Canyon fish ladder was built in the late 1950s to facilitate fish passage. This structure has been damaged, and frequently impedes adult salmonid upstream migration. Currently, a project is underway to repair the fish ladder to allow fish passage to an additional nine miles of spawning habitat over a wider range of flows (CDFG Website 2005). The waterfall at Higgins Hole is currently thought to be the uppermost barrier to anadromous fish migrations (CDFG 2001a).

HARVEST/ANGLING IMPACTS

Most steelhead spawning occurs upstream of the Ecological Reserve where fishing is closed year-round. Therefore, harvest and angling impacts to steelhead are minimized in Big Chico Creek.

WATER TEMPERATURE

The reported optimum water temperature range for steelhead during the spawning period is between 46.0ºF and 52ºF (USFWS 1995b). Mean monthly water temperatures in Big Chico Creek near Chico (DWR gage) from during the spawning period from 1999 through 2005 ranged from approximately 47ºF in November to 54ºF in April. It should be noted that the Chico gage is downstream of the habitat used for steelhead spawning and likely does not reflect the actual water temperatures experienced by steelhead during spawning.

WATER QUALITY

Water quality in Big Chico Creek and Lindo Channel has been degraded by cadmium, mercury, and other metals associated with gold mining in the upper watershed. However, Big Chico Creek currently meets EPA water quality constituent standards and is adequate to support steelhead spawning.

FLOW CONDITIONS

The Iron Canyon fish ladder was built in the late 1950s to facilitate fish passage through Bidwell Park. This structure has been damaged, and frequently impedes adult salmonid upstream migration. Currently, a project is underway to repair the fish ladder to allow fish passage to an additional 9 miles of spawning habitat over a wider range of flows.

Spawning Habitat Availability

A survey of spawning gravels was conducted by DWR in 1997 to determine the gravel size distribution at various spawning sites in Big Chico Creek. The sites were located along Big Chico Creek at Highway 32; below the Five-Mile Area flood control structure; and at Rose Avenue. The gravel sizes ranged from 20 mm to 100 mm (approximately 1 to 4 inches) in mean diameter. Gravels within these ranges are considered to be suitable for salmonid spawning (Big Chico Creek Watershed Alliance Website 2007).

Gravel recruitment downstream of the Five-Mile Flood Diversion Complex is reduced and gravel also becomes trapped in the One-Mile Pond from which it is customarily removed rather than transported downstream (Big Chico Creek Watershed Alliance Website 2007). Additionally, the practice of removing large woody debris from urban and floodway stream reaches has reduced habitat and increased streambed scouring (Big Chico Creek Watershed Alliance Website 2007).

Physical Habitat Alteration

The presence of dams on Big Chico Creek limits the composition and volume of sediments transported which reduces the supply of spawning gravels downstream of the dams. Large volumes of suspended sediment in the bedload are deposited within the stilling pond above Five-Mile area. As a result, coarse sediments are not transported downstream below the Five-Mile area. At Chico’s One Mile Recreation Area, the flow is again reduced and additional volumes of sediment are deposited on the upstream side of the dam. Low-flow silt transport in the Big Chico Creek has been increased by swimming pool clean out and summer water activities by humans, dogs and horses. Unlike high-flow conditions in which silt only deposits where flow velocity is reduced in backwater and overflow sites, silt carried during low flow settles out in riffles and pools where it degrades habitat for spawning (Big Chico Creek Watershed Alliance Website 2007).

Hatchery Effects

Steelhead are produced at both the Feather River Hatchery, south of Big Chico Creek, and the Coleman National Hatchery, north of Big Chico Creek. It is possible that some hatchery produced steelhead could stray into Big Chico Creek.

Embryo Incubation

Harvest/Angling Impacts

Most steelhead spawning occurs upstream of the Ecological Reserve where fishing is closed year-round. Therefore, harvest and angling impacts to developing steelhead embryos are minimized in Big Chico Creek.

Water Temperature

The average monthly water temperature in Big Chico Creek near Chico (DWR Gage) from November through July from 1999 through 2004 ranged from approximately 50ºF in November to approximately 75ºF in July. Water temperatures in the upper reaches of Big Chico Creek are likely more suitable during the peak embryo incubation period; however, developing embryos from late spawning steelhead could be negatively affected by high water temperatures. It should be noted that the Chico gage is downstream of the habitat used for steelhead spawning and likely does not reflect the actual water temperatures experienced by steelhead embryos in the gravels.

WATER QUALITY

Water quality in Big Chico Creek and Lindo Channel has been degraded by cadmium, mercury, and other metals associated with gold mining in the upper watershed. Although, Big Chico Creek currently meets EPA water quality constituent standards, heavy metal contamination may cause decreased survival of developing embryos.

FLOW CONDITIONS

Due to flood control management structures (e.g., Lindo Channel and the Sycamore Creek Bypass Channel) Big Chico Creek lacks the flows necessary to maintain the optimal substrate size distributions for the successful incubation of salmonid embryos. Substrates are often dominated by small gravel, sand, and fine sediments which reduce the interstitial spaces between substrates. Such reductions can result in decreased water flow through redds, leading to low dissolved oxygen concentrations, and poor removal of metabolic wastes. These conditions could reduce embryo growth rates, fitness, and survival. In addition, steelhead embryos are generally less tolerant of fine sediments due to the smaller surface area of the ova.

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

Water temperatures in Big Chico Creek, downstream of Iron Canyon, are not suitable for salmonids during the summer months. Most juvenile rearing of steelhead occurs in the foothill reaches (Big Chico Creek Watershed Alliance Website 2007).

WATER QUALITY

Water quality in Big Chico Creek and Lindo Channel has been degraded by cadmium, mercury, and other metals associated with gold mining in the upper watershed. The California State University, Chico reported significant concentrations of fecal coliform bacteria during the summer months due to Sycamore pool, which is heavily used swimming hole. Although, Big Chico Creek currently meets EPA water quality constituent standards water quality conditions, particularly during the summer months could lead to decreased juvenile survival.

FLOW CONDITIONS

Flows in Big Chico creek begin to decline in the late-spring and are continuous only in the main channel by summer. The Lindo Channel and Mud Creek channels have only intermittent flow during most years during the summer months (DWR 2005a). As a result of these receding flows there is a potential that juvenile fish emigrating later in the spring may be exposed to sub-optimal water temperatures and stranding due to receding flows in Big Chico Creek and its flood control channels (CDFG 2001a).

Lindo Channel often ceases to flow, sometimes trapping downstream migrants several times during a single season (Ward *et al.* 2004). However, a habitat evaluation of Big Chico Creek, Lindo Channel, and Mud Creek conducted by CDFG in 2001 determined that these waterways provided juvenile steelhead with a variety of habitats with suitable cover, substrates, and water temperatures during the winter and early spring (CDFG 2001a).

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Anthropogenic changes in the Big Chico Creek watershed have reduced or degraded riparian habitat. However, some programs are underway to improve riparian habitat by various groups in the area. For example, there has been marked improvement in riparian habitat in Lindo Channel between Manzanita Avenue and Mangrove Avenue (Big Chico Creek Watershed Alliance Website 2007).

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Some of the valley reaches in Lindo Channel, Mud and Rock creeks that are maintained for flood control, lack sufficient vegetation to maintain stream structure (Big Chico Creek Watershed Alliance Website 2007).

LOSS OF FLOODPLAIN HABITAT

Flows in Big Chico Creek, as it emerges onto the Chico Fan at the Five-Mile Recreation area are regulated for flood control by diversion of flows into two bypass channels: Lindo Channel and the Sycamore Creek Bypass Channel. This has resulted in a disconnection of the river to its normal floodplain and likely results in less habitat diversity in the lower reaches of Big Chico Creek (Big Chico Creek Watershed Alliance Website 2007).

ENTRAINMENT

Entrainment and/or impingement of juvenile fish at the various flood control structures and diversions in Big Chico Creek could potentially cause physical harm to rearing and emigrating juveniles during high flows in the winter and early spring. As a result these structures constitute a chronic threat to the juvenile steelhead rearing and emigration life stages.

PREDATION

The extent of predation on juvenile steelhead in the Big Chico Creek is not well documented, however, several known predators of juvenile salmonids are found in the Big Chico Creek. Smallmouth bass are abundant in the valley zone of Big Chico Creek. Smallmouth bass are particularly abundant in dry years while in wet years, high flows typically scour the fish from streams (Big Chico Creek Watershed Alliance Website 2007). Big Chico Creek also supports a population of brown trout which are a known piscivorous species (Big Chico Creek Watershed Alliance Website 2007). Sacramento pikeminnow, which is a native species known to prey on juvenile salmonids is also present in Big Chico Creek. The presence of manmade instream structures may confer an advantage to pikeminnow altering the natural predator-prey dynamics of the two species.

HATCHERY EFFECTS

There are likely no direct effects on juvenile salmonids in Big Chico Creek presented by hatcheries.

4.3.8.9 DEER CREEK

Deer Creek is part of the lower Cascade Mountain Range and drains an area of approximately 229 square miles. Deer Creek meets the Sacramento River near the town of Vina at RM 230.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

The first natural barrier in the stream is a falls about nine miles upstream of Polk Springs and approximately 40 miles from the mouth. This falls is about 16 feet high, and salmon had never been known to pass beyond it until a fish ladder was constructed in 1943. There is a second falls on Deer Creek about ten miles upstream of the falls near Polk Springs. This falls is a sheer drop of about 20 feet. A fish ladder was also constructed at this barrier in early 1950s, and is only functioning during the time steelhead would be migrating upstream (Deer Creek Conservancy Website 2007). The ladder is closed during the time when spring-run Chinook salmon would be migrating upstream because very little holding habitat exists above this point.

There are also diversion dams on Deer Creek that can provide passage impediments to adult steelhead during low flows. All of the diversion structures have CDFG designed and operated fish ladders and screens (Deer Creek Conservancy Website 2007).

HARVEST/ANGLING IMPACTS

Recreational angling on Deer Creek is restricted to catch-and-release only. Additionally, the fishery is closed from November 15 through the end of April which coincides with peak steelhead immigration timing.

WATER TEMPERATURE

Water temperatures in Deer Creek during the late-fall and winter time period are low enough to adequately support steelhead adult immigration.

WATER QUALITY

Water quality monitoring in Deer Creek has shown levels of coliform bacteria, minerals and nutrients to be low and not restrictive to beneficial use (Deer Creek Conservancy Website 2007; DWR 2005a). Concentrations of aluminum have at times exceeded the California Toxic Rule and the EPA chronic criteria for the protection of freshwater organisms (Deer Creek Conservancy Website 2007; DWR 2005a). Deer Creek currently meets EPA water quality standards.

FLOW CONDITIONS

Steelhead begin migration into Deer Creek during the late-fall and winter, primarily when flows increase from storms. Because there are no large storage facilities on Deer Creek, winter flows tend to mimic historic natural conditions.

SPAWNING

Passage Impediments/Barriers

There are no significant barriers to upstream migration within the reach of Deer Creek upstream from Dillon Cove in the lower canyon reach to upper Deer Creek Falls where most steelhead spawning occurs.

Harvest/Angling Impacts

Deer Creek is closed to fishing during the winter months when steelhead would be spawning.

Water Temperature

Water temperatures during the winter months when steelhead would be spawning are sufficiently low to support this life stage.

Water Quality

Water quality in Deer Creek is adequate to support steelhead spawning.

Flow Conditions

There has been no salmonid flow habitat relationships developed for salmonids in Deer Creek. Because there are no major storage facilities on Deer Creek, winter flow patterns in the area where steelhead spawning occurs, mimic natural patterns.

Spawning Habitat Availability

Steelhead habitat in the upper watershed is considered to be excellent with an abundance of spawning gravel (DWR 2005a; USFWS 1999b). Flood protection, cattle grazing and water diversions have had a negative effect on habitat in the lower watershed. Stream channelization has reduced the opportunities for gravel deposition. Gravels that might have been deposited are likely to be washed downstream during high flow events because of the increased shear stress produced in these straightened reaches (DWR 2005a; USFWS 1999b).

Physical Habitat Alteration

While habitat in the upper watershed is relatively pristine, channelization has occurred in the lower watershed reducing opportunities for natural deposition of spawning gravel. Additionally, water diversions have led to low-flow conditions which can effect habitat availability (DWR 2005a; USFWS 1999b).

Hatchery Effects

Deer Creek is likely supporting a small self-sustaining population of steelhead. However, because significant numbers of steelhead are produced by hatcheries in the Central Valley, it is likely that hatchery fish occasionally stray into Deer Creek.

Embryo Incubation

Harvest/Angling Impacts

Deer Creek is closed to fishing during most of the embryo incubation life stage, therefore disturbance of redds by wading anglers should be minimal.

Water Temperature

Water temperatures in Deer Creek, when embryos are incubating, are suitable for this life stage.

WATER QUALITY

Water quality monitoring in Deer Creek has shown levels of coliform bacteria, minerals and nutrients to be low and not restrictive to beneficial use (Deer Creek Conservancy Website 2007; DWR 2005a). Concentrations of aluminum have at times exceeded the California Toxic Rule and the EPA chronic criteria for the protection of freshwater organisms (Deer Creek Conservancy Website 2007; DWR 2005a).Deer Creek currently meets EPA water quality standards and should not present problems to developing embryos.

FLOW CONDITIONS

There are no significant water diversions in the upstream reaches (i.e., primary spawning habitat) of Deer Creek that could result in unnatural flow fluctuations that could cause redd dewatering events.

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

Water temperatures throughout the Deer Creek watershed are suitable for juvenile steelhead rearing except for the summer months when temperatures in the lower watershed become to high to support juvenile steelhead rearing. Cold water refugia are likely available during the summer months in the upper watershed.

WATER QUALITY

Deer Creek currently meets EPA water quality standards and should not present problems to juvenile steelhead.

FLOW CONDITIONS

The explicit time period when juvenile steelhead emigrate from Deer Creek is not known. However, it is likely that it occurs from October through May as seasonal flows increase. The extent to which flow fluctuations from water diversions in Deer Creek may cause juvenile stranding is currently unknown.

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Recent studies have concluded that aquatic habitat in Deer Creek is limited by the current flood control project. Effects of the flood control project include lack of habitat diversity and riparian vegetation due to channel maintenance and clearing (MacWilliams *et al.* 2004)

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Flood control activities such as stream channelization and clearing have led to a lack of habitat diversity by constraining high flow and flood events between the levees (MacWilliams *et al.* 2004).

LOSS OF FLOODPLAIN HABITAT

The Deer Creek Flood Control Project was completed by the USACE in 1953. About 16 km of levees were built along lower Deer Creek to control flooding and the channel was straightened and cleared. As a result of this work, natural geomorphic processes were disrupted and the riparian zone was limited to a small band within the constructed levees effectively severing the connection between Deer Creek and the floodplain (MacWilliams *et al.* 2004).

ENTRAINMENT

Entrainment of juvenile steelhead in Deer Creek is assumed to be low because the three water diversions from Deer Creek have fish screens that comply with CDFG fish screen design criteria. These screens are operated, maintained and monitored by CDFG.

PREDATION

Green sunfish, largemouth and smallmouth bass, striped bass and American shad are all piscivorous species that have been introduced to the Sacramento watershed. It is likely that sunfish and bass species both occur in Deer Creek and the loss of natural stream function associated with flood control measures likely enhances predation opportunities, particularly in the lower reaches of the stream.

HATCHERY EFFECTS

There are likely no direct effects of hatchery operations on juvenile steelhead in Deer Creek.

4.3.8.10 MILL CREEK

Mill Creek is an eastside tributary to the Sacramento River that flows in a southwesterly direction for approximately 60 miles and drains 134 square miles. The creek originates near a thermal spring area in Lassen Volcanic National Park at an elevation of approximately 8,200 feet. It initially flows through meadows and dense forests and then descends rapidly through a steep rock canyon into the Sacramento Valley. Upon emerging from the canyon, the creek flows 8 miles across the Sacramento Valley floor, entering the Sacramento River about 1 mile north of the town of Tehama, near Los Molinos, at an elevation of approximately 200 feet.

The Revised Draft AFRP identifies Mill Creek as one of the high priority tributaries to the upper Sacramento River, particularly for its populations of spring-run Chinook salmon and steelhead.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

Prior to 1997, Clough Dam created a partial barrier to upstream migration in Mill Creek and was utilized as a counting station. In 1997, a flood breached Clough Dam allowing unimpaired access to the Mill Creek watershed (CDFG 1999b).

HARVEST/ANGLING IMPACTS

Catch and release fishing is allowed in Mill Creek. For purposes of fishing regulations, the creek is divided into two reaches. From the Lassen National Park boundary downstream to the USGS gaging station at the mouth of Mill Creek Canyon, fishing with barbless hooks and artificial lures is allowed from the last Saturday in April through November 15. From that point downstream to the mouth, fishing is allowed from June 16 through September 30. Therefore, some migrating steelhead could be affected by the recreational fishery.

WATER TEMPERATURE

Water temperatures are suitable during the late fall and winter months to support steelhead immigration.

WATER QUALITY

Water quality in Mill Creek is adequate to support steelhead adult immigration.

FLOW CONDITIONS

There are no major water storage facilities on Mill Creek and water diversions are not occurring during the time adult steelhead are immigrating to the Mill Creek watershed. Therefore, flows during the adult immigration life stage tend to mimic historic conditions that occurred under natural flow regimes.

SPAWNING

In Mill Creek, steelhead spawning occurs from approximately the Lassen National Park Boundary downstream to the Little Mill Creek confluence (SRCS Report 1997).

PASSAGE IMPEDIMENTS/BARRIERS

There are no known passage impediments for steelhead within the area used for spawning.

HARVEST/ANGLING IMPACTS

Catch and release fishing is allowed in Mill Creek. For proposes of fishing regulations, the creek is divided into two reaches. From the Lassen National Park boundary downstream to the USGS gaging station at the mouth of Mill Creek Canyon, fishing with barbless hooks and artificial lures is allowed from the last Saturday in April through November 15. From that point downstream to the mouth, fishing is allowed from June 16 through September 30. Under existing regulations, spawning steelhead are not likely to be affected by the recreational fishery.

WATER TEMPERATURE

Water temperatures in the upper reaches of Mill Creek during the steelhead spawning period are adequate to support steelhead spawning.

WATER QUALITY

Water quality in Mill Creek is suitable for steelhead spawning.

FLOW CONDITIONS

There have been no flow habitat relationships developed for salmonids in Mill Creek. Because there are no major water storage facilities on Mill Creek and diversions are not occurring during the steelhead spawning season, flows likely mimic natural conditions.

SPAWNING HABITAT AVAILABILITY

The upper reaches of Mill Creek located above diversion dams reportedly provide excellent salmonid spawning habitat (DWR 2005a). Approximately 48 miles of potential spawning habitat exists from the confluence of Little Mill Creek upstream to Morgan Hot Springs (Klamath Resources Information Website 2007).

PHYSICAL HABITAT ALTERATION

The Mill Creek watershed is relatively long and narrow, with steep slopes. Steep slopes adjacent to the main channel have served as barriers to activity and land use allocations have protected these areas such that the mainstem of the stream is essentially undisturbed (CDFG 1999b).

Hatchery Effects

Steelhead are produced at the CNFH and the current steelhead population in Mill Creek may be augmented by hatchery strays.

Embryo Incubation

Harvest/Angling Impacts

Recreational fishing in Mill Creek is not permitted during most of the steelhead embryo incubation life stage.

Water Temperature

Salmonid redds are located in the upstream reaches of Mill Creek which are generally characterized as having favorable water temperatures during the majority of the embryo incubation period.

Water Quality

Water quality monitoring in Mill Creek has shown levels of coliform bacteria, minerals and nutrients to be low and not restrictive to beneficial use (Deer Creek Conservancy Website 2007; DWR 2005a). Concentrations of aluminum and copper have at times exceeded the California Toxic Rule and the EPA chronic criteria for the protection of freshwater organisms (Deer Creek Conservancy Website 2007; DWR 2005a). Erosion from recent volcanic deposits in and near Lassen Volcanic National Park, in the headwaters of Mill Creek, contributes turbidity to the stream nearly year-round (CDFG 1999b). Although not known to occur, any of these water quality factors could negatively impact developing steelhead embryos.

Flow Conditions

Flow conditions in the upstream reaches of Mill Creek are not affected by water diversions. As a result, any changes in flow that could potentially result in decreased oxygen flow, or redd dewatering events would be due to natural fluctuations in streamflow.

Juvenile Rearing and Outmigration

Water Temperature

Mill Creek reportedly provides relatively good habitat for juvenile salmonids (DWR 2005a). Water temperatures within the upper watershed are likely suitable for juvenile steelhead rearing year-round. During summer months, water temperatures in the lower reaches of Mill Creek may become too warm to support steelhead rearing.

Water Quality

Water quality monitoring in Mill Creek has shown levels of coliform bacteria, minerals and nutrients to be low and not restrictive to beneficial use (Deer Creek Conservancy Website 2007; DWR 2005a). Concentrations of aluminum and copper have at times exceeded the California

Toxic Rule and the EPA chronic criteria for the protection of freshwater organisms (Deer Creek Conservancy Website 2007; DWR 2005a). Erosion from recent volcanic deposits in and near Lassen Volcanic National Park, in the headwaters of Mill Creek, contributes turbidity to the stream nearly year-round (CDFG 1999b). Although not reported to have occurred, any of these factors could adversely affect juvenile steelhead.

FLOW CONDITIONS

The extent to which flow fluctuations from water diversions in Mill Creek may affect juvenile salmonid habitat availability and cause juvenile stranding is currently unknown.

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

The Mill Creek watershed is relatively long and narrow, with steep slopes. Steep slopes adjacent to the main channel have served as barriers to activity and land use allocations have protected these areas such that the mainstem of the stream is essentially undisturbed (CDFG 1999b).

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Because the Mill Creek watershed is relatively long and narrow, with steep slopes, little natural river function has been lost

LOSS OF FLOODPLAIN HABITAT

Because Mill Creek is a relatively narrow watershed with steep slopes, there is little natural connection with the floodplain. However, in the lower 8-miles of Mill Creek the creek does connect with the floodplain under high flows.

ENTRAINMENT

In Mill Creek, fish screens have been in place at all diversions, although some mortality of juvenile salmonids is still reported to occur (Klamath Resource Information System Website 2007).

PREDATION

Smallmouth bass, brown trout and green sunfish are all non-native predators known to exist in Mill Creek. The extent of predation that occurs on juvenile steelhead is unknown.

HATCHERY EFFECTS

Hatchery operations within the Central Valley likely have no effect on juvenile steelhead in Mill Creek.

4.3.8.11 ANTELOPE CREEK

Antelope Creek flows southwest from the foothills of the Cascade Range entering the Sacramento River nine miles southeast of the town of Red Bluff. The drainage is approximately 123 square miles and the average stream discharge is 107,200 acre-feet per year.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

Though there are diversion structures in the valley sections of Antelope Creek, there are no major impoundments. Anadromous fish (spring- and fall-run Chinook salmon and steelhead) have been able to maintain passage to the upper watershed (Klamath Resource Information System Website 2007).

HARVEST/ANGLING IMPACTS

Catch and release fishing is allowed in Antelope Creek. For purposes of fishing regulations, the creek is divided into two reaches. From the confluence with the north fork downstream to the USGS gaging station at the mouth of Antelope Creek Canyon, fishing with barbless hooks and artificial lures is allowed from the last Saturday in April through November 15. From that point downstream to the mouth, fishing is allowed from June 16 through September 30. Therefore, the recreational fishery is closed for most of the steelhead adult immigration life stage.

WATER TEMPERATURE

Water temperatures in Antelope Creek are adequate to support adult steelhead immigration during the late fall and winter months.

WATER QUALITY

Water quality in Antelope Creek is sufficient to support adult steelhead immigration.

FLOW CONDITIONS

Because there are no major water storage facilities on Antelope Creek and water diversions normally occur during the late spring and summer months, flows in Antelope Creek during the steelhead immigration time period mimic those of historic conditions.

SPAWNING

Based on reported observations of spring-run Chinook salmon spawning, the potential range and distribution for steelhead spawning is equal to approximately 9 miles, and extends from approximately 1.6 miles downstream of the Paynes Creek crossing upstream to near McClure Place on the North Fork, and to Bucks Flat on the South Fork (Klamath Resource Information System Website 2007). However, as previously noted the actual range of steelhead may exceed that of spring-run Chinook due to their smaller size (i.e., ability to navigate instream obstructions and utilize reaches with decreased channel widths).

PASSAGE IMPEDIMENTS/BARRIERS

There are no known passage impediments affecting steelhead spawning.

HARVEST/ANGLING IMPACTS

Recreational fishing is not permitted during the steelhead spawning period.

WATER TEMPERATURE

Water temperatures in the upper reaches of Antelope Creek, where documented steelhead spawning occurs, are sufficiently cold to support steelhead spawning.

WATER QUALITY

Water quality in Antelope Creek is adequate to support steelhead spawning.

Flow Conditions

Flows in the upper Antelope Creek watershed are unregulated and are not affected during the steelhead spawning period. There have been no flow-habitat relationships developed for salmonids in Antelope Creek.

Spawning Habitat Availability

Vanicek (Vanicek 1993) rated spawning habitat as fair to poor in Antelope Creek. There have been no flow habitat relationships developed for Antelope Creek.

Physical Habitat Alteration

The Antelope Creek watershed is relatively long and narrow with steep slopes. Steep slopes adjacent to the main channel have served as a barrier to human activity and the environment is essentially undisturbed (Klamath Resource Information System Website 2007).

Hatchery Effects

The last report of hatchery steelhead stocking in Antelope Creek occurred in 1980 (Klamath Resource Information System Website 2007). The current population may occasionally be augmented by hatchery strays.

Embryo Incubation

Harvest/Angling Impacts

Recreational fishing in Antelope Creek is not permitted for most of the time when steelhead embryos would be developing in redds.

Water Temperature

Water temperatures in Antelope Creek during the winter and early spring months when steelhead embryos are developing are sufficiently cool.

Water Quality

Although little water quality information on Antelope Creek is available, because Antelope Creek habitat in the upstream watershed is basically undisturbed, water quality in the upstream reaches likely have no adverse effects on embryo incubation.

Flow Conditions

Flow conditions on Antelope Creek during the steelhead embryo incubation period are unaffected by diversions or storage impoundments and are the same as under historic natural conditions.

Juvenile Rearing and Outmigration

Water Temperature

Water temperatures within the upper watershed are likely suitable for juvenile steelhead rearing year-round. During summer months, water temperatures in the lower reaches of Mill Creek may become too warm to support steelhead rearing.

WATER QUALITY

Although little water quality information on Antelope Creek is available, because Antelope Creek habitat in the upstream watershed is basically undisturbed, water quality in the upstream reaches likely have no adverse effects on juvenile salmonids.

FLOW CONDITIONS

The downstream migration of juvenile steelhead likely occurs concurrently with peak flows from January through March. The extent to which flow fluctuations from water diversions in Antelope Creek may affect juvenile salmonid habitat availability and cause juvenile stranding is currently unknown. However, there are two diversions in Antelope Creek at the canyon mouth. One is operated by the Edwards Ranch, which has water rights of 50 cfs, and the other by the Los Molinos Water Company which has a water right of 70 cfs. Flows are diverted between April 1 and October 31. The stream is usually dewatered when both diversions operate (Klamath Resource Information System Website 2007).

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

The Antelope Creek watershed is relatively long and narrow with steep slopes. Steep slopes adjacent to the main channel have served as a barrier to human activity and the environment is essentially undisturbed (Klamath Resource Information System Website 2007).

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Because the upper portion of the Antelope Creek watershed is relatively long and narrow, with steep slopes, little natural river function has been lost in that section. In the lower section, which flows through the valley, diversions have an impact on natural river processes.

LOSS OF FLOODPLAIN HABITAT

Because Antelope Creek is a relatively narrow watershed with steep slopes, there is little natural connection with the floodplain.

ENTRAINMENT

The Antelope Main canal could potentially cause entrainment or impingement of juvenile steelhead. It is unknown how many diversions associated with this canal are equipped with fish screens that meet NMFS and CDFG juvenile fish screen criteria.

PREDATION

Smallmouth bass, brown trout and green sunfish are all non-native predators known to exist in Antelope Creek. The extent of predation that occurs on juvenile steelhead is unknown.

HATCHERY EFFECTS

Central Valley hatchery operations likely do not directly affect juvenile steelhead in Antelope Creek.

4.3.9 BASALT AND POROUS LAVA DIVERSITY GROUP

4.3.9.1 BATTLE CREEK

Battle Creek enters the Sacramento River approximately five miles southeast of the Shasta County town of Cottonwood. It flows into the Sacramento Valley from the east, draining a watershed of approximately 360 square miles.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

The mainstem of Battle Creek has three structures that act as potential impediments to adult anadromous fish migration: (1) the CNFH barrier weir that diverts returning hatchery fish into the hatchery for brood stock collection each year from September through early March; (2) the Orwick seasonal gravel diversion dam; and (3) the tailrace from PG&E's Coleman Powerhouse, which had been known to attract steelhead into an area with little spawning habitat, but has currently been improved by the construction of a fish exclusion weir in 2004.

Natural-origin adult steelhead comprise 10 percent of the broodstock for the steelhead artificial propagation program at CNFH. Steelhead produced at the CNFH are part of the Central Valley steelhead DPS. As of 2005, only natural steelhead (non-clipped) adults are intentionally bypassed into upper Battle Creek as part of the Battle Creek Restoration Project (**Table 4-2**). Based upon parental genotyping, the progeny of bypassed natural steelhead have shown a statistically significant higher adult return rate than that of bypassed hatchery steelhead stock, within one generation (K. Niemela, USFWS, pers. comm.).

HARVEST/ANGLING IMPACTS

Battle Creek supports a popular recreational fishery (e.g., fall-run Chinook salmon, steelhead). As a result, some level of poaching likely occurs. Current fishing regulations do not allow any fishing from the mouth of Battle Creek to 250 feet upstream of the weir at the CNFH. Upstream of that point, catch and release fishing with artificial lures and barbless hooks is allowed from the last Saturday in April to November 15. These regulations likely limit potential adverse effects on immigrating adult steelhead.

Table 4-2. Steelhead Passage Above Coleman National Fish Hatchery Barrier Weir, 2001-2006.

Methodology		2001	2002	2003	2004	2005	2006
Weir Trap Mar - May	Non-clipped	61	103	62	62	44	126
	Clipped	25	13	1	7	0	0
Video May - Aug	Non-clipped	33	80	56	63	30	63
	Clipped	5	1	2	8	0	1
Hatchery Sep – Mar	Non-clipped	131	410	416	179	270	249
	Clipped	1,352	1,428	769	314	0	0
Bypassed	Non-clipped	225	420	546	304	344	431
	Clipped	1,382	1,643	772	329	0	2
Total Bypassed		**1,607**	**2,063**	**1,318**	**633**	**344**	**433**
Source: Newton *et al*. 2007; and Alston *et al*. 2007;							

WATER TEMPERATURE

Water temperatures in Battle Creek during the late fall and winter months are suitable for adult steelhead immigration.

Water Quality

Little information on water quality in Battle Creek is available. However, it is assumed to be quite good as Battle Creek also provides water to the CNFH.

Flow Conditions

Two studies were conducted to determine the flows necessary to facilitate fish passage within the Battle Creek watershed (Kier and Assoc 1999). The results of these two studies were used to develop instream flow alternatives for the *Battle Creek Salmon and Steelhead Restoration Project* (SDEIR 2005).

Spawning

Passage Impediments/Barriers

Prime quality spawning, holding, and rearing habitat for steelhead, winter-run, and spring-run Chinook is upstream of Wildcat and Coleman dams on the north and south forks of Battle Creek, respectively.

Harvest/Angling Impacts

Battle Creek is closed year-round from the mouth to the CNFH. 250 feet upstream of that point, catch and release fishing with artificial lures and barbless hooks is allowed from the last Saturday in April to November 15. These regulations basically serve to close the recreational fishery during the steelhead spawning period.

Water Temperature

Water temperatures in Battle Creek have not been explicitly evaluated for the steelhead life stage given that the majority of steelhead returning to Battle Creek are of hatchery-origin. However, water temperatures in Battle Creek during the late-fall and spring are likely suitable for adult steelhead spawning.

Water Quality

Little information on water quality in Battle Creek is available. However, it is assumed to be quite good as Battle Creek also provides water to the CNFH.

Flow Conditions

There have been no flow habitat relationships developed for steelhead in Battle Creek. However, protective flow regulations exist to protect steelhead spawning.

Spawning Habitat Availability

Brown and Kimmerer (Brown and Kimmerer 2004) report that areas suitable for salmonid spawning – based on substrate particle size – are relatively scarce. However, they also report that in-river conditions are likely not a limiting factor due to the current low population numbers of targeted species.

PHYSICAL HABITAT ALTERATION

Stream channel conditions in Battle Creek during the late 20th century have been considered suitable for salmonid production. Key stream habitat conditions appear to be of sufficient quality such that the abundance of threatened or endangered salmonid populations could be increased by increasing instream flows and constructing fish passage facilities at the Battle Creek Hydroelectric Project diversion dams. Land management activities currently occurring in the watershed appear to have little impact on the potential to restore anadromous salmonids to this watershed (Battle Creek Watershed Conservancy 2004).

HATCHERY EFFECTS

A technical review panel determined that CNFH may pose a significant risk to steelhead recovery in Battle Creek through increased adverse effects of interbreeding as well as increased pathogen exposure (CALFED Bay-Delta Program 2004). The effects of interbreeding may include a reduction in productivity and viability of the wild stock (CALFED Bay-Delta Program 2004). The Battle Creek technical review team also identified several ecological risks to wild steelhead associated with CNFH steelhead introduction in Battle Creek, including increased competition and predation, in addition to CNFH operation related risks, including stranding and isolation, as well as screen entrainment. Currently, hatchery production is dominating the Battle Creek system as indicated by the technical review panel findings of approximately 65 percent of the steelhead passing above CNFH are of hatchery-origin (CALFED Bay-Delta Program 2004).

CNFH releases spent hatchery steelhead adults upon completion of the hatchery spawning season; natural steelhead broodstock are released immediately after their utilization as broodstock. The use of kelts for repeat spawning in the hatchery program diversifies the age structure within the stock and population; kelts are more fecund and contribute larger eggs and subsequently, larger fish, to the population.

CNFH steelhead are residualizing in the upper Sacramento River, and may be the dominant component of the Sacramento River population. Effects of integrating the two populations include possible loss of unique genetic complexes and diversity with homogenization of the gene pool, and increased rates of straying between Battle Creek and the upper Sacramento River. The primary source stock of the current Battle Creek steelhead population is the upper Sacramento River population (Nielsen *et al.* 2003), and continuing supplementation by CNFH may counter natural selection in the Sacramento River population.

CNFH has developed a late fall Chinook salmon run to the hatchery for artificial propagation purposes, and may be maintaining this component of the fall/late fall-run ESU to a great extent. Many of the CNFH late fall-run are raised exclusively for monitoring studies.

CNFH annually releases 12 million fall-run Chinook salmon juveniles into the upper Sacramento River, with possible consequences of the "pied piper" effect and habitat/prey competition with natural salmonids in the system. CNFH fall-run exhibit a high degree of homing back to Battle Creek.

EMBRYO INCUBATION

HARVEST/ANGLING IMPACTS

Currently, recreational fishing during most of the time period when steelhead embryos are developing is not allowed.

WATER TEMPERATURE

Water temperatures in the upper stream reaches of Battle Creek when the majority of steelhead spawning period are reportedly excellent for all life stages (DWR 2005a).

WATER QUALITY

Little information on water quality in Battle Creek is available. However, it is assumed to be quite good as Battle Creek also provides water to the CNFH.

FLOW CONDITIONS

The operations of the Battle Creek Hydroelectric Project causes water level changes in some reaches of Battle Creek that are more frequent and rapid then those which occur naturally. The effects of these flow changes on steelhead redds have not been the direct focus of any study to date. As part of the Battle Creek Salmon and Steelhead Restoration Project, PG&E in cooperation with the resource agencies, has agreed to adaptively manage instream flows in Battle Creek by adjusting flows at diversion dams to prevent redd dewatering events (Reclamation *et al.* 2004).

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

Water temperature problems may occur during some years due to the diversion of coldwater springs into canals away from adjacent stream channels on the North Fork and South Fork of Battle Creek. However, it is unknown the degree to which these operations would potentially affect the steelhead the juvenile rearing and outmigration life stages (Reclamation *et al.* 2004).

WATER QUALITY

Little information on water quality in Battle Creek is available. However, it is assumed to be quite good as Battle Creek also provides water to the CNFH.

FLOW CONDITIONS

Powerhouse operations cause flow fluctuations of up to 200 cfs in some reaches of the Battle Creek watershed which could potentially lead to juvenile stranding events. It has been estimated that powerhouse diversions on the North Fork and South Fork of Battle Creek divert up to 97 percent of the natural unimpaired flow (Reclamation *et al.* 2004).

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Land management activities currently occurring in the watershed appear to have little impact on the potential to restore anadromous salmonids to this watershed (Battle Creek Watershed Conservancy 2004). Restoration of riparian corridors in lower Battle Creek are currently underway (Battle Creek Working Group 1999).

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Stream channel conditions (e.g., gravel distribution and abundance, sedimentation, channel morphology) in Battle Creek are considered to be suitable for salmonid production (Battle Creek Watershed Conservancy 2004). Similarly, land management activities in the watershed are assumed to have little impact on the potential to restore anadromous salmonids to the system (Battle Creek Watershed Conservancy 2004).

Loss of Floodplain Habitat

Flood control measures have resulted in less frequent high flow events and resulted in a loss of connectivity with the river and historic floodplain.

Entrainment

The high volume of surface water diverted from unscreened agricultural and hydroelectric diversions in Battle Creek constitutes a substantial threat to rearing and emigrating juvenile salmonids. However, it is anticipated the installation of positive fish barrier screens in the near future as part of the proposed water management strategy for the Battle Creek watershed will reduce the amount of juvenile entrainment at water diversions (Reclamation *et al.* 2004).

Predation

USFWS has identified predation as one of the ways that juvenile salmonids released from the CNFH may affect natural populations of salmonids (Battle Creek Working Group 1999). However, the actual extent of predation on natural populations by steelhead and Chinook salmon on natural populations is not known (Battle Creek Working Group 1999).

Hatchery Effects

USFWS has expressed concern that predation, disease transmission and competition/displacement are ways in which juvenile salmonids released from the CNFH may affect natural salmonid populations (Battle Creek Working Group 1999). The actual extent of these potential impacts is not known, although there is speculation that these factors are minimal or non-existent (Battle Creek Working Group 1999). However, these conclusions were not based on completed investigations. Furthermore, these conclusions that suggest minimal impact were derived during a period when Chinook salmon and steelhead populations were depressed. As restoration of Battle Creek salmonid populations proceed, increased interactions between hatchery operations and natural fish populations are expected, suggesting that more investigations of possible impacts are required (Battle Creek Working Group 1999).

4.3.9.2 Cow Creek

The Cow Creek watershed encompasses approximately 430 square miles and drains the base and foothills of Mt. Lassen. Cow Creek joins the Sacramento River 23 miles downstream of Shasta Dam.

Adult Immigration and Holding

Passage Impediments/Barriers

Natural barriers restrict anadromous salmonids to the low elevation portions of the Cow Creek Basin. These barriers (waterfalls) occur on all five of the main Cow Creek tributaries

(Hannaford 2000). Agricultural diversions present partial barriers to upstream migration under most flow conditions and particularly during low flows.

HARVEST/ANGLING IMPACTS

Recreational catch-and-release fishing is permitted in Cow Creek from the last Saturday in April through November 15. These regulations are protective of immigrating adult steelhead in that the fishery is closed during the time of peak immigration.

WATER TEMPERATURE

Water temperatures in the mainstem of Cow Creek generally fall below 60°F in the beginning of October and are likely suitable for immigrating adult steelhead (Hannaford 2000).

WATER QUALITY

A portion of Little Cow Creek below the Afterthought Mine is listed as impaired water pursuant to Section 303(d). Hannaford (2000) found high fecal coliform concentrations in three of nine sites sampled in the Cow Creek Basin. Samples taken near the Afterthought Mine on Little Cow Creek have shown high concentrations of heavy metals but these concentrations appear to be quickly diluted downstream on Little Cow Creek (Hannaford 2000) and should not adversely affect adult steelhead. Dissolved oxygen concentrations are normally near saturation.

FLOW CONDITIONS

Flows in the Cow Creek watershed are not controlled, yet is heavily diverted and likely does not mimic historic conditions during the steelhead adult immigration period.

SPAWNING

PASSAGE IMPEDIMENTS/BARRIERS

Natural barriers restrict anadromous salmonids to the low elevation portions of the Cow Creek Basin. These barriers (waterfalls) occur on all five of the main Cow Creek tributaries (Hannaford 2000). There also are numerous passage barriers caused by diversions below the natural barriers.

HARVEST/ANGLING IMPACTS

Recreational catch-and-release fishing is permitted in Cow Creek from the last Saturday in April through November 15. The fishery is closed during the time that steelhead would be spawning.

WATER TEMPERATURE

Water temperatures in Cow Creek are generally below 55°F from December through March and are suitable for steelhead spawning (Hannaford 2000).

WATER QUALITY

A portion of Little Cow Creek below the Afterthought Mine is listed as impaired water pursuant to Section 303(d). Hannaford (2000) found high fecal coliform concentrations in three of nine sites sampled in the Cow Creek Basin. Samples taken near the Afterthought Mine on Little Cow Creek have shown high concentrations of heavy metals but these concentrations appear to be quickly diluted downstream on Little Cow Creek (Hannaford 2000) and should not adversely affect adult steelhead. Dissolved oxygen concentrations are normally near saturation.

Flow Conditions

Flows in the Cow Creek watershed are not regulated by a dam and water is typically not being diverted during the steelhead spawning period.

Spawning Habitat Availability

Steelhead populations have not been estimated in Cow Creek. No specific studies have been conducted on Cow Creek to estimate the size of the steelhead spawning run, although CDFG (1965) estimated that Cow Creek supported annual spawning runs of 500 steelhead (current estimates would be much lower). Adult steelhead have been observed in North Cow, Old Cow and South Cow creeks; however, it is unknown what percentage of the steelhead run utilizes the other tributaries. Most steelhead spawning in South Cow Creek probably occurs above South Cow Creek diversion. The best spawning habitat occurs in the 5-mile reach of stream extending from about 1.5 miles below South Cow Creek Diversion Dam to 3.5 miles above the diversion dam. Additional spawning habitat occurs upstream of this reach, but it is much less abundant. Sightings of adult steelhead have been made at the South Cow Creek Campground (approximately 8.5 miles upstream of the South Cow Creek Diversion Dam) and in Atkins Creek, located just upstream from the campground (SHN 2001).

The *Working Paper on Restoration Needs,* compiled by the AFRP Core Group in 1995, identified Cow Creek and its tributaries as in “relatively good condition” related to salmon and steelhead spawning habitat (SHN 2001).

Physical Habitat Alteration

Substrate composition is a critical factor in spawning suitability. It is vitally important that spawning gravels percolate to deliver fresh oxygen to the eggs and developing embryos. Fine sediment reduces oxygen flow; therefore, adequate substrate crust has low proportions of sand and fine sediment. Water quality in Cow Creek has been significantly affected by siltation and erosion in the upper watershed. Stream banks have been eroded by excessive livestock grazing along Cow Creek and its principal tributaries. The resulting soil erosion and stream channel siltation have degraded salmon and steelhead spawning substrate in Cow Creek and its tributaries (SHN 2001).

Hatchery Effects

The extent of hatchery fish interaction with wild steelhead that may be present in Cow Creek is unknown. However, because of the proximity of the CNFH to Cow Creek, some interaction is likely.

EMBRYO INCUBATION

HARVEST/ANGLING IMPACTS

Recreational fishing is permitted in Cow Creek from the last Saturday in April through November 15. This schedule is protective of steelhead embryos as most embryo development would occur while the fishery is closed.

WATER TEMPERATURE

Water temperatures in Cow Creek are generally below 55°F from December through March and are suitable for steelhead embryo incubation, but warm rapidly in April and are likely marginal for this life stage (Hannaford 2000).

WATER QUALITY

Water quality in Cow Creek is generally good. Dissolved oxygen concentrations are normally near saturation. Hannaford (2000) found high fecal coliform concentrations in three of nine sites sampled in the Cow Creek Basin. Samples taken near the Afterthought Mine on Little Cow Creek have shown high concentrations of heavy metals but these concentrations appear to be quickly diluted downstream on Little Cow Creek (Hannaford 2000).

FLOW CONDITIONS

Flows in the Cow Creek watershed are not controlled and mimic historic conditions during most of the steelhead embryo incubation period. Once irrigation season begins, typically in April, flows may be somewhat diminished by water diversions.

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

Water temperatures in Cow Creek may warm to above 77°F from June through September which may be lethal to juvenile steelhead that cannot find coldwater refuge (Hannaford 2000).

WATER QUALITY

Water quality in Cow Creek is generally good. Dissolved oxygen concentrations are normally near saturation. Hannaford (2000) found high fecal coliform concentrations in three of nine sites sampled in the Cow Creek Basin. Samples taken near the Afterthought Mine on Little Cow Creek have shown high concentrations of heavy metals but these concentrations appear to be quickly diluted downstream on Little Cow Creek (Hannaford 2000).

FLOW CONDITIONS

Although flows in the Cow Creek watershed are not controlled, in that there are no major storage facilities, diversions during the irrigation season diminish flows and likely lead to increased water temperatures (Western Shasta Resource Conservation District and Cow Creek Watershed Management Group 2001).

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Extensive livestock grazing in the Cow Creek watershed has resulted in significant loss of riparian habitat and instream cover (Western Shasta Resource Conservation District and Cow

Creek Watershed Management Group 2001). No detailed riparian inventory or damage assessment has been conducted in the watershed.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Water diversions likely have resulted in some loss of natural river processes, thereby affecting morphology and function.

ENTRAINMENT

Habitat surveys conducted by CDFG identified 14 unscreened permanent and temporary water diversions in the reaches of the main stem of Cow Creek (Hannaford 2000). Water diversions normally extend from April through October, during which time juvenile steelhead may become entrained in the unscreened diversions.

A loss of juvenile migrating fish to water diversions and entrainment of juvenile salmon and steelhead is assumed to occur in Cow Creek and the tributaries. Only the PG&E diversions have fish screens that comply with CDFG fish screen design criteria (Western Shasta Resource Conservation District and Cow Creek Watershed Management Group 2001).

PREDATION

Largemouth and smallmouth bass have been identified in Cow Creek (Thompson *et al*. 2006). Both of these species likely prey on juvenile steelhead. Additionally, brown trout were introduced to Cow Creek in 1931 (Western Shasta Resource Conservation District and Cow Creek Watershed Management Group 2001) and a self-sustaining population now exists. Brown trout are also a likely predator on juvenile salmonids.

HATCHERY EFFECTS

From 1991 to present, North Cow, Clover, Old Cow and South Cow creeks have been planted with a total of 49,492 catchable rainbow trout. Darrah Springs Hatchery also planted Eagle Lake trout in Clover Creek in the early 1990s. The CNFH planted steelhead in North Cow, Old Cow, and South Cow creeks, as well as the mainstem of Cow Creek. Buckhorn Lake and Kilarc Reservoir are also planted twice a year with catchable trout for sportfishing purposes (Western Shasta Resource Conservation District and Cow Creek Watershed Management Group 2001). These planted species may be significant predators on naturally spawned salmonids in Cow Creek.

4.3.9.3 UPPER SACRAMENTO RIVER TRIBUTARIES[10]

Steelhead utilization of upper Sacramento River tributaries including Stillwater, Churn, Sulphur, Olney and Paynes creeks is not well documented. However, it is likely that those same factors that may affect steelhead in the upper Sacramento River as discussed in Section 4.3.7 would apply to these fish.

Extensive mining, road building, railroad construction and sewer line construction in the Sulphur Creek watershed has resulted in large bedload, extreme bank erosion and loss of riparian vegetation, however, Sulphur Creek reportedly supports anadromous salmonids, including

[10] This population includes steelhead utilizing the small tributaries in the Redding area including Stillwater, Churn, Suphur, Salt, Olney, and Paynes creeks.

steelhead (Sacramento Watersheds Action Group 1998). The Churn Creek watershed reportedly exhibited high rates of erosion and subsequent sedimentation, loss of riparian vegetation and chemical and nutrient water pollution in the early 1990s (Churn Creek Task Force 1991). Extensive spawning by Chinook salmon and large rainbow trout/steelhead has been noted on Salt Creek below Highway 299; however, there is no evidence of identified steelhead in Salt Creek (Vestra Resources, Inc. 2005). Spawning Chinook salmon and steelhead have been documented in Olney Creek (Vestra Resources, Inc. 2005). Suitable spawning gravel has been identified up to approximately four miles upstream of the mouth of Olney Creek (Vestra Resources, Inc. 2005).

4.3.10 NORTHWESTERN CALIFORNIA DIVERSITY GROUP

4.3.10.1 STONY CREEK

Stony Creek is a westside stream originating in the Coast Range and draining into the Sacramento River south of Hamilton City. There are three storage reservoirs in the watershed. The lowermost dam, Black Butte, is a barrier to anadromous fish. The GCID canal crosses Stony Creek downstream of Black Butte Dam and consists of a seasonal gravel dam constructed across the creek on the downstream side of the canal. This crossing not only allows the canal to continue flowing south but it also allows capture of Stony Creek water and is a complete barrier to salmon migration. The GCID berm was removed in 1999. Although steelhead spawning has not been documented in Stony Creek in recent years, there is now access to suitable spawning habitat for steelhead in the creek, following the removal of the GCID berm, and it is reasonable to assume that water management can and will have an effect on steelhead numbers, distribution and reproduction in Stony Creek (NMFS 2002b).

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

From the confluence with the Sacramento River, Stony Creek extends 24.6 miles upstream to Black Butte Lake, impounded by the Black Butte Dam. Black Butte Dam presents an impassable barrier to anadromous fish migration and marks the upstream extent of currently accessable steelhead habitat (NMFS 2002b). Four miles downstream of Black Butte Dam is the North Side Diversion Dam that operates during the irrigation season and also for flood control. The Diversion Dam may present a partial obstacle to upstream migration.

HARVEST/ANGLING IMPACTS

Legal harvest of salmonids (5 per day, 10 in possession except the portion of Stony Creek Middle Fork from Red Bridge upstream, only 2 per day) in Stony Creek is permitted from the last Saturday in April through November 15. For the remainder of the year, catch and release fishing with barbless hooks is allowed.

WATER TEMPERATURE

During the winter months, if flows permit access to upstream areas, water temperatures are likely suitable for steelhead immigration.

WATER QUALITY

The surface water quality of streams draining eastward from the Coast Range is generally poor. These streams generally have very high suspended sediment loads due to the metavolcanic bedrock and schist formations which produce clays that stay in suspension during turbulent flow conditions. Soil disturbance within these watersheds can accelerate erosion and sedimentation processes and lead to increased metal and nutrient concentrations. High concentrations of metals and nutrients are commonly present during both low flow and storm runoff events. These concentrations frequently exceed water quality criteria established for the protection of beneficial use or the maintenance of aquatic life. Total phosphorus concentrations are at stimulatory levels for algae (DWR Website 2007b).

Flow Conditions

A minimum flow of 30 cfs is required to be released from Black Butte Dam year round.

Spawning

Passage Impediments/Barriers

Black Butte Dam represents the upstream extent of currently accessable steelhead habitat. Most of the habitat in Stony Creek that may be suitable to steelhead spawning occurs in the four mile reach upstream of the Northside Diversion Dam (NDD). In most years, diversions at the NDD have ceased by mid-November, prior to the initiation of steelhead spawning migrations, and do not resume until late March. During periods of non diversion at NDD, flashboards are removed from the crest of the dam and a large drum gate on the east side of the dam is often raised to allow creek flows to pass through this section of the dam. The level of obstruction caused by the dam during the periods when flashboards are removed is unknown, however a cursory visual inspection of the dam by a NMFS engineer has indicated that the dam is unlikely to pose a significant passage barrier for adult steelhead (NMFS 2000b).

Harvest/Angling Impacts

Harvest of steelhead in Stony Creek is permitted up to November 15 which may affect early spawning steelhead.

Water Temperature

During the winter months, when steelhead spawning in Stony Creek would occur, water temperatures are cool enough to support spawning steelhead without adverse effects. However, water temperatures can rise quickly in the spring, potentially leading to mortality of late spawned embryos. Water temperature data collected at the Black Butte gage indicate that conditions for juvenile steelhead or developing embryos may become to warm as early as mid-April suggesting that successful steelhead spawning could only continue until mid-February (NMFS 2002b).

Water Quality

See the discussion on water quality above in the adult immigration section.

Flow Conditions

The Stony Creek watershed is characterized by cool, wet winters with high flows during the steelhead spawning period.

Spawning Habitat Availability

Current habitat conditions in Stony Creek are at best, marginal (NMFS 2002b). Although in recent years, steelhead spawning has not been documented in Stony Creek, some salmon spawning has been observed near the confluence with the Sacramento River (NMFS 2002b). The construction of Black Butte Dam has blocked the recruitment of spawning gravel to downstream areas. A substrate study conducted in 1998 concluded that "nearly all samples possessed a level of fine particles (sand) within the level of concern for salmonid reproduction" (NMFS 2002b).

Physical Habitat Alteration

Construction of dams and subsequent water diversions have depleted streamflows and contributed to higher water temperatures, lower dissolved oxygen levels, and decreased gravel and large woody debris recruitment. The existing streamflow conditions downstream of Black Butte Dam are highly dependent on flood control operations and water diversions.

Hatchery Effects

Because Stony Creek likely does not support a persistent population of steelhead, it is likely that hatchery steelhead compose a significant portion of any spawning population that may exist.

Embryo Incubation

Harvest/Angling Impacts

Stony Creek is open to recreational fishing year round. Some disruption of redds could occur as a result of wading anglers.

Water Temperature

Water temperatures in Stony Creek during the winter and early spring months are cool enough to support steelhead embryo incubation. Late spawning would likely result in embryos experiencing unsuitable to lethal conditions.

Water Quality

See the discussion on water quality above in the adult immigration section.

Flow Conditions

Flows in Stony Creek during the embryo incubation period are highly dependant on flood control and water storage operations which may lead to of redd dewatering during drier years. Day-to-day flow fluctuations due to flood control operations can be large, on the order of 100 to 1300 percent of the previous days flow, and range in magnitude of from several hundred to 6,000 cfs.

Juvenile Rearing and Outmigration

Water Temperature

Water temperatures in lower Stony Creek during the summer months are likely too warm to support juvenile steelhead rearing.

Water Quality

See the discussion on water quality above in the Adult Immigration section.

Flow Conditions

Flows in Stony Creek during the summer months are maintained at a minimum of 30 cfs, however, because of often lethal water temperatures during the summer months steelhead juveniles are likely not present.

Loss of Riparian Habitat and Instream Cover

The lower reach of Stony Creek has been significantly altered by the construction of flood-control levees and bank protection measures (i.e., riprapping). These measures have resulted in reduced habitat for juvenile steelhead. Additionally, Stony Creek is heavily inundated with arundo (*Arundo donax)* and tamarisk (*Tamarix parviflora)*, one of the worst infestations in a watershed in the north state. This impairs native riparian vegetation recruitment.

Loss of Natural River Morphology and Function

Channel modification projects designed to prevent flood-related damage (e.g., levee construction and bank riprapping) have degraded natural processes which serve to recruit gravel, provide instream cover and forage, and provide habitat diversity in lower Stony Creek. In addition to the levee construction, Stony Creek's heavily braided reach is partly due to instream gravel removal practices, and in part due to arundo (*Arundo donax)* and tamarisk (*Tamarix parviflora)* infestation, along with the disruption of natural sediment routing processes due to dams. These affect the natural channel migration patterns and morphology, thus affecting migration *(i.e.*, stranding, entrainment, etc.) of both adults and juveniles.

Loss of Floodplain Habitat

The construction of levees bank riprapping, instream gravel removal practices and infestation of arundo (*Arundo donax)* and tamarisk (*Tamarix parviflora)* in the of lower Stony Creek have disconnected the channel from its historic floodplain thereby preventing the recruitment of large woody debris and natural processes associated with periodic floodplain inundation.

Entrainment

If adult steelhead are able to pass the NDD and successfully spawn in the reach above the dam, operation of the NDD and North Canal are likely to adversely affect juveniles hatched above the structure. Throughout much of the irrigation season the majority of the water flowing down Stony Creek is diverted into the unscreened North Canal where they are unlikely to survive (NMFS 2002b).

PREDATION

Sacramento pikeminnow is likely the most important predator of juvenile salmonids in Stony Creek. While the pikeminnow is native to these waters, habitat alteration may have changed the predator prey dynamics in the system conferring an advantage to pikeminnow.

HATCHERY EFFECTS

It is possible that some hatchery steelhead released at the CNFH, enter Stony Creek and may compete with naturally spawned steelhead for resources or prey on smaller outmigrating juvenile steelhead.

4.3.10.2 THOMES CREEK

ADULT IMMIGRATION AND HOLDING

Thomes Creek enters the Sacramento River four miles north of the town of Corning. It flows into the Sacramento Valley from the west, draining a watershed of approximately 188 square miles. There are no significant dams on the stream other than two seasonal diversion dams, one near Paskenta and the other near Henleyville. Several small pump diversions are seasonally operated in the stream. The stream is usually dry or intermittent below the USGS stream gage near Paskenta until the first heavy fall rains occur.

PASSAGE IMPEDIMENTS/BARRIERS

There are no significant dams on Thomes Creek other than two seasonal diversion dams, one near Paskenta and the other near Henleyville. Several small pump diversions are seasonally operated in the stream (DWR Website 2007b). These dams would not be in place during the time when steelhead would be immigrating to upstream areas and likely not present obstacles to upstream immigration. Additionally, gravel mining downstream of the Tehama-Colusa Canal siphon crossing has reportedly resulted in a partial barrier to salmonids returning to Thomes Creek to spawn (Vestra Resources, Inc. 2006).

HARVEST/ANGLING IMPACTS

Legal harvest of salmonids in Thomes Creek is not permitted. Angling is permitted but restricted to catch-and-release with barbless hooks and artificial flies and lures only.

WATER TEMPERATURE

During the winter months, if flows permit access to upstream areas, water temperatures are likely suitable for steelhead immigration.

WATER QUALITY

The surface water quality of streams draining eastward from the Coast Range is generally poor. These streams generally have very high suspended sediment loads due to the metavolcanic bedrock and schist formations which produce clays that stay in suspension during turbulent flow conditions. Soil disturbance within these watersheds can accelerate erosion and sedimentation processes and lead to increased metal and nutrient concentrations. High concentrations of metals and nutrients are commonly present during both low flow and storm runoff events. These concentrations frequently exceed water quality criteria established for the protection of beneficial use or the maintenance of aquatic life. Total phosphorus concentrations are at stimulatory levels for algae (DWR Website 2007b).

Flow Conditions

Thomes Creek has an unimpaired natural pattern of flashy winter and spring flows and very low summer and fall flows creating an environment of fairly inconsistent habitat (CALFED 2000d). These conditions are not conducive to supporting a persistent population of steelhead. However, during wet years some steelhead may migrate into Thomes Creek and limited spawning may occur.

Spawning

Passage Impediments/Barriers

There are no identified manmade barriers too upstream migrations during the steelhead spawning season.

Harvest/Angling Impacts

Harvest of steelhead in Thomes Creek by recreational anglers is not permitted.

Water Temperature

During the winter months, when steelhead spawning in Thomes Creek would occur, water temperatures are cool enough to support spawning steelhead without adverse effects.

Water Quality

See the discussion on water quality above in the adult immigration section.

Flow Conditions

Flows in Thomes Creek are not regulated and mimic historic conditions. It is not likely that flows in Thomes Creek are consistent enough over the years to support a self-sustaining population of steelhead. More likely, during wet years, Thomes Creek supports sporadic steelhead spawning by either hatchery strays or upstream migrating adults attracted into Thomes Creek by high flow events.

Spawning Habitat Availability

Historically, there was about 30 river miles of potential steelhead habitat available in Thomes Creek, of which only the lower 4 miles are currently available (NMFS Website 2005).

Physical Habitat Alteration

Channel modification projects designed to prevent flood-related damage (e.g., levee construction and bank riprapping) have degraded natural processes which serve to recruit gravel suitable for steelhead spawning.

Hatchery Effects

Because Thomes Creek likely does not support a persistent population of steelhead, it is likely that hatchery steelhead compose a significant portion of the spawning population.

EMBRYO INCUBATION

HARVEST/ANGLING IMPACTS

Thomes Creek is closed to recreational fishing during most of the steelhead embryo incubation time period.

WATER TEMPERATURE

Water temperatures in Thomes Creek during the winter and early spring months are cool enough to support steelhead embryo incubation.

WATER QUALITY

See the discussion on water quality above in the adult immigration section.

FLOW CONDITIONS

Flows in Thomes Creek are not controlled and are described as flashy. These conditions likely lead to some level of redd dewatering during drier years.

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

Water temperatures in lower Thomes Creek during the summer months are likely too warm to support juvenile steelhead rearing.

WATER QUALITY

See the discussion on water quality above in the Adult Immigration section.

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

The lower reach of Thomes Creek has been significantly altered by the construction of flood-control levees and bank protection measures (i.e., riprapping) (CALFED 2000d). These measures have resulted in reduced habitat for juvenile Chinook salmon. Also extensive gravel mining and the establishment on non-native plants (Arundo and tamarisk) have had negative impacts on riparian habitat.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Channel modification projects designed to prevent flood-related damage (e.g., levee construction and bank riprapping) have degraded natural processes which serve to recruit gravel, provide instream cover and forage, and provide habitat diversity in lower Thomes Creek. Extensive gravel mining and the establishment on non-native plants (Arundo and tamarisk) have resulted in a loss of natural river morphology and function.

LOSS OF FLOODPLAIN HABITAT

The construction of levees and bank riprapping of lower Thomes Creek have disconnected the channel from its historic floodplain thereby preventing the recruitment of large woody debris and natural processes associated with periodic floodplain inundation.

Entrainment

Agricultural diversions on Thomes Creek are unscreened and any outmigrating salmonids likely are susceptible to entrainment in the diversions.

Predation

Sacramento pikeminnow is likely the most important predator of juvenile salmonids in Thomes Creek. While the pikeminnow is native to these waters, habitat alteration may have changed the predator prey dynamics in the system conferring an advantage to pikeminnow.

Hatchery Effects

It is possible that some hatchery steelhead released at the CNFH enter Thomes Creek and may compete with naturally spawned steelhead for resources or prey on smaller outmigrating juvenile steelhead.

4.3.10.3 Cottonwood/Beegum Creek

Cottonwood Creek drains the west side of the Central Valley and enters the Sacramento River a short distance downstream from the Redding-Anderson area.

Adult Immigration and Holding

Passage Impediments/Barriers

There are no known diversion dams in Cottonwood Creek. There is irrigated land in the watershed, but the water comes primarily from ACID. ACID siphons that cross Cottonwood Creek and at least one may be causing problems for steelhead immigration.

Harvest/Angling Impacts

Legal harvest of salmonids in Cottonwood Creek and its tributaries is not permitted. Angling is permitted but restricted to catch-and-release with barbless hooks and artificial flies and lures only. Additionally, angling is not permitted from November 15 through the end of April; therefore the fishery is closed during most of the steelhead immigration time period.

Water Temperature

Water temperatures in Cottonwood and Beegum creeks are likely suitable for supporting steelhead adult immigration during the winter months.

Water Quality

Water quality in Cottonwood Creek does not like adversely affect immigrating adult salmonids.

Flow Conditions

Flow conditions in Cottonwood Creek during the late fall and winter months likely do not impede steelhead upstream migration.

Spawning

Passage Impediments/Barriers

See discussion above under Adult Immigration and Holding.

Harvest/Angling Impacts

Recreational angling is not permitted from November 15 through the end of April; therefore the fishery is closed during most of the steelhead spawning time period.

Water Temperature

Water temperatures in Cottonwood Creek and its tributaries are sufficiently cool during the winter and early spring months to support steelhead spawning.

Water Quality

One major instream gravel extraction project operates in Cottonwood Creek below the Interstate 5 bridge (CALFED 2000d) which likely degrades water quality for a short distance downstream. However, these mining activities occur downstream of where steelhead would be expected to be spawning. There are numerous other gravel extraction projects elsewhere in the watershed, especially in the South Fork Cottonwood Creek watershed.

Flow Conditions

Flows in Cottonwood and Beegum creeks likely mimic historic conditions.

Spawning Habitat Availability

Gravel mining in Cottonwood Creek has reduced gravel recruitment leading to channel armoring and reduced spawning habitat.

Physical Habitat Alteration

There are no large water development projects or comprehensive flood control measures in the Cottonwood Creek drainage. Habitat alteration has arisen from timber harvest in the upper watershed, grazing in the middle watershed and extensive gravel mining in the lower watershed.

Hatchery Effects

There is a potential for native steelhead to interact with strays from the Coleman National Fish Hatchery.

Embryo Incubation

Harvest/Angling Impacts

Cottonwood Creek and tributaries are closed to fishing during the steelhead embryo incubation period.

Water Temperature

Water temperatures in Cottonwood and Beegum creeks are likely suitable for supporting steelhead embryo incubation.

Water Quality

The surface water quality of streams draining eastward from the Coast Range is generally poor. These streams generally have very high suspended sediment loads due to the metavolcanic bedrock and schist formations which produce clays that stay in suspension during turbulent flow conditions. Soil disturbance within these watersheds can accelerate erosion and sedimentation processes and lead to increased metal and nutrient concentrations. High concentrations of metals and nutrients are commonly present during both low flow and storm runoff events. These concentrations frequently exceed water quality criteria established for the protection of beneficial use or the maintenance of aquatic life.

FLOW CONDITIONS

Flows in Cottonwood and Beegum creeks likely mimic historic conditions during the steelhead embryo incubation life stage.

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

Water temperatures in the lower reaches of Cottonwood Creek are likely too warm to support steelhead in the summer months.

WATER QUALITY

See discussion presented above under Embryo Incubation.

FLOW CONDITIONS

Flows in Cottonwood and Beegum creeks likely mimic historic conditions and likely do not adversely affect juvenile steelhead.

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Extensive gravel mining occurs in lower Cottonwood Creek, which has resulted in a loss of riparian habitat. The remaining portion of the watershed is primarily rural which has helped avoid adverse impacts to the riparian areas. There is increasing concern witht the spread of non-native plants such as Arundo and tamarisk.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

There has been little development in the Cottonwood Creek watershed. This has resulted in Cottonwood Creek maintaining most of its historic characteristics and function.

LOSS OF FLOODPLAIN HABITAT

No comprehensive flood control measures (e.g., large levees) have occurred in the Cottonwood Creek drainage resulting in the creek retaining its connection to the floodplain. However, gravel mining and downcutting of the creek are decreasing the chances for floodplain inundation.

ENTRAINMENT

There are no known irrigation diversions in Cottonwood Creek.

PREDATION

Sacramento pikeminnow is likely the most important predator of juvenile salmonids in Cottonwood/Beegum Creek system. While the pikeminnow is native to these waters, habitat alteration may have changed the predator prey dynamics in the system conferring an advantage to pikeminnow.

Hatchery Effects

It is possible that juvenile steelhead released from the CNFH may enter Cottonwood Creek for rearing purposes and compete with naturally spawned steelhead.

4.3.10.4 Clear Creek

Clear Creek, a westside tributary to the upper Sacramento River, enters the mainstem Sacramento River at RM 289 near the south Redding city limits in Shasta County, California. Whiskeytown Dam is a complete barrier to fish passage and is the uppermost boundary of habitat available to anadromous salmon and steelhead. The stream channel below Whiskeytown Dam can be divided into two predominant types at Clear Creek Road Bridge (RM 8.5). Upstream, the creek is mainly confined by steep canyon walls and is characterized by falls, high gradient riffles, and deep pools. The substrate is mainly bedrock, large boulders, and fine sand. Downstream from RM 8.5 is the alluvial reach with a much lower gradient and a much wider valley relatively unconstrained by bedrock. Substrate is mainly a mixture of cobble, gravel, and sand.

Adult Immigration and Holding

Passage Impediments/Barriers

Whiskeytown Dam, at RM 18.1, is a complete barrier to fish migration and represents the upstream extent of currently accessable anadromous salmonid habitat.

Harvest/Angling Impacts

Legal harvest of salmonids in Clear Creek and its tributaries is not permitted. Angling is permitted but restricted to barbless hooks and artificial flies and lures only from last Saturday in April through November 15.

Water Temperature

Water temperatures during the late fall and winter months when steelhead would be immigrating to upstream spawning areas are maintained under 60°F and are suitable for this life stage.

Water Quality

The impact of accumulations of mercury is an issue in Clear Creek. Mercury contamination is the result of historic gold mining practices in the watershed (CDFG 2004b).

Flow Conditions

A flow schedule for Clear Creek has been incorporated into the CVPIA Anadromous Fisheries Restoration Program Plan that is designed to maintain flows in Clear Creek that will allow cool water temperatures conducive to all salmonid life stages. Currently the release schedule call for maintenance of 200 cfs flows from October 1 to June 1 and 150 cfs, or less, from July through September in order to maintain water temperatures below 60°F (USFWS 2003b). These flows are adequate to support steelhead adult immigration and holding.

Spawning

Passage Impediments/Barriers

Whiskeytown Dam, at RM 18.1, is a complete barrier to fish migration and represents the upstream extent of currently accessable anadromous salmonid habitat.

Harvest/Angling Impacts

Legal harvest of salmonids in Clear Creek and its tributaries is not permitted. Angling is permitted but restricted to barbless hooks and artificial flies and lures only from last Saturday in April through November 15.

Water Temperature

Water temperatures in Clear Creek during the winter months when steelhead would be spawning are suitable.

Water Quality

See above section under adult immigration and holding.

Flow Conditions

See above section under adult immigration and holding. The flow schedule described is supportive of steelhead spawning.

Spawning Habitat Availability

The construction of Whiskeytown Dam and significant gravel mining in the Clear Creek watershed has diminished suitable spawning gravel substrate. Currently, gravel replacement projects are being conducted in the watershed (CDFG 2004b).

Physical Habitat Alteration

The Clear Creek watershed has undergone extensive modification because of Whiskeytown Dam, gold mining, dredger mining, and gravel removal projects. Currently, Whiskeytown Dam diverts most of the Clear Creek natural streamflow to Spring Creek. However, extensive watershed rehabilitation efforts are currently underway in the watershed.

Hatchery Effects

Steelhead released from the Coleman National Fish Hatchery may have some interaction with native Clear Creek steelhead.

Embryo Incubation

Harvest/Angling Impacts

Legal harvest of salmonids in Clear Creek and its tributaries is not permitted. Angling is not permitted during winter months when most steelhead embryo incubation would be occurring.

Water Temperature

Water temperatures in Clear Creek during the winter and early spring months are suitable for steelhead embryo incubation.

Water Quality

See above section under adult immigration and holding.

Juvenile Rearing and Outmigration

Water Temperature

Water temperatures during the summer months are kept relatively cool by controlling flows at Whiskeytown dam and are generally suitable year-round for juvenile steelhead rearing.

Water Quality

See above section under adult immigration and holding.

Flow Conditions

In 1999, streamflows in Clear Creek were increased to a minimum of 150 cfs to provide adequate habitat for juvenile steelhead (USFWS 2004).

Loss of Riparian Habitat and Instream Cover

Over 30 years of gravel mining in Clear Creek has led to a reduction in riparian habitat along the lower sections (CDFG 2004b). Riparian habitat provides cover for rearing juveniles as well as insect habitat that serves as an important food source. There have been several riparian habitat restoration projects in Clear Creek.

Loss of Natural River Morphology and Function

Whiskeytown Dam diverts most of the historic flow from Clear Creek into Spring Creek and also regulates flows in Clear Creek such that natural flow regimes no longer occur.

Loss of Floodplain Habitat

Because Clear Creek flows are regulated, the channel has become incised and some connection to the historic floodplain has been lost.

Entrainment

Juvenile entrainment is not a major concern on Clear Creek.

Predation

Sacramento pikeminnow is likely the most important predator of juvenile salmonids in Clear Creek. While the pikeminnow is native to these waters, habitat alteration may have changed the predator prey dynamics in the system conferring an advantage to pikeminnow.

Hatchery Effects

Juvenile steelhead in Clear Creek likely have some interaction with steelhead released from the Coleman National Fish Hatchery.

4.3.10.5 Putah Creek

Putah Creek drains an area of approximately 576 square miles. It is the southernmost major drainage entering the Sacramento Valley from the west. Lower Putah Creek is located in the southwestern corner of the Sacramento Valley and flows 26 miles across the valley floor from the Putah Diversion Dam to the Toe Drain in the Yolo Bypass. Putah Diversion Dam is a reregulating reservoir below Monticello Dam, which controls runoff from 90 percent of the watershed and impounds Lake Berryessa. Steelhead are reported to have historically spawned in the upper tributaries of Putah Creek above the Berryessa Valley (now Lake Berryessa) but there have been no recently confirmed reports of steelhead in Putah Creek (EDAW 2005).

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

Monticello Dam, located at river mile 30 presents an absolute barrier to upstream anadromous salmonid migration. There are three other dams and one road crossing on lower Putah Creek which impede migration at certain flows. The bypass dam and the road crossing are seasonal barriers, which are only impediments to migration when they are in the creek, but they are normally removed by the time upstream migration of steelhead begins (DWR 2005a). The town of Winters Percolation Dam is the unused remains of an old dam. This dam is passable at certain flows but it is not clear what those flows are (DWR 2005a).

HARVEST/ANGLING IMPACTS

Lower Putah Creek has no special fishing regulations. The potential anadromous waters of lower Putah Creek allow fishing all year but no fish may be harvested.

WATER TEMPERATURE

Water temperatures in Putah Creek during the late fall and winter months are suitable for steelhead immigration.

WATER QUALITY

Water quality in lower Putah Creek is monitored by the Solano Irrigation District, the Bureau of Reclamation and the State Water Resources Control Board. Water quality in lower Putah Creek is of sufficient quality to not adversely affect adult immigrating salmonids in the creek.

FLOW CONDITIONS

Water flow has been the biggest deterrent to anadromous fish in Putah Creek since 1957 when the Solano Project dams were built. In May of 2000, as a result of several law suits, an agreement was reached whereby required flows from Monticello Dam were established and are specified by month. The purpose of the required flows is to benefit the fish and habitat of lower Putah Creek (DWR 2005a).

The instream flows and water releases from Monticello Dam became regulated through the May 2000 Putah Creek Accord (Accord) (Solano County Superior Court 2000, *as cited in* EDAW 2005). The purpose of the Accord is to create as natural of a flow regime as feasible (EDAW 2005). Four functional flow requirements are contained in the Accord pertaining to rearing flows, spawning flows for native resident fishes, supplemental flows for anadromous fishes, and drought-year flows (EDAW 2005). **Table 4-3** shows the basic required flow regimes specified by the Accord as prescribed for “normal” and “drought” conditions (EDAW 2005).

Table 4-3. Putah Creek flow summaries before and after construction of the Solano Project.

Summary of Flows at or Near Putah Diversion Dam Before and After Construction of the Solano Project

Variable	Flow (cfs)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pre-Project (1934–1956) [1]												
Max	3,957	6,468	3,506	2,729	452	156	64	32	21	45	807	5,110
Med	794	1,075	736	281	125	42	7	5	6	6	37	296
Min	45	67	151	50	17	7	2	0	2	1	3	9
Post Project (1971–1981, 1985–1990) [1]												
Max	1,239	2,239	3,403	2,020	51	43	43	34	36	20	50	85
Med	38	41	33	46	43	43	43	34	20	20	25	25
Min	25	18	26	45	33	33	33	26	16	15	26	25
Putah Creek Accord Release Schedule [2]												
Normal Year – PDD [3,4,5]	25	16	26	46	43	43	43	34	20	20	25	25
Normal Year – I-80 [3, 4, 5]	15	15	25	30	20	15	15	10	5	5	10	10
Drought Year – PDD [6]	25	16	26	46	33	33	33	26	15	15	25	25
Drought Year – I-80 [6]	2	2	2	2	2	2	2	2	2	2	2	2

1 Adapted from USFWS 1993; years post-project data selected to reflect periods similar to available pre-project conditions.
2 Solano County Superior Court 2000 and Moyle, pers. comm., 2002. Note: specific pulse flow requirements not shown.
3 Normal year rearing flows. Normal year exists when Lake Berryessa storage exceeds 750,000 acre-feet on April 1. Values are shown as daily average flow requirements. Continuous flow must be maintained from the I-80 bridge to the Yolo Bypass.
4 Spawning flows modify the normal year rearing flows, as follows: a) 3-day pulse release at PDD sometime between February 15 and March 31 every year, with minimum of 150 cfs, then 100 cfs, then 80 cfs, each for 24 hours, and following the pulse; b) 30 days of releases sufficient to maintain 50 cfs at I-80 bridge, then ramped down over 7 days to match the normal year rearing requirements.
5 Supplemental flows modify the normal year rearing flows, as follows: a) 5-day pulse is required sometime between November 15 and December 15 (timed following removal of flash boards at Los Rios dam) to maintain at least 50 cfs average daily flow at confluence with East Toe Drain, and following the pulse; b) a minimum of 19 cfs is required at I-80 bridge until March 31; and c) 5 cfs flow at East Toe Drain is required from November 1 to December 15 and from April 1 to May 31.
6 Drought year exists when Lake Berryessa storage is less than 750,000 acre-feet on April 1. Values reported in same format as for normal year flow requirements. Continuous flow is not required at Yolo Bypass.

Source: EDAW 2005, p. 4-7

SPAWNING

PASSAGE IMPEDIMENTS/BARRIERS

See section above describing barriers to upstream migration.

HARVEST/ANGLING IMPACTS

Lower Putah Creek has no special fishing regulations. The potential anadromous waters of lower Putah Creek allow fishing all year but no fish may be harvested.

WATER TEMPERATURE

Water temperatures in lower Putah Creek during the winter months are suitable for steelhead spawning.

WATER QUALITY

See section above describing water quality for upstream migration.

FLOW CONDITIONS

In addition to the flow agreements described above under adult immigration, the agreement also specifies spawning flows to be released from the diversion dam for a three day period between February 15 and March 31 each year. These flows are 150 cfs for the first day, 100 cfs on the second and 80 cfs on the third. For the following 30 days, flows must be at least 50 cfs (DWR 2005a).

SPAWNING HABITAT AVAILABILITY

Overall, gravel is not scarce along lower Putah Creek, however, recent gravel surveys indicate that gravel substrate size is generally smaller than that preferred by salmonids for spawning (Yates 2003). Additionally, both Monticello Dam and the Putah Diversion Dam block the transport of gravel from upstream reaches to potential spawning reaches downstream of the Putah Diversion Dam.

PHYSICAL HABITAT ALTERATION

Habitat in Putah Creek has been drastically altered by human activities over the past 120 years. Construction of levees, channel excavation, gravel mining and groundwater extraction have all led to a deeper, narrower creek channel. This has led to a disconnection with the floodplain. Additionally, construction of the Solano Project dams has resulted in reduced gravel and sediment recruitment, decreasing the natural dynamics of the creek.

HATCHERY EFFECTS

Because Putah Creek does not currently support a persistent unique population of steelhead, it is unlikely that hatchery effects (e.g., straying) would have adverse effects.

EMBRYO INCUBATION

HARVEST/ANGLING IMPACTS

Because recreational fishing is allowed year-round; it is possible that steelhead redds could be disturbed by wading anglers.

WATER TEMPERATURE

Water temperatures during the winter and early spring months are suitable for steelhead embryo incubation. Any late developing embryos (i.e., after April) may experience warmer water temperatures that could potentially reduce survival.

WATER QUALITY

See section above describing water quality for adult upstream migration in Putah Creek.

FLOW CONDITIONS

Flow regimes in Putah Creek are described above under adult immigration and spawning.

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

Water temperatures in Putah Creek normally remain below 60°F rear round just below the Putah Diversion Dam, but during the summer months, water temperatures increase rapidly downstream. For example, water temperatures at the I-505 Bridge normally begin exceeding 70°F in mid-May.

WATER QUALITY

See section above describing water quality for adult upstream migration in Putah Creek.

FLOW CONDITIONS

Flow regimes in Putah Creek are described above under adult immigration and spawning.

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

The riparian zone surrounding Putah Creek has been changed drastically from historic conditions. Human activities related to levee construction, flood control, agricultural encroachment into the riparian zone, burning and dumping of trash have all negatively affected riparian habitat. Currently, the riparian forest is dominated by valley oak, black walnut and eucalyptus.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

The flow regime in lower Putah Creek is highly regulated because Monticello Dam controls a large percentage of the watershed, and because the capacity of Lake Berryessa is much larger than the annual watershed runoff. In particular, high flows that formerly sustained much of the geomorphic processes along the creek have been greatly decreased.

LOSS OF FLOODPLAIN HABITAT

Controlled flows in lower Putah Creek have significantly decreased connectivity with the floodplain. For example, the estimated 100-year peak flow in lower Putah Creek is now only about one-third of pre-dam natural flow (Yates 2003).

ENTRAINMENT

The level of entrainment into unscreened water diversions is unknown at this time.

PREDATION

The level of predation on native anadromous salmonids is unknown. However, Putah Creek is a popular recreational fishery that supports non-native brown trout, a known predator on juvenile salmonids.

HATCHERY EFFECTS

Because Putah Creek does not currently support a persistent unique population of steelhead, it is unlikely that hatchery effects (e.g., straying) would have adverse effects.

4.3.11 SOUTHERN SIERRA NEVADA DIVERSITY GROUP

All steelhead that comprise the Southern Sierra Nevada Diversity group utilize the lower San Joaquin River as a migration corridor. A potential threat common to these steelhead is presented by the operation, usage and maintenance of the Stockton Deep Water Ship Channel (DWSC). Required periodic dredging of the DWSC creates noise pollution that could adversely affect salmonid populations in close proximity to dredging operations. Additionally, dredging would create sediment plumes potentially harmful to juvenile salmonids, mobilize heavy metal pollutants in the sediments, and there is a possibility of entrainment of juveniles in the dredging equipment. Potential threats created by DWSC usage by large ships include both noise pollution and propeller entrainment. Additionally, maintenance of the DWSC requires bank stabilization activities that negatively affect the riparian zone, further disconnect the river from its historic floodplain resulting in a loss of loss of natural river morphology and function. The potentially adverse effects and mitigation measures associated with the DWSC are described in the NMFS 2006 Biological and Conference Opinion for the Stockton Deep Water Ship Channel Maintenance Dredging and Levee Stabilization Project (NMFS 2006b).

Another factor influencing steelhead production in the Southern Sierra Nevada Diversity Group is the different water management practices used in the San Joaquin drainage as opposed to the Sacramento River drainage. Brown and Bauer (2008) compared estimates of full natural runoff before construction of major foothill storage reservoirs with measured discharge after construction. In the Sacramento drainage, pre-dam and pos-dam mean annual discharges were within 10 percent and the hydrograph was flattened. In the San Joaquin River drainage, post-dam mean annual discharges were 42 to 62 percent less than pre-dam values and mean discharges declined in most months, especially during the spring. Brown and Bauer (2008) conclude that when considered with species life history characteristics, these results support the hypothesis that water management has a major influence on the relative success of native and invasive fish species and that water deliveries through natural channels in the Sacramento River drainage appear to favor native species while water diversions in the San Joaquin River drainage appear to favor invasive species.

4.3.11.1 MOKELUMNE RIVER

The Mokelumne River drains an area of approximately 661 square miles with headwaters at an elevation of over 10,000 feet. The lower Mokelumne flows from Camanche Dam, at RM 64, to its confluence with the San Joaquin River. Camanche Dam is an impassable barrier and marks the upstream extent of currently accessable steelhead habitat.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

Camanche Dam, constructed in 1963 at RM 63.7, presents an impassable barrier to upstream migration and marks the upstream extent of currently accessable steelhead habitat in the Mokelumne River. The channel thalweg shifts continuously through this reach (CDFG 1991a). Woodbridge Dam creates Lodi Lake and supplies water to the Woodbridge Canal during the irrigation season. Other than beaver dams and illegal fences there have been no salmonid blockages observed in the river reach below Woodbridge Dam. Woodbridge Dam impounds Lodi Lake which extends upstream for about 8.5 miles. At low flows, there is no dominant flow pattern within the lake which probably delays upstream migration (CDFG 1991a).

HARVEST/ANGLING IMPACTS

The lower Mokelumne River is open to recreational fishing during most of the year and the taking of hatchery steelhead (identified by an adipose fin clip) is allowed. The reach from the confluence upstream to Peltier Road is open year-round and the reach upstream of Peltier Road to Camanche Dam is open from January 1 through March 31 and again from the fourth Saturday in May through October 15.

WATER TEMPERATURE

Upstream adult immigration of steelhead in the Mokelumne River occurs from August through March. Water temperatures in August can be as high as 68°F but normally lower to below 60°F by October (CDFG 1991a).

WATER QUALITY

Prior to 1991, dissolved oxygen levels lethal to salmonids frequently occur in the Mokelumne River (CDFG 1991a). High levels of turbidity have also been observed. Additionally, heavy metals and hydrogen sulfide in concentrations toxic to aquatic life have been shown to cause fish kills in the Mokelumne River. Copper and zinc from Penn Mine were identified as the main metals causing fish kills. Since 1991 these water quality conditions have been alleviated by the District with the addition of a hypolimnetic oxygenation system for Camanche Reservoir and a multi-million project by the State of California and EBMUD to remediate the abandoned Penn Mine to prevent further leakage of heavy metals.

FLOW CONDITIONS

During dry years flows in the Mokelumne River near Woodbridge can be well under 100 cfs from August and September. Increased flows for salmon spawning begin in October. Flows just below Camanche Reservoir typically are fairly constant at 200 to 300 cfs.

SPAWNING

PASSAGE IMPEDIMENTS/BARRIERS

Camanche Dam, constructed in 1963 at RM 63.7, presents an impassable barrier to upstream migration and marks the upstream extent of currently accessable steelhead habitat in the Mokelumne River. A potential low flow migration barrier occurs at Thornton just upstream of tidal influence. The potential barrier extends over a 600-foot section of the river and is characterized by shallow water over a sandy bottom. The channel thalweg shifts continuously through this reach (CDFG 1991a). Woodbridge Dam creates Lodi Lake and supplies water to the Woodbridge Canal during the irrigation season. Woodbridge Dam may present an upstream migration barrier at low flows. CDFG suggests that flows of about 300 cfs are necessary to provide passage over the Woodbridge Dam (CDFG 1991a). Woodbridge Dam impounds Lodi Lake which extends upstream for about 8.5 miles. At low flows, there is no dominant flow pattern within the lake which probably delays upstream migration (CDFG 1991a).

HARVEST/ANGLING IMPACTS

The lower Mokelumne River is open to recreational fishing during most of the year and the taking of hatchery steelhead (identified by an adipose fin clip) is allowed. The reach from the confluence upstream to Peltier Road is open year-round and the reach upstream of Peltier Road to Comanche Dam is open from January 1 through March 31 and again from the fourth Saturday in May through October 15. This time period in the reach above Peltier Road is likely protective of most steelhead natural spawning.

WATER TEMPERATURE

Steelhead spawning in the Mokelumne River occurs from December through April. Water temperatures during this time period are generally below 54°F (CDFG 1991a) which is near the upper temperature limit for successful steelhead spawning (Humpesch 1985; Timoshina 1972).

WATER QUALITY

Dissolved oxygen levels lethal to salmonids frequently occur in the Mokelumne River (CDFG 1991a). High levels of turbidity have also been observed. Additionally, heavy metals and hydrogen sulfide in concentrations toxic to aquatic life have been shown to cause fish kills in the Mokelumne River. Copper and Zinc from Penn Mine were identified as the main metals causing fish kills. Recently, hazardous levels of cadmium have been determined to be present from Penn Mine as well as from the base of Comanche Dam (CDFG 1991a).

FLOW CONDITIONS

Based on IFIM studies, maximum steelhead spawning habitat availability occurs at flows ranging from 100 to 500 cfs (CDFG 1991a). Flows are generally in this range during dry years. During wet years, flows are much more variable and range from about 200 cfs to 1,800 cfs during the steelhead spawning season (CDFG 1991a). CDFG (1991a) suggests that during normal water years, maintaining a flow of about 300 cfs during the mid-October through February time period at Woodbridge will provide maximum spawning habitat for steelhead and Chinook salmon.

SPAWNING HABITAT AVAILABILITY

Potential spawning habitat for salmonids extends approximately nine miles downstream of Comanche Dam (Heady 2008). Recruitment of suitable spawning gravels downstream of Comanche Dam is minimal. The dam blocks the downstream movement of gravel from upstream areas. There is only one gravel mining operation remaining on the lower Mokelumne River, and it occurs off of the main channel. This mining operation provides the gravel used for the spawning gravel enhancement project in the area below Camanche Dam.

PHYSICAL HABITAT ALTERATION

Water developments and diversions, mining activities, and discharge of waste material have had significant adverse effects on aquatic resources in the Mokelumne River. As a result, flows in the river have been substantially reduced and temperature and water quality have deteriorated from conditions that occurred naturally (CDFG 1991a).

HATCHERY EFFECTS

The Mokelumne River Fish Hatchery (MRFH) steelhead program has been founded and heavily supplemented by out-of-DPS (Eel River) or out-of-basin (Feather and American River) stock, and currently is not part of the DPS by lack of genetic confirmation. Steelhead returns back to the hatchery have been poor; experimental releases of CWT marked hatchery stock were conducted from 2004 through 2006 to determine the cause but insufficient recovery of data has hampered this effort. Recently, hydroacoustic-tagged MRFH steelhead adult releases have been found in the American River, indicating straying as one possible factor for poor escapement back to the MRFH, with a high degree of residualization being another. Possible effects of MRFH straying include genetic introgression of native steelhead stocks with the Eel River and Feather River genome, loss of genetic structure of the DPS, competition over spawning habitat and redd superimposition.

The MRFH carries out a number of release protocols: volitional, trucking and release within the watershed, trucking and release into San Pablo Bay, and the Delta. Effects of out-of-basin releases include a high degree of straying of adult returns into other streams in the Central Valley and California coast, with implications to native spring and fall Chinook salmon of competition over habitat. Genetic integrity of the Central Valley stellhead DPS is threatened by high straying rates. For example, straying of fall-run has resulted in the homogeneity of the fall-run component of the Central Valley fall-/late fall-run ESU.

EMBRYO INCUBATION

HARVEST/ANGLING IMPACTS

The lower Mokelumne River is open to recreational fishing during most of the year. The reach from the confluence upstream to Peltier Road is open year-round and the reach upstream of Peltier Road to Comanche Dam is open from January 1 through March 31 and again from the fourth Saturday in May through October 15. This time period overlaps with the embryo incubation life stage and some disruption of redds by wading anglers may occur.

WATER TEMPERATURE

Steelhead spawning in the Mokelumne River occurs from December through April. Therefore, some embryo incubation may extend into June. Water temperatures during this time period are generally below 54°F (CDFG 1991a) which is adequate for steelhead embryo incubation.

WATER QUALITY

See discussion above under adult immigration and holding.

Flow Conditions

Based on IFIM studies, maximum steelhead spawning habitat availability occurs at flows ranging from 100 to 500 cfs (CDFG 1991a). Flows are generally in this range during dry years. During wet years, flows are much more variable and range from about 200 cfs to 1,800 cfs during the steelhead spawning season (CDFG 1991a). CDFG (1991a) suggests that during normal water years, maintaining a flow of about 300 cfs during the mid-October through February time period at Woodbridge will provide maximum spawning habitat for steelhead and Chinook salmon. Variable flows during the embryo incubation life stage may lead to some redd dewatering.

Juvenile Rearing and Outmigration

Water Temperature

Juvenile steelhead rear in the Mokelumne River year-round. Smolt outmigration normally occurs from January through June. Peak water temperatures normally occur in July and August and can reach 68°F. Water temperatures fall below 60°F by October and remain near 54°F from November through May (CDFG 1991a). Steelhead can be found where daytime water temperatures range from nearly 32°F to 81°F in the summer (Moyle 2002). However, an upper water temperature limit of 65°F is preferred for growth and development of Sacramento River and American River juvenile steelhead (NMFS 2002a).

Water Quality

Dissolved oxygen levels lethal to salmonids frequently occur in the Mokelumne River (CDFG 1991a). High levels of turbidity have also been observed. Additionally, heavy metals and hydrogen sulfide in concentrations toxic to aquatic life have been shown to cause fish kills in the Mokelumne River. Copper and zinc from Penn Mine were identified as the main metals causing fish kills. Recently, hazardous levels of cadmium have been determined to be present from Penn Mine as well as from the base of Comanche Dam (CDFG 1991a).

Flow Conditions

CDFG (1991a) suggests that maintaining flows between 350 and 400 cfs at the Woodbridge gage during March and April will prevent the stranding of juvenile steelhead and facilitate movement through Lodi Lake to the Delta. Woodbridge Dam also impounds Lodi Lake and at low flows, dominant flow patterns in Lodi Lake may be difficult to detect. Downstream migrants have their progress slowed considerably upon reaching the lake. These outmigrants may reside in the lake for considerable periods of time during which they are subject to increased predation and warm water conditions (CDFG 1991a).

Loss of Riparian Habitat and Instream Cover

Riparian vegetation is found along most of both banks of the lower Mokelumne River. However, there is no regeneration along the relatively thin riparian corridor in many areas. It is subject to erosion, as well as removal for housing, agriculture, flood control, levee maintenance and gravel mining (CDFG 1991a).

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

The river tends to be wider the first six miles downstream of Camanche Reservoir and with the exception of Lodi Lake tends to be much narrower downstream. Because flows have been substantially reduced in this section of the river, the river characteristics are quite different than those that occurred historically and much side channel habitat has been lost.

In 2005, EBMUD, in cooperation with CDFG and USFWS, acquired funds to engineer 1,915 m^2 of side channel habitat. Monitoring of the engineered habitat has shown usage by both juvenile Chinook salmon and steelhead (Heady 2008). Heady (2008) reports that juvenile salmonids seem to respond to preferred diet items made available by the engineered habitat.

LOSS OF FLOODPLAIN HABITAT

Much of the narrowing of the river channel in the downstream reaches of the lower Mokelumne River can be attributed to flood control levees built to protect homes and agriculture on the historic floodplain. There are approximately 40 miles of levees on the lower Mokelumne River downstream of Camanche Dam (CDFG 1991a).

ENTRAINMENT

The diversion at Woodbridge Dam into Woodbridge Canal during the irrigation season (April 15 through October 15) averages 128 cfs but can be as high as 400 cfs. The diversion was screened in 1968. The screens did not meet CDFG or NMFS standards and some entrainment of juvenile steelhead was likely (CDFG 1991a). State of the art fish screens were installed and became operational in 2008 at the head of Woodbridge Canal. These screens were certified by CDFG and NMFS. Both of the NSJWCD intakes referenced have had new CDFG certified screens installed in the last 3 years.

Two water intakes below Camanche Dam operated by the North San Joaquin Water Conservation District have recently been screened with CDFG certified screens.

PREDATION

Non-native largemouth and smallmouth bass have been introduced to the lower Mokelumne River. Both species are likely predators on juvenile salmonids, particularly as outmigrants are slowed in Lodi Lake. Additionally, introduced striped bass likely prey on juvenile native salmonids in the Mokelumne River downstream of the Woodbridge Dam.

HATCHERY EFFECTS

Because early attempts to create a natural run of steelhead in the Mokelumne River were unsuccessful, the fishery was managed by CDFG as a catchable rainbow trout fishery. Steelhead averaging three to a pound were released annually. These fish likely preyed on juvenile salmonids in the lower river (EBMUD 1992). Except for one year of volitional release, this practice of releasing catchable rainbow trout to support a fishery was discontinued a number of years ago. All hatchery yearling steelhead are released below Woodbridge Dam with most of the fish released at Thornton or the Delta.

4.3.11.2 Calaveras River

The Calaveras River, a tributary to the San Joaquin River, is a relatively small, low elevation Central Valley drainage that receives runoff mainly from winter rainfall. Flow in the Calaveras River is regulated by New Hogan Dam, located approximately 38 miles upstream from the river's mouth at Stockton, where it meets the San Joaquin River. New Hogan Dam marks the upstream extent of currently accessable steelhead habitat in the Calaveras River.

Adult Immigration and Holding

Passage Impediments/Barriers

Currently, New Hogan Dam at RM 36 presents an impassable barrier to upstream migration and marks the upper extent of currently accessable steelhead habitat in the Calaveras River. Bellota Weir at RM 18 can be a barrier to upstream migration at low flows (Marsh 2007). At Bellota weir, the river is split into two channels, the old Calaveras River channel and Mormon Slough. Mormon Slough, converted to a flood control channel in the 1960s, now typically has more flow than the old Calaveras River channel. In recent years, steelhead have been documented using winter and spring flows from rain, runoff and occasional reservoir flood releases to migrate up the river, though barriers such as Bellotta Dam can stop steelhead once flows recede after a storm. Additionally, numerous in-channel migration barriers and dry reaches during low flows present complete or partial barriers to upstream migration below Bellota Weir (Fishery Foundation of California 2004).

Harvest/Angling Impacts

Recreational angling is allowed in the Calaveras River from the fourth Saturday in May through March 31 of the following year. Current regulations allow for the taking of hatchery trout or steelhead (identified by an adipose fin clip).

Water Temperature

A water temperature study was conducted from the spring of 2002 through the winter of 2003. During this study, water temperatures between New Hogan Dam and the Bellota Weir were found to be well within the acceptable limits for steelhead (Fishery Foundation of California 2004).

Water Quality

Environmental conditions such as high water temperatures and low dissolved oxygen concentrations may be a problem for migrating adult salmonids below Bellota Weir (Fishery Foundation of California 2004).

Flow Conditions

Currently, adult steelhead have two potential migration routes to upstream spawning habitat: (1) the old Calaveras River channel downstream of the town of Bellota, and 2) Mormon Slough via the Stockton Diverting Canal. The majority of steelhead migrate through Mormon Slough because there is typically more water in this route. However, in many years, the timing and magnitude of flows below Bellota Weir are not sufficient to allow steelhead to migrate upstream during winter months (Fishery Foundation of California 2004).

SPAWNING

PASSAGE IMPEDIMENTS/BARRIERS

Currently, New Hogan Dam at RM 36 presents an impassable barrier to upstream migration and marks the upper extent of currently accessable steelhead habitat in the Calaveras River. Bellota Weir at RM 18 can be a barrier to upstream migration at low flows (Marsh 2007). At Bellota weir, the river is split into two channels, the old Calaveras River channel and Mormon Slough. Mormon Slough, converted to a flood control channel in the 1960s, now typically has more flow than the old Calaveras River channel. In recent years, steelhead have been documented using winter and spring flows from rain, runoff and occasional reservoir flood releases to migrate up the river, though barriers such as Bellotta Dam can stop steelhead once flows recede after a storm.

HARVEST/ANGLING IMPACTS

Recreational angling is allowed in the Calaveras River from the fourth Saturday in May through March 31 of the following year. Current regulations allow for the taking of hatchery trout or steelhead (identified by an adipose fin clip).

WATER TEMPERATURE

During a water temperature study that was conducted from the spring of 2002 through the winter of 2003, water temperatures between New Hogan Dam and the Bellota Weir were found to be well within the acceptable limits for steelhead (Fishery Foundation of California 2004).

WATER QUALITY

Water quality appears to be adequate to support steelhead spawning upstream of Bellota Weir.

FLOW CONDITIONS

After construction of New Hogan Dam, and subsequent river regulation, barriers in the lower river became serious impediments to upstream migration causing stranding when flows high enough to pass fish over the barriers drops (Marsh 2007).

SPAWNING HABITAT AVAILABILITY

Spawning habitat upstream of Mormon Slough is considered adequate (Marsh 2007). However, the increased shear stress caused by tailing piles and the associated river channel confinement have resulted in the mobilization of spawning size gravel resulting in some loss of spawning habitat (Fishery Foundation of California 2004).

PHYSICAL HABITAT ALTERATION

A reconnaissance survey, conducted in 2002, indicated the extensive nature of gold dredging activities in the basin and encroachment of the river channel by tailings piles, resulting in the confinement of the river channel (Fishery Foundation of California 2004).

HATCHERY EFFECTS

Because Calaveras River does not support a persistent population of steelhead at this time, there are no likely hatchery effects.

EMBRYO INCUBATION

HARVEST/ANGLING IMPACTS

Recreational angling is allowed in the Calaveras River from the fourth Saturday in May through March 31 of the following year. Current regulations allow for the taking of hatchery trout or steelhead (identified by an adipose fin clip). Therefore, it is possible that redds could be inadvertently disturbed by wading anglers.

WATER TEMPERATURE

During a water temperature study that was conducted from the spring of 2002 through the winter of 2003, water temperatures between New Hogan Dam and the Bellota Weir were found to be well within the acceptable limits for steelhead (Fishery Foundation of California 2004).

WATER QUALITY

Water quality appears to be adequate to support egg development and embryo incubation upstream of Bellota Weir.

FLOW CONDITIONS

Flows between New Hogan Reservoir and the Bellota Weir are fairly constant throughout the steelhead embryo incubation period (Fishery Foundation of California 2004).

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

During a water temperature study that was conducted from the spring of 2002 through the winter of 2003, water temperatures between New Hogan Dam and the Bellota Weir were found to be well within the acceptable limits for steelhead (Fishery Foundation of California 2004). However, water temperatures below Bellota Weir often rise above suitable levels for juvenile salmonids (Fishery Foundation of California 2004).

WATER QUALITY

There is no evidence that water quality, other than temperature, may limit juvenile rearing (Fishery Foundation of California 2004).

FLOW CONDITIONS

Significant obstacles impede smolt outmigration in the fall and winter when low or no flow conditions are common and smolts can become stranded (Marsh 2007). From late-winter to the middle of April, flows sufficient to carry smolts from spawning and rearing areas to the San Joaquin River are infrequent (Fishery Foundation of California 2004). Under current flow management practices, before the beginning of the irrigation season, full connection of flows in Mormon Slough between Bellota Weir and the San Joaquin River occurs only when storm runoff below New Hogan Dam results in uncontrolled spill over the top of Bellota Weir. Diversion of flows away from the mouth of the old Calaveras channel and development of extensive irrigation infrastructure in Mormon Slough has likely blocked smolt outmigration to a large degree (Fishery Foundation of California 2004).

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Dewatering of the Old Calaveras River channel and simplification and reduction of riparian cover in Mormon Slough have resulted in higher water temperatures that would not be expected to support significant numbers of rearing juvenile salmonids (Fishery Foundation of California 2004). In contrast to conditions below Bellota Weir, a great deal of rearing habitat is available upstream (Fishery Foundation of California 2004).

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

A reconnaissance survey, conducted in 2002, indicated the extensive nature of gold dredging activities in the basin and encroachment of the river channel by tailings piles, resulting in the confinement of the river channel (Fishery Foundation of California 2004).

LOSS OF FLOODPLAIN HABITAT

According to historical accounts, the Calaveras River's valley reach downstream of Bellota was a large floodplain with many braided streams during times of high flows. This reach has changed from an uncontrolled floodplain of sloughs and oak groves to a system of controlled channels, dams, and levees (Marsh 2007).

ENTRAINMENT

Juvenile steelhead can become entrained at the Bellota Weir (Marsh 2007).

PREDATION

Reconnaissance surveys indicate the presence of large run pools between Jenny Lind Bridge and Shelton Road that may support warmwater prey species such as largemouth and smallmouth bass. Brown (2000) suggests that introduced species found in the lower reaches of tributaries to the San Joaquin River and the lower mainstem San Joaquin River likely compete with and predate upon downstream migrants.

HATCHERY EFFECTS

It is not likely that juvenile steelhead rearing in the Calaveras River are affected by hatchery production.

4.3.11.3 STANISLAUS RIVER

The Stanislaus River is one of the largest tributaries of the San Joaquin River. The river is 65 miles long and has north, middle and south forks. The north and south forks meet several miles upstream from New Melones Lake and the middle fork joins the north fork a few miles before that. The Stanislaus River is extensively dammed and diverted. Donnells Dam on the middle fork forms Donell Lake, high in the Sierra Nevada. Downstream is Beardsley Dam, which forms Beardsley Lake. McKays' Point Diversion Dam diverts water on the north fork for hydroelectricity production and domestic use. The New Melones Dam blocks the river after the confluence of all three forks. Downstream from New Melones Lake, there is Tulloch Dam, which forms Tulloch Reservoir, and Goodwin Dam, which is the first major barrier for anadromous fish on the Stanislaus River. The Stanislaus River historically supported a large population of spring-run Chinook salmon which was extirpated with the construction of Goodwin Dam. Below Goodwin Dam, the Stanislaus eventually meets the San Joaquin River and flows into the Delta.

Adult Immigration and Holding

Passage Impediments/Barriers

Goodwin Dam, at RM 58.4 presents an impassable barrier to anadromous salmonids and marks the upstream extent of currently accessable steelhead habitat on the Stanislaus River.

Harvest/Angling Impacts

There is a catch and release steelhead fishery in the lower Stanislaus River from January 1 through October 15. Artificial lures with barbless hooks are required from Goodwin Dam downstream to the Highway 120 Bridge in Oakdale. Below the bridge, bait fishing is permitted. Poaching and illegal fishing methods are reported to be problems for steelhead in the Stanislaus River (Carl Mesick Consultants and S.P. Cramer & Associates 2002).

Water Temperature

Because steelhead immigration to the Stanislaus River primarily occurs during the winter months, water temperature downstream of Goodwin Dam is likely suitable for steelhead adult immigration. During the steelhead migration period, maximum average daily water temperatures at Caswell are generally below 55°F from the end of November through early March, are between 55 and 65°F through the end of May, and are above 65°F through the end of summer. These temperatures during the majority of the steelhead upstream migrating period are not expected to adversely impact adults. However, any adults attempting to migrate during the summer months may experience reduced egg viability.

Water Quality

Water quality in the Stanislaus River is adequate to support steelhead adult immigration and holding.

Flow Conditions

It is likely that flow conditions in the Stanislaus River are adequate to support steelhead adult immigration during the winter months.

Spawning

Passage Impediments/Barriers

Goodwin Dam, at RM 58.4 presents an impassable barrier to anadromous salmonids and marks the upstream extent of currently accessable steelhead habitat on the Stanislaus River.

Harvest/Angling Impacts

There is a catch and release steelhead fishery in the lower Stanislaus River from January 1 through October 15. Artificial lures with barbless hooks are required from Goodwin Dam downstream to the Highway 120 Bridge in Oakdale. Below the bridge, bait fishing is permitted. Poaching and illegal fishing methods are reported to be problems for steelhead in the Stanislaus River (Carl Mesick Consultants and S.P. Cramer & Associates 2002).

Water Temperature

Because steelhead spawning in the Stanislaus River occurs primarily during the winter months, water temperatures are likely suitable for this life stage in downstream of Goodwin Dam.

WATER QUALITY

Gravel mining and the subsequent production of pits and long flowing ditches have led to reduced dissolved oxygen concentrations in the lower river (Carl Mesick Consultants and S.P. Cramer & Associates 2002). Another potential problem for spawning fish is increased turbidity and siltation from storm run-off as a result of changes in land use, such as new housing developments. For example, following an intensive rainstorm in late January 2000, a thick blanket of clay-sized silt covered the riffles at Knights Ferry and downstream areas, particularly those below the Orange Blossom Bridge.

FLOW CONDITIONS

Reclamation is required to release up to 98,000 acre-feet of water each year from the New Melones Reservoir to the Stanislaus River on a distribution pattern to be specified each year by CDFG for fish and wildlife purposes (Carl Mesick Consultants and S.P. Cramer & Associates 2002).

SPAWNING HABITAT AVAILABILITY

There has been extensive gravel mining in the Stanislaus River. Increased encroachment and reduced gravel recruitment has led to the coarsening of the bed material, particularly in spawning habitat in the unmined reaches of the river below Goodwin Dam (Carl Mesick Consultants and S.P. Cramer & Associates 2002).

PHYSICAL HABITAT ALTERATION

Habitat downstream of Goodwin Dam has been substantially altered by gravel mining. Drag lines were used to dredge the gravel and the spawning habitat from several reaches of the active riverbed. The dredged channels are now either large instream pits or long, uniform ditches that provide almost no spawning habitat (Carl Mesick Consultants and S.P. Cramer & Associates 2002).

HATCHERY EFFECTS

A genetic analysis of steelhead smolts captured in the Stanislaus River indicates that they are closely related to upper Sacramento River steelhead, but not steelhead from the MRFH or the Nimbus Hatchery on the American River and so they appear to be a natural population (Carl Mesick Consultants and S.P. Cramer & Associates 2002).

EMBRYO INCUBATION

HARVEST/ANGLING IMPACTS

There is a catch and release steelhead fishery in the lower Stanislaus River from January 1 through October 15. Artificial lures with barbless hooks are required from Goodwin Dam downstream to the Highway 120 Bridge in Oakdale. Below the bridge, bait fishing is permitted. It is likely that there is some disturbance of steelhead redds by wading anglers during the embryo incubation life stage.

WATER TEMPERATURE

Because embryo incubation of steelhead eggs in the Stanislaus River primarily occurs during the winter and spring months, water temperatures are suitable for this life stage downstream of Goodwin Dam.

WATER QUALITY

Gravel mining and the subsequent production of pits and long flowing ditches have led to reduced dissolved oxygen concentrations in the lower river (Carl Mesick Consultants and S.P. Cramer & Associates 2002).

FLOW CONDITIONS

Flow conditions in the Stanislaus River downstream of Goodwin Dam are likely adequate to support embryo incubation of steelhead. However, turbidity from storm events during January and February have been shown to mobilize fine sediment which may decrease oxygen availability to redds (Carl Mesick Consultants and S.P. Cramer & Associates 2002).

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

Water temperatures reach critical levels during the summer months between Goodwin Dam and the Orange Blossom Bridge (where most steelhead juvenile rearing occurs) (Carl Mesick Consultants and S.P. Cramer & Associates 2002). However, because of hypolimnetic releases of cold water from Goodwin Dam, water temperatures are likely suitable for a short distance downstream of Goodwin Dam even during summer months (Carl Mesick Consultants and S.P. Cramer & Associates 2002). Temperatures may not be low enough (<14 C) to optimize smoltification within the Stanislaus River and increase survival to the ocean (Myrick and Cech 2001).

WATER QUALITY

Dissolved oxygen concentration reach critical levels during the summer months between Goodwin Dam and the Orange Blossom Bridge (where most steelhead juvenile rearing occurs) (Carl Mesick Consultants and S.P. Cramer & Associates 2002).

FLOW CONDITIONS

Stream flow releases from Goodwin Dam are probably adequate to support juvenile rearing of steelhead except under the driest of conditions. Even during relatively hot spells, releases from the dam provide adequate cooling to the river downstream to about Orange Blossom Bridge

(Carl Mesick Consultants and S.P. Cramer & Associates 2002). The magnitude, duration, and frequency of elevated spring flows in the Stanislaus River has been altered by operations of New Melones and Goodwin Dam which may negatively impact migrating juvenile steelhead. A strong coorelation has been established between annual spring flow magnitude and the production of salmon smolt outmigrants from the a tributary, survival of smolts in the Delta and the production of adults in the escapement and ocean harvest (Mesick 2008, Mesick and Marston 2007).

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

No analyses have been conducted to assess the amount of riparian habitat along the lower Stanislaus River that has been converted for agricultural use or commercial gravel mining. CDFG conducted analyses of aerial photographs taken in 1958 and 1965 that indicated that there were approximately 3,300 acres of riparian habitat between Knights Ferry Bridge and the San Joaquin River in 1958, but only 2,550 acres in 1965 as a result of conversion for agricultural uses and commercial gravel mining (Carl Mesick Consultants and S.P. Cramer & Associates 2002). The amount of riparian habitat appears to have stabilized since 1965 based on a third analysis conducted by the USFWS in 1998 (Carl Mesick Consultants and S.P. Cramer & Associates 2002).

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

It is speculated that the construction and subsequent operation of the New Melones Dam has reduced channel diversity and the channel has become incised (Carl Mesick Consultants and S.P. Cramer & Associates 2002).

LOSS OF FLOODPLAIN HABITAT

A study of aerial photographs and field observations indicate that the Stanislaus River has changed from a dynamic river system, characterized by depositional and scour features, to a relatively static and entrenched system. Changes since the construction of New Melones Dam include: (1) large scale vegetation encroachment in the active channel; (2) reduced reproduction of cottonwoods; and (3) substantial encroachment by urban and agricultural development, particularly orchards, in floodplain areas thereby altering the natural river floodplain connection (Carl Mesick Consultants and S.P. Cramer & Associates 2002).

ENTRAINMENT

There are 44 unscreened diversions in the Stanislaus River downstream of Goodwin Dam. However, entrainment rates at these sites have not been studied (Carl Mesick Consultants and S.P. Cramer & Associates 2002).

PREDATION

Dredged channels and pits from gravel mining operations have reduced turbulence and thereby providing habitat for potential predators of juvenile salmonids. Concentrations of predators in slow flowing ditches that lack cover may result in high rates of juvenile mortality through predation (Carl Mesick Consultants and S.P. Cramer & Associates 2002). Brown (2000) suggests that introduced species found in the lower reaches of tributaries to the San Joaquin River and the lower mainstem San Joaquin River likely compete with and predate upon downstream migrants.

HATCHERY EFFECTS

Juvenile steelhead rearing in the Stanislaus River are not likely affected by hatchery production.

4.3.11.4 TUOLUMNE RIVER

The Tuolumne River is the largest tributary of the San Joaquin River. It drains a 1,900-square mile water shed that includes the northern portion of Yosemite National Park. La Grange Dam marks the upstream extent of currently accessable anadromous salmonid habitat. From La Grange Dam, the Tuolumne River flows in a westerly direction for approximately 50 miles before entering the mainstem San Joaquin River. Although some steelhead reportedly persist in the Tuolumne River, debate over historical distribution and less emphasis on commercial value have shifted the primary focus of restoration efforts from steelhead to fall-run Chinook salmon in the Tuolumne Basin (McBain and Trush 2000).

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

The La Grange Dam at RM 52.2 presents an impassable barrier to upstream migrating anadromous salmonids and marks the upstream extent of currently accessable steelhead habitat in the Tuolumne River.

HARVEST/ANGLING IMPACTS

The Tuolumne River, from La Grange Dam downstream to the confluence with the San Joaquin River supports a catch and release recreational trout fishery from January 1 through October 15.

WATER TEMPERATURE

Because steelhead immigration to the Tuolumne River primarily occurs during the winter months, water temperature downstream of La Grange Dam is likely suitable for steelhead adult immigration. However, any adults attempting to migrate during the fall and summer months may experience reduced egg viability.

WATER QUALITY

Water quality in the Tuolumne River is adequate to support steelhead adult immigration and holding.

FLOW CONDITIONS

Prescribed baseflows for October 1 through May 15 range from between100 cfs and 200 cfs for the drier 50 percent exceedance water years, and 300 cfs for the wetter 50 percent exceedance years (McBain and rush 2000). Minimum instream flows during summer are 50 cfs and 250 cfs for critically dry and normal-wet years respectively (McBain and Trush 2000).

Spawning

Passage Impediments/Barriers

The La Grange Dam at RM 52.2 presents an impassable barrier to upstream migrating anadromous salmonids and marks the upstream extent of currently accessable steelhead habitat in the Tuolumne River.

Harvest/Angling Impacts

The Tuolumne River, from La Grange Dam downstream to the confluence with the San Joaquin River supports a catch and release recreational trout fishery from January 1 through October 15. Therefore, it is possible that redds could be inadvertently disrupted by wading anglers.

Water Temperature

Water temperatures in the Tuolumne River during winter months are likely suitable for steelhead spawning.

Water Quality

Water quality in the Tuolumne River likely does not adversely affect steelhead spawning.

Flow Conditions

Flow standards for the protection of steelhead in the Tuolumne River were implemented in 1991.

Spawning Habitat Availability

Habitat suitable for spawning on the Tuolumne River is finite, such that there is an absolute limit on production. A 1986 estimate of spawning habitat enumerated 72 riffles and 2.9 million square feet of riffle area at a flow of 230 cfs (McBain & Trush 1998). Studies on spawning habitat conducted in the 1980s concluded that spawning habitat availability was a significant factor in limiting salmon production in the Tuolumne River.

Physical Habitat Alteration

Dams, aggregate extraction, agricultural and urban encroachment, and other land uses have caused sediment imbalances in the channel. Reduced magnitude, duration and frequency of high flows has allowed fine sediment to accumulate in the Tuolumne River. Additionally, the elimination of coarse sediment from upstream reaches has degraded salmonid spawning habitat (McBain & Trush 1998).

Hatchery Effects

The extent of interaction with steelhead spawning in the Tuolumne River with hatchery produced steelhead is unknown. Genetic studies indicate that Tuolumne River steelhead are closely related to other populations in the San Joaquin Basin.

Embryo Incubation

Harvest/Angling Impacts

The Tuolumne River, from La Grange Dam downstream to the confluence with the San Joaquin River supports a catch and release recreational trout fishery from January 1 through October 15. Therefore, it is possible that redds could be inadvertently disrupted by wading anglers.

WATER TEMPERATURE

Water temperatures in the Tuolumne River during the time period when most steelhead embryos are incubating are likely suitable. However, water temperatures in the Tuolumne River begin rising in the spring and may become unsuitable within redds that were constructed later in the spawning season (DWR 2007).

WATER QUALITY

Water quality in the Tuolumne River likely does not adversely affect steelhead embryo incubation.

FLOW CONDITIONS

Flow standards for the protection of steelhead in the Tuolumne River were implemented in 1991.

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

High water temperatures during summer months are likely a limiting factor for steelhead rearing in the lower Tuolumne River. Water temperatures are particularly problematic at low flows. High daily fluctuations in water temperature at low flows have been observed in the lower river (ranging from 12°F to 14°F daily) (McBain & Trush 1998). Current FERC flow schedules appear to provide suitable rearing habitat for the first 15 miles downstream of La Grange Dam during non-dry years (McBain & Trush 1998). Temperatures may not be low enough (<14 C) to optimize smoltification within the Tuolumne River and increase survival to the ocean (Myrick and Cech 2001).

WATER QUALITY

Water quality in the Tuolumne River likely does not adversely affect juvenile steelhead.

FLOW CONDITIONS

The magnitude, duration, and frequency of elevated spring flows in the Tuolumne River has been altered by operations of LaGrange Dam which may negatively impact migrating juvenile steelhead. A strong coorelation has been established between annual spring flow magnitude and the production of salmon smolt outmigrants from the a tributary, survival of smolts in the Delta and the production of adults in the escapement and ocean harvest (Mesick 2008, Mesick and Marston 2007).

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LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

An area of management concern in the Tuolumne River is the health of the riparian vegetation along the entire rive corridor. The primary concern is that many of the riparian forests on the Tuolumne River consist of mature trees that are not being replaced with new growth (Mesick et al. 2007).

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Controlled flows in the Tuolumne River have reduced the magnitude and frequency of high flow events that are part of the natural flow regime thereby decreasing habitat diversity and complexity in the lower river.

LOSS OF FLOODPLAIN HABITAT

Attenuation of peak flows in the Tuolumne River have reduced the frequency of floodplain inundation and severed the frequency of river connection to the floodplain.

ENTRAINMENT

The extent of entrainment in water diversions occurring on the Tuolumne River ha not been well studied and no data is available to assess effects.

PREDATION

Predation by introduced species of bass may be a dominant source of mortality under low-flow conditions for juvenile salmonids in the Tuolumne River. In-channel aggregate extraction pits appear to provide ideal habitat for predators. The largemouth bass population in the lower Tuolumne River was estimated to be between 10,000 and 11,000 fish in 1992 (McBain & Trush 1998). Brown (2000) suggests that introduced species found in the lower reaches of tributaries to the San Joaquin River and the lower mainstem San Joaquin River likely compete with and predate upon downstream migrants.

HATCHERY EFFECTS

Juvenile steelhead rearing in the Tuolumne River are not likely affected by hatchery production.

4.3.11.5 MERCED RIVER

The Merced River is a tributary to the San Joaquin River in the southern portion of California's Central Valley. The river, which drains an area of 1,276 square miles, originates in Yosemite National Park and flows southwest through the Sierra Nevada, where it joins the San Joaquin River 87 miles south of Sacramento.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

The confluence of the Merced and San Joaquin Rivers is at RM 113 of the San Joaquin River. The first 51 miles of the Merced River is accessible to anadromous salmonids. The Crocker-Huffman Dam at RM 51 presents an impassable barrier to upstream migration and marks the upstream extent of currently accessable steelhead habitat.

HARVEST/ANGLING IMPACTS

The Merced River supports a catch and release fishery from January 1 through October 31. Only artificial lures with barbless hooks are allowed from Crocker-Huffman Dam downstream to the Schaffer Bridge on Oakdale road. From that point downstream to the confluence with the San Joaquin River, bait may be used but with restrictions on hook size.

WATER TEMPERATURE

Water temperatures during the steelhead adult immigration life stage normally range from 50°F to 55°F (Vogel 2003).

WATER QUALITY

The effects on aquatic life from water quality conditions in the Merced River have not been well studied. Factors that may affect aquatic life include nutrients, point source discharges from wastewater treatment facilities and non-point source contaminants from agricultural runoff. For example, the Merced River has been identified as impaired for the agricultural pesticides diazinon, chlorpyrifos, and Group A pesticides. It is not likely that water quality parameters are at a level to adversely affect adult steelhead.

FLOW CONDITIONS

Minimum instream flow requirements in the Merced River are defined under Merced Irrigation District's current licenses and agreements and are attended to provide adequate flows for anadromous salmonids and for the Merced River Riparian Water Users Association diversions (Stillwater Sciences 2001). Flows vary by month but typically range from about 230 cfs to 270 cfs during the steelhead adult immigration life stage (Stillwater Sciences 2001).

SPAWNING

PASSAGE IMPEDIMENTS/BARRIERS

The confluence of the Merced and San Joaquin Rivers is at RM 113 of the San Joaquin River. The first 51 miles of the Merced River, ending at the impassable Crocker-Huffman Dam, is accessible to anadromous salmonids.

HARVEST/ANGLING IMPACTS

The Merced River supports a catch and release fishery from January 1 through October 31. Only artificial lures with barbless hooks are allowed from Crocker-Huffman Dam downstream to the Schaffer Bridge on Oakdale road. From that point downstream to the confluence with the San Joaquin River, bait may be used but with restrictions on hook size.

WATER TEMPERATURE

Water temperatures during the steelhead spawning life stage normally range from 50°F to 55°F (Vogel 2003).

WATER QUALITY

Water quality is discussed above under Adult Immigration. Agricultural runoff likely occurs downstream of steelhead spawning and likely does not adversely affect steelhead spawning.

FLOW CONDITIONS

Minimum instream flow requirements in the Merced River are defined under Merced Irrigation District's current licenses and agreements and are intended to provide adequate flows for anadromous salmonids and for the Merced River Riparian Water Users Association diversions (Stillwater Sciences 2001). Flows vary by month but typically range from about 230 cfs to 270 cfs during the steelhead spawning life stage(Stillwater Sciences 2001)

<u>*SPAWNING HABITAT AVAILABILITY*</u>

Accumulation and retention of coarse sediment suitable for steelhead spawning has been prevented by flow regulation and sediment capture by dams, likely reducing the quantity and quality of spawning habitat.

<u>*PHYSICAL HABITAT ALTERATION*</u>

The lower Merced River has been altered substantially by gravel mining and dredging activities. This has resulted in channelization of the river as well as substrate armoring.

<u>*HATCHERY EFFECTS*</u>

Recent genetic analysis of the Merced River Hatchery (MRH) fall-run stock (Garza *et al*. 2007) found the hatchery stock to be the most divergent of the fall-run populations examined for the study, and genetically distinct from the Merced River fall-run population. Its genetic dichotomy is conjectured as a product of either hybridization with a fall-run genome not found in the Central Valley ESU, or strong natural selection acting on the hatchery stock, although this is questionable as some number of in-river fish are likely incorporated into the broodstock for the program.

MRH fall-run are primarily utilized for the VAMP mark-recapture monitoring activities, and otherwise propagated for recreational purposes. VAMP releases all occur in the Delta, with some component of fish releases never recovered and therefore having the potential to stray as adult returns into streams other than the Merced River. Recent habitat and disease problems in the Merced River have resulted in fewer fish returning to the hatchery and forcing the downsizing or adaptive management of the VAMP study, which would decrease the effects of straying by virtue of smaller release numbers.

<u>**EMBRYO INCUBATION**</u>

<u>*HARVEST/ANGLING IMPACTS*</u>

The Merced River supports a catch and release fishery from January 1 through October 31. It is possible that redds may be disturbed by wading anglers during the embryo incubation life stage.

<u>*WATER TEMPERATURE*</u>

Water temperatures during the steelhead embryo incubation life stage normally range from 50°F to 55°F (Vogel 2003).

<u>*WATER QUALITY*</u>

Water quality is discussed above under Adult Immigration. Agricultural runoff likely occurs downstream of where steelhead spawning occurs and likely does not adversely affect embryo incubation.

<u>*FLOW CONDITIONS*</u>

Minimum instream flow requirements in the Merced River are defined under Merced Irrigation District's current licenses and agreements and are attended to provide adequate flows for anadromous salmonids and for the Merced River Riparian Water Users Association diversions

(Stillwater Sciences 2001). Flows vary by month but typically range from about 230 cfs to 270 cfs during the steelhead embryo incubation life stage (Stillwater Sciences 2001).

JUVENILE REARING AND OUTMIGRATION

WATER TEMPERATURE

Water temperatures in the Merced River, measured at Crocker-Huffman Dam are normally below 60°F year-round other than September and October when temperatures near 63°F (Vogel 2003). In the spring when Crocker-Huffman Dam release flows are reduced (less than 569cfs) warmer water temperatures result (71° F), in comparison to when Crocker-Huffman Dam flows are increased (about 4500 cfs) water temperature during the spring is reduced substantially (59° F). Excessive water temperatures were recorded during the summer period in the primary steelhead rearing area of the lower Merced River (Marston 2007).

WATER QUALITY

Water quality is discussed above under Adult Immigration. Agricultural runoff and pollutants from wastewater treatment facilities likely occur downstream of where most steelhead rearing occurs. However, outmigrating juvenile would be exposed and may exhibit decreased survival particularly during the irrigation season.

FLOW CONDITIONS

Minimum instream flow requirements in the Merced River are defined under Merced Irrigation District's current licenses and agreements and are attended to provide adequate flows for anadromous salmonids and for the Merced River Riparian Water Users Association diversions (Stillwater Sciences 2001). Flows vary by month but typically range from about 230 cfs to 270 cfs during the winter months, increase to about 300 cfs during the spring and begin decreasing in August. Low flows of 65 cfs to 75 cfs occur in October (Stillwater Sciences 2001). The magnitude, duration, and frequency of elevated spring flows in the Merced River has been altered by operations of Cocker-Huffman Dam which may negatively impact migrating juvenile steelhead. A strong coorelation has been established between annual spring flow magnitude and the production of salmon smolt outmigrants from the a tributary, survival of smolts in the Delta and the production of adults in the escapement and ocean harvest (Mesick 2008, Mesick and Marston 2007).

LOSS OF RIPARIAN HABITAT AND INSTREAM COVER

Gravel mining along the Merced River has resulted in significant loss of riparian vegetation, particularly in the seven-mile reach downstream from Crocker Huffman Dam. Farther downstream the riparian zone ranges in width from 100 to 300 feet.

LOSS OF NATURAL RIVER MORPHOLOGY AND FUNCTION

Since the completion of New Exchequer Dam in 1967, mean annual flood discharge has been reduced by 80 percent (based on records from WY 1968 to 2000 at the Snelling gage) (Stillwater Sciences 2003). Operating rules for the Merced Irrigation District imposed by the USACE currently limit releases from New Exchequer Dam to 6,000 cfs. The lower flows reduce the incidence of flow events believed to be geomorphically effective for maintaining properly functioning stream channels and associated riparian and floodplain habitats (Stillwater Sciences (2003).

LOSS OF FLOODPLAIN HABITAT

No state or federal levee system has been constructed on the Merced River and existing levees are limited to privately owned structures. The levee system is, however, extensive, especially downstream of the State Route 99 Bridge at RM 20.5. Private landowners have constructed and maintain these levees which protect agricultural lands and houses. These levees confine the river and floodplain width and isolate the river from its former floodplain (Stillwater Sciences 2001).

ENTRAINMENT

The extent of entrainment in water diversions occurring on the Merced River ha not been well studied and no data is available to assess effects.

PREDATION

Extensive gravel mining in the lower Merced River has resulted in deep instream pits in the river and has also led to a decrease in riffles and riparian cover. These factors likely change predator-prey dynamics in the system likely favoring predators. Brown (2000) suggests that introduced species found in the lower reaches of tributaries to the San Joaquin River and the lower mainstem San Joaquin River likely compete with and predate upon downstream migrants.

HATCHERY EFFECTS

The MRH is located immediately downstream of the Crocker-Huffman Dam. The hatchery raises and releases Chinook salmon to supplement natural production in the Merced River. Although most of the production is released on-site, the hatchery likely has little effect on steelhead juveniles as hatchery Chinook likely migrate downstream upon release.

4.3.11.6 UPPER SAN JOAQUIN RIVER

The San Joaquin River drains the southern portion of California's Central Valley. The river basin is bounded by the Sierra Nevada to the east and the Coast Ranges to the west. The southern boundary of the drainage is the divide that separates it from the Tulare Lake basin, and its northern boundary is the Delta near Stockton. The river, which drains a 13,536-square-mile watershed, originates in the Sierra Nevada and flows for approximately 350 miles before joining the Delta. Elevations in the watershed range from 11,000 feet at the headwaters to sea level at the Delta. Friant Dam (RM 267), which impounds Lake Millerton, is the primary mainstem dam controlling flows on the San Joaquin River. Friant Dam also marks the currently accessable upstream extent of anadromous salmonid habitat.

ADULT IMMIGRATION AND HOLDING

PASSAGE IMPEDIMENTS/BARRIERS

The San Joaquin River upstream of the confluence with the Merced River has no remaining significant native fishery (USACE and Reclamation Board 1999). Although Friant Dam presents an upstream migration barrier to anadromous salmonids, flows released from Friant Dam are insufficient to provide year-round flow except during high flow events (USACE and Reclamation Board 1999).

Harvest/Angling Impacts

The upper San Joaquin River, from Friant Dam downstream to the Highway 140 Bridge is open for trout fishing year-round and the taking of five trout is allowed. From the Highway 140 Bridge downstream to the Interstate 5 Bridge, the fishery is open year-round but trout must be released.

Water Temperature

During the winter months, water temperatures in the San Joaquin River are likely low enough to support steelhead upstream migration.

Water Quality

Water quality in the San Joaquin River varies seasonally, but in periods of low flow is generally degraded due to high temperatures, heavy metals, and pesticides from drainage. During the irrigation season (March through October) and occasionally following the flushing of the drainage water from duck clubs (January and February), degraded quality drainage water makes up a significant portion of the total San Joaquin River flow (USDI *et al.* 1999).

Flow Conditions

Flow releases from Friant Dam are maintained year-round, but the required 5 cfs measured at Gravelly Ford rapidly infiltrates into the gravel substrate near Gravelly Ford. The net result is no flow from Gravelly Ford to Mendota Pool, except during high flow events. The river channel often does not have water again until agricultural return flows begin to make up the majority of flow around Madera Pool (USACE and Reclamation Board 1999).

Spawning

Passage Impediments/Barriers

The San Joaquin River upstream of the confluence with the Merced River has no remaining significant native fishery (USACE and Reclamation Board 1999). Although Friant Dam presents an upstream migration barrier to anadromous salmonids, flows released from Friant Dam are insufficient to provide year-round flow except during high flow events (USACE and Reclamation Board 1999).

Harvest/Angling Impacts

The upper San Joaquin River, from Friant Dam downstream to the Highway 140 Bridge is open for trout fishing year-round and the taking of five trout is allowed. From the Highway 140 Bridge downstream to the Interstate 5 Bridge, the fishery is open year-round but trout must be released.

Water Temperature

During the winter months, water temperatures in the San Joaquin River are likely low enough to support steelhead spawning.

Water Quality

Water quality in the San Joaquin River varies seasonally, but in periods of low flow is generally degraded due to high temperatures, heavy metals, and pesticides from drainage. During the irrigation season (March through October) and occasionally following the flushing of the drainage water from duck clubs (January and February), degraded quality drainage water makes up a significant portion of the total San Joaquin River flow (USDI *et al.* 1999).

Flow Conditions

Flow releases from Friant Dam are maintained year-round, but the required 5 cfs measured at Gravelly Ford rapidly infiltrates into the gravel substrate near Gravelly Ford. The net result is no flow from Gravelly Ford to Mendota Pool, except during high flow events. The river channel often does not have water again until agricultural return flows begin to make up the majority of flow around Madera Pool (USACE and Reclamation Board 1999).

Spawning Habitat Availability

Only limited spawning habitat is available in the San Joaquin River and low flows likely make that habitat unusable. It is likely that the San Joaquin River is utilized only as a migration corridor to habitat in the Stanislaus, Tuolumne and Merced rivers.

Physical Habitat Alteration

The construction of dams and resultant controlled flows and extensive gravel mining have likely destroyed almost all potential spawning habitat in the San Joaquin River.

Hatchery Effects

Hatchery effects on spawning steelhead in the San Joaquin River are not well known.

Embryo Incubation

Harvest/Angling Impacts

The upper San Joaquin River, from Friant Dam downstream to the Highway 140 Bridge, is open for trout fishing year-round and the taking of five trout is allowed. From the Highway 140 Bridge downstream to the Interstate 5 Bridge, the fishery is open year-round but trout must be released. If any steelhead spawning were to occur in the San Joaquin River, redd disruption by wading anglers is likely.

Water Temperature

Water temperatures in the San Joaquin River downstream of Friant Dam are likely cold enough to support steelhead embryo incubation but it is likely that the lack of spawning habitat and low flows preclude the San Joaquin River from steelhead spawning.

Water Quality

Water quality in the San Joaquin River varies seasonally, but in periods of low flow is generally degraded due to high temperatures, heavy metals, and pesticides from drainage. During the irrigation season (March through October) and occasionally following the flushing of the drainage water from duck clubs (January and February), degraded quality drainage water makes up a significant portion of the total San Joaquin River flow (USDI *et al.* 1999).

Flow Conditions

It is not likely that any significant steelhead spawning activity occurs in the San Joaquin River and it is used only as a migration corridor.

Juvenile Rearing and Outmigration

Water Temperature

Water temperatures in the late spring, summer and early fall are likely too warm to support use of the San Joaquin River by steelhead for anything other than a migration corridor.

Water Quality

Water quality in the San Joaquin River varies seasonally, but in periods of low flow is generally degraded due to high temperatures, heavy metals, and pesticides from drainage. During the irrigation season (March through October) and occasionally following the flushing of the drainage water from duck clubs (January and February), degraded quality drainage water makes up a significant portion of the total San Joaquin River flow (USDI *et al.* 1999).

Flow Conditions

During periods of low flow, the San Joaquin River likely provides poor to marginal habitat for steelhead juveniles. Currently, the San Joaquin River is probably only utilized as a migration corridor.

Loss of Riparian Habitat and Instream Cover

Only about eight to ten percent of riparian forests in the San Joaquin Valley still remain; most were converted to agricultural land. At present, urbanization, recreational development, aggregate mining and road construction are considered to be the main stressors, in addition to continuing agricultural encroachment in the floodplain, to the remaining riparian vegetation (USACE and Reclamation Board 1999; USDI *et al.* 1999).

Loss of Natural River Morphology and Function

Confining flood flows in reservoirs and between levees has caused the loss of natural hydrologic and geomorphic processes. Habitat for fish and wildlife has been lost or severely degraded as a result of loss of natural processes (USACE and Reclamation Board 1999; USDI *et al.* 1999).

Loss of Floodplain Habitat

The combination of controlled flow regimes and agricultural encroachment has severed most of the connection between the San Joaquin River and its historical floodplain (USACE and Reclamation Board 1999; USDI *et al.* 1999).

Entrainment

The level of entrainment of juvenile steelhead in the San Joaquin River is not documented.

Predation

The San Joaquin River supports a variety of introduced warmwater fish including black bass species known to prey on juvenile salmonids. Additionally, in-river gravel mining and other disturbances have likely altered habitat and affected predator-prey dynamics likely favoring predators. Brown (2000) suggests that introduced species found in the lower reaches of tributaries to the San Joaquin River and the lower mainstem San Joaquin River likely compete with and predate upon downstream migrants.

HATCHERY EFFECTS

Hatchery production of steelhead likely does not affect juveniles in the San Joaquin River.

4.4 STRESSOR PRIORITIZATION

4.4.1 STRESSOR MATRIX DEVELOPMENT

4.4.1.1 STRESSOR MATRIX OVERVIEW

Stressor matrices, in the form of Microsoft Excel spreadsheets, were developed to structure the steelhead diversity group, population, life stage, and stressor information into hierarchically related tiers so that stressors within each diversity group and population in the DPS could be prioritized. The individual tiers within the matrices, from highest to lowest, are: (1) diversity group; (2) population; (3) life stage; (4) primary stressor category; and (5) specific stressor. These individual tiers were related hierarchically so that each variable within a tier had several associated variables at the next lower tier, except at the lowest tier. The four diversity groups were equally weighted in order to be consistent with the recovery criteria described in this recovery plan, which were, in-part, based on the “representation and redundancy” rule described in Lindley *et al*. (2007). This rule reflects the importance of having multiple diversity groups comprised of multiple independent populations in order to recover the DPS (Lindley *et al.* 2007).

The general steps required to develop and utilize the steelhead matrices are identical to those of spring-run Chinook salmon. Please see Section 3.4.1.1 for a description of those steps.

The completed stressor matrix sorted by normalized weight is a prioritized list of the life stage-specific stressors affecting the DPS. For steelhead, threats were prioritized within each diversity group as well as within each population. Specific information explaining the individual steps taken to generate these prioritized lists is provided in the following sections.

4.4.1.2 POPULATION IDENTIFICATION AND RANKING

The threats assessments for the Central Valley steelhead DPS included rivers that both historically supported, and currently support steelhead populations. For the Central Valley steelhead threats assessment, 26 individual rivers/watersheds that historically supported and currently support populations of steelhead were identified using literature describing the historical population structure of steelhead in the Central Valley (Lindley *et al.* 2006) and by using the best professional knowledge of biologists on the current distribution of steelhead. These 26 steelhead populations were categorized into four diversity groups based on the geographical structure described in Lindley *et al.* (2007) (**Table 4-4**).

Table 4-4. Extant Central Valley Steelhead Populations Included in the Threats Assessment Categorized by Diversity Group

Northern Sierra Nevada Diversity Group	Basalt and Porous Lava Diversity Group	Northwestern California Diversity Group	Southern Sierra Nevada Diversity Group
American River	Battle Creek	Stony Creek	Mokelumne River
Auburn/Coon Creek	Cow Creek	Thomes Creek	Calaveras River
Dry Creek	Upper Sacramento River Tributaries[11]	Cottonwood/Beegum Creek	Stanislaus River
Feather River	Upper Sacramento River (mainstem)	Clear Creek	Tuolumne River
Bear River		Putah Creek	Merced River
Yuba River			San Joaquin River (mainstem)
Butte Creek			
Big Chico Creek			
Deer Creek			
Mill Creek			
Antelope Creek			

Source: (Lindley *et al.* 2007)

It is recognized that more than 26 rivers/watersheds that historically supported and currently support steelhead exist in the Central Valley, however it is assumed that recovery of the Central Valley steelhead DPS is primarily dependent on the 26 populations included in the threats assessment.

The steelhead population ranking procedure was identical to that of spring-run Chinook salmon. Please see Section 3.4.1.2 for a description of the population ranking procedure. The population weight is intended to reflect the relative importance of a population to the viability of the diversity group to which it is categorized. The weighting characteristic scores and population weights for each steelhead population in each of the four diversity groups are presented in **Tables 4-5, 4-6, 4-7, and 4-8**.

Table 4-5. Weighting Characteristic Scores and Population Weights for Each Steelhead Population in the Northern Sierra Nevada Diversity Group

Northern Sierra Nevada Diversity Group	American River	Auburn Ravine/Coon Creek	Dry Creek Drainage (Sac Region)	Feather River	Bear River	Yuba River	Butte Creek	Big Chico Creek	Deer Creek	Mill Creek	Antelope Creek
Abundance	2	2	1	4	1	4	2	2	3	3	3
Genetic Integrity	1	2	4	1	1	2	2	3	4	4	4
Source/Sink	1	1	1	4	1	4	1	1	4	4	4
Natural Historic Population	1	1	1	4	1	2	1	1	4	4	4
Habitat Quantity and Quality	2	2	1	2	1	4	2	2	4	4	3
Restoration Potential	3	2	2	3	3	3	2	2	3	3	3
Distinct Steelhead Life History	1	3	1	2	1	2	3	4	4	4	4
Spatial Consideration	3	3	4	3	4	3	3	2	2	2	2
Sum	14	16	15	23	14	24	16	17	28	28	27
Population Weight (Sum to 1)	0.06	0.07	0.07	0.10	0.06	0.11	0.07	0.08	0.13	0.13	0.12

[11] Includes steelhead utilizing small tributaries in the Redding area including Stillwater, Churn, Sulphur, Salt, Olney, and Paynes creeks.

Table 4-6. Weighting Characteristic Scores and Population Weights for Each Steelhead Population in the Basalt and Porous Lava Diversity Group

Basalt and Porous Lava Diversity Group	Battle Creek	Cow Creek	Upper Sacramento Tributaries (Stillwater, Churn, Sulphur, Salt, Olney, Paynes etc.)	Upper Sacramento River
Abundance	4	3	2	4
Genetic Integrity	2	3	2	2
Source/Sink	4	4	1	4
Natural History Population	3	4	2	4
Habitat Quantity and Quality	2	3	2	3
Restoration Potential	4	3	3	3
Distinct Steelhead Life History	2	4	2	2
Spatial Consideration	2	2	2	1
Sum	23	26	16	23
Population Weight (Sum to 1)	0.26	0.30	0.18	0.26

Table 4-7. Weighting Characteristic Scores and Population Weights for Each Steelhead Population in the Northwestern California Diversity Group

Northwestern California Diversity Group	Stony Creek	Thomes Creek	Cottonwood/Beegum Creeks	Clear Creek	Putah Creek
Abundance	1	1	3	3	1
Genetic Integrity	2	3	4	2	1
Source/Sink	1	1	4	1	1
Natural Historic Population	1	3	3	1	1
Habitat Quantity and Quality	1	2	3	3	1
Restoration Potential	3	2	2	2	2
Distinct Steelhead Life History	1	3	4	3	1
Spatial Consideration	4	4	4	4	3
Sum	14	19	27	19	11
Population Weight (Sum to 1)	0.16	0.21	0.30	0.21	0.12

Table 4-8. Weighting Characteristic Scores and Population Weights for Each Steelhead Population in the Southern Sierra Nevada Diversity Group

Southern Sierra Nevada Diversity Group	Calaveras River	Stanislaus River	Tuolumne River	Merced River	San Joaquin River	Mokelumne River
Abundance	1	1	1	1	1	2
Genetic Integrity	3	4	4	4	1	1
Source/Sink	1	1	1	1	1	1
Natural Historic Population	1	1	1	1	1	1
Habitat Quantity and Quality	2	2	1	1	1	1
Restoration Potential	3	2	2	2	4	3
Distinct Steelhead Life History	3	2	1	1	1	1
Spatial Consideration	4	4	4	4	4	4
Sum	18	17	15	15	14	14
Population Weight (Sum to 1)	0.04	0.03	0.03	0.03	0.03	0.03

4.4.1.3 LIFE STAGE IDENTIFICATION AND RANKING

The life stage identification and ranking procedures for steelhead were identical to that of winter-run Chinook salmon. Please see Section 2.4.1.3 for a description of those procedures. The life stage weightings for each steelhead population are presented in Attachment C.

4.4.1.4 STRESSOR IDENTIFICATION AND RANKING

The stressor identification and ranking procedures for steelhead were identical to that of winter-run Chinook salmon. Please see Section 2.4.1.4 for a description of those procedures.

4.4.2 STRESSOR MATRIX RESULTS

4.4.2.1 NORTHERN SIERRA NEVADA DIVERSITY GROUP

The northern Sierra Nevada diversity group is comprised of the American, Feather, Bear, and Yuba rivers, and Auburn/Coon, Dry, Butte, Big Chico, Deer, Mill, and Antelope creeks. Stressors of high importance were identified for all populations and life stages in this diversity group including:

- Passage impediments and/or barriers affecting adult immigration in all of the rivers and creeks, except for Bear River[12] and Big Chico Creek;
- High water temperatures during the adult immigration and holding life stage in Bear River, and Antelope, Big Chico, Butte, and Dry creeks;
- The Nimbus and Folsom dams on the American River, the Fish Barrier Dam and Oroville Dam on the Feather River, and Englebright Dam on the Yuba River as barriers blocking access to historic holding and spawning habitats;
- The existence trout fisheries supplemented through stocking in the upper sections of Deer, Mill, and Antelope creeks, which likely affects the genetic integrity of anadromous steelhead;

[12] Camp Far West Dam on the Bear River was built at the site of a natural barrier that historically blocked access to upstream habitats.

- Sedimentation in Mill and Deer creeks, and the potential for hazardous spills in Deer Creek[13] affecting the embryo incubation life stage;
- Entrainment of juvenile steelhead in Antelope and Auburn/Coon creeks, and in the Yuba and Bear rivers; and
- Numerous factors affecting the juvenile rearing and outmigration life stage in the Delta and lower Sacramento River such as loss of floodplain habitat, loss of natural river morphology and function, loss of riparian habitat and instream cover, and predation.

Additional stressors were identified as having a very importance to the northern Sierra Nevada steelhead diversity group. The complete prioritized list of life-stage specific stressors to this diversity group is displayed in Attachment C.

4.4.2.2 BASALT AND POROUS LAVA DIVERSITY GROUP

For the purposes of this threats assessment, the basalt and porous lava diversity group is comprised of four populations: Battle and Cow creeks, the mainstem Upper Sacramento River, and the Upper Sacramento River tributaries including Stillwater, Churn, Sulphur, Salt, Olney, and Paynes creeks. Stressors of high importance were identified for all populations and life stages in this diversity group including:

- Passage impediments and/or barriers affecting adult immigration in all of the rivers and creeks;
- High water temperatures during the adult immigration and holding life stage in all of the rivers and creeks;
- Keswick Dam as a barrier blocking access of the mainstem Sacramento River population to historic holding and spawning habitats;
- CNFH-origin steelhead spawning with natural-origin steelhead, potentially affecting the genetic and biological diversity of the Battle Creek population;
- The existence of a trout fishery supplemented through stocking in the upper sections of Cow Creek, which likely affects the genetic integrity of anadromous steelhead;
- Releases of yearling steelhead produced at CNFH competing with and preying on naturally spawned juvenile steelhead in Battle Creek;
- High water temperatures in and poor water quality during the embryo incubation life stage in Cow Creek;
- Entrainment of juvenile steelhead in Cow Creek and the upper Sacramento River tributaries, and entrainment in the Delta, lower Sacramento River, and middle Sacramento River; and
- Numerous factors affecting the juvenile rearing and outmigration life stage in the Delta and lower Sacramento River such as loss of floodplain habitat, loss of natural river morphology and function, loss of riparian habitat and instream cover, and predation.

Additional stressors were identified as having a high importance to the basalt and porous lava steelhead diversity group. The complete prioritized list of life-stage specific stressors to this diversity group is displayed in Attachment C.

[13] Highway 32, a major truck route for petroleum distribution, runs parallel and adjacent to Deer Creek for several miles. During winter, road conditions along this section of the highway are poor and accidents are common.

4.4.2.3 NORTHWESTERN CALIFORNIA DIVERSITY GROUP

For the purposes of this threats assessment, the Northwestern California steelhead diversity group is comprised of Stony, Thomes, Beegum, Clear, and Putah creeks. Stressors of very high importance were identified for all populations and life stages in this diversity group including:

- Passage impediments and/or barriers affecting adult immigration in all of the creeks, including Black Butte Dam on Stony Creek, Solano and Monticello dams on Putah Creek, and Whiskeytown Dam on Clear Creek;
- High water temperatures during the adult immigration and holding life stage in all of the creeks, except for Clear Creek and Putah Creek;
- Limited spawning habitat availability in all of the creeks, except for Putah Creek;
- Sedimentation affecting embryo incubation in Clear Creek, sedimentation affecting this life stage in Beegum Creek, and high water temperatures affecting this life stage in Thomes Creek;
- Numerous factors affecting the juvenile rearing and outmigration life stage in the Delta and Sacramento River such as entrainment, loss of floodplain habitat, loss of natural river morphology and function, loss of riparian habitat and instream cover, and predation.

Additional stressors were identified as having a high importance to the Northwestern California diversity group. The complete prioritized list of life stage-specific stressors to this diversity group is displayed in Attachment C.

4.4.2.4 SOUTHERN SIERRA NEVADA DIVERSITY GROUP

For the purposes of this threats assessment, the Southern Sierra Nevada steelhead diversity group is comprised of the Mokelumne, Calaveras, Stanislaus, Tuolumne, Merced, and San Joaquin rivers. Stressors of high importance were identified for all populations and life stages in this diversity group including:

- Passage impediments and/or barriers affecting adult immigration in all of the rivers, including Sack Dam, Mendota Pool, and Friant Dam on the San Joaquin River, Bellota Weir and flashboard dams on the Calaveras River, Don Pedro and La Grange dams on the Tuolumne River, Tulloch, Goodwin and New Melones dams on the Stanislaus River, Camanche and Pardee dams on the Mokelumne River, and Crocker Huffman, McSwain, and New Exchequer dams on the Merced River;
- High water temperatures and low-flow conditions during the adult immigration and holding life stage in all of the rivers;
- Limited spawning habitat availability in all of the rivers and limited instream gravel supply in all of the rivers except for the San Joaquin River;
- Flow fluctuations affecting the embryo incubation life stage in the Calaveras, Stanislaus, Tuolumne, Mokelumne, and Merced rivers;
- Low flows limiting juvenile rearing habitat availability in the San Joaquin, Calaveras, Merced, Stanislaus, and Tuolumne rivers; and
- Numerous factors affecting the juvenile rearing and outmigration life stage in the Delta and San Joaquin River such as entrainment, loss of floodplain habitat, loss of natural river morphology and function, loss of riparian habitat and instream cover, predation, and poor water quality.

Additional stressors were identified as having a high importance to the Southern Sierra Nevada steelhead diversity group. The complete prioritized list of life stage-specific stressors to this diversity group is displayed in Attachment C.

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Winter-run Chinook Salmon Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	Number of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	1	Adult Immigration and holding	0.1	Passage Impediments/Barriers	0.425	Keswick/Shasta Dam	0.650	2.763	6	16.58	VH
Sacramento River	1	Spawning	0.325	Barrier	0.350	Keswick/Shasta Dam	1.000	11.375	1	11.38	VH
Sacramento River	1	Embryo Incubation	0.25	Flow Conditions	0.250	Flow Fluctuations in upper Sacramento River	1.000	6.250	1.00	6.25	VH
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Loss of Natural Morphologic Function	0.150	Loss of Natural Morphologic Function in the Delta	0.300	1.463	4	5.85	VH
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Loss of Natural Morphologic Function	0.150	Loss of Natural Morphologic Function in the lower Sacramento River	0.300	1.463	4	5.85	VH
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Loss of Riparian Habitat and Instream Cover	0.125	Loss of Riparian Habitat and Instream Cover in the Delta	0.350	1.422	4	5.69	VH
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Loss of Riparian Habitat and Instream Cover	0.125	Loss of Riparian Habitat and Instream Cover in the lower Sacramento River	0.350	1.422	4	5.69	VH
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Predation	0.150	Predation in the Delta	0.225	1.097	5	5.48	VH
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Predation	0.150	Predation in the lower Sacramento River	0.225	1.097	5	5.48	VH
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Predation	0.150	Predation in the middle Sacramento River with emphasis on anthropogenically-created predation opportunities at GCID, RBDD and other structures	0.225	1.097	5	5.48	VH
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Predation	0.150	Predation in the upper Sacramento River with emphasis on anthropogenically-created predation opportunities at ACID and other structures	0.225	1.097	5	5.48	VH
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Flow Conditions	0.125	Changes in Delta Hydrology	0.250	1.016	5	5.08	VH
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Flow Conditions	0.125	Diversion into Central Delta	0.250	1.016	5	5.08	VH
Sacramento River	1	Embryo Incubation	0.25	Short-term Inwater Construction	0.200	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	5.000	1.00	5.00	VH
Sacramento River	1	Embryo Incubation	0.25	Water Quality	0.200	Water Pollution in upper Sacramento River	1.000	5.000	1.00	5.00	VH
Sacramento River	1	Embryo Incubation	0.25	Water Temperature	0.200	Water Temperature in upper Sacramento River	1.000	5.000	1.00	5.00	VH
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Loss of Natural Morphologic Function	0.150	Loss of Natural Morphologic Function in the upper Sacramento River	0.250	1.219	4	4.88	VH
Sacramento River	1	Spawning	0.325	Spawning Habitat Availability	0.150	Habitat Suitability in in upper Sacramento River	1.000	4.875	1	4.88	VH
Sacramento River	1	Spawning	0.325	Water Temperature	0.150	Upper Sacramento River	1.000	4.875	1	4.88	VH
Sacramento River	1	Adult Immigration and holding	0.1	Harvest/Angling Impacts	0.100	Ocean	0.700	0.700	6	4.20	VH

Winter-run Chinook Salmon Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	Number of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Flow Conditions	0.125	Flow Dependent Habitat Availability in the lower Sacramento River	0.200	0.813	5	4.06	**VH**
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Entrainment	0.075	Individual Diversions in the Delta	0.225	0.548	7	3.84	**VH**
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Entrainment	0.075	Jones and Banks Pumping Plants	0.225	0.548	7	3.84	**VH**
Sacramento River	1	Adult Immigration and holding	0.1	Passage Impediments/Barriers	0.425	Red Bluff Diversion Dam	0.150	0.638	6	3.83	**VH**
Sacramento River	1	Embryo Incubation	0.25	Harvest/Angling Impacts	0.150	Redd disturbance in upper Sacramento River	1.000	3.750	1.00	3.75	**H**
Sacramento River	1	Adult Immigration and holding	0.1	Flow Conditions	0.200	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.600	1.200	3	3.60	**H**
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Loss of Floodplain Habitat	0.075	Loss of Floodplain Habitat in the Delta	0.350	0.853	4	3.41	**H**
Sacramento River	1	Spawning	0.325	Flow Conditions	0.100	Flow Fluctuations in upper Sacramento River	1.000	3.250	1	3.25	**H**
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Loss of Riparian Habitat and Instream Cover	0.125	Loss of Riparian Habitat and Instream Cover in the upper Sacramento River	0.200	0.813	4	3.25	**H**
Sacramento River	1	Spawning	0.325	Physical Habitat Alteration	0.100	Limited Instream Gravel Supply in upper Sacramento River	1.000	3.250	1	3.25	**H**
Sacramento River	1	Spawning	0.325	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in upper Sacramento River	1.000	3.250	1	3.25	**H**
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Loss of Natural Morphologic Function	0.150	Loss of Natural Morphologic Function in the middle Sacramento River	0.150	0.731	4	2.93	**H**
Sacramento River	1	Adult Immigration and holding	0.1	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.350	0.525	5	2.63	**H**
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Water Temperature	0.050	Middle Sacramento River	0.400	0.650	4	2.60	**H**
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Entrainment	0.075	Individual Diversions in the lower Sacramento River	0.150	0.366	7	2.56	**H**
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Entrainment	0.075	Individual Diversions in the middle Sacramento River	0.150	0.366	7	2.56	**H**
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Entrainment	0.075	Individual Diversions in the upper Sacramento River	0.150	0.366	7	2.56	**H**
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Flow Conditions	0.125	Flow Dependent Habitat Availability in the middle Sacramento River	0.125	0.508	5	2.54	**H**

Winter-run Chinook Salmon Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	Number of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Flow Conditions	0.125	Flow Dependent Habitat Availability in the upper Sacramento River	0.125	0.508	5	2.54	H
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Predation	0.150	Predation in the Bay	0.100	0.488	5	2.44	H
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Loss of Floodplain Habitat	0.075	Loss of Floodplain Habitat in the middle Sacramento River	0.250	0.609	4	2.44	H
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Loss of Floodplain Habitat	0.075	Loss of Floodplain Habitat in the upper Sacramento River	0.250	0.609	4	2.44	H
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.488	5	2.44	H
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.488	5	2.44	H
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Invasive species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, water hyacinth etc. in the Delta	0.700	1.138	2	2.28	H
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Loss of Tidal Marsh Habitat	0.050	Loss of Tidal Marsh Habitat in the Delta	0.600	0.975	2	1.95	H
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Water Temperature	0.050	Lower Sacramento River	0.300	0.488	4	1.95	H
Sacramento River	1	Spawning	0.325	Harvest/Angling Impacts	0.050	Upper Sacramento River	1.000	1.625	1	1.63	H
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Loss of Riparian Habitat and Instream Cover	0.125	Loss of Riparian Habitat and Instream Cover in the middle Sacramento River	0.100	0.406	4	1.63	H
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.200	0.325	5	1.63	H
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.200	0.325	5	1.63	H
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.200	0.325	5	1.63	H
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.200	0.325	5	1.63	H
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in th Delta	0.200	0.325	5	1.63	H
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Water Quality	0.050	Urban, Heavy Metals in the upper Sacramento River	0.200	0.325	5	1.63	H
Sacramento River	1	Adult Immigration and holding	0.1	Water Temperature	0.100	Upper Sacramento River	0.400	0.400	4	1.60	M
Sacramento River	1	Adult Immigration and holding	0.1	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.300	5	1.50	M
Sacramento River	1	Adult Immigration and holding	0.1	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.300	5	1.50	M

Winter-run Chinook Salmon Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	Number of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Loss of Floodplain Habitat	0.075	Loss of Floodplain Habitat in the lower Sacramento River	0.150	0.366	4	1.46	M
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Hatchery Effects	0.025	Competition, Predation in the upper Sacramento River	0.350	0.284	5	1.42	M
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Loss of Tidal Marsh Habitat	0.050	Loss of Tidal Marsh Habitat in the Bays	0.400	0.650	2	1.30	M
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Water Temperature	0.050	Delta	0.200	0.325	4	1.30	M
Sacramento River	1	Adult Immigration and holding	0.1	Passage Impediments/Barriers	0.425	Sacramento Deep Water Ship Channel	0.050	0.213	6	1.28	M
Sacramento River	1	Adult Immigration and holding	0.1	Passage Impediments/Barriers	0.425	Suisun Marsh Salinity Control Structure	0.050	0.213	6	1.28	M
Sacramento River	1	Adult Immigration and holding	0.1	Passage Impediments/Barriers	0.425	Sutter Bypass - Tisdale Weir	0.050	0.213	6	1.28	M
Sacramento River	1	Adult Immigration and holding	0.1	Passage Impediments/Barriers	0.425	Yolo Bypass-Freemont Weir	0.050	0.213	6	1.28	M
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.150	0.244	5	1.22	M
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Upstream Passage Impediments/Barriers	0.025	Tributary Barriers	0.500	0.406	3	1.22	M
Sacramento River	1	Adult Immigration and holding	0.1	Flow Conditions	0.200	Low Flows - attraction, migratory cues in Middle Sacramento River	0.200	0.400	3	1.20	M
Sacramento River	1	Adult Immigration and holding	0.1	Flow Conditions	0.200	Low Flows - attraction, migratory cues in Upper Sacramento River	0.200	0.400	3	1.20	M
Sacramento River	1	Adult Immigration and holding	0.1	Harvest/Angling Impacts	0.100	Upper Sacramento River	0.200	0.200	6	1.20	M
Sacramento River	1	Adult Immigration and holding	0.1	Water Temperature	0.100	Middle Sacramento River	0.300	0.300	4	1.20	M
Sacramento River	1	Adult Immigration and holding	0.1	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.150	0.225	5	1.13	M
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Flow Conditions	0.125	Reverse Flow Conditions in the Delta	0.050	0.203	5	1.02	M
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Hatchery Effects	0.025	Competition, Predation in the middle Sacramento River	0.250	0.203	5	1.02	M
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Upstream Passage Impediments/Barriers	0.025	Keswick Dam	0.400	0.325	3	0.98	M
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Invasive species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, water hyacinth etc. in the Bays	0.300	0.488	2	0.98	M
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Entrainment	0.075	Contra Costa Power Plant	0.050	0.122	7	0.85	M
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Entrainment	0.075	Pittsburg Power Plant	0.050	0.122	7	0.85	M

Winter-run Chinook Salmon Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	Number of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Hatchery Effects	0.025	Competition, Predation in the lower Sacramento River	0.200	0.163	5	0.81	M
Sacramento River	1	Adult Immigration and holding	0.1	Water Temperature	0.100	Lower Sacramento River	0.200	0.200	4	0.80	L
Sacramento River	1	Adult Immigration and holding	0.1	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.100	0.150	5	0.75	L
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Water Temperature	0.050	Upper Sacramento River	0.100	0.163	4	0.65	L
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Hatchery Effects	0.025	Competition, Predation in the Delta	0.150	0.122	5	0.61	L
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.050	0.081	5	0.41	L
Sacramento River	1	Adult Immigration and holding	0.1	Water Quality	0.025	Urban, Heavy Metals in the upper Sacramento River	0.400	0.100	4	0.40	L
Sacramento River	1	Adult Immigration and holding	0.1	Water Temperature	0.100	Delta	0.100	0.100	4	0.40	L
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Upstream Passage Impediments/Barriers	0.025	ACID Dam	0.100	0.081	3	0.24	L
Sacramento River	1	Juvenile Rearing and Outmigration	0.325	Hatchery Effects	0.025	Competition, Predation in the Bays	0.050	0.041	5	0.20	L
Sacramento River	1	Adult Immigration and holding	0.1	Water Quality	0.025	Ag, Urban in the lower Sacramento River	0.200	0.050	4	0.20	L
Sacramento River	1	Adult Immigration and holding	0.1	Water Quality	0.025	Ag, Urban in the middle Sacramento River	0.200	0.050	4	0.20	L
Sacramento River	1	Adult Immigration and holding	0.1	Water Quality	0.025	DO, Ag, Urban, Heavy Metals in th Delta	0.200	0.050	4	0.20	L
Sacramento River	1	Adult Immigration and holding	0.1	Harvest/Angling Impacts	0.100	Bays	0.025	0.025	6	0.15	L
Sacramento River	1	Adult Immigration and holding	0.1	Harvest/Angling Impacts	0.100	Delta	0.025	0.025	6	0.15	L
Sacramento River	1	Adult Immigration and holding	0.1	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.025	0.025	6	0.15	L
Sacramento River	1	Adult Immigration and holding	0.1	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.025	0.025	6	0.15	L
Sacramento River	1	Adult Immigration and holding	0.1	Passage Impediments/Barriers	0.425	ACID Dam	0.000	0.000	6	0.00	L

Attachment B to Appendix B

Spring-run Chinook Salmon Threats Matrices

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Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Agricultural Diversion Dam(s) in Deer Creek	0.600	0.64	5	**3.19**	**VH**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Agricultural Diversion Dam(s) in Mill Creek	0.600	0.64	5	**3.19**	**VH**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Deer Creek	0.700	0.74	4	**2.98**	**VH**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Mill Creek	0.700	0.74	4	**2.98**	**VH**
Yuba River	0.14	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Englebright Dam	0.650	0.55	5	**2.73**	**VH**
Feather River	0.13	Adult Immigration and Holding	0.150	Passage Impediments/Barriers	0.400	Fish Barrier/Oroville Dam	0.850	0.66	4	**2.65**	**VH**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Antelope Creek	0.700	0.63	4	**2.50**	**VH**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Butte Creek	0.800	0.83	3	**2.48**	**VH**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Agricultural Diversion Dam(s) in Antelope Creek	0.600	0.49	5	**2.44**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Individual or Terminal Diversions and loss of channel connectivity in Antelope Creek	0.500	0.34	7	**2.39**	**VH**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Iron Canyon, City of Chico Swimming Holes and Associated Dams	0.750	0.47	5	**2.34**	**VH**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Big Chico Creek	0.700	0.53	4	**2.10**	**VH**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Butte Creek Diversion Dams and Weirs	0.600	0.34	6	**2.03**	**VH**
Mill Creek	0.17	Spawning	**0.25**	Water Quality	0.450	Turbidity and Sedimentation in Mill Creek	1.000	1.91	1	**1.91**	**VH**
Mill Creek	0.17	Embryo Incubation	**0.15**	Water Quality	0.665	Turbidity and sedimentation in Mill Creek	1.000	1.70	1.00	**1.70**	**VH**
Deer Creek	0.17	Embryo Incubation	**0.15**	Water Quality	0.665	Turbidity, sedimentation, hazardous spills (HWY 32) in Deer Creek	1.000	1.70	1.00	**1.70**	**VH**
Feather River	0.13	Spawning	0.350	Barrier	0.300	Fish Barrier Dam/Oroville Dam - Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	1.37	1	**1.37**	**VH**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.525	0.22	6	**1.34**	**VH**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.525	0.22	6	**1.34**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Lower Sacramento River	0.350	0.33	4	**1.33**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Lower Sacramento River	0.350	0.33	4	**1.33**	**VH**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.350	0.33	4	**1.33**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.350	0.33	4	**1.33**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Middle Sacramento River	0.350	0.33	4	**1.33**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Middle Sacramento River	0.350	0.33	4	**1.33**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.350	0.33	4	**1.33**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.350	0.33	4	**1.33**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Middle Sacramento River	0.350	0.33	4	**1.33**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Middle Sacramento River	0.350	0.33	4	**1.33**	**VH**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.150	Deer Creek	0.400	0.26	5	**1.28**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Natural River Morphology	0.150	Yuba River	0.350	0.31	4	**1.25**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Riparian Habitat and Instream Cover	0.150	Yuba River	0.350	0.31	4	**1.25**	**VH**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in Antelope Creek	0.600	0.39	3	**1.17**	**VH**
Yuba River	0.14	Spawning	0.275	Barrier	0.300	Englebright Dam - Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	1.16	1	**1.16**	**VH**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues in Deer Creek	0.600	0.38	3	**1.15**	**VH**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues in Mill Creek	0.600	0.38	3	**1.15**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Delta	0.300	0.29	4	**1.14**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Delta	0.300	0.29	4	**1.14**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Floodplain Habitat	0.125	Delta	0.375	0.28	4	**1.12**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Predation in the Delta	0.300	0.22	5	**1.12**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the Delta	0.300	0.22	5	**1.12**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the Delta	0.300	0.22	5	**1.12**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the lower Sacramento River	0.300	0.22	5	**1.12**	**VH**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the lower Sacramento River	0.300	0.22	5	**1.12**	**VH**
Yuba River	0.14	Embryo Incubation	0.15	Flow Conditions	0.525	Flow Fluctuations, Flood Events	1.000	1.10	1.00	**1.10**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Predation	0.150	Predation in the Delta	0.350	0.28	4	**1.10**	**VH**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.575	0.22	5	**1.08**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.300	0.27	4	**1.07**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Delta	0.425	0.36	3	**1.07**	**VH**
Deer Creek	0.17	Spawning	**0.25**	Spawning Habitat Availability	0.250	Habitat Availability	1.000	1.06	1	**1.06**	**VH**
Deer Creek	0.17	Spawning	**0.25**	Water Quality	0.250	Turbidity, Sedimentation, Hazardous Spills (Hwy 32) in Deer Creek	1.000	1.06	1	**1.06**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Lower Sacramento River	0.350	0.25	4	**1.02**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.350	0.25	4	**1.02**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.350	0.25	4	**1.02**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.400	0.34	3	**1.01**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Delta	0.425	0.33	3	**1.00**	**VH**
Big Chico Creek	0.1	Spawning	**0.25**	Spawning Habitat Availability	0.400	Habitat Suitability	1.000	1.00	1	**1.00**	**VH**
Yuba River	0.14	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Ocean	0.525	0.17	6	**0.99**	**VH**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.500	0.16	6	**0.98**	**VH**
Deer Creek	0.17	Spawning	**0.25**	Physical Habitat Alteration	0.225	Gravel embeddedness and fines	1.000	0.96	1	**0.96**	**VH**
Mill Creek	0.17	Spawning	**0.25**	Physical Habitat Alteration	0.225	Gravel embeddedness and fines	1.000	0.96	1	**0.96**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Predation	0.150	Predation in the lower Sacramento River	0.300	0.24	4	**0.95**	**VH**
Butte Creek	0.15	Spawning	**0.25**	Spawning Habitat Availability	0.250	Habitat Availability/Suitability	1.000	0.94	1	**0.94**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Predation in the Yuba River	0.250	0.19	5	**0.93**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the middle Sacramento River	0.250	0.19	5	**0.93**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the middle Sacramento River	0.250	0.19	5	**0.93**	**VH**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Feather River	0.13	Adult Immigration and Holding	0.150	Harvest/Angling Impacts	0.150	Ocean	0.625	0.18	5	**0.91**	**VH**
Feather River	0.13	Spawning	0.350	Hatchery Effects	0.200	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.91	1	**0.91**	**VH**
Feather River	0.13	Spawning	0.350	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply	1.000	0.91	1	**0.91**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Natural River Morphology	0.150	Delta	0.250	0.22	4	**0.89**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.250	0.22	4	**0.89**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban, Hazardous Spills (Hwy 32) in Deer Creek	0.600	0.18	5	**0.89**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Delta	0.300	0.22	4	**0.87**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Antelope Creek	0.300	0.22	4	**0.87**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.300	0.22	4	**0.87**	**VH**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.575	0.14	6	**0.86**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the Delta	0.300	0.17	5	**0.85**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the lower Sacramento River	0.300	0.17	5	**0.85**	**VH**
Yuba River	0.14	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Daguerre Point Dam	0.200	0.17	5	**0.84**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.325	0.27	3	**0.82**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.400	0.27	3	**0.82**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.325	0.27	3	**0.82**	**VH**
Antelope Creek	0.13	Spawning	**0.25**	Spawning Habitat Availability	0.250	Habitat Availability	1.000	0.81	1	**0.81**	**VH**
Antelope Creek	0.13	Spawning	**0.25**	Water Quality	0.250	Turbidity, Sedimentation in Antelope Creek	1.000	0.81	1	**0.81**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Diversion into Central Delta	0.300	0.13	6	**0.80**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Diversion into Central Delta	0.300	0.13	6	**0.80**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Predation	0.125	Predation in the Delta	0.350	0.20	4	**0.80**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Predation	0.150	Predation in Butte Creek	0.250	0.20	4	**0.79**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Individual Diversions in the Yuba River and DPD	0.250	0.11	7	**0.78**	**VH**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Antelope Creek	0.13	Embryo Incubation	**0.15**	Water Quality	0.400	Turbidity, sedimentation in Antelope Creek	1.000	0.78	1.00	**0.78**	**VH**
Yuba River	0.14	Spawning	0.275	Hatchery Effects	0.200	Redd superimposition, competition for habitat, genetic integrity	1.000	0.77	1	**0.77**	**VH**
Yuba River	0.14	Spawning	0.275	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply	1.000	0.77	1	**0.77**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.325	0.26	3	**0.77**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Middle Sacramento River	0.200	0.19	4	**0.76**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Middle Sacramento River	0.200	0.19	4	**0.76**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Delta	0.200	0.19	4	**0.76**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Delta	0.200	0.19	4	**0.76**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.200	0.19	4	**0.76**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.200	0.19	4	**0.76**	**VH**
Butte Creek	0.15	Spawning	**0.25**	Flow Conditions	0.200	Flow Fluctuations	1.000	0.75	1	**0.75**	**VH**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Recreational Impacts (Summer inner tubing)	0.200	Summer inner tubing and swimming in Butte Creek	1.000	0.75	1	**0.75**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Predation in the Feather River	0.200	0.15	5	**0.74**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Predation in the lower Sacramento River	0.200	0.15	5	**0.74**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Floodplain Habitat	0.125	Lower Sacramento River	0.250	0.19	4	**0.74**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.350	0.18	4	**0.74**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Middle Sacramento River	0.350	0.18	4	**0.74**	**VH**
Antelope Creek	0.13	Spawning	**0.25**	Physical Habitat Alteration	0.225	Gravel embeddedness and fines	1.000	0.73	1	**0.73**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Floodplain Habitat	0.125	Delta	0.425	0.24	3	**0.73**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Natural River Morphology	0.150	Delta	0.350	0.24	3	**0.72**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.350	0.24	3	**0.72**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.200	0.18	4	**0.71**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the middle Sacramento River	0.250	0.14	5	**0.71**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Butte Creek	0.275	0.23	3	**0.69**	**VH**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in Antelope Creek	0.600	0.14	5	**0.68**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Predation	0.125	Predation in the Feather River	0.300	0.17	4	**0.68**	**VH**
Butte Creek	0.15	Embryo Incubation	**0.15**	Flow Conditions	0.300	Flow Fluctuations	1.000	0.68	1.00	**0.68**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.325	0.22	3	**0.67**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.090	DO, Ag, Urban, Heavy Metals in the Delta	0.350	0.17	4	**0.66**	**VH**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.13	5	**0.64**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Butte Creek	0.250	0.21	3	**0.63**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Delta	0.300	0.16	4	**0.63**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.300	0.16	4	**0.63**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Delta	0.300	0.16	4	**0.63**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.300	0.16	4	**0.63**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Individual Diversions in the Delta	0.200	0.09	7	**0.62**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Individual Diversions in the lower Sacramento River	0.200	0.09	7	**0.62**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Tracy and Banks Pumping Plants	0.200	0.09	7	**0.62**	**VH**
Butte Creek	0.15	Embryo Incubation	**0.15**	Water Quality	0.275	Water Quality, Turbidity in Butte Creek	1.000	0.62	1.00	**0.62**	**VH**
Butte Creek	0.15	Embryo Incubation	**0.15**	Water Temperature	0.275	Water Temperature in Butte Creek	1.000	0.62	1.00	**0.62**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Diversion into Central Delta	0.300	0.10	6	**0.61**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Natural River Morphology	0.150	Feather River	0.300	0.20	3	**0.61**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Tracy and Banks Pumping Plants	0.250	0.09	7	**0.61**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Floodplain Habitat	0.125	Yuba River	0.200	0.15	4	**0.60**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Butte Creek	0.250	0.20	3	**0.59**	**VH**
Antelope Creek	0.13	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.300	Sedimentation, turbidity, physical disturbance	1.000	0.59	1.00	**0.59**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the Delta	0.200	0.08	7	**0.58**	**VH**

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Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the Delta	0.200	0.08	7	**0.58**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the lower Sacramento River	0.200	0.08	7	**0.58**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the lower Sacramento River	0.200	0.08	7	**0.58**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the middle Sacramento River	0.200	0.08	7	**0.58**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the middle Sacramento River	0.200	0.08	7	**0.58**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Jones and Banks Pumping Plants	0.200	0.08	7	**0.58**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Tracy and Banks Pumping Plants	0.200	0.08	7	**0.58**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Middle Sacramento River	0.200	0.15	4	**0.58**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Delta	0.200	0.15	4	**0.58**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Antelope Creek	0.200	0.15	4	**0.58**	**VH**
Yuba River	0.14	Spawning	0.275	Spawning Habitat Availability	0.150	Habitat Suitability	1.000	0.58	1	**0.58**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Deer Creek	0.150	0.14	4	**0.57**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Mill Creek	0.150	0.14	4	**0.57**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Predation	0.125	Predation in the lower Sacramento River	0.250	0.14	4	**0.57**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Riparian Habitat and Instream Cover	0.150	Feather River	0.275	0.19	3	**0.56**	**VH**
Butte Creek	0.15	Spawning	**0.25**	Harvest/Angling Impacts	0.150	Recreational, Poaching, Angler Impacts	1.000	0.56	1	**0.56**	**VH**
Butte Creek	0.15	Spawning	**0.25**	Water Temperature	0.150	Water Temperature in Butte Creek	1.000	0.56	1	**0.56**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Floodplain Habitat	0.125	Lower Sacramento River	0.325	0.18	3	**0.55**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the Delta	0.250	0.09	6	**0.55**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the lower Sacramento River	0.250	0.09	6	**0.55**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Tracy and Banks Pumping Plants	0.250	0.09	6	**0.55**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Natural River Morphology	0.150	Feather River	0.150	0.13	4	**0.54**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Riparian Habitat and Instream Cover	0.150	Feather River	0.150	0.13	4	**0.54**	**VH**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Water Temperature	0.075	Delta	0.300	0.13	4	**0.54**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Water Temperature	0.075	Feather River	0.300	0.13	4	**0.54**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Water Temperature	0.075	Lower Sacramento River	0.300	0.13	4	**0.54**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Changes in Hydrology	0.200	0.09	6	**0.54**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Changes in Hydrology	0.200	0.09	6	**0.54**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Reverse Flow Conditions	0.200	0.09	6	**0.54**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Reverse Flow Conditions	0.200	0.09	6	**0.54**	**VH**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.100	0.11	5	**0.53**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.100	0.11	5	**0.53**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.100	0.11	5	**0.53**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.100	0.11	5	**0.53**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.100	0.11	5	**0.53**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.100	0.11	5	**0.53**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.11	5	**0.53**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.11	5	**0.53**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.11	5	**0.53**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.250	0.11	5	**0.53**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.250	0.11	5	**0.53**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.250	0.11	5	**0.53**	**H**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Delta	0.300	0.11	5	**0.53**	**H**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the lower Sacramento River	0.300	0.11	5	**0.53**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Floodplain Habitat	0.125	Feather River	0.175	0.13	4	**0.52**	**H**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.350	0.10	5	**0.52**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.350	0.10	5	**0.52**	**H**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Yolo Bypass - Freemont Weir	0.150	0.08	6	**0.51**	**H**
Big Chico Creek	0.1	Spawning	**0.25**	Water Temperature	0.200	Water Temperature in Big Chico Creek	1.000	0.50	1	**0.50**	**H**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the Delta	0.200	0.07	7	**0.49**	**H**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the lower Sacramento River	0.200	0.07	7	**0.49**	**H**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the middle Sacramento River	0.200	0.07	7	**0.49**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.150	Ag, Urban in the lower Sacramento River	0.150	0.10	5	**0.48**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.150	Ag, Urban in the middle Sacramento River	0.150	0.10	5	**0.48**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Bay	0.150	0.10	5	**0.48**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Bay	0.150	0.10	5	**0.48**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Delta	0.150	0.10	5	**0.48**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Individual Diversions in the Delta	0.100	0.07	7	**0.48**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Individual Diversions in the lower Sacramento River	0.100	0.07	7	**0.48**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Individual Diversions in the middle Sacramento River	0.100	0.07	7	**0.48**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Tracy and Banks Pumping Plants	0.100	0.07	7	**0.48**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Water Quality	0.075	DO, Ag, Urban, Heavy Metals in the Delta	0.350	0.12	4	**0.48**	**H**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	0.800	0.24	2	**0.48**	**H**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	0.800	0.24	2	**0.48**	**H**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Lower Sacramento River	0.400	0.12	4	**0.48**	**H**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Lower Sacramento River	0.400	0.12	4	**0.48**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.090	Ag, Urban in the lower Sacramento River	0.250	0.12	4	**0.47**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.090	Ag, Urban, Heavy Metals in the Bays	0.250	0.12	4	**0.47**	**H**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Water Quality	0.125	Ag, Urban in Butte Creek	0.333	0.16	3	**0.47**	**H**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Water Quality	0.125	Ag, Urban in the lower Sacramento River	0.333	0.16	3	**0.47**	**H**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Water Quality	0.125	DO, Ag, Urban, Heavy Metals in the Delta	0.333	0.16	3	**0.47**	**H**
Feather River	0.13	Spawning	0.350	Spawning Habitat Availability	0.100	Habitat Suitability	1.000	0.46	1	**0.46**	**H**
Feather River	0.13	Spawning	0.350	Water Temperature	0.100	Water Temperature	1.000	0.46	1	**0.46**	**H**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in the lower Sacramento River	0.600	0.23	2	**0.45**	**H**
Big Chico Creek	0.1	Embryo Incubation	**0.15**	Water Temperature	0.300	Water Temperature in Big Chico Creek	1.000	0.45	1.00	**0.45**	**H**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.09	5	**0.45**	**H**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.09	5	**0.45**	**H**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.09	5	**0.45**	**H**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.09	5	**0.45**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in Butte Creek	0.200	0.07	6	**0.44**	**H**
Feather River	0.13	Adult Immigration and Holding	0.150	Water Temperature	0.150	Feather River	0.500	0.15	3	**0.44**	**H**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the middle Sacramento River	0.250	0.09	5	**0.44**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Antelope Creek	0.150	0.11	4	**0.44**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Middle Sacramento River	0.150	0.11	4	**0.44**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Middle Sacramento River	0.150	0.11	4	**0.44**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Floodplain Habitat	0.125	Feather River	0.250	0.14	3	**0.43**	**H**
Deer Creek	0.17	Spawning	**0.25**	Harvest/Angling Impacts	0.100	Recreational, Poaching, Angler Impacts	1.000	0.43	1	**0.43**	**H**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.17	Spawning	**0.25**	Harvest/Angling Impacts	0.100	Recreational, Poaching, Angler Impacts	1.000	0.43	1	**0.43**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.09	5	**0.43**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Delta	0.100	0.11	4	**0.43**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Delta	0.100	0.11	4	**0.43**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Lower Sacramento River	0.100	0.11	4	**0.43**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Lower Sacramento River	0.100	0.11	4	**0.43**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Middle Sacramento River	0.100	0.11	4	**0.43**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Middle Sacramento River	0.100	0.11	4	**0.43**	**H**
Deer Creek	0.17	Spawning	**0.25**	Water Temperature	0.100	Water Temperature in Deer Creek	1.000	0.43	1	**0.43**	**H**
Mill Creek	0.17	Spawning	**0.25**	Water Temperature	0.100	Water Temperature in Mill Creek	1.000	0.43	1	**0.43**	**H**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Butte Creek	0.225	0.08	5	**0.42**	**H**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Big Chico Creek	0.200	0.11	4	**0.42**	**H**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Middle Sacramento River	0.200	0.11	4	**0.42**	**H**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Big Chico Creek	0.200	0.11	4	**0.42**	**H**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Middle Sacramento River	0.200	0.11	4	**0.42**	**H**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.200	0.11	4	**0.42**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Changes in Hydrology	0.200	0.07	6	**0.41**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Reverse Flow Conditions	0.200	0.07	6	**0.41**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Water Temperature	0.075	Feather River	0.400	0.14	3	**0.41**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.100	0.08	5	**0.41**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.100	0.08	5	**0.41**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.100	0.08	5	**0.41**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.08	5	**0.41**	**H**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Flow Conditions	0.050	Flow Dependent Habitat Availability in the Yuba River	0.225	0.07	6	**0.40**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.375	0.10	4	**0.39**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.200	0.13	3	**0.39**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.13	3	**0.39**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.200	0.13	3	**0.38**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.200	0.13	3	**0.38**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.13	3	**0.38**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.13	3	**0.38**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Deer Creek	0.150	0.06	6	**0.38**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Mill Creek	0.150	0.06	6	**0.38**	**H**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Deer Creek	0.100	0.10	4	**0.38**	**H**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Mill Creek	0.100	0.10	4	**0.38**	**H**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Deer Creek	0.100	0.10	4	**0.38**	**H**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Mill Creek	0.100	0.10	4	**0.38**	**H**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.08	5	**0.38**	**H**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.08	5	**0.38**	**H**
Butte Creek	0.15	Spawning	**0.25**	Water Quality	0.100	Water Quality, Turbidity in Butte Creek	1.000	0.38	1	**0.38**	**H**
Big Chico Creek	0.1	Embryo Incubation	**0.15**	Watershed disturbance	0.250	Sedimentation	1.000	0.38	1.00	**0.38**	**H**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the Bays	0.100	0.07	5	**0.37**	**H**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the Bays	0.100	0.07	5	**0.37**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.07	5	**0.37**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.250	0.07	5	**0.37**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.250	0.07	5	**0.37**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.050	Delta	0.350	0.09	4	**0.37**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.050	Lower Sacramento River	0.350	0.09	4	**0.37**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.07	5	**0.37**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	0.800	0.18	2	**0.36**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Lower Sacramento River	0.400	0.09	4	**0.36**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Delta	0.100	0.09	4	**0.36**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Lower Sacramento River	0.100	0.09	4	**0.36**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Middle Sacramento River	0.100	0.09	4	**0.36**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Flow Conditions	0.050	Diversion into Central Delta	0.200	0.06	6	**0.36**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Flow Conditions	0.050	Reverse Flow Conditions	0.200	0.06	6	**0.36**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, water hyacinth, etc. in the Delta	0.600	0.18	2	**0.36**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Tidal Marsh Habitat	0.050	Delta	0.600	0.18	2	**0.36**	**H**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Middle Sacramento River	0.300	0.09	4	**0.36**	**H**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Middle Sacramento River	0.300	0.09	4	**0.36**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.07	5	**0.34**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.07	5	**0.34**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Entrainment	0.050	Individual Diversions in the Delta	0.250	0.06	6	**0.34**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Entrainment	0.050	Individual Diversions in the lower Sacramento River	0.250	0.06	6	**0.34**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Entrainment	0.050	Tracy and Banks Pumping Plants	0.250	0.06	6	**0.34**	**H**
Feather River	0.13	Adult Immigration and Holding	0.150	Flow Conditions	0.125	Low Flows - attraction, migratory cues in the Feather River	0.700	0.17	2	**0.34**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Antelope Creek	0.175	0.06	6	**0.34**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.375	0.09	4	**0.34**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Water Quality	0.075	Ag, Urban in the lower Sacramento River	0.250	0.09	4	**0.34**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Water Quality	0.075	Ag, Urban, Heavy Metals in the Bays	0.250	0.09	4	**0.34**	**H**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Centerville Head Dam	0.100	0.06	6	**0.34**	**H**
Yuba River	0.14	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Yuba River	0.175	0.06	6	**0.33**	**H**
Feather River	0.13	Embryo Incubation	0.125	Flow Conditions	0.200	Flow Fluctuations, Flooding	1.000	0.33	1.00	**0.33**	**H**
Antelope Creek	0.13	Spawning	**0.25**	Harvest/Angling Impacts	0.100	Recreational, Poaching, Angler Impacts	1.000	0.33	1	**0.33**	**H**
Feather River	0.13	Embryo Incubation	0.125	Harvest/Angling Impacts	0.200	Redd disturbance	1.000	0.33	1.00	**0.33**	**H**
Feather River	0.13	Embryo Incubation	0.125	Short-term Inwater Construction	0.200	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.33	1.00	**0.33**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.200	0.07	5	**0.33**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.200	0.07	5	**0.33**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Antelope Creek	0.200	0.07	5	**0.33**	**H**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Bay	0.200	0.07	5	**0.33**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.200	0.07	5	**0.33**	**H**
Feather River	0.13	Embryo Incubation	0.125	Water Quality	0.200	Water Pollution	1.000	0.33	1.00	**0.33**	**H**
Antelope Creek	0.13	Spawning	**0.25**	Water Temperature	0.100	Water Temperature in Antelope Creek	1.000	0.33	1	**0.33**	**H**
Feather River	0.13	Embryo Incubation	0.125	Water Temperature	0.200	Water Temperature in the Feather River	1.000	0.33	1.00	**0.33**	**H**
Antelope Creek	0.13	Embryo Incubation	**0.15**	Water Temperature	0.165	Water Temperature in Antelope Creek	1.000	0.32	1.00	**0.32**	**H**
Deer Creek	0.17	Embryo Incubation	**0.15**	Flow Conditions	0.125	Flow Fluctuations	1.000	0.32	1.00	**0.32**	**H**
Mill Creek	0.17	Embryo Incubation	**0.15**	Flow Conditions	0.125	Flow Fluctuations	1.000	0.32	1.00	**0.32**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.06	5	**0.32**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.06	5	**0.32**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.050	Delta	0.600	0.16	2	**0.32**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Predation	0.150	Predation in the Bays	0.100	0.08	4	**0.32**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.08	4	**0.32**	**H**
Yuba River	0.14	Adult Immigration and Holding	0.15	Water Temperature	0.125	Feather River	0.300	0.08	4	**0.32**	**H**
Yuba River	0.14	Adult Immigration and Holding	0.15	Water Temperature	0.125	Lower Sacramento River	0.300	0.08	4	**0.32**	**H**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.16	2	**0.32**	**H**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Delta	0.600	0.16	2	**0.32**	**H**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.06	5	**0.31**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Individual Diversions in the Feather River	0.100	0.04	7	**0.31**	**H**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Delta	0.100	0.10	3	**0.31**	**H**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Lower Sacramento River	0.100	0.10	3	**0.31**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Water Temperature	0.075	Delta	0.300	0.10	3	**0.31**	**H**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Water Temperature	0.075	Lower Sacramento River	0.300	0.10	3	**0.31**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.06	5	**0.30**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.400	0.10	3	**0.30**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues in the middle Sacramento River	0.400	0.10	3	**0.30**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.300	0.08	4	**0.30**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.300	0.08	4	**0.30**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.300	0.08	4	**0.30**	**M**
Big Chico Creek	0.1	Embryo Incubation	**0.15**	Flow Conditions	0.200	Flow Fluctuations	1.000	0.30	1.00	**0.30**	**M**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues in Butte Creek	0.400	0.15	2	**0.30**	**M**
Big Chico Creek	0.1	Embryo Incubation	**0.15**	Water Quality	0.200	Water Quality in Big Chico Creek	1.000	0.30	1.00	**0.30**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Delta	0.100	0.08	4	**0.30**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Lower Sacramento River	0.100	0.08	4	**0.30**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Middle Sacramento River	0.100	0.08	4	**0.30**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.06	5	**0.30**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.06	5	**0.30**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.200	0.06	5	**0.30**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.200	0.06	5	**0.30**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in Mill Creek	0.200	0.06	5	**0.30**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.200	0.06	5	**0.30**	**M**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.200	0.06	5	**0.30**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.225	0.06	5	**0.30**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.225	0.06	5	**0.30**	**M**
Feather River	0.13	Adult Immigration and Holding	0.150	Harvest/Angling Impacts	0.150	Feather River	0.200	0.06	5	**0.29**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in Deer Creek	0.100	0.04	7	**0.29**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in Mill Creek	0.100	0.04	7	**0.29**	**M**
Yuba River	0.14	Spawning	0.275	Flow Conditions	0.075	Flow Fluctuations	1.000	0.29	1	**0.29**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Water Temperature	0.125	Delta	0.275	0.07	4	**0.29**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the Bays	0.100	0.06	5	**0.28**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues in the Yuba River	0.450	0.09	3	**0.28**	**M**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.090	Ag, Urban in Butte Creek	0.150	0.07	4	**0.28**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Entrainment	0.050	Individual Diversions in the Feather River	0.200	0.05	6	**0.27**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.14	2	**0.27**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Tidal Marsh Habitat	0.050	Delta	0.600	0.14	2	**0.27**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.07	4	**0.27**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Middle Sacramento River	0.300	0.07	4	**0.27**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Flow Conditions	0.050	Changes in Delta Hydrology	0.150	0.04	6	**0.27**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in Deer Creek	0.100	0.04	6	**0.27**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in Mill Creek	0.100	0.04	6	**0.27**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.04	6	**0.27**	**M**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.04	6	**0.27**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.04	6	**0.27**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.04	6	**0.27**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Delta	0.300	0.05	5	**0.27**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Delta	0.300	0.05	5	**0.27**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Lower Sacramento River	0.300	0.05	5	**0.27**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Lower Sacramento River	0.300	0.05	5	**0.27**	**M**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.05	5	**0.27**	**M**
Yuba River	0.14	Embryo Incubation	0.15	Harvest/Angling Impacts	0.125	Redd disturbance	1.000	0.26	1.00	**0.26**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.05	5	**0.26**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.05	5	**0.26**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.05	5	**0.26**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Yuba River	0.200	0.05	5	**0.26**	**M**
Yuba River	0.14	Embryo Incubation	0.15	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.26	1.00	**0.26**	**M**
Yuba River	0.14	Embryo Incubation	0.15	Water Quality	0.125	Water Pollution above Daguerre Point Dam	1.000	0.26	1.00	**0.26**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Hatchery Effects (Competition and Predation)	0.025	Feather River	0.350	0.05	5	**0.26**	**M**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Flow Conditions	0.050	Diversion into Central Delta	0.225	0.05	5	**0.26**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Flow Conditions	0.050	Flow Dependent Habitat Availability in the Feather River	0.225	0.05	5	**0.26**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Flow Conditions	0.050	Reverse Flow Conditions	0.225	0.05	5	**0.26**	**M**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.100	0.04	6	**0.26**	**M**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.100	0.04	6	**0.26**	**M**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.100	0.04	6	**0.26**	**M**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.100	0.04	6	**0.26**	**M**
Deer Creek	0.17	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.26	1.00	**0.26**	**M**
Mill Creek	0.17	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.26	1.00	**0.26**	**M**
Deer Creek	0.17	Embryo Incubation	**0.15**	Water Temperature	0.100	Water Temperature in Deer Creek	1.000	0.26	1.00	**0.26**	**M**
Mill Creek	0.17	Embryo Incubation	**0.15**	Water Temperature	0.100	Water Temperature in Mill Creek	1.000	0.26	1.00	**0.26**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues in the Feather River	0.400	0.08	3	**0.25**	**M**
Big Chico Creek	0.1	Spawning	**0.25**	Barrier	0.100	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.25	1	**0.25**	**M**
Big Chico Creek	0.1	Spawning	**0.25**	Flow Conditions	0.100	Flow Fluctuations	1.000	0.25	1	**0.25**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.05	5	**0.25**	**M**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.05	5	**0.24**	**M**
Antelope Creek	0.13	Embryo Incubation	**0.15**	Flow Conditions	0.125	Flow Fluctuations	1.000	0.24	1.00	**0.24**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Contra Costa Power Plant	0.050	0.03	7	**0.24**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Pittsburg Power Plant	0.050	0.03	7	**0.24**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.12	2	**0.24**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Tidal Marsh Habitat	0.050	Bays	0.400	0.12	2	**0.24**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Deer Creek	0.200	0.06	4	**0.24**	**M**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Mill Creek	0.200	0.06	4	**0.24**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.05	5	**0.23**	**M**
Feather River	0.13	Spawning	0.350	Flow Conditions	0.050	Flow Fluctuations	1.000	0.23	1	**0.23**	**M**
Feather River	0.13	Spawning	0.350	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.23	1	**0.23**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Passage Impediments/Barriers	0.025	Fish Barrier/Oroville Dam	1.000	0.11	2	**0.23**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Predation	0.125	Predation in the Bays	0.100	0.06	4	**0.23**	**M**
Butte Creek	0.15	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.100	Redd disturbance	1.000	0.23	1.00	**0.23**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Flow Conditions	0.050	Flow Dependent Habitat Availability in the lower Sacramento River	0.125	0.04	6	**0.22**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Feather River	0.150	0.04	5	**0.22**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Yuba River	0.150	0.04	5	**0.22**	**M**
Feather River	0.13	Adult Immigration and Holding	0.150	Water Temperature	0.150	Delta	0.250	0.07	3	**0.22**	**M**
Feather River	0.13	Adult Immigration and Holding	0.150	Water Temperature	0.150	Lower Sacramento River	0.250	0.07	3	**0.22**	**M**
Deer Creek	0.17	Spawning	**0.25**	Flow Conditions	0.050	Flow Fluctuations	1.000	0.21	1	**0.21**	**M**
Mill Creek	0.17	Spawning	**0.25**	Flow Conditions	0.050	Flow Fluctuations	1.000	0.21	1	**0.21**	**M**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in Mill Creek	0.100	0.04	5	**0.21**	**M**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.04	5	**0.21**	**M**
Mill Creek	0.17	Spawning	**0.25**	Spawning Habitat Availability	0.050	Habitat Suitability	1.000	0.21	1	**0.21**	**M**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Mill Creek	0.100	0.04	5	**0.21**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Sacramento Deep Water Ship Channel	0.050	0.04	5	**0.21**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Suisun Marsh Salinity Control Structure	0.050	0.04	5	**0.21**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Yolo Bypass - Freemont Weir	0.050	0.04	5	**0.21**	**M**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.050	Bays	0.400	0.11	2	**0.21**	**M**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Butte Creek	0.200	0.05	4	**0.21**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Water Quality	0.100	Ag, Urban in the Feather River	0.250	0.05	4	**0.21**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.250	0.05	4	**0.21**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.250	0.05	4	**0.21**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Water Quality	0.100	Yuba River	0.250	0.05	4	**0.21**	**M**
Yuba River	0.14	Embryo Incubation	0.15	Water Temperature	0.100	Water Temperature above Daguerre Point Dam	1.000	0.21	1.00	**0.21**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.11	2	**0.21**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Big Chico Creek	0.100	0.05	4	**0.21**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Bays	0.400	0.11	2	**0.21**	**M**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.275	0.05	4	**0.21**	**M**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.275	0.05	4	**0.21**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in Antelope Creek	0.100	0.03	6	**0.20**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.03	6	**0.20**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.03	6	**0.20**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Delta	0.300	0.04	5	**0.20**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Lower Sacramento River	0.300	0.04	5	**0.20**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Water Quality	0.075	Ag, Urban in the Feather River	0.150	0.05	4	**0.20**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Flow Conditions	0.050	Changes in Delta Hydrology	0.175	0.04	5	**0.20**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Feather River	0.150	0.04	5	**0.20**	**M**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.100	0.03	6	**0.20**	**M**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.100	0.03	6	**0.20**	**M**
Feather River	0.13	Adult Immigration and Holding	0.150	Water Quality	0.100	Ag, Urban in the Feather River	0.333	0.06	3	**0.19**	**M**
Feather River	0.13	Adult Immigration and Holding	0.150	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.333	0.06	3	**0.19**	**M**
Feather River	0.13	Adult Immigration and Holding	0.150	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.333	0.06	3	**0.19**	**M**
Yuba River	0.14	Spawning	0.275	Water Temperature	0.050	Water Temperature in the Yuba River	1.000	0.19	1	**0.19**	**M**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.075	0.03	6	**0.19**	**M**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.075	0.03	6	**0.19**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Delta	0.100	0.03	6	**0.19**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Lower Sacramento River	0.100	0.03	6	**0.19**	**M**
Butte Creek	0.15	Spawning	**0.25**	Barrier	0.050	Centerville Head Dam - Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.19	1	**0.19**	**M**
Butte Creek	0.15	Spawning	**0.25**	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.19	1	**0.19**	**M**
Butte Creek	0.15	Spawning	**0.25**	Physical Habitat Alteration	0.050	Limited Instream Gravel Supply	1.000	0.19	1	**0.19**	**M**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.250	0.05	4	**0.19**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Hatchery Effects (Competition and Predation)	0.025	Lower Sacramento River	0.250	0.04	5	**0.19**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Hatchery Effects (Competition and Predation)	0.025	Yuba River	0.250	0.04	5	**0.19**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in Deer Creek	0.050	0.04	5	**0.19**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in Mill Creek	0.050	0.04	5	**0.19**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Predation in the Bay	0.050	0.04	5	**0.19**	**M**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.050	Butte Creek	0.175	0.05	4	**0.18**	**M**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.04	5	**0.18**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.09	2	**0.18**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Tidal Marsh Habitat	0.050	Bays	0.400	0.09	2	**0.18**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Feather River	0.200	0.05	4	**0.18**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Antelope Creek	0.200	0.05	4	**0.18**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Flow Conditions	0.050	Flow Dependent Habitat Availability in the Feather River	0.100	0.03	6	**0.18**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Passage Impediments/Barriers	0.025	Daguerre Point Dam	0.600	0.09	2	**0.18**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Water Temperature	0.075	Yuba River	0.100	0.04	4	**0.18**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	1.000	0.18	1	**0.18**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in Big Chico Creek	0.100	0.04	5	**0.18**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.04	5	**0.18**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Big Chico Creek	0.500	0.04	4	**0.18**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Flow Conditions	0.050	Flow Dependent Habitat Availability in the lower Sacramento River	0.150	0.03	5	**0.17**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Hatchery Effects (Competition and Predation)	0.025	Feather River	0.375	0.04	4	**0.17**	**M**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Sacramento Deep Water Ship Channel	0.050	0.03	6	**0.17**	**M**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Suisun Marsh Salinity Control Structure	0.050	0.03	6	**0.17**	**M**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Sutter Bypass - Tisdale Weir	0.050	0.03	6	**0.17**	**M**
Antelope Creek	0.13	Spawning	**0.25**	Flow Conditions	0.050	Flow Fluctuations	1.000	0.16	1	**0.16**	**M**
Feather River	0.13	Adult Immigration and Holding	0.150	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.275	0.04	4	**0.16**	**M**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Feather River	0.13	Adult Immigration and Holding	0.150	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.275	0.04	4	**0.16**	**M**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.03	5	**0.16**	**M**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Butte Creek	0.400	0.05	3	**0.16**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Diversion into Central Delta	0.300	0.03	6	**0.16**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.050	0.03	5	**0.16**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.050	0.03	5	**0.16**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.050	0.03	5	**0.16**	**M**
Feather River	0.13	Adult Immigration and Holding	0.150	Passage Impediments/Barriers	0.400	Sacramento Deep Water Ship Channel	0.050	0.04	4	**0.16**	**M**
Feather River	0.13	Adult Immigration and Holding	0.150	Passage Impediments/Barriers	0.400	Suisun Marsh Salinity Control Structure	0.050	0.04	4	**0.16**	**M**
Feather River	0.13	Adult Immigration and Holding	0.150	Passage Impediments/Barriers	0.400	Yolo Bypass - Freemont Weir	0.050	0.04	4	**0.16**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues in Big Chico Creek	0.200	0.05	3	**0.15**	**L**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Big Chico Creek	0.100	0.03	6	**0.15**	**L**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.100	0.03	6	**0.15**	**L**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.100	0.03	6	**0.15**	**L**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Butte Creek	0.200	0.04	4	**0.15**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Deer Creek	0.100	0.03	5	**0.15**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Mill Creek	0.100	0.03	5	**0.15**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.03	5	**0.15**	**L**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.03	5	**0.15**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.03	5	**0.15**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.100	0.03	5	**0.15**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.100	0.03	5	**0.15**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Water Quality	0.050	Ag, Urban in the Feather River	0.100	0.03	5	**0.15**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.100	0.03	5	**0.15**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.100	0.03	5	**0.15**	**L**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Hatchery Effects (Competition and Predation)	0.025	Lower Sacramento River	0.325	0.04	4	**0.15**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Diversion into Central Delta	0.225	0.03	5	**0.15**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in Butte Creek	0.225	0.03	5	**0.15**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Reverse Flow Conditions	0.225	0.03	5	**0.15**	**L**
Feather River	0.13	Adult Immigration and Holding	0.150	Flow Conditions	0.125	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.300	0.07	2	**0.15**	**L**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.075	0.02	6	**0.15**	**L**
Feather River	0.13	Adult Immigration and Holding	0.150	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.250	0.04	4	**0.15**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Contra Costa Power Plant	0.050	0.02	7	**0.15**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Contra Costa Power Plant	0.050	0.02	7	**0.15**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Pittsburg Power Plant	0.050	0.02	7	**0.15**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Pittsburg Power Plant	0.050	0.02	7	**0.15**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in Antelope Creek	0.050	0.03	5	**0.14**	**L**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.075	0.03	5	**0.14**	**L**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.075	0.03	5	**0.14**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Middle Sacramento River	0.150	0.03	5	**0.13**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Middle Sacramento River	0.150	0.03	5	**0.13**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.050	Bays	0.125	0.03	4	**0.13**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Delta	0.300	0.03	5	**0.13**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Lower Sacramento River	0.300	0.03	5	**0.13**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.125	0.03	4	**0.13**	**L**
Yuba River	0.14	Adult Immigration and Holding	0.15	Water Temperature	0.125	Yuba River	0.125	0.03	4	**0.13**	**L**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.050	0.02	6	**0.13**	**L**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.050	0.02	6	**0.13**	**L**
Big Chico Creek	0.1	Spawning	**0.25**	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.13	1	**0.13**	**L**
Big Chico Creek	0.1	Spawning	**0.25**	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.13	1	**0.13**	**L**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in Big Chico Creek	0.100	0.03	5	**0.13**	**L**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.100	0.03	5	**0.13**	**L**
Big Chico Creek	0.1	Spawning	**0.25**	Water Quality	0.050	Water Quality in Big Chico Creek	1.000	0.13	1	**0.13**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Contra Costa Power Plant	0.050	0.02	7	**0.12**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in Big Chico Creek	0.050	0.02	7	**0.12**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Pittsburg Power Plant	0.050	0.02	7	**0.12**	**L**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in Antelope Creek	0.100	0.02	5	**0.12**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Dam(s)	0.200	0.06	2	**0.12**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Dam(s)	0.200	0.06	2	**0.12**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Passage Impediments/Barriers	0.025	Englebright Dam	0.400	0.06	2	**0.12**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Delta	0.100	0.03	4	**0.12**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Delta	0.100	0.03	4	**0.12**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Delta	0.300	0.04	3	**0.12**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Lower Sacramento River	0.300	0.04	3	**0.12**	**L**
Feather River	0.13	Adult Immigration and Holding	0.150	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the Feather River	0.200	0.03	4	**0.12**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Changes in Delta Hydrology	0.175	0.02	5	**0.11**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Antelope Creek	0.100	0.02	5	**0.11**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.02	5	**0.11**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.100	0.02	5	**0.11**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.100	0.02	5	**0.11**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.100	0.02	5	**0.11**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.100	0.02	5	**0.11**	**L**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.125	0.03	4	**0.11**	**L**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.075	0.02	6	**0.11**	**L**
Butte Creek	0.15	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.11	1.00	**0.11**	**L**
Feather River	0.13	Adult Immigration and Holding	0.150	Harvest/Angling Impacts	0.150	Lower Sacramento River	0.075	0.02	5	**0.11**	**L**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Deer Creek	0.17	Spawning	**0.25**	Hatchery Effects	0.025	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.11	1	**0.11**	**L**
Mill Creek	0.17	Spawning	**0.25**	Hatchery Effects	0.025	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.11	1	**0.11**	**L**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Deer Creek	0.100	0.02	5	**0.11**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Changes in Hydrology	0.200	0.02	6	**0.11**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Reverse Flow Conditions	0.200	0.02	6	**0.11**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Middle Sacramento River	0.150	0.02	5	**0.10**	**L**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in Big Chico Creek	0.100	0.03	4	**0.10**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the lower Sacramento River	0.150	0.02	5	**0.10**	**L**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.050	0.02	6	**0.10**	**L**
Yuba River	0.14	Spawning	0.275	Harvest/Angling Impacts	0.025	Recreational, Poaching, Angler Impacts	1.000	0.10	1	**0.10**	**L**
Yuba River	0.14	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.150	0.03	3	**0.09**	**L**
Yuba River	0.14	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Bays	0.050	0.02	6	**0.09**	**L**
Yuba River	0.14	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Feather River	0.050	0.02	6	**0.09**	**L**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.050	0.02	5	**0.09**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Dam(s)	0.200	0.05	2	**0.09**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Delta	0.100	0.02	4	**0.09**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Bays	0.100	0.02	5	**0.09**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Bays	0.100	0.02	5	**0.09**	**L**

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Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Deer Creek	0.100	0.02	5	**0.09**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Mill Creek	0.100	0.02	5	**0.09**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Bays	0.050	0.02	5	**0.09**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Big Chico Creek	0.100	0.02	5	**0.09**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.02	5	**0.09**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the lower Sacramento River	0.200	0.02	5	**0.09**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the middle Sacramento River	0.200	0.02	5	**0.09**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in Big Chico Creek	0.200	0.02	5	**0.09**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban, Heavy Metals in the Bays	0.200	0.02	5	**0.09**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	DO, Ag, Urban, Heavy Metals in the Delta	0.200	0.02	5	**0.09**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.010	Agricultural, Wildlife and Terminal Diversions	0.800	0.04	2	**0.08**	**L**
Antelope Creek	0.13	Spawning	**0.25**	Hatchery Effects	0.025	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.08	1	**0.08**	**L**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Hatchery Effects (Competition and Predation)	0.025	Delta	0.175	0.02	4	**0.08**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Contra Costa Power Plant	0.025	0.01	7	**0.08**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Pittsburg Power Plant	0.025	0.01	7	**0.08**	**L**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.050	0.01	6	**0.08**	**L**
Big Chico Creek	0.1	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.050	Redd disturbance	1.000	0.08	1.00	**0.08**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Hatchery Effects (Competition and Predation)	0.025	Delta	0.100	0.01	5	**0.07**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Water Quality	0.050	Yuba River	0.050	0.01	5	**0.07**	**L**
Feather River	0.13	Adult Immigration and Holding	0.150	Harvest/Angling Impacts	0.150	Bays	0.050	0.01	5	**0.07**	**L**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Feather River	0.13	Adult Immigration and Holding	0.150	Harvest/Angling Impacts	0.150	Delta	0.050	0.01	5	**0.07**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.04	2	**0.07**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.04	2	**0.07**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.010	Delta	0.600	0.04	2	**0.07**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.010	Delta	0.600	0.04	2	**0.07**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Lower Sacramento River	0.200	0.02	4	**0.07**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Middle Sacramento River	0.200	0.02	4	**0.07**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Antelope Creek	0.100	0.01	5	**0.07**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Bays	0.100	0.01	5	**0.07**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Middle Sacramento River	0.150	0.01	5	**0.07**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.03	2	**0.06**	**L**
Big Chico Creek	0.1	Spawning	**0.25**	Physical Habitat Alteration	0.050	Limited Instream Gravel Supply	0.500	0.06	1	**0.06**	**L**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Hatchery Effects (Competition and Predation)	0.025	Bays	0.125	0.01	4	**0.06**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Contra Costa Power Plant	0.025	0.01	6	**0.06**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Pittsburg Power Plant	0.025	0.01	6	**0.06**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.03	2	**0.05**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.010	Delta	0.600	0.03	2	**0.05**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in Big Chico Creek	0.100	0.01	6	**0.05**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.01	6	**0.05**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.01	6	**0.05**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.02	2	**0.05**	**L**

Northern Sierra Nevada Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.02	2	**0.05**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.010	Bays	0.400	0.02	2	**0.05**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.010	Bays	0.400	0.02	2	**0.05**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Bays	0.100	0.01	5	**0.04**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Big Chico Creek	0.100	0.01	5	**0.04**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.02	2	**0.04**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Hatchery Effects (Competition and Predation)	0.025	Bays	0.050	0.01	5	**0.04**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.02	2	**0.04**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.010	Bays	0.400	0.02	2	**0.04**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Delta	0.100	0.01	4	**0.04**	**L**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Entrainment	0.050	Contra Costa Power Plant	0.025	0.01	6	**0.03**	**L**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Entrainment	0.050	Pittsburg Power Plant	0.025	0.01	6	**0.03**	**L**
Deer Creek	0.17	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.010	Redd disturbance	1.000	0.03	1.00	**0.03**	**L**
Mill Creek	0.17	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.010	Redd disturbance	1.000	0.03	1.00	**0.03**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.010	Tributary Barriers	0.200	0.01	2	**0.02**	**L**
Antelope Creek	0.13	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.010	Redd disturbance	1.000	0.02	1.00	**0.02**	**L**

Basalt and Porous Lava Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.57	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	North Fork Dams	0.325	1.62	7	**11.35**	**VH**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	South Fork Dams	0.325	1.62	7	**11.35**	**VH**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Keswick Dam	0.525	1.35	7	**9.48**	**VH**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Temperature	0.175	Battle Creek	0.550	1.37	5	**6.86**	**VH**
Sacramento River	0.43	Spawning	0.3	Barrier/Genetics	0.450	Keswick/Shasta Dam	1.000	5.81	1	**5.81**	**VH**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Red Bluff Diversion Dam	0.300	0.77	7	**5.42**	**VH**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Red Bluff Diversion Dam	0.150	0.75	7	**5.24**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Hatchery Effects (Competition and Predation)	0.125	Battle Creek	0.350	0.87	6	**5.24**	**VH**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Flow Conditions	0.200	Low Flows - attraction, migratory cues in Battle Creek	0.400	1.14	4	**4.56**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the Delta	0.300	0.75	6	**4.49**	**VH**
Battle Creek	0.57	Spawning	0.25	Flow Conditions	0.300	Low instream flows per FERC license	1.000	4.28	1	**4.28**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in Battle Creek	0.250	0.50	8	**3.99**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Natural Morphologic Function	0.160	Loss of Natural Morphologic Function in the lower Sacramento River	0.350	0.96	4	**3.85**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Delta	0.350	0.70	5	**3.49**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Delta	0.350	0.70	5	**3.49**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Delta	0.350	0.70	5	**3.49**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Floodplain Habitat	0.160	Loss of Floodplain Habitat in the Delta	0.300	0.83	4	**3.30**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Floodplain Habitat	0.160	Loss of Floodplain Habitat in the lower Sacramento River	0.300	0.83	4	**3.30**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Natural Morphologic Function	0.160	Loss of Natural Morphologic Function in the Delta	0.300	0.83	4	**3.30**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Riparian Habitat and Instream Cover	0.160	Loss of Riparian Habitat and Instream Cover in the Delta	0.300	0.83	4	**3.30**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Riparian Habitat and Instream Cover	0.160	Loss of Riparian Habitat and Instream Cover in the lower Sacramento River	0.300	0.83	4	**3.30**	**VH**

Basalt and Porous Lava Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Predation in the Delta	0.250	0.65	5	**3.23**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Predation in the lower Sacramento River	0.250	0.65	5	**3.23**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Tracy and Banks Pumping Plants	0.200	0.40	8	**3.19**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the upper Sacramento River	0.400	0.62	5	**3.10**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Lower Sacramento River	0.300	0.60	5	**2.99**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Lower Sacramento River	0.300	0.60	5	**2.99**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Lower Sacramento River	0.300	0.60	5	**2.99**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Hatchery Effects (Competition and Predation)	0.125	Upper Sacramento River	0.200	0.50	6	**2.99**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the lower Sacramento River	0.200	0.50	6	**2.99**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Non-site specific and structure (GCID, RBDD) related in the middle Sacramento River	0.225	0.58	5	**2.90**	**VH**
Battle Creek	0.57	Spawning	0.25	Barriers	0.200	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	2.85	1	**2.85**	**VH**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Flow Conditions	0.200	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.250	0.71	4	**2.85**	**VH**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Ocean	0.725	0.47	6	**2.81**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Flow Dependent Habitat Availability in Battle Creek	0.400	0.40	7	**2.79**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Ag, Urban in the lower Sacramento River	0.300	0.45	6	**2.69**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	DO, Ag, Urban, Heavy Metals in the Delta	0.300	0.45	6	**2.69**	**VH**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.375	0.53	5	**2.67**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Lower Sacramento River	0.350	0.52	5	**2.62**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the middle Sacramento River	0.175	0.44	6	**2.62**	**VH**
Sacramento River	0.43	Spawning	0.3	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply in upper Sacramento River	1.000	2.58	1	**2.58**	**VH**

Basalt and Porous Lava Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.57	Spawning	0.25	Hatchery Effects	0.175	Redd superimposition, competition for habitat, Genetic Integrity	1.000	2.49	1	**2.49**	**VH**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Ocean	0.500	0.36	7	**2.49**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in the Delta	0.150	0.30	8	**2.39**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in the lower Sacramento River	0.150	0.30	8	**2.39**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in the middle Sacramento River	0.150	0.30	8	**2.39**	**VH**
Battle Creek	0.57	Embryo Incubation	**0.15**	Flow Conditions	0.275	Flow Fluctuations	1.000	2.35	1.00	**2.35**	**VH**
Battle Creek	0.57	Embryo Incubation	**0.15**	Water Temperature	0.275	Water Temperature in Battle Creek	1.000	2.35	1.00	**2.35**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the middle Sacramento River	0.300	0.46	5	**2.32**	**VH**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.57	4	**2.28**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Non-site specific and structure (ACID) related in the upper Sacramento River	0.175	0.45	5	**2.26**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Hatchery Effects (Competition and Predation)	0.125	Lower Sacramento River	0.150	0.37	6	**2.24**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Hatchery Effects (Competition and Predation)	0.125	Middle Sacramento River	0.150	0.37	6	**2.24**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Delta	0.300	0.45	5	**2.24**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Floodplain Habitat	0.160	Loss of Floodplain Habitat in the middle Sacramento River	0.200	0.55	4	**2.20**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Floodplain Habitat	0.160	Loss of Floodplain Habitat in the upper Sacramento River	0.200	0.55	4	**2.20**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Natural Morphologic Function	0.160	Loss of Natural Morphologic Function in the upper Sacramento River	0.200	0.55	4	**2.20**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Riparian Habitat and Instream Cover	0.160	Loss of Riparian Habitat and Instream Cover in the middle Sacramento River	0.200	0.55	4	**2.20**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Riparian Habitat and Instream Cover	0.160	Loss of Riparian Habitat and Instream Cover in the upper Sacramento River	0.200	0.55	4	**2.20**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in Battle Creek	0.200	0.36	6	**2.14**	**H**

Basalt and Porous Lava Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.57	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.36	6	**2.14**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.36	6	**2.14**	**H**
Battle Creek	0.57	Spawning	0.25	Spawning Habitat Availability	0.150	Habitat Suitability	1.000	2.14	1	**2.14**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Middle Sacramento River	0.200	0.40	5	**2.00**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Middle Sacramento River	0.200	0.40	5	**2.00**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.275	0.39	5	**1.96**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in Battle Creek	0.125	0.31	6	**1.87**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.30	6	**1.80**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Sacramento Deep Water Ship Channel	0.050	0.25	7	**1.75**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Suisun Marsh Salinity Control Structure	0.050	0.25	7	**1.75**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Sutter Bypass - Tisdale Weir	0.050	0.25	7	**1.75**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Yolo Bypass - Freemont Weir	0.050	0.25	7	**1.75**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the upper Sacramento River	0.150	0.43	4	**1.71**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Individual Diversions in the Delta	0.200	0.24	7	**1.69**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Individual Diversions in the lower Sacramento River	0.200	0.24	7	**1.69**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Individual Diversions in the middle Sacramento River	0.200	0.24	7	**1.69**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Tracy and Banks Pumping Plants	0.200	0.24	7	**1.69**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Natural Morphologic Function	0.160	Loss of Natural Morphologic Function in the middle Sacramento River	0.150	0.41	4	**1.65**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.150	0.27	6	**1.60**	**H**

Basalt and Porous Lava Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.57	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.27	6	**1.60**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Temperature	0.175	Lower Sacramento River	0.125	0.31	5	**1.56**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Temperature	0.175	Middle Sacramento River	0.125	0.31	5	**1.56**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Middle Sacramento River	0.150	0.30	5	**1.50**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Battle Creek	0.200	0.30	5	**1.50**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Hatchery Effects (Competition and Predation)	0.125	Delta	0.100	0.25	6	**1.50**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the Bays	0.100	0.25	6	**1.50**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the upper Sacramento River	0.100	0.25	6	**1.50**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.25	6	**1.50**	**H**
Sacramento River	0.43	Embryo Incubation	0.15	Flow Conditions	0.225	Flow Fluctuations in upper Sacramento River	1.000	1.45	1	**1.45**	**H**
Sacramento River	0.43	Embryo Incubation	0.15	Water Quality	0.225	Water Pollution in upper Sacramento River	1.000	1.45	1	**1.45**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Diversion into Central Delta	0.200	0.20	7	**1.40**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Water Temperature	0.050	Delta	0.400	0.34	4	**1.38**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Ag, Urban, Heavy Metals in the Bays	0.150	0.22	6	**1.35**	**H**
Sacramento River	0.43	Spawning	0.3	Flow Conditions	0.100	Flow Fluctuations in upper Sacramento River	1.000	1.29	1	**1.29**	**H**
Sacramento River	0.43	Spawning	0.3	Harvest/Angling Impacts	0.100	Upper Sacramento River	1.000	1.29	1	**1.29**	**H**
Sacramento River	0.43	Embryo Incubation	0.15	Water Temperature	0.200	Water Temperature in upper Sacramento River	1.000	1.29	1	**1.29**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Predation in the Bay	0.100	0.26	5	**1.29**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.300	0.26	5	**1.29**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.300	0.26	5	**1.29**	**H**

Basalt and Porous Lava Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	Urban, Heavy Metals in the upper Sacramento River	0.300	0.26	5	**1.29**	**H**
Battle Creek	0.57	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.150	Redd disturbance	1.000	1.28	1.00	**1.28**	**H**
Battle Creek	0.57	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	1.28	1.00	**1.28**	**H**
Battle Creek	0.57	Embryo Incubation	**0.15**	Water Quality	0.150	Water Quality in Battle Creek	1.000	1.28	1.00	**1.28**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Temperature	0.175	Delta	0.100	0.25	5	**1.25**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Temperature	0.175	Upper Sacramento River	0.100	0.25	5	**1.25**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.175	0.25	5	**1.25**	**H**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.250	0.24	5	**1.21**	**H**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.24	5	**1.21**	**H**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.250	0.24	5	**1.21**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Passage Impediments/Barriers	0.050	North Fork Dams	0.400	0.40	3	**1.20**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Passage Impediments/Barriers	0.050	South Fork Dams	0.400	0.40	3	**1.20**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.275	0.24	5	**1.18**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.275	0.24	5	**1.18**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.275	0.24	5	**1.18**	**M**
Sacramento River	0.43	Embryo Incubation	0.15	Harvest/Angling Impacts	0.175	Redd disturbance in upper Sacramento River	1.000	1.13	1.00	**1.13**	**M**
Sacramento River	0.43	Embryo Incubation	0.15	Short-term Inwater Construction	0.175	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	1.13	1	**1.13**	**M**

Basalt and Porous Lava Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.57	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.100	0.18	6	**1.07**	**M**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Quality	0.100	Urban, Heavy Metals in the upper Sacramento River	0.150	0.21	5	**1.07**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Water Temperature	0.050	Lower Sacramento River	0.300	0.26	4	**1.03**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Upper Sacramento River	0.100	0.20	5	**1.00**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Upper Sacramento River	0.100	0.20	5	**1.00**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Battle Creek	0.100	0.20	5	**1.00**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Upper Sacramento River	0.100	0.20	5	**1.00**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Water Temperature	0.125	Lower Sacramento River	0.400	0.32	3	**0.97**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Water Temperature	0.125	Middle Sacramento River	0.400	0.32	3	**0.97**	**M**
Sacramento River	0.43	Spawning	0.3	Spawning Habitat Availability	0.075	Habitat Suitability in in upper Sacramento River	1.000	0.97	1	**0.97**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Water Quality	0.125	DO, Ag, Urban, Heavy Metals in the Delta	0.300	0.24	4	**0.97**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Changes in Delta Hydrology	0.300	0.15	6	**0.93**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Reverse Flow Conditions in the Delta	0.300	0.15	6	**0.93**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Yolo Bypass-Freemont Weir	0.050	0.13	7	**0.90**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.15	6	**0.90**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.150	0.15	6	**0.90**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Urban, Heavy Metals in the upper Sacramento River	0.100	0.15	6	**0.90**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Ag, Urban in the middle Sacramento River	0.100	0.15	6	**0.90**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Individual Diversions in the upper Sacramento River	0.100	0.12	7	**0.84**	**M**

Basalt and Porous Lava Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in the upper Sacramento River	0.050	0.10	8	**0.80**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the Bays	0.100	0.15	5	**0.77**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the Delta	0.100	0.15	5	**0.77**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the lower Sacramento River	0.100	0.15	5	**0.77**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Diversion into Central Delta	0.250	0.13	6	**0.77**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Middle Sacramento River	0.100	0.15	5	**0.75**	**M**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Battle Creek	0.150	0.11	7	**0.75**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Hatchery Effects (Competition and Predation)	0.125	Bays	0.050	0.12	6	**0.75**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.15	5	**0.73**	**M**
Battle Creek	0.57	Spawning	0.25	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.71	1	**0.71**	**M**
Battle Creek	0.57	Spawning	0.25	Physical Habitat Alteration	0.050	Limited Instream Gravel Supply	1.000	0.71	1	**0.71**	**M**
Battle Creek	0.57	Spawning	0.25	Water Temperature	0.050	Water Temperature in Battle Creek	1.000	0.71	1	**0.71**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Changes in Hydrology	0.100	0.10	7	**0.70**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.10	7	**0.70**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Invasive Species/Food Web Disruption	0.025	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.35	2	**0.70**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Water Temperature	0.050	Middle Sacramento River	0.200	0.17	4	**0.69**	**M**
Sacramento River	0.43	Spawning	0.3	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in upper Sacramento River	1.000	0.65	1	**0.65**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Water Quality	0.125	Ag, Urban in the lower Sacramento River	0.200	0.16	4	**0.65**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Water Quality	0.125	Ag, Urban in the middle Sacramento River	0.200	0.16	4	**0.65**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Water Quality	0.125	Urban, Heavy Metals in the upper Sacramento River	0.200	0.16	4	**0.65**	**M**

Basalt and Porous Lava Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	0.43	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.333	0.21	3	**0.64**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues in Middle Sacramento River	0.333	0.21	3	**0.64**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues in Upper Sacramento River	0.333	0.21	3	**0.64**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Sacramento Deep Water Ship Channel	0.035	0.09	7	**0.63**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Suisun Marsh Salinity Control Structure	0.035	0.09	7	**0.63**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Sutter Bypass - Tisdale Weir	0.035	0.09	7	**0.63**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Tidal Marsh Habitat	0.025	Delta	0.600	0.30	2	**0.60**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Passage Impediments/Barriers	0.050	Tributary Barriers	0.200	0.20	3	**0.60**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.10	6	**0.60**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Flow Dependent Habitat Availability in the middle Sacramento River	0.075	0.07	7	**0.52**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Flow Dependent Habitat Availability in the upper Sacramento River	0.075	0.07	7	**0.52**	**L**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Upper Sacramento River	0.100	0.07	7	**0.50**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Battle Creek	0.050	0.10	5	**0.50**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Battle Creek	0.050	0.10	5	**0.50**	**L**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.10	5	**0.48**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Ag, Urban in Battle Creek	0.050	0.07	6	**0.45**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.09	5	**0.43**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Contra Costa Power Plant	0.050	0.06	7	**0.42**	**L**

Basalt and Porous Lava Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Pittsburg Power Plant	0.050	0.06	7	**0.42**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Contra Costa Power Plant	0.025	0.05	8	**0.40**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Pittsburg Power Plant	0.025	0.05	8	**0.40**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Tidal Marsh Habitat	0.025	Bays	0.400	0.20	2	**0.40**	**L**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Upper Sacramento River	0.100	0.06	6	**0.39**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.090	0.08	5	**0.39**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Upper Sacramento River	0.050	0.07	5	**0.37**	**L**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Lower Sacramento River	0.075	0.05	7	**0.37**	**L**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Middle Sacramento River	0.075	0.05	7	**0.37**	**L**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	ACID Dam	0.020	0.05	7	**0.36**	**L**
Battle Creek	0.57	Spawning	0.25	Water Quality	0.025	Water Quality in Battle Creek	1.000	0.36	1	**0.36**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Reverse Flow Conditions	0.050	0.05	7	**0.35**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Water Temperature	0.050	Upper Sacramento River	0.100	0.09	4	**0.34**	**L**
Sacramento River	0.43	Spawning	0.3	Water Temperature	0.025	Upper Sacramento River	1.000	0.32	1	**0.32**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.075	0.06	5	**0.32**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Invasive Species/Food Web Disruption	0.025	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.15	2	**0.30**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Battle Creek	0.050	0.05	6	**0.30**	**L**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.075	0.05	6	**0.29**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Invasive species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, water hyacinth etc. in the Delta	0.800	0.14	2	**0.28**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Tidal Marsh Habitat	0.010	Loss of Tidal Marsh Habitat in the Delta	0.800	0.14	2	**0.28**	**L**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Bays	0.050	0.04	7	**0.25**	**L**

Basalt and Porous Lava Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.57	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Delta	0.050	0.04	7	**0.25**	**L**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Water Temperature	0.125	Delta	0.100	0.08	3	**0.24**	**L**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Water Temperature	0.125	Upper Sacramento River	0.100	0.08	3	**0.24**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Passage Impediments/Barriers	0.010	Keswick Dam	0.400	0.07	3	**0.21**	**L**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.050	0.03	6	**0.19**	**L**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Quality	0.100	Battle Creek	0.025	0.04	5	**0.18**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Flow Dependent Habitat Availability in the lower Sacramento River	0.050	0.03	6	**0.15**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Flow Dependent Habitat Availability in the middle Sacramento River	0.050	0.03	6	**0.15**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Flow Dependent Habitat Availability in the upper Sacramento River	0.050	0.03	6	**0.15**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Passage Impediments/Barriers	0.010	ACID Dam	0.300	0.05	3	**0.15**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Passage Impediments/Barriers	0.010	Tributary Barriers	0.300	0.05	3	**0.15**	**L**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Bays	0.025	0.02	6	**0.10**	**L**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Delta	0.025	0.02	6	**0.10**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Invasive species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, water hyacinth etc. in the Bays	0.200	0.03	2	**0.07**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Tidal Marsh Habitat	0.010	Loss of Tidal Marsh Habitat in the Bays	0.200	0.03	2	**0.07**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.010	0.01	5	**0.04**	**L**

Northwestern California Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Beegum Creek	0.600	1.43	5	**7.13**	**VH**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Ag Diversion Dams, Braiding, Natural Channel Gradient	0.750	1.17	5	**5.86**	**VH**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Thomes Creek	0.700	1.31	4	**5.25**	**VH**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	RBDD	0.550	1.05	5	**5.23**	**VH**
Clear Creek	0.38	Spawning	0.4	Physical Habitat Alteration	0.250	Limited Instream Gravel Supply	1.000	3.80	1	**3.80**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Red Bluff Diversion Dam	0.410	0.62	6	**3.74**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Temperature	0.300	Clear Creek	0.400	0.91	4	**3.65**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Whiskeytown Dam	0.355	0.54	6	**3.24**	**VH**
Clear Creek	0.38	Spawning	0.4	Spawning Habitat Availability	0.200	Habitat Suitability	1.000	3.04	1	**3.04**	**VH**
Clear Creek	0.38	Spawning	0.4	Water Temperature	0.200	Water Temperature in Clear Creek	1.000	3.04	1	**3.04**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Delta	0.300	0.60	5	**2.99**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.300	0.60	5	**2.99**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Delta	0.300	0.60	5	**2.99**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.300	0.60	5	**2.99**	**VH**
Beegum Creek	0.38	Spawning	**0.25**	Spawning Habitat Availability	0.300	Habitat Suitability	1.000	2.85	1	**2.85**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.275	0.55	5	**2.74**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.275	0.55	5	**2.74**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.350	0.53	5	**2.66**	**VH**
Thomes Creek	0.25	Spawning	**0.25**	Spawning Habitat Availability	0.400	Habitat Suitability	1.000	2.50	1	**2.50**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Beegum Creek	0.250	0.50	5	**2.49**	**VH**
Clear Creek	0.38	Spawning	0.4	Flow Conditions	0.150	Flow Fluctuations	1.000	2.28	1	**2.28**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Flow Conditions	0.250	Low Flows - attraction, migratory cues in Clear Creek	0.400	0.76	3	**2.28**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Delta	0.300	0.46	5	**2.28**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the Delta	0.200	0.27	8	**2.13**	**VH**

Northwestern California Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the lower Sacramento River	0.200	0.27	8	**2.13**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the middle Sacramento River	0.200	0.27	8	**2.13**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Tracy and Banks Pumping Plants	0.200	0.27	8	**2.13**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.350	0.53	4	**2.13**	**VH**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.300	0.29	7	**2.00**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Middle Sacramento River	0.200	0.40	5	**2.00**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Beegum Creek	0.200	0.40	5	**2.00**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Delta	0.250	0.33	6	**2.00**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the lower Sacramento River	0.250	0.33	6	**2.00**	**VH**
Clear Creek	0.38	Embryo Incubation	**0.15**	Water Quality	0.350	Sedimentation in Clear Creek	1.000	2.00	1.00	**2.00**	**VH**
Beegum Creek	0.38	Embryo Incubation	**0.15**	Watershed disturbance	0.350	Sedimentation	1.000	2.00	1.00	**2.00**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Flow Dependent Habitat Availability in Clear Creek	0.450	0.32	6	**1.92**	**VH**
Beegum Creek	0.38	Spawning	**0.25**	Flow Conditions	0.200	Flow Fluctuations	1.000	1.90	1	**1.90**	**VH**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.250	0.48	4	**1.90**	**VH**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in Beegum Creek	0.250	0.48	4	**1.90**	**VH**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the middle Sacramento River	0.250	0.48	4	**1.90**	**VH**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the Upper Sacramento River	0.250	0.48	4	**1.90**	**VH**
Beegum Creek	0.38	Spawning	**0.25**	Water Temperature	0.200	Water Temperature in Beegum Creek	1.000	1.90	1	**1.90**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Lower Sacramento River	0.250	0.38	5	**1.90**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.350	0.46	4	**1.84**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Middle Sacramento River	0.350	0.46	4	**1.84**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the Delta	0.250	0.30	6	**1.78**	**VH**

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Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.38	Embryo Incubation	**0.15**	Flow Conditions	0.300	Flow Fluctuations	1.000	1.71	1.00	**1.71**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the middle Sacramento River	0.200	0.27	6	**1.60**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Delta	0.300	0.39	4	**1.58**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.300	0.39	4	**1.58**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Delta	0.300	0.39	4	**1.58**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.300	0.39	4	**1.58**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Tracy and Banks Pumping Plants	0.250	0.22	7	**1.53**	**VH**
Clear Creek	0.38	Spawning	0.4	Barriers	0.100	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	1.52	1	**1.52**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Clear Creek	0.200	0.30	5	**1.52**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Clear Creek	0.200	0.30	5	**1.52**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Delta	0.200	0.30	5	**1.52**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Middle Sacramento River	0.200	0.30	5	**1.52**	**VH**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	Yolo Bypass - Freemont Weir	0.150	0.29	5	**1.43**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the lower Sacramento River	0.200	0.24	6	**1.43**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the middle Sacramento River	0.200	0.24	6	**1.43**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the upper Sacramento River	0.200	0.24	6	**1.43**	**VH**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.250	0.24	6	**1.43**	**VH**
Clear Creek	0.38	Embryo Incubation	**0.15**	Water Temperature	0.250	Water Temperature in Clear Creek	1.000	1.43	1.00	**1.43**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Quality	0.150	Ag, Urban in the lower Sacramento River	0.200	0.23	6	**1.37**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Quality	0.150	Clear Creek	0.200	0.23	6	**1.37**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Delta	0.200	0.23	6	**1.37**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Temperature	0.300	Delta	0.150	0.34	4	**1.37**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Temperature	0.300	Lower Sacramento River	0.150	0.34	4	**1.37**	**VH**

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Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Temperature	0.300	Middle Sacramento River	0.150	0.34	4	**1.37**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Temperature	0.300	Upper Sacramento River	0.150	0.34	4	**1.37**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Delta	0.300	0.26	5	**1.31**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the lower Sacramento River	0.300	0.26	5	**1.31**	**VH**
Beegum Creek	0.38	Embryo Incubation	**0.15**	Flow Conditions	0.225	Flow Fluctuations	1.000	1.28	1.00	**1.28**	**VH**
Beegum Creek	0.38	Embryo Incubation	**0.15**	Water Quality	0.225	Water Quality in Beegum Creek	1.000	1.28	1.00	**1.28**	**VH**
Thomes Creek	0.25	Spawning	**0.25**	Water Temperature	0.200	Water Temperature in Thomes Creek	1.000	1.25	1	**1.25**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the Delta	0.200	0.18	7	**1.23**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the lower Sacramento River	0.200	0.18	7	**1.23**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the middle Sacramento River	0.200	0.18	7	**1.23**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Clear Creek	0.200	0.30	4	**1.22**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.200	0.30	4	**1.22**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Middle Sacramento River	0.200	0.30	4	**1.22**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the upper Sacramento River	0.150	0.20	6	**1.20**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.20	6	**1.20**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.20	6	**1.20**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.60	2	**1.20**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Delta	0.600	0.60	2	**1.20**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Delta	0.100	0.24	5	**1.19**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Lower Sacramento River	0.100	0.24	5	**1.19**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Middle Sacramento River	0.100	0.24	5	**1.19**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Upper Sacramento River	0.100	0.24	5	**1.19**	**H**

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Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.38	Adult Immigration and Holding	0.2	Flow Conditions	0.250	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.200	0.38	3	**1.14**	**H**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Flow Conditions	0.250	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.38	3	**1.14**	**H**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Flow Conditions	0.250	Low Flows - attraction, migratory cues in the upper Sacramento River	0.200	0.38	3	**1.14**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.19	6	**1.14**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.19	6	**1.14**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.200	0.19	6	**1.14**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.200	0.19	6	**1.14**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the upper Sacramento River	0.200	0.19	6	**1.14**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Upper Sacramento River	0.150	0.23	5	**1.14**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.300	0.19	6	**1.13**	**H**
Thomes Creek	0.25	Embryo Incubation	**0.15**	Water Temperature	0.300	Water Temperature in Thomes Creek	1.000	1.13	1.00	**1.13**	**H**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the middle Sacramento River	0.250	0.22	5	**1.09**	**H**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Middle Sacramento River	0.200	0.26	4	**1.05**	**H**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Thomes Creek	0.200	0.26	4	**1.05**	**H**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Middle Sacramento River	0.200	0.26	4	**1.05**	**H**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Thomes Creek	0.200	0.26	4	**1.05**	**H**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.200	0.26	4	**1.05**	**H**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Quality	0.150	Ag, Urban in the middle Sacramento River	0.150	0.17	6	**1.03**	**H**

Northwestern California Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Quality	0.150	Urban, Heavy Metals in the upper Sacramento River	0.150	0.17	6	**1.03**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Beegum Creek	0.100	0.20	5	**1.00**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Upper Sacramento River	0.100	0.20	5	**1.00**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Middle Sacramento River	0.100	0.20	5	**1.00**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Upper Sacramento River	0.100	0.20	5	**1.00**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Middle Sacramento River	0.100	0.20	5	**1.00**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Upper Sacramento River	0.100	0.20	5	**1.00**	**H**
Beegum Creek	0.38	Spawning	**0.25**	Barrier	0.100	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.95	1	**0.95**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	Sacramento Deep Water Ship Channel	0.100	0.19	5	**0.95**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	Suisun Marsh Salinity Control Structure	0.100	0.19	5	**0.95**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	Sutter Bypass - Tisdale Weir	0.100	0.19	5	**0.95**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.19	5	**0.94**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.19	5	**0.94**	**H**
Thomes Creek	0.25	Embryo Incubation	**0.15**	Watershed disturbance	0.250	Sedimentation	1.000	0.94	1.00	**0.94**	**H**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Ocean	0.350	0.13	7	**0.93**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in the Delta	0.175	0.12	8	**0.93**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in the lower Sacramento River	0.175	0.12	8	**0.93**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in the middle Sacramento River	0.175	0.12	8	**0.93**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Tracy and Banks Pumping Plants	0.175	0.12	8	**0.93**	**H**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Yolo Bypass - Freemont Weir	0.100	0.15	6	**0.91**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Diversion into Central Delta	0.200	0.14	6	**0.86**	**H**

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Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.150	0.14	6	**0.86**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.14	6	**0.86**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.150	0.14	6	**0.86**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.125	0.12	7	**0.83**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.125	0.12	7	**0.83**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.125	0.12	7	**0.83**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Upper Sacramento River	0.125	0.12	7	**0.83**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Lower Sacramento River	0.350	0.17	5	**0.83**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Beegum Creek	0.500	0.17	5	**0.83**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in Beegum Creek	0.100	0.13	6	**0.80**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.13	6	**0.80**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.40	2	**0.80**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Bays	0.400	0.40	2	**0.80**	**H**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.39	2	**0.79**	**H**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Delta	0.600	0.39	2	**0.79**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.16	5	**0.78**	**H**
Clear Creek	0.38	Spawning	0.4	Water Quality	0.050	Water Quality in Clear Creek	1.000	0.76	1	**0.76**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Middle Sacramento River	0.100	0.15	5	**0.76**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.400	0.25	3	**0.75**	**H**

Northwestern California Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues in the middle Sacramento River	0.400	0.25	3	**0.75**	**H**
Thomes Creek	0.25	Embryo Incubation	**0.15**	Flow Conditions	0.200	Flow Fluctuations	1.000	0.75	1.00	**0.75**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.300	0.19	4	**0.75**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.300	0.19	4	**0.75**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.300	0.19	4	**0.75**	**H**
Thomes Creek	0.25	Embryo Incubation	**0.15**	Water Quality	0.200	Water Quality in Thomes Creek	1.000	0.75	1.00	**0.75**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Delta	0.100	0.19	4	**0.75**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Lower Sacramento River	0.100	0.19	4	**0.75**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Middle Sacramento River	0.100	0.19	4	**0.75**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in Clear Creek	0.100	0.12	6	**0.71**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Middle Sacramento River	0.300	0.14	5	**0.71**	**H**
Beegum Creek	0.38	Embryo Incubation	**0.15**	Water Temperature	0.125	Water Temperature in Beegum Creek	1.000	0.71	1.00	**0.71**	**H**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Bay	0.100	0.11	6	**0.68**	**M**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.100	0.10	7	**0.67**	**M**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Beegum Creek	0.100	0.10	7	**0.67**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Tributary Barriers	0.700	0.33	2	**0.67**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	1.000	0.67	1	**0.67**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.13	5	**0.66**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.13	5	**0.66**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.13	5	**0.63**	**M**
Thomes Creek	0.25	Spawning	**0.25**	Barrier	0.100	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.63	1	**0.63**	**M**
Thomes Creek	0.25	Spawning	**0.25**	Flow Conditions	0.100	Flow Fluctuations	1.000	0.63	1	**0.63**	**M**

Northwestern California Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in Beegum Creek	0.100	0.10	6	**0.57**	**M**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in Beegum Creek	0.100	0.10	6	**0.57**	**M**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the Bay	0.100	0.10	6	**0.57**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.150	0.09	6	**0.56**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.150	0.09	6	**0.56**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.150	0.09	6	**0.56**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.150	0.09	6	**0.56**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in Clear Creek	0.100	0.07	8	**0.53**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in the upper Sacramento River	0.100	0.07	8	**0.53**	**M**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Clear Creek	0.200	0.08	7	**0.53**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Contra Costa Power Plant	0.050	0.07	8	**0.53**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in Beegum Creek	0.050	0.07	8	**0.53**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the upper Sacramento River	0.050	0.07	8	**0.53**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Pittsburg Power Plant	0.050	0.07	8	**0.53**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.26	2	**0.53**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Thomes Creek	0.100	0.13	4	**0.53**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Bays	0.400	0.26	2	**0.53**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Delta	0.250	0.08	6	**0.50**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the lower Sacramento River	0.250	0.08	6	**0.50**	**M**
Beegum Creek	0.38	Spawning	**0.25**	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.48	1	**0.48**	**M**
Beegum Creek	0.38	Spawning	**0.25**	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.48	1	**0.48**	**M**

Northwestern California Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Clear Creek	0.200	0.10	5	**0.48**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.10	5	**0.48**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.10	5	**0.48**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.200	0.10	5	**0.48**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Urban, Heavy Metals in the upper Sacramento River	0.200	0.10	5	**0.48**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.200	0.10	5	**0.48**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.200	0.10	5	**0.48**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in Clear Creek	0.200	0.10	5	**0.48**	**M**
Beegum Creek	0.38	Spawning	**0.25**	Water Quality	0.050	Water Quality in Beegum Creek	1.000	0.48	1	**0.48**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Clear Creek	0.200	0.10	5	**0.48**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Changes in Hydrology	0.200	0.07	7	**0.47**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Diversion into Central Delta	0.200	0.07	7	**0.47**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Reverse Flow Conditions	0.200	0.07	7	**0.47**	**M**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Sacramento Deep Water Ship Channel	0.050	0.08	6	**0.46**	**M**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Suisun Marsh Salinity Control Structure	0.050	0.08	6	**0.46**	**M**
Clear Creek	0.38	Spawning	0.4	Harvest/Angling Impacts	0.030	Recreational, Poaching, Angler Impacts	1.000	0.46	1	**0.46**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in Thomes Creek	0.100	0.09	5	**0.44**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.09	5	**0.44**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	1.000	0.44	1	**0.44**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Thomes Creek	0.500	0.11	4	**0.44**	**M**

Northwestern California Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Changes in Hydrology	0.100	0.07	6	**0.43**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Reverse Flow Conditions	0.100	0.07	6	**0.43**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Hatchery Effects (Competition and Predation)	0.030	Delta	0.300	0.09	5	**0.43**	**M**
Beegum Creek	0.38	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.075	Redd disturbance	1.000	0.43	1.00	**0.43**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Lower Sacramento River	0.200	0.07	6	**0.40**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Middle Sacramento River	0.200	0.07	6	**0.40**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Upper Sacramento River	0.200	0.07	6	**0.40**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Bays	0.050	0.07	6	**0.40**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.07	6	**0.40**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the middle Sacramento River	0.200	0.07	6	**0.40**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the upper Sacramento River	0.200	0.07	6	**0.40**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Diversion into Central Delta	0.300	0.07	6	**0.39**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.050	0.08	5	**0.39**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.050	0.08	5	**0.39**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.050	0.08	5	**0.39**	**M**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.08	5	**0.38**	**M**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.08	5	**0.38**	**M**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.200	0.08	5	**0.38**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Upper Sacramento River	0.050	0.08	5	**0.38**	**M**

Northwestern California Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues in Thomes Creek	0.200	0.13	3	**0.38**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Thomes Creek	0.100	0.06	6	**0.38**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the Bays	0.050	0.06	6	**0.36**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.07	5	**0.36**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Lower Sacramento River	0.200	0.07	5	**0.33**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Delta	0.300	0.07	5	**0.33**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Lower Sacramento River	0.300	0.07	5	**0.33**	**M**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Sutter Bypass - Tisdale Weir	0.035	0.05	6	**0.32**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.100	0.06	5	**0.31**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in Thomes Creek	0.100	0.06	5	**0.31**	**M**
Thomes Creek	0.25	Spawning	**0.25**	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.31	1	**0.31**	**M**
Thomes Creek	0.25	Spawning	**0.25**	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.31	1	**0.31**	**M**
Thomes Creek	0.25	Spawning	**0.25**	Water Quality	0.050	Water Quality in Thomes Creek	1.000	0.31	1	**0.31**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Contra Costa Power Plant	0.050	0.04	7	**0.31**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in Thomes Creek	0.050	0.04	7	**0.31**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Pittsburg Power Plant	0.050	0.04	7	**0.31**	**M**
Clear Creek	0.38	Spawning	0.4	Hatchery Effects	0.020	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.30	1	**0.30**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Upper Sacramento River	0.050	0.08	4	**0.30**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	DO, Ag, Urban, Heavy Metals in the Delta	0.150	0.05	6	**0.30**	**L**
Clear Creek	0.38	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.050	Redd disturbance	1.000	0.29	1.00	**0.29**	**L**

Northwestern California Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Hatchery Effects (Competition and Predation)	0.030	Lower Sacramento River	0.200	0.06	5	**0.29**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Hatchery Effects (Competition and Predation)	0.030	Middle Sacramento River	0.200	0.06	5	**0.29**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Hatchery Effects (Competition and Predation)	0.030	Upper Sacramento River	0.200	0.06	5	**0.29**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Whiskeytown Dam	0.300	0.14	2	**0.29**	**L**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Clear Creek	0.150	0.06	5	**0.29**	**L**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.06	5	**0.29**	**L**
Clear Creek	0.38	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.29	1.00	**0.29**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Contra Costa Power Plant	0.050	0.03	8	**0.27**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Pittsburg Power Plant	0.050	0.03	8	**0.27**	**L**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Delta	0.100	0.04	7	**0.27**	**L**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Lower Sacramento River	0.100	0.04	7	**0.27**	**L**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Middle Sacramento River	0.100	0.04	7	**0.27**	**L**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Upper Sacramento River	0.100	0.04	7	**0.27**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Changes in Hydrology	0.200	0.04	6	**0.26**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Reverse Flow Conditions	0.200	0.04	6	**0.26**	**L**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in Thomes Creek	0.100	0.06	4	**0.25**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Middle Sacramento River	0.150	0.05	5	**0.25**	**L**
Beegum Creek	0.38	Spawning	**0.25**	Physical Habitat Alteration	0.050	Limited Instream Gravel Supply	0.500	0.24	1	**0.24**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.100	0.05	5	**0.24**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.100	0.05	5	**0.24**	**L**

Northwestern California Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Delta	0.100	0.05	5	**0.24**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in Beegum Creek	0.100	0.03	7	**0.23**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.03	7	**0.23**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.03	7	**0.23**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the upper Sacramento River	0.100	0.03	7	**0.23**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Bays	0.050	0.04	5	**0.22**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.04	5	**0.22**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Thomes Creek	0.100	0.04	5	**0.22**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the lower Sacramento River	0.200	0.04	5	**0.22**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the middle Sacramento River	0.200	0.04	5	**0.22**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in Thomes Creek	0.200	0.04	5	**0.22**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban, Heavy Metals in the Bays	0.200	0.04	5	**0.22**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	DO, Ag, Urban, Heavy Metals in the Delta	0.200	0.04	5	**0.22**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Flow Dependent Habitat Availability in the lower Sacramento River	0.050	0.04	6	**0.21**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Flow Dependent Habitat Availability in the middle Sacramento River	0.050	0.04	6	**0.21**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Flow Dependent Habitat Availability in the upper Sacramento River	0.050	0.04	6	**0.21**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Bays	0.100	0.03	6	**0.20**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Beegum Creek	0.050	0.03	6	**0.20**	**L**

Northwestern California Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.050	0.03	6	**0.20**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in Beegum Creek	0.100	0.03	6	**0.20**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban, Heavy Metals in the Bays	0.100	0.03	6	**0.20**	**L**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.100	0.04	5	**0.19**	**L**
Thomes Creek	0.25	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.050	Redd disturbance	1.000	0.19	1.00	**0.19**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Lower Sacramento River	0.200	0.04	4	**0.18**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Middle Sacramento River	0.200	0.04	4	**0.18**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Delta	0.100	0.03	5	**0.17**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Middle Sacramento River	0.150	0.03	5	**0.16**	**L**
Thomes Creek	0.25	Spawning	**0.25**	Physical Habitat Alteration	0.050	Limited Instream Gravel Supply	0.500	0.16	1	**0.16**	**L**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Bays	0.050	0.02	7	**0.13**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.02	6	**0.13**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.02	6	**0.13**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in Thomes Creek	0.100	0.02	6	**0.13**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.050	0.02	5	**0.12**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Upper Sacramento River	0.050	0.02	5	**0.12**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.06	2	**0.11**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.010	Delta	0.600	0.06	2	**0.11**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Bays	0.100	0.02	5	**0.11**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Thomes Creek	0.100	0.02	5	**0.11**	**L**

Northwestern California Spring-run Chinook Salmon Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Beegum Creek	0.050	0.02	6	**0.10**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Delta	0.100	0.02	4	**0.09**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Upper Sacramento River	0.050	0.02	5	**0.08**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.04	2	**0.08**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.010	Bays	0.400	0.04	2	**0.08**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Hatchery Effects (Competition and Predation)	0.030	Bays	0.050	0.01	5	**0.07**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Hatchery Effects (Competition and Predation)	0.030	Clear Creek	0.050	0.01	5	**0.07**	**L**

Spring-run Chinook Salmon Stressor Matrix - Antelope Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Antelope Creek	0.700	0.63	4	**2.50**	**VH**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Agricultural Diversion Dam(s) in Antelope Creek	0.600	0.49	5	**2.44**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Individual or Terminal Diversions and loss of channel connectivity in Antelope Creek	0.500	0.34	7	**2.39**	**VH**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in Antelope Creek	0.600	0.39	3	**1.17**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Lower Sacramento River	0.350	0.25	4	**1.02**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.350	0.25	4	**1.02**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.350	0.25	4	**1.02**	**VH**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.500	0.16	6	**0.98**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Delta	0.300	0.22	4	**0.87**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Antelope Creek	0.300	0.22	4	**0.87**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.300	0.22	4	**0.87**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the Delta	0.300	0.17	5	**0.85**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the lower Sacramento River	0.300	0.17	5	**0.85**	**VH**
Antelope Creek	0.13	Spawning	**0.25**	Spawning Habitat Availability	0.250	Habitat Availability	1.000	0.81	1	**0.81**	**VH**
Antelope Creek	0.13	Spawning	**0.25**	Water Quality	0.250	Turbidity, Sedimentation in Antelope Creek	1.000	0.81	1	**0.81**	**VH**
Antelope Creek	0.13	Embryo Incubation	**0.15**	Water Quality	0.400	Turbidity, sedimentation in Antelope Creek	1.000	0.78	1.00	**0.78**	**VH**
Antelope Creek	0.13	Spawning	**0.25**	Physical Habitat Alteration	0.225	Gravel embeddedness and fines	1.000	0.73	1	**0.73**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the middle Sacramento River	0.250	0.14	5	**0.71**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in Antelope Creek	0.600	0.14	5	**0.68**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Diversion into Central Delta	0.300	0.10	6	**0.61**	**VH**
Antelope Creek	0.13	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.300	Sedimentation, turbidity, physical disturbance	1.000	0.59	1.00	**0.59**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Middle Sacramento River	0.200	0.15	4	**0.58**	**VH**

Spring-run Chinook Salmon Stressor Matrix - Antelope Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Delta	0.200	0.15	4	**0.58**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Antelope Creek	0.200	0.15	4	**0.58**	**VH**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Individual Diversions in the Delta	0.100	0.07	7	**0.48**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Individual Diversions in the lower Sacramento River	0.100	0.07	7	**0.48**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Individual Diversions in the middle Sacramento River	0.100	0.07	7	**0.48**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Tracy and Banks Pumping Plants	0.100	0.07	7	**0.48**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Antelope Creek	0.150	0.11	4	**0.44**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Middle Sacramento River	0.150	0.11	4	**0.44**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Middle Sacramento River	0.150	0.11	4	**0.44**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Changes in Hydrology	0.200	0.07	6	**0.41**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Reverse Flow Conditions	0.200	0.07	6	**0.41**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.100	0.08	5	**0.41**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.100	0.08	5	**0.41**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.100	0.08	5	**0.41**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.08	5	**0.41**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.200	0.13	3	**0.39**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.13	3	**0.39**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.07	5	**0.37**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	0.800	0.18	2	**0.36**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Lower Sacramento River	0.400	0.09	4	**0.36**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Delta	0.100	0.09	4	**0.36**	**H**

Spring-run Chinook Salmon Stressor Matrix - Antelope Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Lower Sacramento River	0.100	0.09	4	**0.36**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Middle Sacramento River	0.100	0.09	4	**0.36**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.07	5	**0.34**	**H**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.07	5	**0.34**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Antelope Creek	0.175	0.06	6	**0.34**	**H**
Antelope Creek	0.13	Spawning	**0.25**	Harvest/Angling Impacts	0.100	Recreational, Poaching, Angler Impacts	1.000	0.33	1	**0.33**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.200	0.07	5	**0.33**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.200	0.07	5	**0.33**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Antelope Creek	0.200	0.07	5	**0.33**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Bay	0.200	0.07	5	**0.33**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.200	0.07	5	**0.33**	**H**
Antelope Creek	0.13	Spawning	**0.25**	Water Temperature	0.100	Water Temperature in Antelope Creek	1.000	0.33	1	**0.33**	**H**
Antelope Creek	0.13	Embryo Incubation	**0.15**	Water Temperature	0.165	Water Temperature in Antelope Creek	1.000	0.32	1.00	**0.32**	**H**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.06	5	**0.30**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the Bays	0.100	0.06	5	**0.28**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Middle Sacramento River	0.300	0.07	4	**0.27**	**M**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.05	5	**0.24**	**M**
Antelope Creek	0.13	Embryo Incubation	**0.15**	Flow Conditions	0.125	Flow Fluctuations	1.000	0.24	1.00	**0.24**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Contra Costa Power Plant	0.050	0.03	7	**0.24**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Pittsburg Power Plant	0.050	0.03	7	**0.24**	**M**

Spring-run Chinook Salmon Stressor Matrix - Antelope Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.05	5	**0.23**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in Antelope Creek	0.100	0.03	6	**0.20**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.03	6	**0.20**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.03	6	**0.20**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Delta	0.300	0.04	5	**0.20**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Lower Sacramento River	0.300	0.04	5	**0.20**	**M**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.100	0.03	6	**0.20**	**M**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.100	0.03	6	**0.20**	**M**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.04	5	**0.18**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Antelope Creek	0.200	0.05	4	**0.18**	**M**
Antelope Creek	0.13	Spawning	**0.25**	Flow Conditions	0.050	Flow Fluctuations	1.000	0.16	1	**0.16**	**M**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.075	0.02	6	**0.15**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in Antelope Creek	0.050	0.03	5	**0.14**	**M**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in Antelope Creek	0.100	0.02	5	**0.12**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Antelope Creek	0.100	0.02	5	**0.11**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.02	5	**0.11**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.100	0.02	5	**0.11**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.100	0.02	5	**0.11**	**M**

Spring-run Chinook Salmon Stressor Matrix - Antelope Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.100	0.02	5	**0.11**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.100	0.02	5	**0.11**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Middle Sacramento River	0.150	0.02	5	**0.10**	**L**
Antelope Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.050	0.02	6	**0.10**	**M**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Dam(s)	0.200	0.05	2	**0.09**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Delta	0.100	0.02	4	**0.09**	**L**
Antelope Creek	0.13	Spawning	**0.25**	Hatchery Effects	0.025	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.08	1	**0.08**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Antelope Creek	0.100	0.01	5	**0.07**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Bays	0.100	0.01	5	**0.07**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.03	2	**0.05**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.010	Delta	0.600	0.03	2	**0.05**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.02	2	**0.04**	**L**
Antelope Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.010	Bays	0.400	0.02	2	**0.04**	**L**
Antelope Creek	0.13	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.010	Redd disturbance	1.000	0.02	1.00	**0.02**	**L**

Spring-run Chinook Salmon Stressor Matrix - Battle Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.57	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	North Fork Dams	0.325	1.62	7	**11.35**	**VH**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	South Fork Dams	0.325	1.62	7	**11.35**	**VH**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Temperature	0.175	Battle Creek	0.550	1.37	5	**6.86**	**VH**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Red Bluff Diversion Dam	0.150	0.75	7	**5.24**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Hatchery Effects (Competition and Predation)	0.125	Battle Creek	0.350	0.87	6	**5.24**	**VH**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Flow Conditions	0.200	Low Flows - attraction, migratory cues in Battle Creek	0.400	1.14	4	**4.56**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the Delta	0.300	0.75	6	**4.49**	**VH**
Battle Creek	0.57	Spawning	0.25	Flow Conditions	0.300	Low instream flows per FERC license	1.000	4.28	1	**4.28**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in Battle Creek	0.250	0.50	8	**3.99**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Delta	0.350	0.70	5	**3.49**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Delta	0.350	0.70	5	**3.49**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Delta	0.350	0.70	5	**3.49**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Tracy and Banks Pumping Plants	0.200	0.40	8	**3.19**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Lower Sacramento River	0.300	0.60	5	**2.99**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Lower Sacramento River	0.300	0.60	5	**2.99**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Lower Sacramento River	0.300	0.60	5	**2.99**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Hatchery Effects (Competition and Predation)	0.125	Upper Sacramento River	0.200	0.50	6	**2.99**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the lower Sacramento River	0.200	0.50	6	**2.99**	**VH**
Battle Creek	0.57	Spawning	0.25	Barriers	0.200	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	2.85	1	**2.85**	**VH**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Flow Conditions	0.200	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.250	0.71	4	**2.85**	**VH**

Spring-run Chinook Salmon Stressor Matrix - Battle Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Flow Dependent Habitat Availability in Battle Creek	0.400	0.40	7	**2.79**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Ag, Urban in the lower Sacramento River	0.300	0.45	6	**2.69**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	DO, Ag, Urban, Heavy Metals in the Delta	0.300	0.45	6	**2.69**	**VH**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.375	0.53	5	**2.67**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Lower Sacramento River	0.350	0.52	5	**2.62**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the middle Sacramento River	0.175	0.44	6	**2.62**	**VH**
Battle Creek	0.57	Spawning	0.25	Hatchery Effects	0.175	Redd superimposition, competition for habitat, Genetic Integrity	1.000	2.49	1	**2.49**	**VH**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Ocean	0.500	0.36	7	**2.49**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in the Delta	0.150	0.30	8	**2.39**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in the lower Sacramento River	0.150	0.30	8	**2.39**	**VH**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in the middle Sacramento River	0.150	0.30	8	**2.39**	**VH**
Battle Creek	0.57	Embryo Incubation	**0.15**	Flow Conditions	0.275	Flow Fluctuations	1.000	2.35	1.00	**2.35**	**H**
Battle Creek	0.57	Embryo Incubation	**0.15**	Water Temperature	0.275	Water Temperature in Battle Creek	1.000	2.35	1.00	**2.35**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.57	4	**2.28**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Hatchery Effects (Competition and Predation)	0.125	Lower Sacramento River	0.150	0.37	6	**2.24**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Hatchery Effects (Competition and Predation)	0.125	Middle Sacramento River	0.150	0.37	6	**2.24**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Delta	0.300	0.45	5	**2.24**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in Battle Creek	0.200	0.36	6	**2.14**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.36	6	**2.14**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.36	6	**2.14**	**H**

Spring-run Chinook Salmon Stressor Matrix - Battle Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.57	Spawning	0.25	Spawning Habitat Availability	0.150	Habitat Suitability	1.000	2.14	1	**2.14**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Middle Sacramento River	0.200	0.40	5	**2.00**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Middle Sacramento River	0.200	0.40	5	**2.00**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.275	0.39	5	**1.96**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in Battle Creek	0.125	0.31	6	**1.87**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.30	6	**1.80**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Sacramento Deep Water Ship Channel	0.050	0.25	7	**1.75**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Suisun Marsh Salinity Control Structure	0.050	0.25	7	**1.75**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Sutter Bypass - Tisdale Weir	0.050	0.25	7	**1.75**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Yolo Bypass - Freemont Weir	0.050	0.25	7	**1.75**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the upper Sacramento River	0.150	0.43	4	**1.71**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.150	0.27	6	**1.60**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.27	6	**1.60**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Temperature	0.175	Lower Sacramento River	0.125	0.31	5	**1.56**	**H**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Temperature	0.175	Middle Sacramento River	0.125	0.31	5	**1.56**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Middle Sacramento River	0.150	0.30	5	**1.50**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Battle Creek	0.200	0.30	5	**1.50**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Hatchery Effects (Competition and Predation)	0.125	Delta	0.100	0.25	6	**1.50**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the Bays	0.100	0.25	6	**1.50**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the upper Sacramento River	0.100	0.25	6	**1.50**	**H**

Spring-run Chinook Salmon Stressor Matrix - Battle Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.25	6	**1.50**	**H**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Diversion into Central Delta	0.200	0.20	7	**1.40**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Ag, Urban, Heavy Metals in the Bays	0.150	0.22	6	**1.35**	**M**
Battle Creek	0.57	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.150	Redd disturbance	1.000	1.28	1.00	**1.28**	**M**
Battle Creek	0.57	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	1.28	1.00	**1.28**	**M**
Battle Creek	0.57	Embryo Incubation	**0.15**	Water Quality	0.150	Water Quality in Battle Creek	1.000	1.28	1.00	**1.28**	**M**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Temperature	0.175	Delta	0.100	0.25	5	**1.25**	**M**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Temperature	0.175	Upper Sacramento River	0.100	0.25	5	**1.25**	**M**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.175	0.25	5	**1.25**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Passage Impediments/Barriers	0.050	North Fork Dams	0.400	0.40	3	**1.20**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Passage Impediments/Barriers	0.050	South Fork Dams	0.400	0.40	3	**1.20**	**M**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.100	0.18	6	**1.07**	**M**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Quality	0.100	Urban, Heavy Metals in the upper Sacramento River	0.150	0.21	5	**1.07**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Upper Sacramento River	0.100	0.20	5	**1.00**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Upper Sacramento River	0.100	0.20	5	**1.00**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Battle Creek	0.100	0.20	5	**1.00**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Upper Sacramento River	0.100	0.20	5	**1.00**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.15	6	**0.90**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.150	0.15	6	**0.90**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Urban, Heavy Metals in the upper Sacramento River	0.100	0.15	6	**0.90**	**M**

Spring-run Chinook Salmon Stressor Matrix - Battle Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Ag, Urban in the middle Sacramento River	0.100	0.15	6	**0.90**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in the upper Sacramento River	0.050	0.10	8	**0.80**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Middle Sacramento River	0.100	0.15	5	**0.75**	**M**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Battle Creek	0.150	0.11	7	**0.75**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Hatchery Effects (Competition and Predation)	0.125	Bays	0.050	0.12	6	**0.75**	**M**
Battle Creek	0.57	Spawning	0.25	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.71	1	**0.71**	**M**
Battle Creek	0.57	Spawning	0.25	Physical Habitat Alteration	0.050	Limited Instream Gravel Supply	1.000	0.71	1	**0.71**	**M**
Battle Creek	0.57	Spawning	0.25	Water Temperature	0.050	Water Temperature in Battle Creek	1.000	0.71	1	**0.71**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Changes in Hydrology	0.100	0.10	7	**0.70**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.10	7	**0.70**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Invasive Species/Food Web Disruption	0.025	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.35	2	**0.70**	**M**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Tidal Marsh Habitat	0.025	Delta	0.600	0.30	2	**0.60**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Passage Impediments/Barriers	0.050	Tributary Barriers	0.200	0.20	3	**0.60**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.10	6	**0.60**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Flow Dependent Habitat Availability in the middle Sacramento River	0.075	0.07	7	**0.52**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Flow Dependent Habitat Availability in the upper Sacramento River	0.075	0.07	7	**0.52**	**L**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Upper Sacramento River	0.100	0.07	7	**0.50**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Battle Creek	0.050	0.10	5	**0.50**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Battle Creek	0.050	0.10	5	**0.50**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Ag, Urban in Battle Creek	0.050	0.07	6	**0.45**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Contra Costa Power Plant	0.025	0.05	8	**0.40**	**L**

Spring-run Chinook Salmon Stressor Matrix - Battle Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Pittsburg Power Plant	0.025	0.05	8	**0.40**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Loss of Tidal Marsh Habitat	0.025	Bays	0.400	0.20	2	**0.40**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Upper Sacramento River	0.050	0.07	5	**0.37**	**L**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Lower Sacramento River	0.075	0.05	7	**0.37**	**L**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Middle Sacramento River	0.075	0.05	7	**0.37**	**L**
Battle Creek	0.57	Spawning	0.25	Water Quality	0.025	Water Quality in Battle Creek	1.000	0.36	1	**0.36**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Reverse Flow Conditions	0.050	0.05	7	**0.35**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Invasive Species/Food Web Disruption	0.025	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.15	2	**0.30**	**L**
Battle Creek	0.57	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Battle Creek	0.050	0.05	6	**0.30**	**L**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Bays	0.050	0.04	7	**0.25**	**L**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Delta	0.050	0.04	7	**0.25**	**L**
Battle Creek	0.57	Adult Immigration and Holding	0.25	Water Quality	0.100	Battle Creek	0.025	0.04	5	**0.18**	**L**

Spring-run Chinook Salmon Stressor Matrix - Beegum Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Beegum Creek	0.600	1.43	5	**7.13**	**VH**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	RBDD	0.550	1.05	5	**5.23**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Delta	0.300	0.60	5	**2.99**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.300	0.60	5	**2.99**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Delta	0.300	0.60	5	**2.99**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.300	0.60	5	**2.99**	**VH**
Beegum Creek	0.38	Spawning	**0.25**	Spawning Habitat Availability	0.300	Habitat Suitability	1.000	2.85	1	**2.85**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.275	0.55	5	**2.74**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.275	0.55	5	**2.74**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Beegum Creek	0.250	0.50	5	**2.49**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the Delta	0.200	0.27	8	**2.13**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the lower Sacramento River	0.200	0.27	8	**2.13**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the middle Sacramento River	0.200	0.27	8	**2.13**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Tracy and Banks Pumping Plants	0.200	0.27	8	**2.13**	**VH**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.300	0.29	7	**2.00**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Delta	0.250	0.33	6	**2.00**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the lower Sacramento River	0.250	0.33	6	**2.00**	**VH**
Beegum Creek	0.38	Embryo Incubation	**0.15**	Watershed disturbance	0.350	Sedimentation	1.000	2.00	1.00	**2.00**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Middle Sacramento River	0.200	0.40	5	**2.00**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Beegum Creek	0.200	0.40	5	**2.00**	**VH**
Beegum Creek	0.38	Spawning	**0.25**	Flow Conditions	0.200	Flow Fluctuations	1.000	1.90	1	**1.90**	**VH**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.250	0.48	4	**1.90**	**VH**

Spring-run Chinook Salmon Stressor Matrix - Beegum Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in Beegum Creek	0.250	0.48	4	**1.90**	**VH**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the middle Sacramento River	0.250	0.48	4	**1.90**	**VH**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the Upper Sacramento River	0.250	0.48	4	**1.90**	**VH**
Beegum Creek	0.38	Spawning	**0.25**	Water Temperature	0.200	Water Temperature in Beegum Creek	1.000	1.90	1	**1.90**	**VH**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the middle Sacramento River	0.200	0.27	6	**1.60**	**VH**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	Yolo Bypass - Freemont Weir	0.150	0.29	5	**1.43**	**VH**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.250	0.24	6	**1.43**	**VH**
Beegum Creek	0.38	Embryo Incubation	**0.15**	Flow Conditions	0.225	Flow Fluctuations	1.000	1.28	1.00	**1.28**	**H**
Beegum Creek	0.38	Embryo Incubation	**0.15**	Water Quality	0.225	Water Quality in Beegum Creek	1.000	1.28	1.00	**1.28**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the upper Sacramento River	0.150	0.20	6	**1.20**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.20	6	**1.20**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.20	6	**1.20**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.60	2	**1.20**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Delta	0.600	0.60	2	**1.20**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Delta	0.100	0.24	5	**1.19**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Lower Sacramento River	0.100	0.24	5	**1.19**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Middle Sacramento River	0.100	0.24	5	**1.19**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Upper Sacramento River	0.100	0.24	5	**1.19**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.19	6	**1.14**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.19	6	**1.14**	**H**

Spring-run Chinook Salmon Stressor Matrix - Beegum Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.200	0.19	6	**1.14**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.200	0.19	6	**1.14**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the upper Sacramento River	0.200	0.19	6	**1.14**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Beegum Creek	0.100	0.20	5	**1.00**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Upper Sacramento River	0.100	0.20	5	**1.00**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Middle Sacramento River	0.100	0.20	5	**1.00**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Upper Sacramento River	0.100	0.20	5	**1.00**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Middle Sacramento River	0.100	0.20	5	**1.00**	**H**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Upper Sacramento River	0.100	0.20	5	**1.00**	**H**
Beegum Creek	0.38	Spawning	**0.25**	Barrier	0.100	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.95	1	**0.95**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	Sacramento Deep Water Ship Channel	0.100	0.19	5	**0.95**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	Suisun Marsh Salinity Control Structure	0.100	0.19	5	**0.95**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	Sutter Bypass - Tisdale Weir	0.100	0.19	5	**0.95**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.150	0.14	6	**0.86**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.14	6	**0.86**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.150	0.14	6	**0.86**	**H**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.125	0.12	7	**0.83**	**M**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.125	0.12	7	**0.83**	**M**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.125	0.12	7	**0.83**	**M**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Upper Sacramento River	0.125	0.12	7	**0.83**	**M**

Spring-run Chinook Salmon Stressor Matrix - Beegum Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Beegum Creek	0.500	0.17	5	**0.83**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in Beegum Creek	0.100	0.13	6	**0.80**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.13	6	**0.80**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.40	2	**0.80**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Bays	0.400	0.40	2	**0.80**	**M**
Beegum Creek	0.38	Embryo Incubation	**0.15**	Water Temperature	0.125	Water Temperature in Beegum Creek	1.000	0.71	1.00	**0.71**	**M**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.100	0.10	7	**0.67**	**M**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Beegum Creek	0.100	0.10	7	**0.67**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	1.000	0.67	1	**0.67**	**M**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in Beegum Creek	0.100	0.10	6	**0.57**	**M**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in Beegum Creek	0.100	0.10	6	**0.57**	**M**
Beegum Creek	0.38	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the Bay	0.100	0.10	6	**0.57**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Contra Costa Power Plant	0.050	0.07	8	**0.53**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in Beegum Creek	0.050	0.07	8	**0.53**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the upper Sacramento River	0.050	0.07	8	**0.53**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Pittsburg Power Plant	0.050	0.07	8	**0.53**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Delta	0.250	0.08	6	**0.50**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the lower Sacramento River	0.250	0.08	6	**0.50**	**M**
Beegum Creek	0.38	Spawning	**0.25**	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.48	1	**0.48**	**M**
Beegum Creek	0.38	Spawning	**0.25**	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.48	1	**0.48**	**M**
Beegum Creek	0.38	Spawning	**0.25**	Water Quality	0.050	Water Quality in Beegum Creek	1.000	0.48	1	**0.48**	**M**

Spring-run Chinook Salmon Stressor Matrix - Beegum Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Changes in Hydrology	0.200	0.07	7	**0.47**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Diversion into Central Delta	0.200	0.07	7	**0.47**	**M**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Reverse Flow Conditions	0.200	0.07	7	**0.47**	**M**
Beegum Creek	0.38	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.075	Redd disturbance	1.000	0.43	1.00	**0.43**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Lower Sacramento River	0.200	0.07	6	**0.40**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Middle Sacramento River	0.200	0.07	6	**0.40**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Upper Sacramento River	0.200	0.07	6	**0.40**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Bays	0.050	0.07	6	**0.40**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.07	6	**0.40**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the middle Sacramento River	0.200	0.07	6	**0.40**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the upper Sacramento River	0.200	0.07	6	**0.40**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Lower Sacramento River	0.200	0.07	5	**0.33**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	DO, Ag, Urban, Heavy Metals in the Delta	0.150	0.05	6	**0.30**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Middle Sacramento River	0.150	0.05	5	**0.25**	**L**
Beegum Creek	0.38	Spawning	**0.25**	Physical Habitat Alteration	0.050	Limited Instream Gravel Supply	0.500	0.24	1	**0.24**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in Beegum Creek	0.100	0.03	7	**0.23**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.03	7	**0.23**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.03	7	**0.23**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the upper Sacramento River	0.100	0.03	7	**0.23**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Bays	0.100	0.03	6	**0.20**	**L**

Spring-run Chinook Salmon Stressor Matrix - Beegum Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Beegum Creek	0.050	0.03	6	**0.20**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.050	0.03	6	**0.20**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in Beegum Creek	0.100	0.03	6	**0.20**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban, Heavy Metals in the Bays	0.100	0.03	6	**0.20**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Delta	0.100	0.03	5	**0.17**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Beegum Creek	0.050	0.02	6	**0.10**	**L**
Beegum Creek	0.38	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Upper Sacramento River	0.050	0.02	5	**0.08**	**L**

Spring-run Chinook Salmon Stressor Matrix - Big Chico Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Iron Canyon, City of Chico Swimming Holes and Associated Dams	0.750	0.47	5	**2.34**	**VH**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Big Chico Creek	0.700	0.53	4	**2.10**	**VH**
Big Chico Creek	0.1	Spawning	**0.25**	Spawning Habitat Availability	0.400	Habitat Suitability	1.000	1.00	1	**1.00**	**VH**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.575	0.14	6	**0.86**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.350	0.18	4	**0.74**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Middle Sacramento River	0.350	0.18	4	**0.74**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Delta	0.300	0.16	4	**0.63**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.300	0.16	4	**0.63**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Delta	0.300	0.16	4	**0.63**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.300	0.16	4	**0.63**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Tracy and Banks Pumping Plants	0.250	0.09	7	**0.61**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Delta	0.300	0.11	5	**0.53**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the lower Sacramento River	0.300	0.11	5	**0.53**	**VH**
Big Chico Creek	0.1	Spawning	**0.25**	Water Temperature	0.200	Water Temperature in Big Chico Creek	1.000	0.50	1	**0.50**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the Delta	0.200	0.07	7	**0.49**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the lower Sacramento River	0.200	0.07	7	**0.49**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the middle Sacramento River	0.200	0.07	7	**0.49**	**VH**
Big Chico Creek	0.1	Embryo Incubation	**0.15**	Water Temperature	0.300	Water Temperature in Big Chico Creek	1.000	0.45	1.00	**0.45**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the middle Sacramento River	0.250	0.09	5	**0.44**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Big Chico Creek	0.200	0.11	4	**0.42**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Middle Sacramento River	0.200	0.11	4	**0.42**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Big Chico Creek	0.200	0.11	4	**0.42**	**VH**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Middle Sacramento River	0.200	0.11	4	**0.42**	**VH**

Spring-run Chinook Salmon Stressor Matrix - Big Chico Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.200	0.11	4	**0.42**	**VH**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.08	5	**0.38**	**H**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.08	5	**0.38**	**H**
Big Chico Creek	0.1	Embryo Incubation	**0.15**	Watershed disturbance	0.250	Sedimentation	1.000	0.38	1.00	**0.38**	**H**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.16	2	**0.32**	**H**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Delta	0.600	0.16	2	**0.32**	**H**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.06	5	**0.31**	**H**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.400	0.10	3	**0.30**	**H**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues in the middle Sacramento River	0.400	0.10	3	**0.30**	**H**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.300	0.08	4	**0.30**	**H**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.300	0.08	4	**0.30**	**H**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.300	0.08	4	**0.30**	**H**
Big Chico Creek	0.1	Embryo Incubation	**0.15**	Flow Conditions	0.200	Flow Fluctuations	1.000	0.30	1.00	**0.30**	**H**
Big Chico Creek	0.1	Embryo Incubation	**0.15**	Water Quality	0.200	Water Quality in Big Chico Creek	1.000	0.30	1.00	**0.30**	**H**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Delta	0.100	0.08	4	**0.30**	**H**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Lower Sacramento River	0.100	0.08	4	**0.30**	**H**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Middle Sacramento River	0.100	0.08	4	**0.30**	**H**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.05	5	**0.26**	**H**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.05	5	**0.26**	**H**

Spring-run Chinook Salmon Stressor Matrix - Big Chico Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Big Chico Creek	0.1	Spawning	**0.25**	Barrier	0.100	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.25	1	**0.25**	**H**
Big Chico Creek	0.1	Spawning	**0.25**	Flow Conditions	0.100	Flow Fluctuations	1.000	0.25	1	**0.25**	**H**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.05	5	**0.25**	**H**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.11	2	**0.21**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Big Chico Creek	0.100	0.05	4	**0.21**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Bays	0.400	0.11	2	**0.21**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	1.000	0.18	1	**0.18**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in Big Chico Creek	0.100	0.04	5	**0.18**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.04	5	**0.18**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Big Chico Creek	0.500	0.04	4	**0.18**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Diversion into Central Delta	0.300	0.03	6	**0.16**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.050	0.03	5	**0.16**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.050	0.03	5	**0.16**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.050	0.03	5	**0.16**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues in Big Chico Creek	0.200	0.05	3	**0.15**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Big Chico Creek	0.100	0.03	6	**0.15**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.100	0.03	6	**0.15**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.100	0.03	6	**0.15**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Delta	0.300	0.03	5	**0.13**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Lower Sacramento River	0.300	0.03	5	**0.13**	**M**

Spring-run Chinook Salmon Stressor Matrix - Big Chico Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Big Chico Creek	0.1	Spawning	**0.25**	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.13	1	**0.13**	**M**
Big Chico Creek	0.1	Spawning	**0.25**	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.13	1	**0.13**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in Big Chico Creek	0.100	0.03	5	**0.13**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.100	0.03	5	**0.13**	**M**
Big Chico Creek	0.1	Spawning	**0.25**	Water Quality	0.050	Water Quality in Big Chico Creek	1.000	0.13	1	**0.13**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Contra Costa Power Plant	0.050	0.02	7	**0.12**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in Big Chico Creek	0.050	0.02	7	**0.12**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Pittsburg Power Plant	0.050	0.02	7	**0.12**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.075	0.02	6	**0.11**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Changes in Hydrology	0.200	0.02	6	**0.11**	**M**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Reverse Flow Conditions	0.200	0.02	6	**0.11**	**M**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in Big Chico Creek	0.100	0.03	4	**0.10**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Bays	0.050	0.02	5	**0.09**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Big Chico Creek	0.100	0.02	5	**0.09**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.02	5	**0.09**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the lower Sacramento River	0.200	0.02	5	**0.09**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the middle Sacramento River	0.200	0.02	5	**0.09**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in Big Chico Creek	0.200	0.02	5	**0.09**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban, Heavy Metals in the Bays	0.200	0.02	5	**0.09**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	DO, Ag, Urban, Heavy Metals in the Delta	0.200	0.02	5	**0.09**	**L**
Big Chico Creek	0.1	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.050	0.01	6	**0.08**	**L**

Spring-run Chinook Salmon Stressor Matrix - Big Chico Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Big Chico Creek	0.1	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.050	Redd disturbance	1.000	0.08	1.00	**0.08**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Lower Sacramento River	0.200	0.02	4	**0.07**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Middle Sacramento River	0.200	0.02	4	**0.07**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Middle Sacramento River	0.150	0.01	5	**0.07**	**L**
Big Chico Creek	0.1	Spawning	**0.25**	Physical Habitat Alteration	0.050	Limited Instream Gravel Supply	0.500	0.06	1	**0.06**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in Big Chico Creek	0.100	0.01	6	**0.05**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.01	6	**0.05**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.01	6	**0.05**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Bays	0.100	0.01	5	**0.04**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Big Chico Creek	0.100	0.01	5	**0.04**	**L**
Big Chico Creek	0.1	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Delta	0.100	0.01	4	**0.04**	**L**

Spring-run Chinook Salmon Stressor Matrix - Butte Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Butte Creek	0.800	0.83	3	**2.48**	**VH**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Butte Creek Diversion Dams and Weirs	0.600	0.34	6	**2.03**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Predation	0.150	Predation in the Delta	0.350	0.28	4	**1.10**	**VH**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.575	0.22	5	**1.08**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Delta	0.425	0.36	3	**1.07**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.400	0.34	3	**1.01**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Delta	0.425	0.33	3	**1.00**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Predation	0.150	Predation in the lower Sacramento River	0.300	0.24	4	**0.95**	**VH**
Butte Creek	0.15	Spawning	**0.25**	Spawning Habitat Availability	0.250	Habitat Availability/Suitability	1.000	0.94	1	**0.94**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.325	0.27	3	**0.82**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.325	0.27	3	**0.82**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Predation	0.150	Predation in Butte Creek	0.250	0.20	4	**0.79**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.325	0.26	3	**0.77**	**VH**
Butte Creek	0.15	Spawning	**0.25**	Flow Conditions	0.200	Flow Fluctuations	1.000	0.75	1	**0.75**	**VH**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Recreational Impacts (Summer inner tubing)	0.200	Summer inner tubing and swimming in Butte Creek	1.000	0.75	1	**0.75**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Butte Creek	0.275	0.23	3	**0.69**	**VH**
Butte Creek	0.15	Embryo Incubation	**0.15**	Flow Conditions	0.300	Flow Fluctuations	1.000	0.68	1.00	**0.68**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.090	DO, Ag, Urban, Heavy Metals in the Delta	0.350	0.17	4	**0.66**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Butte Creek	0.250	0.21	3	**0.63**	**VH**
Butte Creek	0.15	Embryo Incubation	**0.15**	Water Quality	0.275	Water Quality, Turbidity in Butte Creek	1.000	0.62	1.00	**0.62**	**VH**
Butte Creek	0.15	Embryo Incubation	**0.15**	Water Temperature	0.275	Water Temperature in Butte Creek	1.000	0.62	1.00	**0.62**	**VH**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Butte Creek	0.250	0.20	3	**0.59**	**H**
Butte Creek	0.15	Spawning	**0.25**	Harvest/Angling Impacts	0.150	Recreational, Poaching, Angler Impacts	1.000	0.56	1	**0.56**	**H**
Butte Creek	0.15	Spawning	**0.25**	Water Temperature	0.150	Water Temperature in Butte Creek	1.000	0.56	1	**0.56**	**H**

Spring-run Chinook Salmon Stressor Matrix - Butte Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the Delta	0.250	0.09	6	**0.55**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the lower Sacramento River	0.250	0.09	6	**0.55**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Tracy and Banks Pumping Plants	0.250	0.09	6	**0.55**	**H**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Yolo Bypass - Freemont Weir	0.150	0.08	6	**0.51**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.090	Ag, Urban in the lower Sacramento River	0.250	0.12	4	**0.47**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.090	Ag, Urban, Heavy Metals in the Bays	0.250	0.12	4	**0.47**	**H**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Water Quality	0.125	Ag, Urban in Butte Creek	0.333	0.16	3	**0.47**	**H**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Water Quality	0.125	Ag, Urban in the lower Sacramento River	0.333	0.16	3	**0.47**	**H**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Water Quality	0.125	DO, Ag, Urban, Heavy Metals in the Delta	0.333	0.16	3	**0.47**	**H**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in the lower Sacramento River	0.600	0.23	2	**0.45**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in Butte Creek	0.200	0.07	6	**0.44**	**H**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Butte Creek	0.225	0.08	5	**0.42**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.375	0.10	4	**0.39**	**H**
Butte Creek	0.15	Spawning	**0.25**	Water Quality	0.100	Water Quality, Turbidity in Butte Creek	1.000	0.38	1	**0.38**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.050	Delta	0.350	0.09	4	**0.37**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.050	Lower Sacramento River	0.350	0.09	4	**0.37**	**H**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Centerville Head Dam	0.100	0.06	6	**0.34**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.050	Delta	0.600	0.16	2	**0.32**	**H**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Predation	0.150	Predation in the Bays	0.100	0.08	4	**0.32**	**H**

Spring-run Chinook Salmon Stressor Matrix - Butte Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.08	4	**0.32**	**H**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Delta	0.100	0.10	3	**0.31**	**M**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Lower Sacramento River	0.100	0.10	3	**0.31**	**M**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues in Butte Creek	0.400	0.15	2	**0.30**	**M**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.090	Ag, Urban in Butte Creek	0.150	0.07	4	**0.28**	**M**
Butte Creek	0.15	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.100	Redd disturbance	1.000	0.23	1.00	**0.23**	**M**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.050	Bays	0.400	0.11	2	**0.21**	**M**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Butte Creek	0.200	0.05	4	**0.21**	**M**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.275	0.05	4	**0.21**	**M**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.275	0.05	4	**0.21**	**M**
Butte Creek	0.15	Spawning	**0.25**	Barrier	0.050	Centerville Head Dam - Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.19	1	**0.19**	**M**
Butte Creek	0.15	Spawning	**0.25**	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.19	1	**0.19**	**M**
Butte Creek	0.15	Spawning	**0.25**	Physical Habitat Alteration	0.050	Limited Instream Gravel Supply	1.000	0.19	1	**0.19**	**M**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.250	0.05	4	**0.19**	**M**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.050	Butte Creek	0.175	0.05	4	**0.18**	**M**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Sacramento Deep Water Ship Channel	0.050	0.03	6	**0.17**	**M**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Suisun Marsh Salinity Control Structure	0.050	0.03	6	**0.17**	**M**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Sutter Bypass - Tisdale Weir	0.050	0.03	6	**0.17**	**M**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Butte Creek	0.400	0.05	3	**0.16**	**M**

Spring-run Chinook Salmon Stressor Matrix - Butte Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Butte Creek	0.200	0.04	4	**0.15**	**M**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Diversion into Central Delta	0.225	0.03	5	**0.15**	**M**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in Butte Creek	0.225	0.03	5	**0.15**	**M**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Reverse Flow Conditions	0.225	0.03	5	**0.15**	**M**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.075	0.03	5	**0.14**	**M**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.075	0.03	5	**0.14**	**M**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.050	Bays	0.125	0.03	4	**0.13**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.125	0.03	4	**0.13**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Delta	0.300	0.04	3	**0.12**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Lower Sacramento River	0.300	0.04	3	**0.12**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Changes in Delta Hydrology	0.175	0.02	5	**0.11**	**L**
Butte Creek	0.15	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.11	1.00	**0.11**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the lower Sacramento River	0.150	0.02	5	**0.10**	**L**
Butte Creek	0.15	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.050	0.02	5	**0.09**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.010	Agricultural, Wildlife and Terminal Diversions	0.800	0.04	2	**0.08**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.03	2	**0.06**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Contra Costa Power Plant	0.025	0.01	6	**0.06**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Pittsburg Power Plant	0.025	0.01	6	**0.06**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.02	2	**0.04**	**L**
Butte Creek	0.15	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.010	Tributary Barriers	0.200	0.01	2	**0.02**	**L**

Spring-run Chinook Salmon Stressor Matrix - Clear Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.38	Spawning	0.4	Physical Habitat Alteration	0.250	Limited Instream Gravel Supply	1.000	3.80	1	**3.80**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Red Bluff Diversion Dam	0.410	0.62	6	**3.74**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Temperature	0.300	Clear Creek	0.400	0.91	4	**3.65**	**VH**
~~Clear Creek~~	~~0.38~~	~~Adult Immigration and Holding~~	~~0.2~~	~~Passage Impediments/Barriers~~	~~0.200~~	~~Whiskeytown Dam~~	~~0.355~~	~~0.54~~	~~6~~	**~~3.24~~**	**~~VH~~**
Clear Creek	0.38	Spawning	0.4	Spawning Habitat Availability	0.200	Habitat Suitability	1.000	3.04	1	**3.04**	**VH**
Clear Creek	0.38	Spawning	0.4	Water Temperature	0.200	Water Temperature in Clear Creek	1.000	3.04	1	**3.04**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.350	0.53	5	**2.66**	**VH**
Clear Creek	0.38	Spawning	0.4	Flow Conditions	0.150	Flow Fluctuations	1.000	2.28	1	**2.28**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Flow Conditions	0.250	Low Flows - attraction, migratory cues in Clear Creek	0.400	0.76	3	**2.28**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Delta	0.300	0.46	5	**2.28**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.350	0.53	4	**2.13**	**VH**
Clear Creek	0.38	Embryo Incubation	**0.15**	Water Quality	0.350	Sedimentation in Clear Creek	1.000	2.00	1.00	**2.00**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Flow Dependent Habitat Availability in Clear Creek	0.450	0.32	6	**1.92**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Lower Sacramento River	0.250	0.38	5	**1.90**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the Delta	0.250	0.30	6	**1.78**	**VH**
Clear Creek	0.38	Embryo Incubation	**0.15**	Flow Conditions	0.300	Flow Fluctuations	1.000	1.71	1.00	**1.71**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Clear Creek	0.200	0.30	5	**1.52**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Clear Creek	0.200	0.30	5	**1.52**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Delta	0.200	0.30	5	**1.52**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Middle Sacramento River	0.200	0.30	5	**1.52**	**VH**
Clear Creek	0.38	Spawning	0.4	Barriers	0.100	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	1.52	1	**1.52**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the lower Sacramento River	0.200	0.24	6	**1.43**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the middle Sacramento River	0.200	0.24	6	**1.43**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the upper Sacramento River	0.200	0.24	6	**1.43**	**VH**
Clear Creek	0.38	Embryo Incubation	**0.15**	Water Temperature	0.250	Water Temperature in Clear Creek	1.000	1.43	1.00	**1.43**	**VH**

Spring-run Chinook Salmon Stressor Matrix - Clear Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Quality	0.150	Ag, Urban in the lower Sacramento River	0.200	0.23	6	**1.37**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Quality	0.150	Clear Creek	0.200	0.23	6	**1.37**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Delta	0.200	0.23	6	**1.37**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Temperature	0.300	Delta	0.150	0.34	4	**1.37**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Temperature	0.300	Lower Sacramento River	0.150	0.34	4	**1.37**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Temperature	0.300	Middle Sacramento River	0.150	0.34	4	**1.37**	**VH**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Temperature	0.300	Upper Sacramento River	0.150	0.34	4	**1.37**	**VH**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Clear Creek	0.200	0.30	4	**1.22**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.200	0.30	4	**1.22**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Middle Sacramento River	0.200	0.30	4	**1.22**	**H**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Flow Conditions	0.250	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.200	0.38	3	**1.14**	**H**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Flow Conditions	0.250	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.38	3	**1.14**	**H**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Flow Conditions	0.250	Low Flows - attraction, migratory cues in the upper Sacramento River	0.200	0.38	3	**1.14**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Upper Sacramento River	0.150	0.23	5	**1.14**	**H**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Quality	0.150	Ag, Urban in the middle Sacramento River	0.150	0.17	6	**1.03**	**H**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Quality	0.150	Urban, Heavy Metals in the upper Sacramento River	0.150	0.17	6	**1.03**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in the Delta	0.175	0.12	8	**0.93**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in the lower Sacramento River	0.175	0.12	8	**0.93**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in the middle Sacramento River	0.175	0.12	8	**0.93**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Tracy and Banks Pumping Plants	0.175	0.12	8	**0.93**	**H**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Ocean	0.350	0.13	7	**0.93**	**H**

Spring-run Chinook Salmon Stressor Matrix - Clear Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.38	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Yolo Bypass - Freemont Weir	0.100	0.15	6	**0.91**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Diversion into Central Delta	0.200	0.14	6	**0.86**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Lower Sacramento River	0.350	0.17	5	**0.83**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Middle Sacramento River	0.100	0.15	5	**0.76**	**H**
Clear Creek	0.38	Spawning	0.4	Water Quality	0.050	Water Quality in Clear Creek	1.000	0.76	1	**0.76**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in Clear Creek	0.100	0.12	6	**0.71**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Middle Sacramento River	0.300	0.14	5	**0.71**	**H**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Bay	0.100	0.11	6	**0.68**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Tributary Barriers	0.700	0.33	2	**0.67**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in Clear Creek	0.100	0.07	8	**0.53**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in the upper Sacramento River	0.100	0.07	8	**0.53**	**H**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Clear Creek	0.200	0.08	7	**0.53**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Clear Creek	0.200	0.10	5	**0.48**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.10	5	**0.48**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.10	5	**0.48**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.200	0.10	5	**0.48**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Urban, Heavy Metals in the upper Sacramento River	0.200	0.10	5	**0.48**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.200	0.10	5	**0.48**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.200	0.10	5	**0.48**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in Clear Creek	0.200	0.10	5	**0.48**	**H**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Clear Creek	0.200	0.10	5	**0.48**	**H**

Spring-run Chinook Salmon Stressor Matrix - Clear Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.38	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Sacramento Deep Water Ship Channel	0.050	0.08	6	**0.46**	**M**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Suisun Marsh Salinity Control Structure	0.050	0.08	6	**0.46**	**M**
Clear Creek	0.38	Spawning	0.4	Harvest/Angling Impacts	0.030	Recreational, Poaching, Angler Impacts	1.000	0.46	1	**0.46**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Changes in Hydrology	0.100	0.07	6	**0.43**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Reverse Flow Conditions	0.100	0.07	6	**0.43**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Hatchery Effects (Competition and Predation)	0.030	Delta	0.300	0.09	5	**0.43**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Upper Sacramento River	0.050	0.08	5	**0.38**	**M**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.08	5	**0.38**	**M**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.08	5	**0.38**	**M**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.200	0.08	5	**0.38**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the Bays	0.050	0.06	6	**0.36**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.07	5	**0.36**	**M**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Sutter Bypass - Tisdale Weir	0.035	0.05	6	**0.32**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Upper Sacramento River	0.050	0.08	4	**0.30**	**M**
Clear Creek	0.38	Spawning	0.4	Hatchery Effects	0.020	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.30	1	**0.30**	**M**
Clear Creek	0.38	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.050	Redd disturbance	1.000	0.29	1.00	**0.29**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Hatchery Effects (Competition and Predation)	0.030	Lower Sacramento River	0.200	0.06	5	**0.29**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Hatchery Effects (Competition and Predation)	0.030	Middle Sacramento River	0.200	0.06	5	**0.29**	**M**

Spring-run Chinook Salmon Stressor Matrix - Clear Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Hatchery Effects (Competition and Predation)	0.030	Upper Sacramento River	0.200	0.06	5	**0.29**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Whiskeytown Dam	0.300	0.14	2	**0.29**	**M**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Clear Creek	0.150	0.06	5	**0.29**	**M**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.06	5	**0.29**	**M**
Clear Creek	0.38	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.29	1.00	**0.29**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Contra Costa Power Plant	0.050	0.03	8	**0.27**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Pittsburg Power Plant	0.050	0.03	8	**0.27**	**M**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Delta	0.100	0.04	7	**0.27**	**M**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Lower Sacramento River	0.100	0.04	7	**0.27**	**M**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Middle Sacramento River	0.100	0.04	7	**0.27**	**M**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Upper Sacramento River	0.100	0.04	7	**0.27**	**M**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.100	0.05	5	**0.24**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.100	0.05	5	**0.24**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Delta	0.100	0.05	5	**0.24**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Flow Dependent Habitat Availability in the lower Sacramento River	0.050	0.04	6	**0.21**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Flow Dependent Habitat Availability in the middle Sacramento River	0.050	0.04	6	**0.21**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Flow Dependent Habitat Availability in the upper Sacramento River	0.050	0.04	6	**0.21**	**L**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.100	0.04	5	**0.19**	**L**
Clear Creek	0.38	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Bays	0.050	0.02	7	**0.13**	**L**

Spring-run Chinook Salmon Stressor Matrix - Clear Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.050	0.02	5	**0.12**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Upper Sacramento River	0.050	0.02	5	**0.12**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.06	2	**0.11**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.010	Delta	0.600	0.06	2	**0.11**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.04	2	**0.08**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.010	Bays	0.400	0.04	2	**0.08**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Hatchery Effects (Competition and Predation)	0.030	Bays	0.050	0.01	5	**0.07**	**L**
Clear Creek	0.38	Juvenile Rearing and Outmigration	0.25	Hatchery Effects (Competition and Predation)	0.030	Clear Creek	0.050	0.01	5	**0.07**	**L**

Spring-run Chinook Salmon Stressor Matrix - Deer Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Agricultural Diversion Dam(s) in Deer Creek	0.600	0.64	5	**3.19**	**VH**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Deer Creek	0.700	0.74	4	**2.98**	**VH**
Deer Creek	0.17	Embryo Incubation	**0.15**	Water Quality	0.665	Turbidity, sedimentation, hazardous spills (HWY 32) in Deer Creek	1.000	1.70	1.00	**1.70**	**VH**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.525	0.22	6	**1.34**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Lower Sacramento River	0.350	0.33	4	**1.33**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.350	0.33	4	**1.33**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Middle Sacramento River	0.350	0.33	4	**1.33**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.350	0.33	4	**1.33**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Middle Sacramento River	0.350	0.33	4	**1.33**	**VH**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.150	Deer Creek	0.400	0.26	5	**1.28**	**VH**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues in Deer Creek	0.600	0.38	3	**1.15**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Delta	0.300	0.29	4	**1.14**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the Delta	0.300	0.22	5	**1.12**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the lower Sacramento River	0.300	0.22	5	**1.12**	**VH**
Deer Creek	0.17	Spawning	**0.25**	Spawning Habitat Availability	0.250	Habitat Availability	1.000	1.06	1	**1.06**	**VH**
Deer Creek	0.17	Spawning	**0.25**	Water Quality	0.250	Turbidity, Sedimentation, Hazardous Spills (Hwy 32) in Deer Creek	1.000	1.06	1	**1.06**	**VH**
Deer Creek	0.17	Spawning	**0.25**	Physical Habitat Alteration	0.225	Gravel embeddedness and fines	1.000	0.96	1	**0.96**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the middle Sacramento River	0.250	0.19	5	**0.93**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban, Hazardous Spills (Hwy 32) in Deer Creek	0.600	0.18	5	**0.89**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Diversion into Central Delta	0.300	0.13	6	**0.80**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Middle Sacramento River	0.200	0.19	4	**0.76**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Delta	0.200	0.19	4	**0.76**	**VH**

Spring-run Chinook Salmon Stressor Matrix - Deer Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.200	0.19	4	**0.76**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the Delta	0.200	0.08	7	**0.58**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the lower Sacramento River	0.200	0.08	7	**0.58**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the middle Sacramento River	0.200	0.08	7	**0.58**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Jones and Banks Pumping Plants	0.200	0.08	7	**0.58**	**VH**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Deer Creek	0.150	0.14	4	**0.57**	**H**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Changes in Hydrology	0.200	0.09	6	**0.54**	**H**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Reverse Flow Conditions	0.200	0.09	6	**0.54**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.100	0.11	5	**0.53**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.100	0.11	5	**0.53**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.100	0.11	5	**0.53**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.11	5	**0.53**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.150	Ag, Urban in the lower Sacramento River	0.150	0.10	5	**0.48**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.150	Ag, Urban in the middle Sacramento River	0.150	0.10	5	**0.48**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Bay	0.150	0.10	5	**0.48**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Delta	0.150	0.10	5	**0.48**	**H**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	0.800	0.24	2	**0.48**	**H**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Lower Sacramento River	0.400	0.12	4	**0.48**	**H**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.09	5	**0.45**	**H**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.09	5	**0.45**	**H**
Deer Creek	0.17	Spawning	**0.25**	Harvest/Angling Impacts	0.100	Recreational, Poaching, Angler Impacts	1.000	0.43	1	**0.43**	**H**

Spring-run Chinook Salmon Stressor Matrix - Deer Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Delta	0.100	0.11	4	**0.43**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Lower Sacramento River	0.100	0.11	4	**0.43**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Middle Sacramento River	0.100	0.11	4	**0.43**	**H**
Deer Creek	0.17	Spawning	**0.25**	Water Temperature	0.100	Water Temperature in Deer Creek	1.000	0.43	1	**0.43**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.200	0.13	3	**0.38**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.13	3	**0.38**	**H**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Deer Creek	0.150	0.06	6	**0.38**	**H**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Deer Creek	0.100	0.10	4	**0.38**	**H**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Deer Creek	0.100	0.10	4	**0.38**	**H**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the Bays	0.100	0.07	5	**0.37**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Middle Sacramento River	0.300	0.09	4	**0.36**	**M**
Deer Creek	0.17	Embryo Incubation	**0.15**	Flow Conditions	0.125	Flow Fluctuations	1.000	0.32	1.00	**0.32**	**M**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.06	5	**0.32**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.06	5	**0.30**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in Deer Creek	0.100	0.04	7	**0.29**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in Deer Creek	0.100	0.04	6	**0.27**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.04	6	**0.27**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.04	6	**0.27**	**M**

Spring-run Chinook Salmon Stressor Matrix - Deer Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Delta	0.300	0.05	5	**0.27**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Lower Sacramento River	0.300	0.05	5	**0.27**	**M**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.05	5	**0.27**	**M**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.100	0.04	6	**0.26**	**M**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.100	0.04	6	**0.26**	**M**
Deer Creek	0.17	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.26	1.00	**0.26**	**M**
Deer Creek	0.17	Embryo Incubation	**0.15**	Water Temperature	0.100	Water Temperature in Deer Creek	1.000	0.26	1.00	**0.26**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Deer Creek	0.200	0.06	4	**0.24**	**M**
Deer Creek	0.17	Spawning	**0.25**	Flow Conditions	0.050	Flow Fluctuations	1.000	0.21	1	**0.21**	**M**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.04	5	**0.21**	**M**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.075	0.03	6	**0.19**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in Deer Creek	0.050	0.04	5	**0.19**	**M**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.03	5	**0.16**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Deer Creek	0.100	0.03	5	**0.15**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.03	5	**0.15**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.100	0.03	5	**0.15**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.100	0.03	5	**0.15**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.100	0.03	5	**0.15**	**M**

Spring-run Chinook Salmon Stressor Matrix - Deer Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.100	0.03	5	**0.15**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Contra Costa Power Plant	0.050	0.02	7	**0.15**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Pittsburg Power Plant	0.050	0.02	7	**0.15**	**M**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Middle Sacramento River	0.150	0.03	5	**0.13**	**L**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.050	0.02	6	**0.13**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Dam(s)	0.200	0.06	2	**0.12**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Delta	0.100	0.03	4	**0.12**	**L**
Deer Creek	0.17	Spawning	**0.25**	Hatchery Effects	0.025	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.11	1	**0.11**	**L**
Deer Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Deer Creek	0.100	0.02	5	**0.11**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Bays	0.100	0.02	5	**0.09**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Deer Creek	0.100	0.02	5	**0.09**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.04	2	**0.07**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.010	Delta	0.600	0.04	2	**0.07**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.02	2	**0.05**	**L**
Deer Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.010	Bays	0.400	0.02	2	**0.05**	**L**
Deer Creek	0.17	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.010	Redd disturbance	1.000	0.03	1.00	**0.03**	**L**

Spring-run Chinook Salmon Stressor Matrix - Feather River

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Feather River	0.13	Adult Immigration and Holding	0.150	Passage Impediments/Barriers	0.400	Fish Barrier/Oroville Dam	0.850	0.66	4	**2.65**	**VH**
Feather River	0.13	Spawning	0.350	Barrier	0.300	Fish Barrier Dam/Oroville Dam - Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	1.37	1	**1.37**	**VH**
Feather River	0.13	Adult Immigration and Holding	0.150	Harvest/Angling Impacts	0.150	Ocean	0.625	0.18	5	**0.91**	**VH**
Feather River	0.13	Spawning	0.350	Hatchery Effects	0.200	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.91	1	**0.91**	**VH**
Feather River	0.13	Spawning	0.350	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply	1.000	0.91	1	**0.91**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.400	0.27	3	**0.82**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Predation	0.125	Predation in the Delta	0.350	0.20	4	**0.80**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Floodplain Habitat	0.125	Delta	0.425	0.24	3	**0.73**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Natural River Morphology	0.150	Delta	0.350	0.24	3	**0.72**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.350	0.24	3	**0.72**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Predation	0.125	Predation in the Feather River	0.300	0.17	4	**0.68**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.325	0.22	3	**0.67**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Natural River Morphology	0.150	Feather River	0.300	0.20	3	**0.61**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Predation	0.125	Predation in the lower Sacramento River	0.250	0.14	4	**0.57**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Riparian Habitat and Instream Cover	0.150	Feather River	0.275	0.19	3	**0.56**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Floodplain Habitat	0.125	Lower Sacramento River	0.325	0.18	3	**0.55**	**VH**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Water Quality	0.075	DO, Ag, Urban, Heavy Metals in the Delta	0.350	0.12	4	**0.48**	**VH**
Feather River	0.13	Spawning	0.350	Spawning Habitat Availability	0.100	Habitat Suitability	1.000	0.46	1	**0.46**	**VH**
Feather River	0.13	Spawning	0.350	Water Temperature	0.100	Water Temperature	1.000	0.46	1	**0.46**	**VH**
Feather River	0.13	Adult Immigration and Holding	0.150	Water Temperature	0.150	Feather River	0.500	0.15	3	**0.44**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Floodplain Habitat	0.125	Feather River	0.250	0.14	3	**0.43**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Water Temperature	0.075	Feather River	0.400	0.14	3	**0.41**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Entrainment	0.050	Individual Diversions in the Delta	0.250	0.06	6	**0.34**	**H**

Spring-run Chinook Salmon Stressor Matrix - Feather River

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Entrainment	0.050	Individual Diversions in the lower Sacramento River	0.250	0.06	6	**0.34**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Entrainment	0.050	Tracy and Banks Pumping Plants	0.250	0.06	6	**0.34**	**H**
Feather River	0.13	Adult Immigration and Holding	0.150	Flow Conditions	0.125	Low Flows - attraction, migratory cues in the Feather River	0.700	0.17	2	**0.34**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.375	0.09	4	**0.34**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Water Quality	0.075	Ag, Urban in the lower Sacramento River	0.250	0.09	4	**0.34**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Water Quality	0.075	Ag, Urban, Heavy Metals in the Bays	0.250	0.09	4	**0.34**	**H**
Feather River	0.13	Embryo Incubation	0.125	Flow Conditions	0.200	Flow Fluctuations, Flooding	1.000	0.33	1.00	**0.33**	**H**
Feather River	0.13	Embryo Incubation	0.125	Harvest/Angling Impacts	0.200	Redd disturbance	1.000	0.33	1.00	**0.33**	**H**
Feather River	0.13	Embryo Incubation	0.125	Short-term Inwater Construction	0.200	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.33	1.00	**0.33**	**H**
Feather River	0.13	Embryo Incubation	0.125	Water Quality	0.200	Water Pollution	1.000	0.33	1.00	**0.33**	**H**
Feather River	0.13	Embryo Incubation	0.125	Water Temperature	0.200	Water Temperature in the Feather River	1.000	0.33	1.00	**0.33**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Water Temperature	0.075	Delta	0.300	0.10	3	**0.31**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Water Temperature	0.075	Lower Sacramento River	0.300	0.10	3	**0.31**	**H**
Feather River	0.13	Adult Immigration and Holding	0.150	Harvest/Angling Impacts	0.150	Feather River	0.200	0.06	5	**0.29**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Entrainment	0.050	Individual Diversions in the Feather River	0.200	0.05	6	**0.27**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.14	2	**0.27**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Tidal Marsh Habitat	0.050	Delta	0.600	0.14	2	**0.27**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.07	4	**0.27**	**H**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Flow Conditions	0.050	Diversion into Central Delta	0.225	0.05	5	**0.26**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Flow Conditions	0.050	Flow Dependent Habitat Availability in the Feather River	0.225	0.05	5	**0.26**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Flow Conditions	0.050	Reverse Flow Conditions	0.225	0.05	5	**0.26**	**M**
Feather River	0.13	Spawning	0.350	Flow Conditions	0.050	Flow Fluctuations	1.000	0.23	1	**0.23**	**M**
Feather River	0.13	Spawning	0.350	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.23	1	**0.23**	**M**

Spring-run Chinook Salmon Stressor Matrix - Feather River

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Passage Impediments/Barriers	0.025	Fish Barrier/Oroville Dam	1.000	0.11	2	**0.23**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Predation	0.125	Predation in the Bays	0.100	0.06	4	**0.23**	**M**
Feather River	0.13	Adult Immigration and Holding	0.150	Water Temperature	0.150	Delta	0.250	0.07	3	**0.22**	**M**
Feather River	0.13	Adult Immigration and Holding	0.150	Water Temperature	0.150	Lower Sacramento River	0.250	0.07	3	**0.22**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Water Quality	0.075	Ag, Urban in the Feather River	0.150	0.05	4	**0.20**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Flow Conditions	0.050	Changes in Delta Hydrology	0.175	0.04	5	**0.20**	**M**
Feather River	0.13	Adult Immigration and Holding	0.150	Water Quality	0.100	Ag, Urban in the Feather River	0.333	0.06	3	**0.19**	**M**
Feather River	0.13	Adult Immigration and Holding	0.150	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.333	0.06	3	**0.19**	**M**
Feather River	0.13	Adult Immigration and Holding	0.150	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.333	0.06	3	**0.19**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.09	2	**0.18**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Loss of Tidal Marsh Habitat	0.050	Bays	0.400	0.09	2	**0.18**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Feather River	0.200	0.05	4	**0.18**	**M**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Flow Conditions	0.050	Flow Dependent Habitat Availability in the lower Sacramento River	0.150	0.03	5	**0.17**	**L**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Hatchery Effects (Competition and Predation)	0.025	Feather River	0.375	0.04	4	**0.17**	**L**
Feather River	0.13	Adult Immigration and Holding	0.150	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.275	0.04	4	**0.16**	**L**
Feather River	0.13	Adult Immigration and Holding	0.150	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.275	0.04	4	**0.16**	**L**
Feather River	0.13	Adult Immigration and Holding	0.150	Passage Impediments/Barriers	0.400	Sacramento Deep Water Ship Channel	0.050	0.04	4	**0.16**	**L**
Feather River	0.13	Adult Immigration and Holding	0.150	Passage Impediments/Barriers	0.400	Suisun Marsh Salinity Control Structure	0.050	0.04	4	**0.16**	**L**
Feather River	0.13	Adult Immigration and Holding	0.150	Passage Impediments/Barriers	0.400	Yolo Bypass - Freemont Weir	0.050	0.04	4	**0.16**	**L**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Hatchery Effects (Competition and Predation)	0.025	Lower Sacramento River	0.325	0.04	4	**0.15**	**L**

Spring-run Chinook Salmon Stressor Matrix - Feather River

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Feather River	0.13	Adult Immigration and Holding	0.150	Flow Conditions	0.125	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.300	0.07	2	**0.15**	**L**
Feather River	0.13	Adult Immigration and Holding	0.150	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.250	0.04	4	**0.15**	**L**
Feather River	0.13	Adult Immigration and Holding	0.150	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the Feather River	0.200	0.03	4	**0.12**	**L**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.125	0.03	4	**0.11**	**L**
Feather River	0.13	Adult Immigration and Holding	0.150	Harvest/Angling Impacts	0.150	Lower Sacramento River	0.075	0.02	5	**0.11**	**L**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Hatchery Effects (Competition and Predation)	0.025	Delta	0.175	0.02	4	**0.08**	**L**
Feather River	0.13	Adult Immigration and Holding	0.150	Harvest/Angling Impacts	0.150	Bays	0.050	0.01	5	**0.07**	**L**
Feather River	0.13	Adult Immigration and Holding	0.150	Harvest/Angling Impacts	0.150	Delta	0.050	0.01	5	**0.07**	**L**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Hatchery Effects (Competition and Predation)	0.025	Bays	0.125	0.01	4	**0.06**	**L**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Entrainment	0.050	Contra Costa Power Plant	0.025	0.01	6	**0.03**	**L**
Feather River	0.13	Juvenile Rearing and Outmigration	0.350	Entrainment	0.050	Pittsburg Power Plant	0.025	0.01	6	**0.03**	**L**

Spring-run Chinook Salmon Stressor Matrix - Mill Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Agricultural Diversion Dam(s) in Mill Creek	0.600	0.64	5	**3.19**	**VH**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Mill Creek	0.700	0.74	4	**2.98**	**VH**
Mill Creek	0.17	Spawning	**0.25**	Water Quality	0.450	Turbidity and Sedimentation in Mill Creek	1.000	1.91	1	**1.91**	**VH**
Mill Creek	0.17	Embryo Incubation	**0.15**	Water Quality	0.665	Turbidity and sedimentation in Mill Creek	1.000	1.70	1.00	**1.70**	**VH**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.525	0.22	6	**1.34**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Lower Sacramento River	0.350	0.33	4	**1.33**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.350	0.33	4	**1.33**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Middle Sacramento River	0.350	0.33	4	**1.33**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.350	0.33	4	**1.33**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Middle Sacramento River	0.350	0.33	4	**1.33**	**VH**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues in Mill Creek	0.600	0.38	3	**1.15**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Delta	0.300	0.29	4	**1.14**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the Delta	0.300	0.22	5	**1.12**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the lower Sacramento River	0.300	0.22	5	**1.12**	**VH**
Mill Creek	0.17	Spawning	**0.25**	Physical Habitat Alteration	0.225	Gravel embeddedness and fines	1.000	0.96	1	**0.96**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the middle Sacramento River	0.250	0.19	5	**0.93**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Diversion into Central Delta	0.300	0.13	6	**0.80**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Middle Sacramento River	0.200	0.19	4	**0.76**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Delta	0.200	0.19	4	**0.76**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.200	0.19	4	**0.76**	**VH**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.13	5	**0.64**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the Delta	0.200	0.08	7	**0.58**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the lower Sacramento River	0.200	0.08	7	**0.58**	**VH**

Spring-run Chinook Salmon Stressor Matrix - Mill Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the middle Sacramento River	0.200	0.08	7	**0.58**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Tracy and Banks Pumping Plants	0.200	0.08	7	**0.58**	**VH**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Mill Creek	0.150	0.14	4	**0.57**	**H**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Changes in Hydrology	0.200	0.09	6	**0.54**	**H**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Reverse Flow Conditions	0.200	0.09	6	**0.54**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.100	0.11	5	**0.53**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.100	0.11	5	**0.53**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.100	0.11	5	**0.53**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.11	5	**0.53**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.11	5	**0.53**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.250	0.11	5	**0.53**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.250	0.11	5	**0.53**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.250	0.11	5	**0.53**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Bay	0.150	0.10	5	**0.48**	**H**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	0.800	0.24	2	**0.48**	**H**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Lower Sacramento River	0.400	0.12	4	**0.48**	**H**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.09	5	**0.45**	**H**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.09	5	**0.45**	**H**
Mill Creek	0.17	Spawning	**0.25**	Harvest/Angling Impacts	0.100	Recreational, Poaching, Angler Impacts	1.000	0.43	1	**0.43**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.09	5	**0.43**	**H**

Spring-run Chinook Salmon Stressor Matrix - Mill Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Delta	0.100	0.11	4	**0.43**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Lower Sacramento River	0.100	0.11	4	**0.43**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Middle Sacramento River	0.100	0.11	4	**0.43**	**H**
Mill Creek	0.17	Spawning	**0.25**	Water Temperature	0.100	Water Temperature in Mill Creek	1.000	0.43	1	**0.43**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.200	0.13	3	**0.38**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.13	3	**0.38**	**H**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Mill Creek	0.150	0.06	6	**0.38**	**H**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Mill Creek	0.100	0.10	4	**0.38**	**H**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Mill Creek	0.100	0.10	4	**0.38**	**H**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the Bays	0.100	0.07	5	**0.37**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Middle Sacramento River	0.300	0.09	4	**0.36**	**M**
Mill Creek	0.17	Embryo Incubation	**0.15**	Flow Conditions	0.125	Flow Fluctuations	1.000	0.32	1.00	**0.32**	**M**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.06	5	**0.32**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.06	5	**0.30**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.200	0.06	5	**0.30**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.200	0.06	5	**0.30**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in Mill Creek	0.200	0.06	5	**0.30**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.200	0.06	5	**0.30**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.200	0.06	5	**0.30**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in Mill Creek	0.100	0.04	7	**0.29**	**M**

Spring-run Chinook Salmon Stressor Matrix - Mill Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in Mill Creek	0.100	0.04	6	**0.27**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.04	6	**0.27**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.04	6	**0.27**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Delta	0.300	0.05	5	**0.27**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Lower Sacramento River	0.300	0.05	5	**0.27**	**M**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.100	0.04	6	**0.26**	**M**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.100	0.04	6	**0.26**	**M**
Mill Creek	0.17	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.26	1.00	**0.26**	**M**
Mill Creek	0.17	Embryo Incubation	**0.15**	Water Temperature	0.100	Water Temperature in Mill Creek	1.000	0.26	1.00	**0.26**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Mill Creek	0.200	0.06	4	**0.24**	**M**
Mill Creek	0.17	Spawning	**0.25**	Flow Conditions	0.050	Flow Fluctuations	1.000	0.21	1	**0.21**	**M**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in Mill Creek	0.100	0.04	5	**0.21**	**M**
Mill Creek	0.17	Spawning	**0.25**	Spawning Habitat Availability	0.050	Habitat Suitability	1.000	0.21	1	**0.21**	**M**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Mill Creek	0.100	0.04	5	**0.21**	**M**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.075	0.03	6	**0.19**	**M**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in Mill Creek	0.050	0.04	5	**0.19**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Mill Creek	0.100	0.03	5	**0.15**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.03	5	**0.15**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Contra Costa Power Plant	0.050	0.02	7	**0.15**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Pittsburg Power Plant	0.050	0.02	7	**0.15**	**L**

Spring-run Chinook Salmon Stressor Matrix - Mill Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Middle Sacramento River	0.150	0.03	5	**0.13**	**L**
Mill Creek	0.17	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.050	0.02	6	**0.13**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Dam(s)	0.200	0.06	2	**0.12**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Delta	0.100	0.03	4	**0.12**	**L**
Mill Creek	0.17	Spawning	**0.25**	Hatchery Effects	0.025	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.11	1	**0.11**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Bays	0.100	0.02	5	**0.09**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.030	Mill Creek	0.100	0.02	5	**0.09**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.04	2	**0.07**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.010	Delta	0.600	0.04	2	**0.07**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.02	2	**0.05**	**L**
Mill Creek	0.17	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.010	Bays	0.400	0.02	2	**0.05**	**L**
Mill Creek	0.17	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.010	Redd disturbance	1.000	0.03	1.00	**0.03**	**L**

Spring-run Chinook Salmon Stressor Matrix - Sacramento River

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	0.43	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Keswick Dam	0.525	1.35	7	**9.48**	**VH**
Sacramento River	0.43	Spawning	0.3	Barrier/Genetics	0.450	Keswick/Shasta Dam	1.000	5.81	1	**5.81**	**VH**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Red Bluff Diversion Dam	0.300	0.77	7	**5.42**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Natural Morphologic Function	0.160	Loss of Natural Morphologic Function in the lower Sacramento River	0.350	0.96	4	**3.85**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Floodplain Habitat	0.160	Loss of Floodplain Habitat in the Delta	0.300	0.83	4	**3.30**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Floodplain Habitat	0.160	Loss of Floodplain Habitat in the lower Sacramento River	0.300	0.83	4	**3.30**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Natural Morphologic Function	0.160	Loss of Natural Morphologic Function in the Delta	0.300	0.83	4	**3.30**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Riparian Habitat and Instream Cover	0.160	Loss of Riparian Habitat and Instream Cover in the Delta	0.300	0.83	4	**3.30**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Riparian Habitat and Instream Cover	0.160	Loss of Riparian Habitat and Instream Cover in the lower Sacramento River	0.300	0.83	4	**3.30**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Predation in the Delta	0.250	0.65	5	**3.23**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Predation in the lower Sacramento River	0.250	0.65	5	**3.23**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the upper Sacramento River	0.400	0.62	5	**3.10**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Non-site specific and structure (GCID, RBDD) related in the middle Sacramento River	0.225	0.58	5	**2.90**	**VH**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Ocean	0.725	0.47	6	**2.81**	**VH**
Sacramento River	0.43	Spawning	0.3	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply in upper Sacramento River	1.000	2.58	1	**2.58**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the middle Sacramento River	0.300	0.46	5	**2.32**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Non-site specific and structure (ACID) related in the upper Sacramento River	0.175	0.45	5	**2.26**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Floodplain Habitat	0.160	Loss of Floodplain Habitat in the middle Sacramento River	0.200	0.55	4	**2.20**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Floodplain Habitat	0.160	Loss of Floodplain Habitat in the upper Sacramento River	0.200	0.55	4	**2.20**	**VH**

Spring-run Chinook Salmon Stressor Matrix - Sacramento River

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Natural Morphologic Function	0.160	Loss of Natural Morphologic Function in the upper Sacramento River	0.200	0.55	4	**2.20**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Riparian Habitat and Instream Cover	0.160	Loss of Riparian Habitat and Instream Cover in the middle Sacramento River	0.200	0.55	4	**2.20**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Riparian Habitat and Instream Cover	0.160	Loss of Riparian Habitat and Instream Cover in the upper Sacramento River	0.200	0.55	4	**2.20**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Individual Diversions in the Delta	0.200	0.24	7	**1.69**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Individual Diversions in the lower Sacramento River	0.200	0.24	7	**1.69**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Individual Diversions in the middle Sacramento River	0.200	0.24	7	**1.69**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Tracy and Banks Pumping Plants	0.200	0.24	7	**1.69**	**VH**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Natural Morphologic Function	0.160	Loss of Natural Morphologic Function in the middle Sacramento River	0.150	0.41	4	**1.65**	**H**
Sacramento River	0.43	Embryo Incubation	0.15	Flow Conditions	0.225	Flow Fluctuations in upper Sacramento River	1.000	1.45	1	**1.45**	**H**
Sacramento River	0.43	Embryo Incubation	0.15	Water Quality	0.225	Water Pollution in upper Sacramento River	1.000	1.45	1	**1.45**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Water Temperature	0.050	Delta	0.400	0.34	4	**1.38**	**H**
Sacramento River	0.43	Spawning	0.3	Flow Conditions	0.100	Flow Fluctuations in upper Sacramento River	1.000	1.29	1	**1.29**	**H**
Sacramento River	0.43	Spawning	0.3	Harvest/Angling Impacts	0.100	Upper Sacramento River	1.000	1.29	1	**1.29**	**H**
Sacramento River	0.43	Embryo Incubation	0.15	Water Temperature	0.200	Water Temperature in upper Sacramento River	1.000	1.29	1	**1.29**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Predation in the Bay	0.100	0.26	5	**1.29**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.300	0.26	5	**1.29**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.300	0.26	5	**1.29**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	Urban, Heavy Metals in the upper Sacramento River	0.300	0.26	5	**1.29**	**H**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.250	0.24	5	**1.21**	**H**

Spring-run Chinook Salmon Stressor Matrix - Sacramento River

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	0.43	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.24	5	**1.21**	**H**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.250	0.24	5	**1.21**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.275	0.24	5	**1.18**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.275	0.24	5	**1.18**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.275	0.24	5	**1.18**	**H**
Sacramento River	0.43	Embryo Incubation	0.15	Harvest/Angling Impacts	0.175	Redd disturbance in upper Sacramento River	1.000	1.13	1.00	**1.13**	**H**
Sacramento River	0.43	Embryo Incubation	0.15	Short-term Inwater Construction	0.175	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	1.13	1	**1.13**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Water Temperature	0.050	Lower Sacramento River	0.300	0.26	4	**1.03**	**H**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Water Temperature	0.125	Lower Sacramento River	0.400	0.32	3	**0.97**	**H**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Water Temperature	0.125	Middle Sacramento River	0.400	0.32	3	**0.97**	**H**
Sacramento River	0.43	Spawning	0.3	Spawning Habitat Availability	0.075	Habitat Suitability in in upper Sacramento River	1.000	0.97	1	**0.97**	**H**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Water Quality	0.125	DO, Ag, Urban, Heavy Metals in the Delta	0.300	0.24	4	**0.97**	**H**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Changes in Delta Hydrology	0.300	0.15	6	**0.93**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Reverse Flow Conditions in the Delta	0.300	0.15	6	**0.93**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Yolo Bypass-Freemont Weir	0.050	0.13	7	**0.90**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Individual Diversions in the upper Sacramento River	0.100	0.12	7	**0.84**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the Bays	0.100	0.15	5	**0.77**	**M**

Spring-run Chinook Salmon Stressor Matrix - Sacramento River

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the Delta	0.100	0.15	5	**0.77**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the lower Sacramento River	0.100	0.15	5	**0.77**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Diversion into Central Delta	0.250	0.13	6	**0.77**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.15	5	**0.73**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Water Temperature	0.050	Middle Sacramento River	0.200	0.17	4	**0.69**	**M**
Sacramento River	0.43	Spawning	0.3	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in upper Sacramento River	1.000	0.65	1	**0.65**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Water Quality	0.125	Ag, Urban in the lower Sacramento River	0.200	0.16	4	**0.65**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Water Quality	0.125	Ag, Urban in the middle Sacramento River	0.200	0.16	4	**0.65**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Water Quality	0.125	Urban, Heavy Metals in the upper Sacramento River	0.200	0.16	4	**0.65**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.333	0.21	3	**0.64**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues in Middle Sacramento River	0.333	0.21	3	**0.64**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues in Upper Sacramento River	0.333	0.21	3	**0.64**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Sacramento Deep Water Ship Channel	0.035	0.09	7	**0.63**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Suisun Marsh Salinity Control Structure	0.035	0.09	7	**0.63**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Sutter Bypass - Tisdale Weir	0.035	0.09	7	**0.63**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.10	5	**0.48**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.09	5	**0.43**	**M**

Spring-run Chinook Salmon Stressor Matrix - Sacramento River

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Contra Costa Power Plant	0.050	0.06	7	**0.42**	**M**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Pittsburg Power Plant	0.050	0.06	7	**0.42**	**M**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Upper Sacramento River	0.100	0.06	6	**0.39**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.090	0.08	5	**0.39**	**L**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	ACID Dam	0.020	0.05	7	**0.36**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Water Temperature	0.050	Upper Sacramento River	0.100	0.09	4	**0.34**	**L**
Sacramento River	0.43	Spawning	0.3	Water Temperature	0.025	Upper Sacramento River	1.000	0.32	1	**0.32**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.075	0.06	5	**0.32**	**L**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.075	0.05	6	**0.29**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Invasive species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, water hyacinth etc. in the Delta	0.800	0.14	2	**0.28**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Tidal Marsh Habitat	0.010	Loss of Tidal Marsh Habitat in the Delta	0.800	0.14	2	**0.28**	**L**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Water Temperature	0.125	Delta	0.100	0.08	3	**0.24**	**L**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Water Temperature	0.125	Upper Sacramento River	0.100	0.08	3	**0.24**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Passage Impediments/Barriers	0.010	Keswick Dam	0.400	0.07	3	**0.21**	**L**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.050	0.03	6	**0.19**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Flow Dependent Habitat Availability in the lower Sacramento River	0.050	0.03	6	**0.15**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Flow Dependent Habitat Availability in the middle Sacramento River	0.050	0.03	6	**0.15**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Flow Dependent Habitat Availability in the upper Sacramento River	0.050	0.03	6	**0.15**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Passage Impediments/Barriers	0.010	ACID Dam	0.300	0.05	3	**0.15**	**L**

Spring-run Chinook Salmon Stressor Matrix - Sacramento River

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Passage Impediments/Barriers	0.010	Tributary Barriers	0.300	0.05	3	**0.15**	**L**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Bays	0.025	0.02	6	**0.10**	**L**
Sacramento River	0.43	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Delta	0.025	0.02	6	**0.10**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Invasive species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, water hyacinth etc. in the Bays	0.200	0.03	2	**0.07**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Loss of Tidal Marsh Habitat	0.010	Loss of Tidal Marsh Habitat in the Bays	0.200	0.03	2	**0.07**	**L**
Sacramento River	0.43	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.010	0.01	5	**0.04**	**L**

Spring-run Chinook Salmon Stressor Matrix - Thomes Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Ag Diversion Dams, Braiding, Natural Channel Gradient	0.750	1.17	5	**5.86**	**VH**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Thomes Creek	0.700	1.31	4	**5.25**	**VH**
Thomes Creek	0.25	Spawning	**0.25**	Spawning Habitat Availability	0.400	Habitat Suitability	1.000	2.50	1	**2.50**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.350	0.46	4	**1.84**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Middle Sacramento River	0.350	0.46	4	**1.84**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Delta	0.300	0.39	4	**1.58**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.300	0.39	4	**1.58**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Delta	0.300	0.39	4	**1.58**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.300	0.39	4	**1.58**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Tracy and Banks Pumping Plants	0.250	0.22	7	**1.53**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Delta	0.300	0.26	5	**1.31**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the lower Sacramento River	0.300	0.26	5	**1.31**	**VH**
Thomes Creek	0.25	Spawning	**0.25**	Water Temperature	0.200	Water Temperature in Thomes Creek	1.000	1.25	1	**1.25**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the Delta	0.200	0.18	7	**1.23**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the lower Sacramento River	0.200	0.18	7	**1.23**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the middle Sacramento River	0.200	0.18	7	**1.23**	**VH**
Thomes Creek	0.25	Embryo Incubation	**0.15**	Water Temperature	0.300	Water Temperature in Thomes Creek	1.000	1.13	1.00	**1.13**	**VH**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.300	0.19	6	**1.13**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the middle Sacramento River	0.250	0.22	5	**1.09**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Thomes Creek	0.200	0.26	4	**1.05**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Middle Sacramento River	0.200	0.26	4	**1.05**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Thomes Creek	0.200	0.26	4	**1.05**	**VH**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Middle Sacramento River	0.200	0.26	4	**1.05**	**VH**

Spring-run Chinook Salmon Stressor Matrix - Thomes Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.200	0.26	4	**1.05**	**VH**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.19	5	**0.94**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.19	5	**0.94**	**H**
Thomes Creek	0.25	Embryo Incubation	**0.15**	Watershed disturbance	0.250	Sedimentation	1.000	0.94	1.00	**0.94**	**H**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.39	2	**0.79**	**H**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Delta	0.600	0.39	2	**0.79**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.16	5	**0.78**	**H**
Thomes Creek	0.25	Embryo Incubation	**0.15**	Flow Conditions	0.200	Flow Fluctuations	1.000	0.75	1.00	**0.75**	**H**
Thomes Creek	0.25	Embryo Incubation	**0.15**	Water Quality	0.200	Water Quality in Thomes Creek	1.000	0.75	1.00	**0.75**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.400	0.25	3	**0.75**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues in the middle Sacramento River	0.400	0.25	3	**0.75**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.300	0.19	4	**0.75**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.300	0.19	4	**0.75**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.300	0.19	4	**0.75**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Delta	0.100	0.19	4	**0.75**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Lower Sacramento River	0.100	0.19	4	**0.75**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Middle Sacramento River	0.100	0.19	4	**0.75**	**H**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.13	5	**0.66**	**H**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.13	5	**0.66**	**H**

Spring-run Chinook Salmon Stressor Matrix - Thomes Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Thomes Creek	0.25	Spawning	**0.25**	Barrier	0.100	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.63	1	**0.63**	**H**
Thomes Creek	0.25	Spawning	**0.25**	Flow Conditions	0.100	Flow Fluctuations	1.000	0.63	1	**0.63**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.13	5	**0.63**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.150	0.09	6	**0.56**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.150	0.09	6	**0.56**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.150	0.09	6	**0.56**	**H**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.150	0.09	6	**0.56**	**H**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.26	2	**0.53**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Thomes Creek	0.100	0.13	4	**0.53**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Bays	0.400	0.26	2	**0.53**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in Thomes Creek	0.100	0.09	5	**0.44**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.09	5	**0.44**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	1.000	0.44	1	**0.44**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Thomes Creek	0.500	0.11	4	**0.44**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Diversion into Central Delta	0.300	0.07	6	**0.39**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.050	0.08	5	**0.39**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.050	0.08	5	**0.39**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.050	0.08	5	**0.39**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues in Thomes Creek	0.200	0.13	3	**0.38**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Thomes Creek	0.100	0.06	6	**0.38**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Delta	0.300	0.07	5	**0.33**	**M**

Spring-run Chinook Salmon Stressor Matrix - Thomes Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Lower Sacramento River	0.300	0.07	5	**0.33**	**M**
Thomes Creek	0.25	Spawning	**0.25**	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.31	1	**0.31**	**M**
Thomes Creek	0.25	Spawning	**0.25**	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.31	1	**0.31**	**M**
Thomes Creek	0.25	Spawning	**0.25**	Water Quality	0.050	Water Quality in Thomes Creek	1.000	0.31	1	**0.31**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in Thomes Creek	0.100	0.06	5	**0.31**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.100	0.06	5	**0.31**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Contra Costa Power Plant	0.050	0.04	7	**0.31**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in Thomes Creek	0.050	0.04	7	**0.31**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Pittsburg Power Plant	0.050	0.04	7	**0.31**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Changes in Hydrology	0.200	0.04	6	**0.26**	**M**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Reverse Flow Conditions	0.200	0.04	6	**0.26**	**M**
Thomes Creek	0.25	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in Thomes Creek	0.100	0.06	4	**0.25**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Bays	0.050	0.04	5	**0.22**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Thomes Creek	0.100	0.04	5	**0.22**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.04	5	**0.22**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the lower Sacramento River	0.200	0.04	5	**0.22**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the middle Sacramento River	0.200	0.04	5	**0.22**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in Thomes Creek	0.200	0.04	5	**0.22**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban, Heavy Metals in the Bays	0.200	0.04	5	**0.22**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	DO, Ag, Urban, Heavy Metals in the Delta	0.200	0.04	5	**0.22**	**L**
Thomes Creek	0.25	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.050	Redd disturbance	1.000	0.19	1.00	**0.19**	**L**

Spring-run Chinook Salmon Stressor Matrix - Thomes Creek

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Lower Sacramento River	0.200	0.04	4	**0.18**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Middle Sacramento River	0.200	0.04	4	**0.18**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Middle Sacramento River	0.150	0.03	5	**0.16**	**L**
Thomes Creek	0.25	Spawning	**0.25**	Physical Habitat Alteration	0.050	Limited Instream Gravel Supply	0.500	0.16	1	**0.16**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in Thomes Creek	0.100	0.02	6	**0.13**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.02	6	**0.13**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.02	6	**0.13**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Bays	0.100	0.02	5	**0.11**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects (Competition and Predation)	0.025	Thomes Creek	0.100	0.02	5	**0.11**	**L**
Thomes Creek	0.25	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Delta	0.100	0.02	4	**0.09**	**L**

Spring-run Chinook Salmon Stressor Matrix - Yuba River

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Yuba River	0.14	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Englebright Dam	0.650	0.55	5	**2.73**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Natural River Morphology	0.150	Yuba River	0.350	0.31	4	**1.25**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Riparian Habitat and Instream Cover	0.150	Yuba River	0.350	0.31	4	**1.25**	**VH**
Yuba River	0.14	Spawning	0.275	Barrier	0.300	Englebright Dam - Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	1.16	1	**1.16**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Floodplain Habitat	0.125	Delta	0.375	0.28	4	**1.12**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Predation in the Delta	0.300	0.22	5	**1.12**	**VH**
Yuba River	0.14	Embryo Incubation	0.15	Flow Conditions	0.525	Flow Fluctuations, Flood Events	1.000	1.10	1.00	**1.10**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.300	0.27	4	**1.07**	**VH**
Yuba River	0.14	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Ocean	0.525	0.17	6	**0.99**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Predation in the Yuba River	0.250	0.19	5	**0.93**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Natural River Morphology	0.150	Delta	0.250	0.22	4	**0.89**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.250	0.22	4	**0.89**	**VH**
Yuba River	0.14	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Daguerre Point Dam	0.200	0.17	5	**0.84**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Individual Diversions in the Yuba River and DPD	0.250	0.11	7	**0.78**	**VH**
Yuba River	0.14	Spawning	0.275	Hatchery Effects	0.200	Redd superimposition, competition for habitat, genetic integrity	1.000	0.77	1	**0.77**	**VH**
Yuba River	0.14	Spawning	0.275	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply	1.000	0.77	1	**0.77**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Predation in the Feather River	0.200	0.15	5	**0.74**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Predation in the lower Sacramento River	0.200	0.15	5	**0.74**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Floodplain Habitat	0.125	Lower Sacramento River	0.250	0.19	4	**0.74**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.200	0.18	4	**0.71**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Individual Diversions in the Delta	0.200	0.09	7	**0.62**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Individual Diversions in the lower Sacramento River	0.200	0.09	7	**0.62**	**VH**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Tracy and Banks Pumping Plants	0.200	0.09	7	**0.62**	**VH**

Spring-run Chinook Salmon Stressor Matrix - Yuba River

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Floodplain Habitat	0.125	Yuba River	0.200	0.15	4	**0.60**	**VH**
Yuba River	0.14	Spawning	0.275	Spawning Habitat Availability	0.150	Habitat Suitability	1.000	0.58	1	**0.58**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Natural River Morphology	0.150	Feather River	0.150	0.13	4	**0.54**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Riparian Habitat and Instream Cover	0.150	Feather River	0.150	0.13	4	**0.54**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Water Temperature	0.075	Delta	0.300	0.13	4	**0.54**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Water Temperature	0.075	Feather River	0.300	0.13	4	**0.54**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Water Temperature	0.075	Lower Sacramento River	0.300	0.13	4	**0.54**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Floodplain Habitat	0.125	Feather River	0.175	0.13	4	**0.52**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.350	0.10	5	**0.52**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.350	0.10	5	**0.52**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Flow Conditions	0.050	Flow Dependent Habitat Availability in the Yuba River	0.225	0.07	6	**0.40**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.07	5	**0.37**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.250	0.07	5	**0.37**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.250	0.07	5	**0.37**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Flow Conditions	0.050	Diversion into Central Delta	0.200	0.06	6	**0.36**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Flow Conditions	0.050	Reverse Flow Conditions	0.200	0.06	6	**0.36**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, water hyacinth, etc. in the Delta	0.600	0.18	2	**0.36**	**H**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Tidal Marsh Habitat	0.050	Delta	0.600	0.18	2	**0.36**	**H**
Yuba River	0.14	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Yuba River	0.175	0.06	6	**0.33**	**H**
Yuba River	0.14	Adult Immigration and Holding	0.15	Water Temperature	0.125	Feather River	0.300	0.08	4	**0.32**	**H**
Yuba River	0.14	Adult Immigration and Holding	0.15	Water Temperature	0.125	Lower Sacramento River	0.300	0.08	4	**0.32**	**H**

Spring-run Chinook Salmon Stressor Matrix - Yuba River

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Individual Diversions in the Feather River	0.100	0.04	7	**0.31**	**H**
Yuba River	0.14	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.225	0.06	5	**0.30**	**H**
Yuba River	0.14	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.225	0.06	5	**0.30**	**H**
Yuba River	0.14	Spawning	0.275	Flow Conditions	0.075	Flow Fluctuations	1.000	0.29	1	**0.29**	**H**
Yuba River	0.14	Adult Immigration and Holding	0.15	Water Temperature	0.125	Delta	0.275	0.07	4	**0.29**	**H**
Yuba River	0.14	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues in the Yuba River	0.450	0.09	3	**0.28**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Flow Conditions	0.050	Changes in Delta Hydrology	0.150	0.04	6	**0.27**	**M**
Yuba River	0.14	Embryo Incubation	0.15	Harvest/Angling Impacts	0.125	Redd disturbance	1.000	0.26	1.00	**0.26**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.05	5	**0.26**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Yuba River	0.200	0.05	5	**0.26**	**M**
Yuba River	0.14	Embryo Incubation	0.15	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.26	1.00	**0.26**	**M**
Yuba River	0.14	Embryo Incubation	0.15	Water Quality	0.125	Water Pollution above Daguerre Point Dam	1.000	0.26	1.00	**0.26**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Hatchery Effects (Competition and Predation)	0.025	Feather River	0.350	0.05	5	**0.26**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues in the Feather River	0.400	0.08	3	**0.25**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.12	2	**0.24**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Loss of Tidal Marsh Habitat	0.050	Bays	0.400	0.12	2	**0.24**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Flow Conditions	0.050	Flow Dependent Habitat Availability in the lower Sacramento River	0.125	0.04	6	**0.22**	**M**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Feather River	0.150	0.04	5	**0.22**	**M**

Spring-run Chinook Salmon Stressor Matrix - Yuba River

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Yuba River	0.150	0.04	5	**0.22**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Sacramento Deep Water Ship Channel	0.050	0.04	5	**0.21**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Suisun Marsh Salinity Control Structure	0.050	0.04	5	**0.21**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Yolo Bypass - Freemont Weir	0.050	0.04	5	**0.21**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Water Quality	0.100	Ag, Urban in the Feather River	0.250	0.05	4	**0.21**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.250	0.05	4	**0.21**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.250	0.05	4	**0.21**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Water Quality	0.100	Yuba River	0.250	0.05	4	**0.21**	**M**
Yuba River	0.14	Embryo Incubation	0.15	Water Temperature	0.100	Water Temperature above Daguerre Point Dam	1.000	0.21	1.00	**0.21**	**M**
Yuba River	0.14	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Feather River	0.150	0.04	5	**0.20**	**L**
Yuba River	0.14	Spawning	0.275	Water Temperature	0.050	Water Temperature in the Yuba River	1.000	0.19	1	**0.19**	**L**
Yuba River	0.14	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Delta	0.100	0.03	6	**0.19**	**L**
Yuba River	0.14	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Lower Sacramento River	0.100	0.03	6	**0.19**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Hatchery Effects (Competition and Predation)	0.025	Lower Sacramento River	0.250	0.04	5	**0.19**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Hatchery Effects (Competition and Predation)	0.025	Yuba River	0.250	0.04	5	**0.19**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Predation in the Bay	0.050	0.04	5	**0.19**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Flow Conditions	0.050	Flow Dependent Habitat Availability in the Feather River	0.100	0.03	6	**0.18**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Passage Impediments/Barriers	0.025	Daguerre Point Dam	0.600	0.09	2	**0.18**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Water Temperature	0.075	Yuba River	0.100	0.04	4	**0.18**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.03	5	**0.15**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Water Quality	0.050	Ag, Urban in the Feather River	0.100	0.03	5	**0.15**	**L**

Spring-run Chinook Salmon Stressor Matrix - Yuba River

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Yuba River	0.14	Adult Immigration and Holding	0.15	Water Temperature	0.125	Yuba River	0.125	0.03	4	**0.13**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Passage Impediments/Barriers	0.025	Englebright Dam	0.400	0.06	2	**0.12**	**L**
Yuba River	0.14	Spawning	0.275	Harvest/Angling Impacts	0.025	Recreational, Poaching, Angler Impacts	1.000	0.10	1	**0.10**	**L**
Yuba River	0.14	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.150	0.03	3	**0.09**	**L**
Yuba River	0.14	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Bays	0.050	0.02	6	**0.09**	**L**
Yuba River	0.14	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Feather River	0.050	0.02	6	**0.09**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Contra Costa Power Plant	0.025	0.01	7	**0.08**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Pittsburg Power Plant	0.025	0.01	7	**0.08**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Hatchery Effects (Competition and Predation)	0.025	Delta	0.100	0.01	5	**0.07**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Water Quality	0.050	Yuba River	0.050	0.01	5	**0.07**	**L**
Yuba River	0.14	Juvenile Rearing and Outmigration	0.425	Hatchery Effects (Competition and Predation)	0.025	Bays	0.050	0.01	5	**0.04**	**L**

Attachment C to Appendix B

Steelhead Threats Matrices

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Northern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Passage Impediments/Barriers	0.850	Impediments/Barriers in the Auburn Ravine and Coon Creek drainage	0.990	2.356	3	**7.07**	**VH**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Agricultural Diversion Dam(s) in Deer Creek	0.600	0.49	5	**2.44**	**VH**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Agricultural Diversion Dam(s) in Mill Creek	0.600	0.49	5	**2.44**	**VH**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Antelope Creek	0.700	0.58	4	**2.31**	**VH**
Bear River	0.06	Adult Immigration and Holding	0.20	Water Temperature	0.500	Bear River	0.950	0.570	4	**2.28**	**VH**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Deer Creek	0.700	0.57	4	**2.28**	**VH**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Mill Creek	0.700	0.57	4	**2.28**	**VH**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Agricultural Diversion Dam(s) in Antelope Creek	0.600	0.45	5	**2.25**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Individual or Terminal Diversions and loss of channel connectivity in Antelope Creek	0.500	0.32	7	**2.21**	**VH**
Yuba River	0.11	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Englebright Dam	0.650	0.43	5	**2.15**	**VH**
Feather River	0.10	Adult Immigration and Holding	0.150	Passage Impediments/Barriers	0.400	Fish Barrier/Oroville Dam	0.850	0.51	4	**2.04**	**VH**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Iron Canyon, City of Chico Swimming Holes and Associated Dams	0.750	0.38	5	**1.88**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.300	Flow Dependent Habitat Availability in the Bear River	0.550	0.297	6	**1.78**	**VH**
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.450	Impediments/Barriers in the Dry Creek drainage	0.900	0.567	3	**1.70**	**VH**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Big Chico Creek	0.700	0.42	4	**1.68**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.250	Bear River	0.850	0.383	4	**1.53**	**VH**
Bear River	0.06	Adult Immigration and Holding	0.20	Flow Conditions	0.450	Low Flows - attraction, migratory cues in the Bear River	0.850	0.459	3	**1.38**	**VH**
Mill Creek	0.13	Embryo Incubation	**0.15**	Water Quality	0.665	Turbidity and sedimentation in Mill Creek	1.000	1.30	1.00	**1.30**	**VH**
Deer Creek	0.13	Embryo Incubation	**0.15**	Water Quality	0.665	Turbidity, sedimentation, hazardous spills (HWY 32) in Deer Creek	1.000	1.30	1.00	**1.30**	**VH**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Water Quality	0.200	Ag, Urban in the Dry Creek drainage	0.700	0.294	4	**1.18**	**VH**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Butte Creek	0.800	0.39	3	**1.16**	**VH**
American River	0.06	Spawning	0.40	Barrier	0.450	Historical spawning habitat blocked	1.000	1.080	1	**1.08**	**VH**

Northern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in Antelope Creek	0.600	0.36	3	**1.08**	**VH**
Feather River	0.10	Spawning	0.350	Barrier	0.300	Fish Barrier Dam/Oroville Dam - Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	1.05	1	**1.05**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Lower Sacramento River	0.350	0.25	4	**1.02**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Lower Sacramento River	0.350	0.25	4	**1.02**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.350	0.25	4	**1.02**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.350	0.25	4	**1.02**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Middle Sacramento River	0.350	0.25	4	**1.02**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Middle Sacramento River	0.350	0.25	4	**1.02**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.350	0.25	4	**1.02**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.350	0.25	4	**1.02**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Middle Sacramento River	0.350	0.25	4	**1.02**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Middle Sacramento River	0.350	0.25	4	**1.02**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Natural River Morphology	0.150	Yuba River	0.350	0.25	4	**0.98**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Riparian Habitat and Instream Cover	0.150	Yuba River	0.350	0.25	4	**0.98**	**VH**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.150	Deer Creek	0.400	0.20	5	**0.98**	**VH**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Butte Creek Diversion Dams and Weirs	0.600	0.16	6	**0.95**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Lower Sacramento River	0.350	0.24	4	**0.94**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.350	0.24	4	**0.94**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.350	0.24	4	**0.94**	**VH**
Yuba River	0.11	Spawning	0.275	Barrier	0.300	Englebright Dam - Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.91	1	**0.91**	**VH**
Deer Creek	0.13	Spawning	**0.25**	Hatchery Effects	0.275	Put-and-take rainbow trout fishery in upper Deer Creek, Genetic Integrity	1.000	0.89	1	**0.89**	**VH**

Northern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.13	Spawning	**0.25**	Hatchery Effects	0.275	Stocked trout fishery in upper Mill Creek drainage competition for habitat, Genetic Integrity	1.000	0.89	1	**0.89**	**VH**
Mill Creek	0.13	Spawning	**0.25**	Water Quality	0.275	Turbidity and Sedimentation in Mill Creek	1.000	0.89	1	**0.89**	**VH**
American River	0.06	Adult Immigration and Holding	0.10	Passage Impediments/Barriers	0.500	Nimbus/Folsom Dams	0.980	0.294	3	**0.88**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.200	American River	0.700	0.294	3	**0.88**	**VH**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues in Deer Creek	0.600	0.29	3	**0.88**	**VH**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues in Mill Creek	0.600	0.29	3	**0.88**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Floodplain Habitat	0.125	Delta	0.375	0.22	4	**0.88**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Non-site specific and structure related in the Delta	0.300	0.18	5	**0.88**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Delta	0.300	0.22	4	**0.87**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Delta	0.300	0.22	4	**0.87**	**VH**
Yuba River	0.11	Embryo Incubation	0.15	Flow Conditions	0.525	Flow Fluctuations, Flood Events	1.000	0.87	1.00	**0.87**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Non-site specific and structure related in the Delta	0.300	0.17	5	**0.85**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Non-site specific and structure related in the Delta	0.300	0.17	5	**0.85**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Non-site specific and structure related in the lower Sacramento River	0.300	0.17	5	**0.85**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Non-site specific and structure related in the lower Sacramento River	0.300	0.17	5	**0.85**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.300	0.21	4	**0.84**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Delta	0.300	0.20	4	**0.81**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Antelope Creek	0.300	0.20	4	**0.81**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.300	0.20	4	**0.81**	**VH**
Big Chico Creek	0.08	Spawning	**0.25**	Spawning Habitat Availability	0.400	Habitat Suitability	1.000	0.80	1	**0.80**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Non-site specific and structure related in the Delta	0.300	0.16	5	**0.79**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Non-site specific and structure related in the lower Sacramento River	0.300	0.16	5	**0.79**	**VH**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.400	0.13	6	**0.78**	**VH**

Northern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.400	0.13	6	**0.78**	**VH**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.150	Dry Creek drainage	0.800	0.252	3	**0.76**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Predation	0.150	Non-site specific and structure related in the American River	0.600	0.189	4	**0.76**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Spawning	0.30	Passage Impediments/Barriers	0.350	Impediments/Barriers in the Auburn Ravine and Coon Creek drainage	1.000	0.735	1	**0.74**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Non-site specific and structure related in the Yuba River	0.250	0.15	5	**0.73**	**VH**
Antelope Creek	0.12	Embryo Incubation	**0.15**	Water Quality	0.400	Turbidity, sedimentation in Antelope Creek	1.000	0.72	1.00	**0.72**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Non-site specific and structure related in the middle Sacramento River	0.250	0.14	5	**0.71**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Non-site specific and structure related in the middle Sacramento River	0.250	0.14	5	**0.71**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.150	American River	0.750	0.236	3	**0.71**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Natural River Morphology	0.150	Delta	0.250	0.18	4	**0.70**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.250	0.18	4	**0.70**	**VH**
Feather River	0.10	Spawning	0.350	Hatchery Effects	0.200	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.70	1	**0.70**	**VH**
Feather River	0.10	Spawning	0.350	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply	1.000	0.70	1	**0.70**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban, Hazardous Spills (Hwy 32) in Deer Creek	0.600	0.14	5	**0.68**	**VH**
Antelope Creek	0.12	Spawning	**0.25**	Hatchery Effects	0.225	Stocked trout fishery in upper Antelope drainage - competition for habitat, genetic integrity	1.000	0.68	1	**0.68**	**VH**
Yuba River	0.11	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Daguerre Point Dam	0.200	0.13	5	**0.66**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Non-site specific and structure related in the middle Sacramento River	0.250	0.13	5	**0.66**	**VH**
Deer Creek	0.13	Spawning	**0.25**	Spawning Habitat Availability	0.200	Habitat Availability	1.000	0.65	1	**0.65**	**VH**
Deer Creek	0.13	Spawning	**0.25**	Water Quality	0.200	Turbidity, Sedimentation, Hazardous Spills (Hwy 32) in Deer Creek	1.000	0.65	1	**0.65**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Entrainment	0.200	Individual Diversions in the Auburn Ravine and Coon Creek drainage	0.450	0.126	5	**0.63**	**VH**

Northern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Flow Conditions	0.150	Flow Dependent Habitat Availability in the Auburn Ravine and Coon Creek drainage	0.600	0.126	5	**0.63**	**VH**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.100	Flow Dependent Habitat Availability in the Dry Creek drainage	0.600	0.126	5	**0.63**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.400	0.21	3	**0.63**	**VH**
Bear River	0.06	Spawning	0.30	Flow Conditions	0.350	Flow Fluctuations	1.000	0.630	1	**0.63**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in Antelope Creek	0.600	0.13	5	**0.63**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Diversion into Central Delta	0.300	0.10	6	**0.61**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Diversion into Central Delta	0.300	0.10	6	**0.61**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Individual Diversions in the Yuba River and DPD	0.250	0.09	7	**0.61**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Predation	0.125	Non-site specific and structure related in the Delta	0.350	0.15	4	**0.61**	**VH**
Yuba River	0.11	Spawning	0.275	Hatchery Effects	0.200	Redd superimposition, competition for habitat, genetic integrity	1.000	0.61	1	**0.61**	**VH**
Yuba River	0.11	Spawning	0.275	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply	1.000	0.61	1	**0.61**	**VH**
Antelope Creek	0.12	Spawning	**0.25**	Physical Habitat Alteration	0.200	Gravel embeddedness and fines	1.000	0.60	1	**0.60**	**VH**
Antelope Creek	0.12	Spawning	**0.25**	Water Quality	0.200	Turbidity, Sedimentation in Antelope Creek	1.000	0.60	1	**0.60**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Individual Diversions in the Bear River	0.950	0.086	7	**0.60**	**VH**
Yuba River	0.11	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Ocean	0.400	0.10	6	**0.59**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.350	0.15	4	**0.59**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Middle Sacramento River	0.350	0.15	4	**0.59**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Non-site specific and structure related in the Feather River	0.200	0.12	5	**0.58**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Non-site specific and structure related in the lower Sacramento River	0.200	0.12	5	**0.58**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Floodplain Habitat	0.125	Lower Sacramento River	0.250	0.15	4	**0.58**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Middle Sacramento River	0.200	0.15	4	**0.58**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Middle Sacramento River	0.200	0.15	4	**0.58**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Delta	0.200	0.15	4	**0.58**	**VH**

Northern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Delta	0.200	0.15	4	**0.58**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.200	0.15	4	**0.58**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.200	0.15	4	**0.58**	**VH**
Mill Creek	0.13	Spawning	**0.25**	Physical Habitat Alteration	0.175	Gravel embeddedness and fines	1.000	0.57	1	**0.57**	**VH**
Deer Creek	0.13	Spawning	**0.25**	Physical Habitat Alteration	0.175	Gravel embeddedness and fines	1.000	0.57	1	**0.57**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Diversion into Central Delta	0.300	0.09	6	**0.57**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.200	0.14	4	**0.56**	**VH**
Dry Creek drainage (Sacramento Region)	0.07	Spawning	0.40	Barrier	0.200	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.560	1	**0.56**	**VH**
Dry Creek drainage (Sacramento Region)	0.07	Spawning	0.40	Spawning Habitat Availability	0.200	Habitat Suitability	1.000	0.560	1	**0.56**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Floodplain Habitat	0.125	Delta	0.425	0.19	3	**0.56**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Natural River Morphology	0.150	Delta	0.350	0.18	3	**0.55**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.350	0.18	3	**0.55**	**VH**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.300	0.09	6	**0.54**	**VH**
Bear River	0.06	Embryo Incubation	0.20	Water Temperature	0.450	Water Temperature in the Bear River	1.000	0.540	1	**0.54**	**VH**
Antelope Creek	0.12	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.300	Sedimentation, turbidity, physical disturbance	1.000	0.54	1.00	**0.54**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Middle Sacramento River	0.200	0.13	4	**0.54**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Delta	0.200	0.13	4	**0.54**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Antelope Creek	0.200	0.13	4	**0.54**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	American River	0.500	0.105	5	**0.53**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Predation	0.125	Non-site specific and structure related in the Feather River	0.300	0.13	4	**0.53**	**VH**
Antelope Creek	0.12	Spawning	**0.25**	Spawning Habitat Availability	0.175	Habitat Availability	1.000	0.53	1	**0.53**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Predation	0.150	Non-site specific and structure related in the Delta	0.350	0.13	4	**0.51**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.050	Deer Creek	0.450	0.10	5	**0.51**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.325	0.17	3	**0.51**	**VH**

Northern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Flow Conditions	0.100	Low Flows - attraction, migratory cues in the Auburn Ravine and Coon Creek drainage	0.900	0.252	2	**0.50**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Delta	0.300	0.13	4	**0.50**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.300	0.13	4	**0.50**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Delta	0.300	0.13	4	**0.50**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.300	0.13	4	**0.50**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Delta	0.425	0.17	3	**0.50**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Individual Diversions in the Delta	0.200	0.07	7	**0.49**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Individual Diversions in the lower Sacramento River	0.200	0.07	7	**0.49**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Jones and Banks Pumping Plants	0.200	0.07	7	**0.49**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Jones and Banks Pumping Plants	0.250	0.07	7	**0.49**	**VH**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.10	5	**0.49**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Loss of Floodplain Habitat	0.075	Bear River	0.600	0.081	6	**0.49**	**VH**
Bear River	0.06	Embryo Incubation	0.20	Flow Conditions	0.400	Flow Fluctuations	1.000	0.480	1	**0.48**	**VH**
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Water Temperature	0.150	Dry Creek drainage	0.750	0.158	3	**0.47**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Natural River Morphology	0.150	Feather River	0.300	0.16	3	**0.47**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.400	0.16	3	**0.47**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Delta	0.425	0.16	3	**0.47**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Floodplain Habitat	0.125	Yuba River	0.200	0.12	4	**0.47**	**VH**
Yuba River	0.11	Spawning	0.275	Spawning Habitat Availability	0.150	Habitat Suitability	1.000	0.45	1	**0.45**	**VH**
Feather River	0.10	Adult Immigration and Holding	0.150	Harvest/Angling Impacts	0.150	Ocean	0.400	0.09	5	**0.45**	**VH**
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the Dry Creek drainage	0.800	0.224	2	**0.45**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Water Quality	0.100	Ag, Urban in the Auburn Ravine and Coon Creek drainage	0.800	0.112	4	**0.45**	**VH**

Northern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the Delta	0.200	0.06	7	**0.45**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the lower Sacramento River	0.200	0.06	7	**0.45**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the middle Sacramento River	0.200	0.06	7	**0.45**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Jones and Banks Pumping Plants	0.200	0.06	7	**0.45**	**VH**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Loss of Natural River Morphology	0.100	Dry Creek drainage	0.700	0.147	3	**0.44**	**VH**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Loss of Riparian Habitat and Instream Cover	0.100	Dry Creek drainage	0.700	0.147	3	**0.44**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Predation	0.150	Non-site specific and structure related in the lower Sacramento River	0.300	0.11	4	**0.44**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Individual Diversions in the Delta	0.100	0.06	7	**0.44**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Individual Diversions in the lower Sacramento River	0.100	0.06	7	**0.44**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Individual Diversions in the middle Sacramento River	0.100	0.06	7	**0.44**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Jones and Banks Pumping Plants	0.100	0.06	7	**0.44**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	American River	0.700	0.147	3	**0.44**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Predation	0.125	Non-site specific and structure related in the lower Sacramento River	0.250	0.11	4	**0.44**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Deer Creek	0.150	0.11	4	**0.44**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Mill Creek	0.150	0.11	4	**0.44**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Riparian Habitat and Instream Cover	0.150	Feather River	0.275	0.14	3	**0.43**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Floodplain Habitat	0.125	Lower Sacramento River	0.325	0.14	3	**0.43**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Natural River Morphology	0.150	Feather River	0.150	0.11	4	**0.42**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Riparian Habitat and Instream Cover	0.150	Feather River	0.150	0.11	4	**0.42**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Water Temperature	0.075	Delta	0.300	0.11	4	**0.42**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Water Temperature	0.075	Feather River	0.300	0.11	4	**0.42**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Water Temperature	0.075	Lower Sacramento River	0.300	0.11	4	**0.42**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Spawning	0.30	Flow Conditions	0.200	Flow Fluctuations	1.000	0.420	1	**0.42**	**VH**

Northern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Loss of Natural River Morphology	0.125	Auburn Ravine and Coon Creek drainage	0.800	0.140	3	**0.42**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Loss of Riparian Habitat and Instream Cover	0.125	Auburn Ravine and Coon Creek drainage	0.800	0.140	3	**0.42**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Loss of Tidal Marsh Habitat	0.050	Delta	0.800	0.084	5	**0.42**	**VH**
Dry Creek drainage (Sacramento Region)	0.07	Spawning	0.40	Physical Habitat Alteration	0.150	Limited Instream Gravel Supply	1.000	0.420	1	**0.42**	**VH**
Dry Creek drainage (Sacramento Region)	0.07	Spawning	0.40	Water Quality	0.150	Dry Creek drainage	1.000	0.420	1	**0.42**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Non-site specific and structure related in the Delta	0.300	0.08	5	**0.42**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Non-site specific and structure related in the lower Sacramento River	0.300	0.08	5	**0.42**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Changes in Hydrology	0.200	0.07	6	**0.41**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Changes in Hydrology	0.200	0.07	6	**0.41**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Reverse Flow Conditions	0.200	0.07	6	**0.41**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Reverse Flow Conditions	0.200	0.07	6	**0.41**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.350	0.08	5	**0.41**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.350	0.08	5	**0.41**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Floodplain Habitat	0.125	Feather River	0.175	0.10	4	**0.41**	**VH**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.100	0.08	5	**0.41**	**VH**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.100	0.08	5	**0.41**	**VH**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.100	0.08	5	**0.41**	**VH**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.100	0.08	5	**0.41**	**VH**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.100	0.08	5	**0.41**	**VH**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.100	0.08	5	**0.41**	**VH**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.08	5	**0.41**	**VH**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.08	5	**0.41**	**VH**

Northern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.08	5	**0.41**	**VH**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.250	0.08	5	**0.41**	**VH**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.250	0.08	5	**0.41**	**VH**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.250	0.08	5	**0.41**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Antelope Creek	0.150	0.10	4	**0.40**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Middle Sacramento River	0.150	0.10	4	**0.40**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Middle Sacramento River	0.150	0.10	4	**0.40**	**VH**
Big Chico Creek	0.08	Spawning	**0.25**	Water Temperature	0.200	Water Temperature in Big Chico Creek	1.000	0.40	1	**0.40**	**VH**
Butte Creek	0.07	Spawning	**0.25**	Spawning Habitat Availability	0.225	Habitat Availability/Suitability	1.000	0.39	1	**0.39**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the Delta	0.200	0.06	7	**0.39**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the lower Sacramento River	0.200	0.06	7	**0.39**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the middle Sacramento River	0.200	0.06	7	**0.39**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.080	Butte Creek - stocked rainbow trout fishery - competition for habitat and resources	0.500	0.10	4	**0.39**	**VH**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Deer Creek	0.200	0.07	6	**0.39**	**VH**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Mill Creek	0.200	0.07	6	**0.39**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.325	0.13	3	**0.38**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.325	0.13	3	**0.38**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Water Temperature	0.100	Auburn Ravine and Coon Creek drainage	0.900	0.126	3	**0.38**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Changes in Hydrology	0.200	0.06	6	**0.38**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Reverse Flow Conditions	0.200	0.06	6	**0.38**	**VH**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.100	0.08	5	**0.38**	**VH**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.100	0.08	5	**0.38**	**VH**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.100	0.08	5	**0.38**	**VH**

Northern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.08	5	**0.38**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Predation	0.150	Non-site specific and structure related in Butte Creek	0.250	0.09	4	**0.37**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Water Quality	0.075	DO, Ag, Urban, Heavy Metals in the Delta	0.350	0.09	4	**0.37**	**VH**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.150	Ag, Urban in the lower Sacramento River	0.150	0.07	5	**0.37**	**VH**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.150	Ag, Urban in the middle Sacramento River	0.150	0.07	5	**0.37**	**VH**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Bay	0.150	0.07	5	**0.37**	**VH**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Bay	0.150	0.07	5	**0.37**	**VH**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Delta	0.150	0.07	5	**0.37**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	0.800	0.18	2	**0.36**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	0.800	0.18	2	**0.36**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Predation	0.100	Non-site specific and structure related in the Auburn Ravine and Coon Creek drainage	0.650	0.091	4	**0.36**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Lower Sacramento River	0.400	0.09	4	**0.36**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Lower Sacramento River	0.400	0.09	4	**0.36**	**VH**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.200	0.12	3	**0.36**	**VH**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.12	3	**0.36**	**VH**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Antelope Creek	0.200	0.06	6	**0.36**	**VH**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.300	0.06	6	**0.36**	**VH**
American River	0.06	Spawning	0.40	Hatchery Effects	0.150	Competition for habitat, Genetic Integrity	1.000	0.360	1	**0.36**	**VH**
Bear River	0.06	Spawning	0.30	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply	1.000	0.360	1	**0.36**	**VH**
Bear River	0.06	Spawning	0.30	Spawning Habitat Availability	0.200	Habitat Suitability	1.000	0.360	1	**0.36**	**VH**
Big Chico Creek	0.08	Embryo Incubation	**0.15**	Water Temperature	0.300	Water Temperature in Big Chico Creek	1.000	0.36	1.00	**0.36**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.325	0.12	3	**0.36**	**VH**

Northern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Water Quality	0.100	Ag, Urban in the Dry Creek drainage	0.850	0.119	3	**0.36**	**VH**

Basalt and Porous Lava Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Cow Creek	0.3	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Impediments/Barriers in Cow Creek	0.86	2.322	6	**13.93**	**VH**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Temperature	**0.300**	Cow Creek	0.95	2.565	4	**10.26**	**VH**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Impediments/Barriers in the Upper Sacramento Tributaries	0.76	1.231	6	**7.39**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Entrainment	0.250	Individual Diversions in Cow Creek	0.4	0.900	8	**7.20**	**VH**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Flow Conditions	**0.250**	Low Flows - attraction, migratory cues in Cow Creek	0.75	1.688	4	**6.75**	**VH**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Keswick Dam	0.525	0.82	7	**5.73**	**VH**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	North Fork Dams	0.325	0.74	7	**5.18**	**VH**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	South Fork Dams	0.325	0.74	7	**5.18**	**VH**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Temperature	**0.250**	Upper Sacramento Tributaries	0.95	1.283	4	**5.13**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.200	Upper Sacramento Tributaries	0.8	0.864	5	**4.32**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.150	Cow Creek	0.6	0.810	5	**4.05**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.150	Cow Creek	0.75	1.013	4	**4.05**	**VH**
Cow Creek	0.3	Spawning	0.3	Barriers	0.400	Redd superimposition, competition for habitat, hybridization/genetic integrity	1	3.600	1	**3.60**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Entrainment	0.250	Jones and Banks Pumping Plants	0.2	0.450	8	**3.60**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.100	Cow Creek	0.8	0.720	5	**3.60**	**VH**
Sacramento River	0.26	Spawning	0.3	Barrier/Genetics	0.450	Keswick/Shasta Dam	1.000	3.51	1	**3.51**	**VH**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Red Bluff Diversion Dam	0.300	0.47	7	**3.28**	**VH**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Flow Conditions	**0.200**	Low Flows - attraction, migratory cues in the Upper Sacramento Tributaries	0.75	0.810	4	**3.24**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Flow Dependent Habitat Availability in Cow Creek	0.5	0.450	7	**3.15**	**VH**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Temperature	0.175	Battle Creek	0.550	0.63	5	**3.13**	**VH**
Cow Creek	0.3	Spawning	0.3	Hatchery Effects	0.300	Stocked trout fishery in upper Cow Creek - competition for habitat, genetic integrity	1	2.700	1	**2.70**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Entrainment	0.150	Individual Diversions in the Upper Sacramento Tributaries	0.4	0.324	8	**2.59**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Hatchery Effects	0.125	Battle Creek - Coleman - Competition for habitat and food	0.350	0.40	6	**2.39**	**VH**

Basalt and Porous Lava Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.26	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Red Bluff Diversion Dam	0.150	0.34	7	**2.39**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Natural Morphologic Function	0.160	Loss of Natural Morphologic Function in the lower Sacramento River	0.350	0.58	4	**2.33**	**VH**
Upper Sacramento Tributaries	0.18	Spawning	0.3	Barriers	0.400	Redd superimposition, competition for habitat, hybridization/genetic integrity	1	2.160	1	**2.16**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in Cow Creek	0.4	0.360	6	**2.16**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the upper Sacramento River	0.4	0.360	6	**2.16**	**VH**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Flow Conditions	0.200	Low Flows - attraction, migratory cues in Battle Creek	0.400	0.52	4	**2.08**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the Delta	0.300	0.34	6	**2.05**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.150	Upper Sacramento River	0.3	0.405	5	**2.03**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Floodplain Habitat	0.160	Loss of Floodplain Habitat in the Delta	0.300	0.50	4	**2.00**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Floodplain Habitat	0.160	Loss of Floodplain Habitat in the lower Sacramento River	0.300	0.50	4	**2.00**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Natural Morphologic Function	0.160	Loss of Natural Morphologic Function in the Delta	0.300	0.50	4	**2.00**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Riparian Habitat and Instream Cover	0.160	Loss of Riparian Habitat and Instream Cover in the Delta	0.300	0.50	4	**2.00**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Riparian Habitat and Instream Cover	0.160	Loss of Riparian Habitat and Instream Cover in the lower Sacramento River	0.300	0.50	4	**2.00**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Predation in the Delta	0.250	0.39	5	**1.95**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Predation in the lower Sacramento River	0.250	0.39	5	**1.95**	**VH**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Red Bluff Diversion Dam	0.2	0.324	6	**1.94**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Flow Dependent Habitat Availability in the Upper Sacramento Tributaries	0.5	0.270	7	**1.89**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the upper Sacramento River	0.400	0.37	5	**1.87**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in Battle Creek	0.250	0.23	8	**1.82**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Entrainment	0.250	Individual Diversions in the Delta	0.1	0.225	8	**1.80**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Entrainment	0.250	Individual Diversions in the middle Sacramento River	0.1	0.225	8	**1.80**	**VH**

Basalt and Porous Lava Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Non-site specific and structure (GCID, RBDD) related in the middle Sacramento River	0.225	0.35	5	**1.76**	**VH**
Battle Creek	0.26	Spawning	0.25	Barriers	0.250	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	1.63	1	**1.63**	**VH**
Battle Creek	0.26	Spawning	0.25	Flow Conditions	0.250	Low instream flows per FERC license	1.000	1.63	1	**1.63**	**VH**
Battle Creek	0.26	Spawning	0.25	Hatchery Effects	0.250	Coleman - competition for habitat, genetic integrity	1.000	1.63	1	**1.63**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.100	Upper Sacramento Tributaries	0.75	0.405	4	**1.62**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Delta	0.350	0.32	5	**1.59**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Delta	0.350	0.32	5	**1.59**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Delta	0.350	0.32	5	**1.59**	**VH**
Sacramento River	0.26	Spawning	0.3	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply in upper Sacramento River	1.000	1.56	1	**1.56**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Jones and Banks Pumping Plants	0.200	0.18	8	**1.46**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the middle Sacramento River	0.300	0.28	5	**1.40**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Lower Sacramento River	0.300	0.27	5	**1.37**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Lower Sacramento River	0.300	0.27	5	**1.37**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Lower Sacramento River	0.300	0.27	5	**1.37**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Non-site specific and structure (ACID) related in the upper Sacramento River	0.175	0.27	5	**1.37**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Hatchery Effects	0.125	Upper Sacramento River	0.200	0.23	6	**1.37**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the lower Sacramento River	0.200	0.23	6	**1.37**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.150	Cow Creek	0.2	0.270	5	**1.35**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.2	0.270	5	**1.35**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.150	Middle Sacramento River	0.2	0.270	5	**1.35**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.150	Delta	0.2	0.270	5	**1.35**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Floodplain Habitat	0.160	Loss of Floodplain Habitat in the middle Sacramento River	0.200	0.33	4	**1.33**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Floodplain Habitat	0.160	Loss of Floodplain Habitat in the upper Sacramento River	0.200	0.33	4	**1.33**	**VH**

Basalt and Porous Lava Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Natural Morphologic Function	0.160	Loss of Natural Morphologic Function in the upper Sacramento River	0.200	0.33	4	**1.33**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Riparian Habitat and Instream Cover	0.160	Loss of Riparian Habitat and Instream Cover in the middle Sacramento River	0.200	0.33	4	**1.33**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Riparian Habitat and Instream Cover	0.160	Loss of Riparian Habitat and Instream Cover in the upper Sacramento River	0.200	0.33	4	**1.33**	**VH**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Flow Conditions	0.200	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.250	0.33	4	**1.30**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the upper Sacramento River	0.4	0.216	6	**1.30**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the Upper Sacramento Tributaries	0.4	0.216	6	**1.30**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Entrainment	0.150	Jones and Banks Pumping Plants	0.2	0.162	8	**1.30**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Flow Dependent Habitat Availability in Battle Creek	0.400	0.18	7	**1.27**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Changes in Hydrology	0.2	0.180	7	**1.26**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Ag, Urban in the lower Sacramento River	0.300	0.20	6	**1.23**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	DO, Ag, Urban, Heavy Metals in the Delta	0.300	0.20	6	**1.23**	**VH**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.375	0.24	5	**1.22**	**VH**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Quality	**0.150**	Upper Sacramento Tributaries	0.3	0.243	5	**1.22**	**VH**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Quality	**0.150**	Urban, Heavy Metals in the upper Sacramento River	0.3	0.243	5	**1.22**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the middle Sacramento River	0.175	0.20	6	**1.19**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Lower Sacramento River	0.350	0.24	5	**1.19**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in the Delta	0.150	0.14	8	**1.09**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in the lower Sacramento River	0.150	0.14	8	**1.09**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in the middle Sacramento River	0.150	0.14	8	**1.09**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Passage Impediments/Barriers	0.200	Impediments/Barriers in the Upper Sacramento Tributaries	0.5	0.540	2	**1.08**	**VH**

Basalt and Porous Lava Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Passage Impediments/Barriers	0.200	Tributary Barriers	0.5	0.540	2	**1.08**	**VH**
Upper Sacramento Tributaries	0.18	Spawning	0.3	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply	1	1.080	1	**1.08**	**VH**
Battle Creek	0.26	Embryo Incubation	**0.15**	Flow Conditions	0.275	Flow Fluctuations	1.000	1.07	1.00	**1.07**	**VH**
Battle Creek	0.26	Embryo Incubation	**0.15**	Water Temperature	0.275	Water Temperature in Battle Creek	1.000	1.07	1.00	**1.07**	**VH**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.26	4	**1.04**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Hatchery Effects	0.125	Lower Sacramento River	0.150	0.17	6	**1.02**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Hatchery Effects	0.125	Middle Sacramento River	0.150	0.17	6	**1.02**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Delta	0.300	0.20	5	**1.02**	**VH**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.090**	Upper Sacramento River	0.3	0.146	7	**1.02**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Individual Diversions in the Delta	0.200	0.15	7	**1.02**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Individual Diversions in the lower Sacramento River	0.200	0.15	7	**1.02**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Individual Diversions in the middle Sacramento River	0.200	0.15	7	**1.02**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Jones and Banks Pumping Plants	0.200	0.15	7	**1.02**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Natural Morphologic Function	0.160	Loss of Natural Morphologic Function in the middle Sacramento River	0.150	0.25	4	**1.00**	**VH**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in Battle Creek	0.200	0.16	6	**0.98**	**VH**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.16	6	**0.98**	**VH**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.16	6	**0.98**	**VH**
Battle Creek	0.26	Spawning	0.25	Spawning Habitat Availability	0.150	Habitat Suitability	1.000	0.98	1	**0.98**	**VH**
Cow Creek	0.3	Embryo Incubation	**0.10**	Water Quality	0.325	Water Quality in Cow Creek	1.00	0.975	1.00	**0.98**	**VH**
Cow Creek	0.3	Embryo Incubation	**0.10**	Water Temperature	0.325	Water Temperature in Cow Creek	1.00	0.975	1	**0.98**	**VH**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.050**	Upper Sacramento River	0.3	0.135	7	**0.95**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Middle Sacramento River	0.200	0.18	5	**0.91**	**H**

Basalt and Porous Lava Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Middle Sacramento River	0.200	0.18	5	**0.91**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Entrainment	0.250	Contra Costa Power Plant	0.05	0.113	8	**0.90**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Entrainment	0.250	Individual Diversions in the lower Sacramento River	0.05	0.113	8	**0.90**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Entrainment	0.250	Individual Diversions in the upper Sacramento River	0.05	0.113	8	**0.90**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Entrainment	0.250	Pittsburg Power Plant	0.05	0.113	8	**0.90**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Flow Conditions	**0.250**	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.1	0.225	4	**0.90**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Flow Conditions	**0.250**	Low Flows - attraction, migratory cues in the middle Sacramento River	0.1	0.225	4	**0.90**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Flow Conditions	**0.250**	Low Flows - attraction, migratory cues in the upper Sacramento River	0.1	0.225	4	**0.90**	**H**
Cow Creek	0.3	Spawning	0.3	Physical Habitat Alteration	0.100	Limited Instream Gravel Supply	1	0.900	1	**0.90**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.050**	Sedimentation, turbidity, acoustic effects, hazardous spills in Cow Creek	0.4	0.180	5	**0.90**	**H**
Cow Creek	0.3	Spawning	0.3	Water Temperature	0.100	Water Temperature in Cow Creek	1	0.900	1	**0.90**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.275	0.18	5	**0.89**	**H**
Sacramento River	0.26	Embryo Incubation	0.15	Flow Conditions	0.225	Flow Fluctuations in upper Sacramento River	1.000	0.88	1	**0.88**	**H**
Sacramento River	0.26	Embryo Incubation	0.15	Water Quality	0.225	Water Pollution in upper Sacramento River	1.000	0.88	1	**0.88**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in Battle Creek	0.125	0.14	6	**0.85**	**H**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.090**	Middle Sacramento River	0.25	0.122	7	**0.85**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Water Temperature	0.050	Delta	0.400	0.21	4	**0.83**	**H**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Ocean	0.350	0.14	6	**0.82**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.14	6	**0.82**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.050	Upper Sacramento Tributaries	0.6	0.162	5	**0.81**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Red Bluff Diversion Dam	0.05	0.135	6	**0.81**	**H**

Basalt and Porous Lava Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Passage Impediments/Barriers	0.050	Impediments/Barriers in Cow Creek	0.9	0.405	2	**0.81**	**H**
Upper Sacramento Tributaries	0.18	Spawning	0.3	Spawning Habitat Availability	0.150	Habitat Suitability	1	0.810	1	**0.81**	**H**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Quality	**0.150**	Ag, Urban in the middle Sacramento River	0.2	0.162	5	**0.81**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Sacramento Deep Water Ship Channel	0.050	0.11	7	**0.80**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Suisun Marsh Salinity Control Structure	0.050	0.11	7	**0.80**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Sutter Bypass - Tisdale Weir	0.050	0.11	7	**0.80**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Yolo Bypass - Freemont Weir	0.050	0.11	7	**0.80**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.050**	Middle Sacramento River	0.25	0.113	7	**0.79**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Predation in the Bay	0.100	0.16	5	**0.78**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.300	0.16	5	**0.78**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.300	0.16	5	**0.78**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	Urban, Heavy Metals in the upper Sacramento River	0.300	0.16	5	**0.78**	**H**
Sacramento River	0.26	Spawning	0.3	Flow Conditions	0.100	Flow Fluctuations in upper Sacramento River	1.000	0.78	1	**0.78**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the upper Sacramento River	0.150	0.20	4	**0.78**	**H**
Sacramento River	0.26	Spawning	0.3	Harvest/Angling Impacts	0.100	Upper Sacramento River	1.000	0.78	1	**0.78**	**H**
Sacramento River	0.26	Embryo Incubation	0.15	Water Temperature	0.200	Water Temperature in upper Sacramento River	1.000	0.78	1	**0.78**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Changes in Hydrology	0.2	0.108	7	**0.76**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.150	0.12	6	**0.73**	**H**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.250	0.15	5	**0.73**	**H**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.15	5	**0.73**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.12	6	**0.73**	**H**

Basalt and Porous Lava Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	0.26	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.250	0.15	5	**0.73**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.275	0.14	5	**0.72**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.275	0.14	5	**0.72**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.275	0.14	5	**0.72**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Temperature	0.175	Lower Sacramento River	0.125	0.14	5	**0.71**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Temperature	0.175	Middle Sacramento River	0.125	0.14	5	**0.71**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Middle Sacramento River	0.150	0.14	5	**0.68**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Ocean	0.300	0.10	7	**0.68**	**H**
Sacramento River	0.26	Embryo Incubation	0.15	Harvest/Angling Impacts	0.175	Redd disturbance in upper Sacramento River	1.000	0.68	1.00	**0.68**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Hatchery Effects	0.125	Delta	0.100	0.11	6	**0.68**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the Bays	0.100	0.11	6	**0.68**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the upper Sacramento River	0.100	0.11	6	**0.68**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.11	6	**0.68**	**H**
Sacramento River	0.26	Embryo Incubation	0.15	Short-term Inwater Construction	0.175	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.68	1	**0.68**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Battle Creek	0.200	0.14	5	**0.68**	**H**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.090**	Upper Sacramento Tributaries	0.2	0.097	7	**0.68**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.150	Delta	0.1	0.135	5	**0.68**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.150	Upper Sacramento River	0.1	0.135	5	**0.68**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Quality	**0.050**	Cow Creek	0.3	0.135	5	**0.68**	**H**

Basalt and Porous Lava Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Quality	**0.050**	Urban, Heavy Metals in the upper Sacramento River	0.3	0.135	5	**0.68**	**H**
Upper Sacramento Tributaries	0.18	Embryo Incubation	**0.10**	Water Temperature	0.375	Water Temperature in the Upper Sacramento Tributaries	1.00	0.675	1	**0.68**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Entrainment	0.150	Individual Diversions in the Delta	0.1	0.081	8	**0.65**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Entrainment	0.150	Individual Diversions in the middle Sacramento River	0.1	0.081	8	**0.65**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Diversion into Central Delta	0.200	0.09	7	**0.64**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Flow Dependent Habitat Availability in the upper Sacramento River	0.1	0.090	7	**0.63**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.050**	Cow Creek	0.2	0.090	7	**0.63**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Water Temperature	0.050	Lower Sacramento River	0.300	0.16	4	**0.62**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Ag, Urban, Heavy Metals in the Bays	0.150	0.10	6	**0.61**	**H**
Cow Creek	0.3	Embryo Incubation	**0.10**	Flow Conditions	0.200	Flow Fluctuations	1	0.600	1	**0.60**	**H**
Battle Creek	0.26	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.150	Redd disturbance	1.000	0.59	1.00	**0.59**	**H**
Battle Creek	0.26	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.59	1.00	**0.59**	**H**
Sacramento River	0.26	Spawning	0.3	Spawning Habitat Availability	0.075	Habitat Suitability in in upper Sacramento River	1.000	0.59	1	**0.59**	**H**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Water Quality	0.125	DO, Ag, Urban, Heavy Metals in the Delta	0.300	0.15	4	**0.59**	**H**
Battle Creek	0.26	Embryo Incubation	**0.15**	Water Quality	0.150	Water Quality in Battle Creek	1.000	0.59	1.00	**0.59**	**H**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Water Temperature	0.125	Lower Sacramento River	0.400	0.20	3	**0.59**	**H**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Water Temperature	0.125	Middle Sacramento River	0.400	0.20	3	**0.59**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.175	0.11	5	**0.57**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Temperature	0.175	Delta	0.100	0.11	5	**0.57**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Temperature	0.175	Upper Sacramento River	0.100	0.11	5	**0.57**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.050**	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.25	0.113	5	**0.56**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Changes in Delta Hydrology	0.300	0.09	6	**0.56**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Reverse Flow Conditions in the Delta	0.300	0.09	6	**0.56**	**H**

Basalt and Porous Lava Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Passage Impediments/Barriers	0.050	North Fork Dams	0.400	0.18	3	**0.55**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Passage Impediments/Barriers	0.050	South Fork Dams	0.400	0.18	3	**0.55**	**H**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Yolo Bypass-Freemont Weir	0.050	0.08	7	**0.55**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.150	Middle Sacramento River	0.1	0.135	4	**0.54**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.150	Upper Sacramento River	0.1	0.135	4	**0.54**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the middle Sacramento River	0.1	0.090	6	**0.54**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.200	Middle Sacramento River	0.1	0.108	5	**0.54**	**H**
Upper Sacramento Tributaries	0.18	Spawning	0.3	Water Temperature	0.100	Water Temperature in the Upper Sacramento Tributaries	1	0.540	1	**0.54**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Individual Diversions in the upper Sacramento River	0.100	0.07	7	**0.51**	**H**
Upper Sacramento Tributaries	0.18	Embryo Incubation	**0.10**	Water Quality	0.275	Water Quality in the Upper Sacramento Tributaries	1.00	0.495	1.00	**0.50**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.100	0.08	6	**0.49**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Quality	0.100	Urban, Heavy Metals in the upper Sacramento River	0.150	0.10	5	**0.49**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the Bays	0.100	0.09	5	**0.47**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the Delta	0.100	0.09	5	**0.47**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the lower Sacramento River	0.100	0.09	5	**0.47**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Diversion into Central Delta	0.250	0.08	6	**0.47**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Upper Sacramento River	0.100	0.09	5	**0.46**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Upper Sacramento River	0.100	0.09	5	**0.46**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Battle Creek	0.100	0.09	5	**0.46**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Upper Sacramento River	0.100	0.09	5	**0.46**	**H**
Cow Creek	0.3	Spawning	0.3	Flow Conditions	0.050	Flow Fluctuations	1	0.450	1	**0.45**	**M**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.050**	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.2	0.090	5	**0.45**	**M**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Quality	**0.050**	Ag, Urban in the middle Sacramento River	0.2	0.090	5	**0.45**	**M**

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Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.100	Middle Sacramento River	0.1	0.090	5	**0.45**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.150	0.09	5	**0.44**	**M**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Flow Conditions	**0.200**	Low Flows - attraction, migratory cues in the middle Sacramento	0.1	0.108	4	**0.43**	**M**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Flow Conditions	**0.200**	Low Flows - attraction, migratory cues in the upper Sacramento	0.1	0.108	4	**0.43**	**M**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Water Temperature	0.050	Middle Sacramento River	0.200	0.10	4	**0.42**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.150	0.07	6	**0.41**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.150	0.07	6	**0.41**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Urban, Heavy Metals in the upper Sacramento River	0.100	0.07	6	**0.41**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Ag, Urban in the middle Sacramento River	0.100	0.07	6	**0.41**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.050	Upper Sacramento River	0.3	0.081	5	**0.41**	**M**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Quality	**0.150**	Ag, Urban in the lower Sacramento River	0.1	0.081	5	**0.41**	**M**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Quality	**0.150**	DO, Ag, Urban, Heavy Metals in th Delta	0.1	0.081	5	**0.41**	**M**
Sacramento River	0.26	Spawning	0.3	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in upper	1.000	0.39	1	**0.39**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Water Quality	0.125	Ag, Urban in the lower Sacramento River	0.200	0.10	4	**0.39**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Water Quality	0.125	Ag, Urban in the middle Sacramento River	0.200	0.10	4	**0.39**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Water Quality	0.125	Urban, Heavy Metals in the upper Sacramento River	0.200	0.10	4	**0.39**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues AND Flood Flows - non-natal	0.333	0.13	3	**0.39**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues in Middle Sacramento River	0.333	0.13	3	**0.39**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues in Upper Sacramento River	0.333	0.13	3	**0.39**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Sacramento Deep Water Ship Channel	0.035	0.05	7	**0.38**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Suisun Marsh Salinity Control Structure	0.035	0.05	7	**0.38**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Sutter Bypass - Tisdale Weir	0.035	0.05	7	**0.38**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Flow Dependent Habitat Availability in the upper Sacramento River	0.1	0.054	7	**0.38**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in the upper Sacramento River	0.050	0.05	8	**0.36**	**M**
Upper Sacramento Tributaries	0.18	Embryo Incubation	**0.10**	Flow Conditions	0.200	Flow Fluctuations	1	0.360	1	**0.36**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Upper Sacramento River	0.150	0.06	6	**0.35**	**M**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Battle Creek	0.150	0.05	7	**0.34**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Hatchery Effects	0.125	Bays	0.050	0.06	6	**0.34**	**M**

Basalt and Porous Lava Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Middle Sacramento River	0.100	0.07	5	**0.34**	**M**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.090**	Delta	0.1	0.049	7	**0.34**	**M**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.090**	Lower Sacramento River	0.1	0.049	7	**0.34**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.05	0.068	5	**0.34**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.150	Middle Sacramento River	0.05	0.068	5	**0.34**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the middle Sacramento River	0.1	0.054	6	**0.32**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Entrainment	0.150	Contra Costa Power Plant	0.05	0.041	8	**0.32**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Entrainment	0.150	Individual Diversions in the lower Sacramento River	0.05	0.041	8	**0.32**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Entrainment	0.150	Individual Diversions in the upper Sacramento River	0.05	0.041	8	**0.32**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Entrainment	0.150	Pittsburg Power Plant	0.05	0.041	8	**0.32**	**M**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Temperature	**0.300**	Middle Sacramento River	0.03	0.081	4	**0.32**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Changes in Hydrology	0.100	0.05	7	**0.32**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.05	7	**0.32**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Invasive Species/Food Web Disruption	0.025	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.16	2	**0.32**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Diversion into Central Delta	0.05	0.045	7	**0.32**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Flow Dependent Habitat Availability in the lower Sacramento River	0.05	0.045	7	**0.32**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Flow Dependent Habitat Availability in the middle Sacramento River	0.05	0.045	7	**0.32**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Reverse Flow Conditions	0.05	0.045	7	**0.32**	**M**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.050**	Delta	0.1	0.045	7	**0.32**	**M**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.050**	Lower Sacramento River	0.1	0.045	7	**0.32**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.100	0.06	5	**0.29**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Bays	0.125	0.05	6	**0.29**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Delta	0.125	0.05	6	**0.29**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.125	0.05	6	**0.29**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.125	0.05	6	**0.29**	**M**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Middle Sacramento River	0.125	0.04	7	**0.28**	**M**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Upper Sacramento River	0.125	0.04	7	**0.28**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Tidal Marsh Habitat	0.025	Delta	0.600	0.14	2	**0.27**	**M**

Basalt and Porous Lava Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Passage Impediments/Barriers	0.050	Tributary Barriers	0.200	0.09	3	**0.27**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.100	0.05	6	**0.27**	**M**
Upper Sacramento Tributaries	0.18	Spawning	0.3	Flow Conditions	0.050	Flow Fluctuations	1	0.270	1	**0.27**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.050	Lower Sacramento River	0.2	0.054	5	**0.27**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.050	Middle Sacramento River	0.2	0.054	5	**0.27**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.050	Upper Sacramento Tributaries	0.2	0.054	5	**0.27**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.050	Delta	0.2	0.054	5	**0.27**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.05	0.068	4	**0.27**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the lower Sacramento River	0.05	0.045	6	**0.27**	**M**
Upper Sacramento Tributaries	0.18	Spawning	0.3	Water Quality	0.050	Water Quality in the Upper Sacramento Tributaries	1	0.270	1	**0.27**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.200	Upper Sacramento River	0.05	0.054	5	**0.27**	**M**
Cow Creek	0.3	Spawning	0.3	Water Quality	0.030	Water Quality in Cow Creek	1	0.270	1	**0.27**	**M**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.100	0.05	5	**0.26**	**M**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Contra Costa Power Plant	0.050	0.04	7	**0.25**	**M**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Pittsburg Power Plant	0.050	0.04	7	**0.25**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in Cow	0.45	0.041	6	**0.24**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Flow Dependent Habitat Availability in the middle Sacramento River	0.075	0.03	7	**0.24**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Flow Dependent Habitat Availability in the upper Sacramento River	0.075	0.03	7	**0.24**	**M**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.090	0.05	5	**0.23**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Battle Creek	0.050	0.05	5	**0.23**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Battle Creek	0.050	0.05	5	**0.23**	**M**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Bays	0.100	0.03	7	**0.23**	**M**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Delta	0.100	0.03	7	**0.23**	**M**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Lower Sacramento River	0.100	0.03	7	**0.23**	**M**
Cow Creek	0.3	Embryo Incubation	**0.10**	Harvest/Angling Impacts	0.075	Redd disturbance	1.00	0.225	1.00	**0.23**	**M**
Cow Creek	0.3	Embryo Incubation	**0.10**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills, physical	1	0.225	1	**0.23**	**M**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Quality	**0.050**	Ag, Urban in the lower Sacramento River	0.1	0.045	5	**0.23**	**M**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Quality	**0.050**	DO, Ag, Urban, Heavy Metals in th Delta	0.1	0.045	5	**0.23**	**M**

Basalt and Porous Lava Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.100	Upper Sacramento River	0.05	0.045	5	**0.23**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	ACID Dam	0.020	0.03	7	**0.22**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.200	Lower Sacramento River	0.04	0.043	5	**0.22**	**M**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Flow Conditions	**0.200**	Low Flows - attraction, migratory cues AND Flood Flows - non-natal	0.05	0.054	4	**0.22**	**M**
Upper Sacramento Tributaries	0.18	Spawning	0.3	Hatchery Effects	0.040	Redd superimposition, competition for habitat, Genetic Integrity	1	0.216	1	**0.22**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.100	Middle Sacramento River	0.1	0.054	4	**0.22**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.100	Upper Sacramento River	0.1	0.054	4	**0.22**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the Delta	0.04	0.036	6	**0.22**	**M**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Water Temperature	0.050	Upper Sacramento River	0.100	0.05	4	**0.21**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Ag, Urban in Battle Creek	0.050	0.03	6	**0.20**	**M**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.075	0.04	5	**0.20**	**M**
Sacramento River	0.26	Spawning	0.3	Water Temperature	0.025	Upper Sacramento River	1.000	0.20	1	**0.20**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Diversion into Central Delta	0.05	0.027	7	**0.19**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Flow Dependent Habitat Availability in the lower Sacramento River	0.05	0.027	7	**0.19**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Flow Dependent Habitat Availability in the middle Sacramento River	0.05	0.027	7	**0.19**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Reverse Flow Conditions	0.05	0.027	7	**0.19**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Ag, Urban in Cow Creek	0.35	0.032	6	**0.19**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Contra Costa Power Plant	0.025	0.02	8	**0.18**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Pittsburg Power Plant	0.025	0.02	8	**0.18**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Tidal Marsh Habitat	0.025	Bays	0.400	0.09	2	**0.18**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.100	Lower Sacramento River	0.04	0.036	5	**0.18**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Upper Sacramento River	0.050	0.03	5	**0.17**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Invasive species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, water hyacinth etc. in the Delta	0.800	0.08	2	**0.17**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Tidal Marsh Habitat	0.010	Loss of Tidal Marsh Habitat in the Delta	0.800	0.08	2	**0.17**	**L**
Battle Creek	0.26	Spawning	0.25	Harvest/Angling Impacts	0.025	Recreational, Poaching, Angler Impacts	1.000	0.16	1	**0.16**	**L**
Battle Creek	0.26	Spawning	0.25	Physical Habitat Alteration	0.025	Limited Instream Gravel Supply	1.000	0.16	1	**0.16**	**L**
Battle Creek	0.26	Spawning	0.25	Water Quality	0.025	Water Quality in Battle Creek	1.000	0.16	1	**0.16**	**L**
Battle Creek	0.26	Spawning	0.25	Water Temperature	0.025	Water Temperature in Battle Creek	1.000	0.16	1	**0.16**	**L**

Basalt and Porous Lava Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Cow Creek	0.3	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Sacramento Deep Water Ship Channel	0.01	0.027	6	**0.16**	**L**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Suisun Marsh Salinity Control Structure	0.01	0.027	6	**0.16**	**L**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Sutter Bypass - Tisdale Weir	0.01	0.027	6	**0.16**	**L**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Yolo Bypass - Freemont Weir	0.01	0.027	6	**0.16**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the lower Sacramento River	0.05	0.027	6	**0.16**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Urban, Heavy Metals in the upper Sacramento River	0.3	0.027	6	**0.16**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Ag, Urban in the middle Sacramento River	0.3	0.027	6	**0.16**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Temperature	**0.250**	Middle Sacramento River	0.03	0.041	4	**0.16**	**L**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Reverse Flow Conditions	0.050	0.02	7	**0.16**	**L**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Water Temperature	0.125	Delta	0.100	0.05	3	**0.15**	**L**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Water Temperature	0.125	Upper Sacramento River	0.100	0.05	3	**0.15**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.45	0.024	6	**0.15**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.8	0.072	2	**0.14**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Tidal Marsh Habitat	0.010	Delta	0.8	0.072	2	**0.14**	**L**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Invasive Species/Food Web Disruption	0.025	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.07	2	**0.14**	**L**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Battle	0.050	0.02	6	**0.14**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Delta	0.3	0.027	5	**0.14**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Middle Sacramento River	0.3	0.027	5	**0.14**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.050	Delta	0.1	0.027	5	**0.14**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.050	Upper Sacramento River	0.1	0.027	5	**0.14**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.25	0.023	6	**0.14**	**L**
Upper Sacramento Tributaries	0.18	Embryo Incubation	**0.10**	Harvest/Angling Impacts	0.075	Redd disturbance	1.00	0.135	1.00	**0.14**	**L**
Upper Sacramento Tributaries	0.18	Embryo Incubation	**0.10**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills, physical	1	0.135	1	**0.14**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the Delta	0.04	0.022	6	**0.13**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Passage Impediments/Barriers	0.010	Keswick Dam	0.400	0.04	3	**0.12**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Ag, Urban in the Upper Sacramento Tributaries	0.35	0.019	6	**0.11**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.2	0.018	6	**0.11**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.010**	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.4	0.022	5	**0.11**	**L**

Basalt and Porous Lava Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.100	Lower Sacramento River	0.05	0.027	4	**0.11**	**L**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Temperature	**0.300**	Lower Sacramento River	0.01	0.027	4	**0.11**	**L**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Temperature	**0.300**	Upper Sacramento River	0.01	0.027	4	**0.11**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.090**	Bays	0.03	0.015	7	**0.10**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Delta	0.3	0.016	6	**0.10**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Middle Sacramento River	0.3	0.016	6	**0.10**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Sacramento Deep Water Ship Channel	0.01	0.016	6	**0.10**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Suisun Marsh Salinity Control Structure	0.01	0.016	6	**0.10**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Sutter Bypass - Tisdale Weir	0.01	0.016	6	**0.10**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Yolo Bypass - Freemont Weir	0.01	0.016	6	**0.10**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Urban, Heavy Metals in the upper Sacramento River	0.3	0.016	6	**0.10**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Ag, Urban in the middle Sacramento River	0.3	0.016	6	**0.10**	**L**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.050**	Bays	0.03	0.014	7	**0.09**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Passage Impediments/Barriers	0.010	ACID Dam	0.300	0.03	3	**0.09**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Passage Impediments/Barriers	0.010	Tributary Barriers	0.300	0.03	3	**0.09**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Flow Dependent Habitat Availability in the lower Sacramento River	0.050	0.02	6	**0.09**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Flow Dependent Habitat Availability in the middle Sacramento River	0.050	0.02	6	**0.09**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Flow Dependent Habitat Availability in the upper Sacramento River	0.050	0.02	6	**0.09**	**L**
Cow Creek	0.3	Spawning	0.3	Harvest/Angling Impacts	0.010	Recreational, Poaching, Angler Impacts	1	0.090	1	**0.09**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Passage Impediments/Barriers	0.050	Tributary Barriers	0.1	0.045	2	**0.09**	**L**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.050**	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.04	0.018	5	**0.09**	**L**
Cow Creek	0.3	Spawning	0.3	Spawning Habitat Availability	0.010	Habitat Suitability	1	0.090	1	**0.09**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.8	0.043	2	**0.09**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Tidal Marsh Habitat	0.010	Delta	0.8	0.043	2	**0.09**	**L**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Quality	0.100	Battle Creek	0.025	0.02	5	**0.08**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.25	0.014	6	**0.08**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.010**	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.3	0.016	5	**0.08**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.090**	Ocean	0.02	0.010	7	**0.07**	**L**

Basalt and Porous Lava Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Lower Sacramento River	0.15	0.014	5	**0.07**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Upper Sacramento River	0.15	0.014	5	**0.07**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.050	Lower Sacramento River	0.05	0.014	5	**0.07**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.050	Middle Sacramento River	0.05	0.014	5	**0.07**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.010**	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.25	0.014	5	**0.07**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.2	0.011	6	**0.06**	**L**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.050**	Ocean	0.02	0.009	7	**0.06**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Ag, Urban in the lower Sacramento River	0.1	0.009	6	**0.05**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.200	Delta	0.01	0.011	5	**0.05**	**L**
Upper Sacramento Tributaries	0.18	Spawning	0.3	Harvest/Angling Impacts	0.010	Recreational, Poaching, Angler Impacts	1	0.054	1	**0.05**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Temperature	**0.250**	Lower Sacramento River	0.01	0.014	4	**0.05**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Temperature	**0.250**	Upper Sacramento River	0.01	0.014	4	**0.05**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the Bays	0.01	0.009	6	**0.05**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Lower Sacramento River	0.15	0.008	6	**0.05**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Upper Sacramento River	0.15	0.008	6	**0.05**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Cow Creek	0.1	0.009	5	**0.05**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.100	Delta	0.01	0.009	5	**0.05**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Invasive species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, water hyacinth etc. in the Bays	0.200	0.02	2	**0.04**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Tidal Marsh Habitat	0.010	oss of Tidal Marsh Habitat in the Bay	0.200	0.02	2	**0.04**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.2	0.018	2	**0.04**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Tidal Marsh Habitat	0.010	Bays	0.2	0.018	2	**0.04**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Upper Sacramento Tributaries	0.1	0.005	6	**0.03**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the Bays	0.01	0.005	6	**0.03**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Ag, Urban in the lower Sacramento River	0.1	0.005	6	**0.03**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.05	0.005	6	**0.03**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.010	0.01	5	**0.03**	**L**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.050**	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.01	0.005	5	**0.02**	**L**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.050**	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.01	0.005	5	**0.02**	**L**

Basalt and Porous Lava Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.2	0.011	2	**0.02**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Tidal Marsh Habitat	0.010	Bays	0.2	0.011	2	**0.02**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.04	0.004	6	**0.02**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	DO, Ag, Urban, Heavy Metals in th Delta	0.04	0.004	6	**0.02**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.05	0.003	6	**0.02**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.04	0.002	6	**0.01**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	DO, Ag, Urban, Heavy Metals in th Delta	0.04	0.002	6	**0.01**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.010**	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.04	0.002	5	**0.01**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.01	0.001	6	**0.01**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Ag, Urban, Heavy Metals in the Bays	0.01	0.001	6	**0.01**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.01	0.001	6	**0.00**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Ag, Urban, Heavy Metals in the Bays	0.01	0.001	6	**0.00**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.010**	Sedimentation, turbidity, acoustic effects, hazardous spills in the	0.01	0.001	5	**0.00**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Bays	0	0.000	5		
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0	0.000	4		
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Temperature	**0.300**	Delta	0	0.000	4		

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Stony Creek	0.16	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.300	Black Butte Dam	0.960	1.382	5	**6.91**	**VH**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Ag Diversion Dams, Braiding, Natural Channel Gradient	0.750	0.61	5	**3.05**	**VH**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Water Temperature	0.300	Stony Creek	0.500	0.720	4	**2.88**	**VH**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Thomes Creek	0.700	0.68	4	**2.73**	**VH**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Beegum Creek	0.600	0.49	5	**2.44**	**VH**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Flow Conditions	0.250	Low Flows - attraction, migratory cues in Stony Creek	0.600	0.720	3	**2.16**	**VH**
Clear Creek	0.21	Spawning	0.4	Physical Habitat Alteration	0.250	Limited Instream Gravel Supply	1.000	2.10	1	**2.10**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Red Bluff Diversion Dam	0.410	0.34	6	**2.07**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Temperature	0.300	Clear Creek	0.400	0.50	4	**2.02**	**VH**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Passage Impediments/Barriers	0.350	Solano Dam	0.550	0.462	4	**1.85**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Whiskeytown Dam	0.355	0.30	6	**1.79**	**VH**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	RBDD	0.550	0.36	5	**1.79**	**VH**
Clear Creek	0.21	Spawning	0.4	Spawning Habitat Availability	0.200	Habitat Suitability	1.000	1.68	1	**1.68**	**VH**
Clear Creek	0.21	Spawning	0.4	Water Temperature	0.200	Water Temperature in Clear Creek	1.000	1.68	1	**1.68**	**VH**
Stony Creek	0.16	Spawning	0.35	Barrier	0.300	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	1.680	1	**1.68**	**VH**
Stony Creek	0.16	Spawning	0.35	Spawning Habitat Availability	0.300	Habitat Suitability	1.000	1.680	1	**1.68**	**VH**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.150	Flow Dependent Habitat Availability in Stony Creek	0.450	0.270	6	**1.62**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.350	0.29	5	**1.47**	**VH**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.150	Stony Creek	0.600	0.360	4	**1.44**	**VH**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Passage Impediments/Barriers	0.350	Montecello Dam	0.400	0.336	4	**1.34**	**VH**
Thomes Creek	0.13	Spawning	**0.25**	Spawning Habitat Availability	0.400	Habitat Suitability	1.000	1.30	1	**1.30**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Flow Conditions	0.250	Low Flows - attraction, migratory cues in Clear Creek	0.400	0.42	3	**1.26**	**VH**
Clear Creek	0.21	Spawning	0.4	Flow Conditions	0.150	Flow Fluctuations	1.000	1.26	1	**1.26**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Delta	0.300	0.25	5	**1.26**	**VH**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Flow Conditions	0.150	Flow Dependent Habitat Availability in Putah Creek	0.600	0.297	4	**1.19**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.350	0.29	4	**1.18**	**VH**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Water Temperature	0.300	Delta	0.200	0.288	4	**1.15**	**VH**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Water Temperature	0.300	Lower Sacramento River	0.200	0.288	4	**1.15**	**VH**
Clear Creek	0.21	Embryo Incubation	**0.15**	Water Quality	0.350	Sedimentation in Clear Creek	1.000	1.10	1.00	**1.10**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Flow Dependent Habitat Availability in Clear Creek	0.450	0.18	6	**1.06**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Lower Sacramento River	0.250	0.21	5	**1.05**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Delta	0.300	0.20	5	**1.02**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.300	0.20	5	**1.02**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Delta	0.300	0.20	5	**1.02**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.300	0.20	5	**1.02**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the Delta	0.250	0.16	6	**0.98**	**VH**
Beegum Creek	0.13	Spawning	**0.25**	Spawning Habitat Availability	0.300	Habitat Suitability	1.000	0.98	1	**0.98**	**VH**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Flow Conditions	0.400	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Putah Creek	1.000	0.960	1	**0.96**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.350	0.24	4	**0.96**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Middle Sacramento River	0.350	0.24	4	**0.96**	**VH**
Clear Creek	0.21	Embryo Incubation	**0.15**	Flow Conditions	0.300	Flow Fluctuations	1.000	0.95	1.00	**0.95**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.275	0.19	5	**0.94**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.275	0.19	5	**0.94**	**VH**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.150	Diversion into Central Delta	0.250	0.150	6	**0.90**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Beegum Creek	0.250	0.17	5	**0.85**	**VH**
Clear Creek	0.21	Spawning	0.4	Barriers	0.100	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.84	1	**0.84**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Clear Creek	0.200	0.17	5	**0.84**	**VH**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Clear Creek	0.200	0.17	5	**0.84**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Delta	0.200	0.17	5	**0.84**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Middle Sacramento River	0.200	0.17	5	**0.84**	**VH**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.150	Delta	0.350	0.210	4	**0.84**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Delta	0.300	0.20	4	**0.82**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.300	0.20	4	**0.82**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Delta	0.300	0.20	4	**0.82**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.300	0.20	4	**0.82**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Jones and Banks Pumping Plants	0.250	0.11	7	**0.80**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the lower Sacramento River	0.200	0.13	6	**0.79**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the middle Sacramento River	0.200	0.13	6	**0.79**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the upper Sacramento River	0.200	0.13	6	**0.79**	**VH**
Clear Creek	0.21	Embryo Incubation	**0.15**	Water Temperature	0.250	Water Temperature in Clear Creek	1.000	0.79	1.00	**0.79**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Quality	0.150	Ag, Urban in the lower Sacramento River	0.200	0.13	6	**0.76**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Quality	0.150	Clear Creek	0.200	0.13	6	**0.76**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Delta	0.200	0.13	6	**0.76**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Temperature	0.300	Delta	0.150	0.19	4	**0.76**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Temperature	0.300	Lower Sacramento River	0.150	0.19	4	**0.76**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Temperature	0.300	Middle Sacramento River	0.150	0.19	4	**0.76**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Temperature	0.300	Upper Sacramento River	0.150	0.19	4	**0.76**	**VH**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Water Temperature	0.150	Putah Creek	0.750	0.371	2	**0.74**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the Delta	0.200	0.09	8	**0.73**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the lower Sacramento River	0.200	0.09	8	**0.73**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the middle Sacramento River	0.200	0.09	8	**0.73**	**VH**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Jones and Banks Pumping Plants	0.200	0.09	8	**0.73**	**VH**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Flow Conditions	0.250	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.200	0.240	3	**0.72**	**VH**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Flow Conditions	0.250	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.240	3	**0.72**	**VH**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Harvest/Angling Impacts	0.100	Putah Creek	0.750	0.180	4	**0.72**	**VH**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.300	0.180	4	**0.72**	**VH**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Loss of Floodplain Habitat	0.150	Putah Creek	0.700	0.347	2	**0.69**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Delta	0.300	0.14	5	**0.68**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the lower Sacramento River	0.300	0.14	5	**0.68**	**VH**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.300	0.10	7	**0.68**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Delta	0.250	0.11	6	**0.68**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the lower Sacramento River	0.250	0.11	6	**0.68**	**VH**
Beegum Creek	0.13	Embryo Incubation	**0.15**	Watershed disturbance	0.350	Sedimentation	1.000	0.68	1.00	**0.68**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Middle Sacramento River	0.200	0.14	5	**0.68**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Beegum Creek	0.200	0.14	5	**0.68**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Clear Creek	0.200	0.17	4	**0.67**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.200	0.17	4	**0.67**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Middle Sacramento River	0.200	0.17	4	**0.67**	**VH**
Beegum Creek	0.13	Spawning	**0.25**	Flow Conditions	0.200	Flow Fluctuations	1.000	0.65	1	**0.65**	**VH**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.250	0.16	4	**0.65**	**VH**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in Beegum Creek	0.250	0.16	4	**0.65**	**VH**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the middle Sacramento River	0.250	0.16	4	**0.65**	**VH**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the Upper Sacramento River	0.250	0.16	4	**0.65**	**VH**
Beegum Creek	0.13	Spawning	**0.25**	Water Temperature	0.200	Water Temperature in Beegum Creek	1.000	0.65	1	**0.65**	**VH**
Thomes Creek	0.13	Spawning	**0.25**	Water Temperature	0.200	Water Temperature in Thomes Creek	1.000	0.65	1	**0.65**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the Delta	0.200	0.09	7	**0.64**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the lower Sacramento River	0.200	0.09	7	**0.64**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the middle Sacramento River	0.200	0.09	7	**0.64**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Flow Conditions	0.250	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.200	0.21	3	**0.63**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Flow Conditions	0.250	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.21	3	**0.63**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Flow Conditions	0.250	Low Flows - attraction, migratory cues in the upper Sacramento River	0.200	0.21	3	**0.63**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Upper Sacramento River	0.150	0.13	5	**0.63**	**VH**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Flow Conditions	0.150	Changes in Hydrology	0.300	0.149	4	**0.59**	**VH**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.300	0.10	6	**0.59**	**VH**
Thomes Creek	0.13	Embryo Incubation	**0.15**	Water Temperature	0.300	Water Temperature in Thomes Creek	1.000	0.59	1.00	**0.59**	**VH**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Ocean	0.400	0.096	6	**0.58**	**VH**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Water Temperature	0.300	Middle Sacramento River	0.100	0.144	4	**0.58**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the middle Sacramento River	0.250	0.11	5	**0.57**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Quality	0.150	Ag, Urban in the middle Sacramento River	0.150	0.09	6	**0.57**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Quality	0.150	Urban, Heavy Metals in the upper Sacramento River	0.150	0.09	6	**0.57**	**VH**
Stony Creek	0.16	Spawning	0.35	Flow Conditions	0.100	Flow Fluctuations	1.000	0.560	1	**0.56**	**VH**
Stony Creek	0.16	Spawning	0.35	Physical Habitat Alteration	0.100	Limited Instream Gravel Supply	1.000	0.560	1	**0.56**	**VH**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the middle Sacramento River	0.200	0.09	6	**0.55**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Middle Sacramento River	0.200	0.14	4	**0.55**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Thomes Creek	0.200	0.14	4	**0.55**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Middle Sacramento River	0.200	0.14	4	**0.55**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Thomes Creek	0.200	0.14	4	**0.55**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.200	0.14	4	**0.55**	**VH**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Predation	0.100	Predation in Putah Creek	0.550	0.182	3	**0.54**	**VH**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.150	Changes in Hydrology	0.150	0.090	6	**0.54**	**VH**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Predation	0.075	Predation in the Delta	0.350	0.105	5	**0.53**	**H**
Stony Creek	0.16	Embryo Incubation	**0.10**	Water Quality	0.325	Water Quality in Stony Creek	1.000	0.520	1.00	**0.52**	**H**
Stony Creek	0.16	Embryo Incubation	**0.10**	Water Temperature	0.325	Water Temperature in Stony Creek	1.000	0.520	1	**0.52**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in the Delta	0.175	0.06	8	**0.51**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in the lower Sacramento River	0.175	0.06	8	**0.51**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in the middle Sacramento River	0.175	0.06	8	**0.51**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Jones and Banks Pumping Plants	0.175	0.06	8	**0.51**	**H**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Ocean	0.350	0.07	7	**0.51**	**H**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Yolo Bypass - Freemont Weir	0.100	0.08	6	**0.50**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Jones and Banks Pumping Plants	0.350	0.070	7	**0.49**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	Yolo Bypass - Freemont Weir	0.150	0.10	5	**0.49**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.10	5	**0.49**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.10	5	**0.49**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.250	0.08	6	**0.49**	**H**
Thomes Creek	0.13	Embryo Incubation	**0.15**	Watershed disturbance	0.250	Sedimentation	1.000	0.49	1.00	**0.49**	**H**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.150	Stony Creek	0.200	0.120	4	**0.48**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.150	Delta	0.200	0.120	4	**0.48**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Diversion into Central Delta	0.200	0.08	6	**0.47**	**H**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Loss of Natural River Morphology	0.100	Putah Creek	0.700	0.231	2	**0.46**	**H**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Loss of Riparian Habitat and Instream Cover	0.100	Putah Creek	0.700	0.231	2	**0.46**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Lower Sacramento River	0.350	0.09	5	**0.46**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.075	North Diversion Dam	0.500	0.150	3	**0.45**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.075	Tributary Barriers	0.500	0.150	3	**0.45**	**H**
Beegum Creek	0.13	Embryo Incubation	**0.15**	Flow Conditions	0.225	Flow Fluctuations	1.000	0.44	1.00	**0.44**	**H**
Beegum Creek	0.13	Embryo Incubation	**0.15**	Water Quality	0.225	Water Quality in Beegum Creek	1.000	0.44	1.00	**0.44**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Middle Sacramento River	0.100	0.08	5	**0.42**	**H**
Clear Creek	0.21	Spawning	0.4	Water Quality	0.050	Water Quality in Clear Creek	1.000	0.42	1	**0.42**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.075	Delta	0.350	0.105	4	**0.42**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.075	Delta	0.350	0.105	4	**0.42**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the upper Sacramento River	0.150	0.07	6	**0.41**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.07	6	**0.41**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.07	6	**0.41**	**H**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.20	2	**0.41**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.20	2	**0.41**	**H**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Delta	0.600	0.20	2	**0.41**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Delta	0.600	0.20	2	**0.41**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.08	5	**0.41**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Delta	0.100	0.08	5	**0.41**	**H**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Lower Sacramento River	0.100	0.08	5	**0.41**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Middle Sacramento River	0.100	0.08	5	**0.41**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Upper Sacramento River	0.100	0.08	5	**0.41**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in th Delta	0.400	0.080	5	**0.40**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in Clear Creek	0.100	0.07	6	**0.39**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Middle Sacramento River	0.300	0.08	5	**0.39**	**H**
Thomes Creek	0.13	Embryo Incubation	**0.15**	Flow Conditions	0.200	Flow Fluctuations	1.000	0.39	1.00	**0.39**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.400	0.13	3	**0.39**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues in the middle Sacramento River	0.400	0.13	3	**0.39**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.07	6	**0.39**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.07	6	**0.39**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.200	0.07	6	**0.39**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.300	0.10	4	**0.39**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.300	0.10	4	**0.39**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.200	0.07	6	**0.39**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the upper Sacramento River	0.200	0.07	6	**0.39**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.300	0.10	4	**0.39**	**H**
Thomes Creek	0.13	Embryo Incubation	**0.15**	Water Quality	0.200	Water Quality in Thomes Creek	1.000	0.39	1.00	**0.39**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Delta	0.100	0.10	4	**0.39**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Lower Sacramento River	0.100	0.10	4	**0.39**	**H**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Middle Sacramento River	0.100	0.10	4	**0.39**	**H**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in th Delta	0.400	0.096	4	**0.38**	**H**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Bay	0.100	0.06	6	**0.38**	**H**
Putah Creek	0.12	Embryo Incubation	0.150	Flow Conditions	0.550	Flow Fluctuations	0.375	0.371	1	**0.37**	**H**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Water Quality	0.075	Ag, Urban in Putah Creek	0.500	0.124	3	**0.37**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Tributary Barriers	0.700	0.18	2	**0.37**	**H**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.072	5	**0.36**	**H**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.072	5	**0.36**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.150	Middle Sacramento River	0.150	0.090	4	**0.36**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.075	Lower Sacramento River	0.300	0.090	4	**0.36**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Unscreened Diversions in the Delta	0.250	0.050	7	**0.35**	**H**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.173	2	**0.35**	**H**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.07	5	**0.34**	**H**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.07	5	**0.34**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Beegum Creek	0.100	0.07	5	**0.34**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Upper Sacramento River	0.100	0.07	5	**0.34**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Middle Sacramento River	0.100	0.07	5	**0.34**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Upper Sacramento River	0.100	0.07	5	**0.34**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Middle Sacramento River	0.100	0.07	5	**0.34**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Upper Sacramento River	0.100	0.07	5	**0.34**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.075	Lower Sacramento River	0.275	0.083	4	**0.33**	**H**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.075	Stony Creek	0.275	0.083	4	**0.33**	**H**
Thomes Creek	0.13	Spawning	**0.25**	Barrier	0.100	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.33	1	**0.33**	**H**
Beegum Creek	0.13	Spawning	**0.25**	Barrier	0.100	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.33	1	**0.33**	**H**
Thomes Creek	0.13	Spawning	**0.25**	Flow Conditions	0.100	Flow Fluctuations	1.000	0.33	1	**0.33**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	Sacramento Deep Water Ship Channel	0.100	0.07	5	**0.33**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	Suisun Marsh Salinity Control Structure	0.100	0.07	5	**0.33**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	Sutter Bypass - Tisdale Weir	0.100	0.07	5	**0.33**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.07	5	**0.33**	**H**
Stony Creek	0.16	Embryo Incubation	**0.10**	Flow Conditions	0.200	Flow Fluctuations	1.000	0.320	1	**0.32**	**H**
Putah Creek	0.12	Spawning	0.375	Physical Habitat Alteration	0.150	Limited Instream Gravel Supply	0.450	0.304	1	**0.30**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Predation	0.075	Predation in the lower Sacramento River	0.200	0.060	5	**0.30**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.060	5	**0.30**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.060	5	**0.30**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.300	0.060	5	**0.30**	**H**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Predation	0.100	Predation in the Delta	0.300	0.099	3	**0.30**	**H**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Loss of Floodplain Habitat	0.150	Delta	0.300	0.149	2	**0.30**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in Clear Creek	0.100	0.04	8	**0.29**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in the upper Sacramento River	0.100	0.04	8	**0.29**	**H**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Clear Creek	0.200	0.04	7	**0.29**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.150	0.05	6	**0.29**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.150	0.05	6	**0.29**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.150	0.05	6	**0.29**	**H**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.150	0.05	6	**0.29**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.150	0.05	6	**0.29**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.05	6	**0.29**	**H**
Putah Creek	0.12	Spawning	0.375	Spawning Habitat Availability	0.200	Habitat Suitability	0.325	0.293	1	**0.29**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.150	0.05	6	**0.29**	**H**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Middle Sacramento River	0.200	0.048	6	**0.29**	**H**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.300	0.072	4	**0.29**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.125	0.04	7	**0.28**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.125	0.04	7	**0.28**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.125	0.04	7	**0.28**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Upper Sacramento River	0.125	0.04	7	**0.28**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Beegum Creek	0.500	0.06	5	**0.28**	**H**
Stony Creek	0.16	Spawning	0.35	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.280	1	**0.28**	**H**
Stony Creek	0.16	Spawning	0.35	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.280	1	**0.28**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.140	2	**0.28**	**H**
Stony Creek	0.16	Spawning	0.35	Water Quality	0.050	Water Quality in Stony Creek	1.000	0.280	1	**0.28**	**H**
Stony Creek	0.16	Spawning	0.35	Water Temperature	0.050	Water Temperature in Stony Creek	1.000	0.280	1	**0.28**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in Beegum Creek	0.100	0.05	6	**0.27**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.05	6	**0.27**	**H**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.14	2	**0.27**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.14	2	**0.27**	**H**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Thomes Creek	0.100	0.07	4	**0.27**	**H**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Bays	0.400	0.14	2	**0.27**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Bays	0.400	0.14	2	**0.27**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.150	Flow Dependent Habitat Availability in the lower Sacramento River	0.075	0.045	6	**0.27**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Clear Creek	0.200	0.05	5	**0.26**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.05	5	**0.26**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.05	5	**0.26**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.200	0.05	5	**0.26**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Urban, Heavy Metals in the upper Sacramento River	0.200	0.05	5	**0.26**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.200	0.05	5	**0.26**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.200	0.05	5	**0.26**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in Clear Creek	0.200	0.05	5	**0.26**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Clear Creek	0.200	0.05	5	**0.26**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Sacramento Deep Water Ship Channel	0.050	0.04	6	**0.25**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Suisun Marsh Salinity Control Structure	0.050	0.04	6	**0.25**	**M**
Clear Creek	0.21	Spawning	0.4	Harvest/Angling Impacts	0.030	Recreational, Poaching, Angler Impacts	1.000	0.25	1	**0.25**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Water Temperature	0.150	Delta	0.250	0.124	2	**0.25**	**M**
Beegum Creek	0.13	Embryo Incubation	**0.15**	Water Temperature	0.125	Water Temperature in Beegum Creek	1.000	0.24	1.00	**0.24**	**M**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Stony Creek	0.200	0.048	5	**0.24**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.075	Stony Creek	0.200	0.060	4	**0.24**	**M**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.150	Lower Sacramento River	0.100	0.060	4	**0.24**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.150	Middle Sacramento River	0.100	0.060	4	**0.24**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Changes in Hydrology	0.100	0.04	6	**0.24**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Reverse Flow Conditions	0.100	0.04	6	**0.24**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.030	Delta	0.300	0.05	5	**0.24**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in Thomes Creek	0.100	0.05	5	**0.23**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.05	5	**0.23**	**M**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.100	0.03	7	**0.23**	**M**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Beegum Creek	0.100	0.03	7	**0.23**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	1.000	0.23	1	**0.23**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	1.000	0.23	1	**0.23**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Thomes Creek	0.500	0.06	4	**0.23**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.075	Black Butte Dam	0.250	0.075	3	**0.23**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Predation	0.075	Predation in Stony Creek	0.150	0.045	5	**0.23**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Predation	0.075	Predation in the Bays	0.150	0.045	5	**0.23**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Predation	0.075	Predation in the middle Sacramento River	0.150	0.045	5	**0.23**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Water Quality	0.075	DO, Ag, Urban, Heavy Metals in th Delta	0.300	0.074	3	**0.22**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.04	5	**0.21**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.04	5	**0.21**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.200	0.04	5	**0.21**	**M**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Upper Sacramento River	0.050	0.04	5	**0.21**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Unscreened Diversions in Stony Creek	0.150	0.030	7	**0.21**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Diversion into Central Delta	0.300	0.03	6	**0.20**	**M**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.050	0.04	5	**0.20**	**M**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.050	0.04	5	**0.20**	**M**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.050	0.04	5	**0.20**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Stony Creek	0.200	0.040	5	**0.20**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Loss of Natural River Morphology	0.100	Delta	0.300	0.099	2	**0.20**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Loss of Riparian Habitat and Instream Cover	0.100	Delta	0.300	0.099	2	**0.20**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the Bays	0.050	0.03	6	**0.20**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.04	5	**0.20**	**M**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues in Thomes Creek	0.200	0.07	3	**0.20**	**M**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Thomes Creek	0.100	0.03	6	**0.20**	**M**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in Beegum Creek	0.100	0.03	6	**0.20**	**M**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in Beegum Creek	0.100	0.03	6	**0.20**	**M**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the Bay	0.100	0.03	6	**0.20**	**M**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Water Quality	0.050	Ag, Urban in Putah Creek	0.800	0.096	2	**0.19**	**M**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.200	0.048	4	**0.19**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Entrainment	0.025	Jones and Banks Pumping Plants	0.450	0.037	5	**0.19**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Passage Impediments/Barriers	0.025	Solano Dam	0.750	0.062	3	**0.19**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Contra Costa Power Plant	0.050	0.02	8	**0.18**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in Beegum Creek	0.050	0.02	8	**0.18**	**M**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the upper Sacramento River	0.050	0.02	8	**0.18**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Pittsburg Power Plant	0.050	0.02	8	**0.18**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.150	Flow Dependent Habitat Availability in the middle Sacramento River	0.050	0.030	6	**0.18**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.075	Middle Sacramento River	0.150	0.045	4	**0.18**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Sutter Bypass - Tisdale Weir	0.035	0.03	6	**0.18**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Delta	0.300	0.03	5	**0.17**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Lower Sacramento River	0.300	0.03	5	**0.17**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Delta	0.250	0.03	6	**0.17**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the lower Sacramento River	0.250	0.03	6	**0.17**	**M**
Clear Creek	0.21	Spawning	0.4	Hatchery Effects	0.020	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.17	1	**0.17**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Upper Sacramento River	0.050	0.04	4	**0.17**	**M**
Thomes Creek	0.13	Spawning	**0.25**	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.16	1	**0.16**	**M**
Beegum Creek	0.13	Spawning	**0.25**	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.16	1	**0.16**	**M**
Thomes Creek	0.13	Spawning	**0.25**	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.16	1	**0.16**	**M**
Beegum Creek	0.13	Spawning	**0.25**	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.16	1	**0.16**	**M**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.100	0.03	5	**0.16**	**M**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in Thomes Creek	0.100	0.03	5	**0.16**	**M**
Beegum Creek	0.13	Spawning	**0.25**	Water Quality	0.050	Water Quality in Beegum Creek	1.000	0.16	1	**0.16**	**M**
Thomes Creek	0.13	Spawning	**0.25**	Water Quality	0.050	Water Quality in Thomes Creek	1.000	0.16	1	**0.16**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Contra Costa Power Plant	0.050	0.02	7	**0.16**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in Thomes Creek	0.050	0.02	7	**0.16**	**M**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Pittsburg Power Plant	0.050	0.02	7	**0.16**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Changes in Hydrology	0.200	0.02	7	**0.16**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Diversion into Central Delta	0.200	0.02	7	**0.16**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Reverse Flow Conditions	0.200	0.02	7	**0.16**	**M**
Clear Creek	0.21	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.050	Redd disturbance	1.000	0.16	1.00	**0.16**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Whiskeytown Dam	0.300	0.08	2	**0.16**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Clear Creek	0.150	0.03	5	**0.16**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.03	5	**0.16**	**M**
Clear Creek	0.21	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.16	1.00	**0.16**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.030	Lower Sacramento River	0.200	0.03	5	**0.16**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.030	Middle Sacramento River	0.200	0.03	5	**0.16**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.030	Upper Sacramento River	0.200	0.03	5	**0.16**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Predation	0.100	Predation in the Bays	0.150	0.050	3	**0.15**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in Putah Creek	0.600	0.050	3	**0.15**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Water Quality	0.075	Ag, Urban, Heavy Metals in the Bays	0.200	0.050	3	**0.15**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.074	2	**0.15**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Contra Costa Power Plant	0.050	0.02	8	**0.15**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Pittsburg Power Plant	0.050	0.02	8	**0.15**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Delta	0.100	0.02	7	**0.15**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Lower Sacramento River	0.100	0.02	7	**0.15**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Middle Sacramento River	0.100	0.02	7	**0.15**	**M**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.21	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Upper Sacramento River	0.100	0.02	7	**0.15**	**M**
Beegum Creek	0.13	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.075	Redd disturbance	1.000	0.15	1.00	**0.15**	**M**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Bays	0.100	0.024	6	**0.14**	**M**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Delta	0.100	0.024	6	**0.14**	**M**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Harvest/Angling Impacts	0.100	Delta	0.150	0.036	4	**0.14**	**M**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Lower Sacramento River	0.100	0.024	6	**0.14**	**M**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Stony Creek	0.100	0.024	6	**0.14**	**M**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Putah Creek	0.400	0.048	3	**0.14**	**M**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.400	0.048	3	**0.14**	**M**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Water Temperature	0.050	Delta	0.600	0.072	2	**0.14**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Unscreened Diversions in the lower Sacramento River	0.100	0.020	7	**0.14**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Changes in Hydrology	0.200	0.02	6	**0.14**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Reverse Flow Conditions	0.200	0.02	6	**0.14**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Lower Sacramento River	0.200	0.02	6	**0.14**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Middle Sacramento River	0.200	0.02	6	**0.14**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Upper Sacramento River	0.200	0.02	6	**0.14**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Bays	0.050	0.02	6	**0.14**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.02	6	**0.14**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the middle Sacramento River	0.200	0.02	6	**0.14**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the upper Sacramento River	0.200	0.02	6	**0.14**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.100	0.03	5	**0.13**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.100	0.03	5	**0.13**	**L**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Delta	0.100	0.03	5	**0.13**	**L**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in Thomes Creek	0.100	0.03	4	**0.13**	**L**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Hatchery Effects	0.025	Delta	0.500	0.041	3	**0.12**	**L**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.100	0.024	5	**0.12**	**L**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.100	0.024	5	**0.12**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.075	Middle Sacramento River	0.100	0.030	4	**0.12**	**L**
Stony Creek	0.16	Embryo Incubation	**0.10**	Harvest/Angling Impacts	0.075	Redd disturbance	1.000	0.120	1.00	**0.12**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.060	2	**0.12**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.025	Delta	0.600	0.060	2	**0.12**	**L**
Stony Creek	0.16	Embryo Incubation	**0.10**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.120	1	**0.12**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Flow Dependent Habitat Availability in the lower Sacramento River	0.050	0.02	6	**0.12**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Flow Dependent Habitat Availability in the middle Sacramento River	0.050	0.02	6	**0.12**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Flow Dependent Habitat Availability in the upper Sacramento River	0.050	0.02	6	**0.12**	**L**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Loss of Tidal Marsh Habitat	0.025	Delta	0.700	0.058	2	**0.12**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Bays	0.050	0.02	5	**0.11**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.02	5	**0.11**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Thomes Creek	0.100	0.02	5	**0.11**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the lower Sacramento River	0.200	0.02	5	**0.11**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the middle Sacramento River	0.200	0.02	5	**0.11**	**L**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in Thomes Creek	0.200	0.02	5	**0.11**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban, Heavy Metals in the Bays	0.200	0.02	5	**0.11**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	DO, Ag, Urban, Heavy Metals in the Delta	0.200	0.02	5	**0.11**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Lower Sacramento River	0.200	0.02	5	**0.11**	**L**
Putah Creek	0.12	Embryo Incubation	0.150	Water Temperature	0.300	Water Temperature in Putah Creek	0.200	0.108	1	**0.11**	**L**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.100	0.02	5	**0.11**	**L**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Entrainment	0.025	Individual Diversions in Putah Creek	0.250	0.021	5	**0.10**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	DO, Ag, Urban, Heavy Metals in the Delta	0.150	0.02	6	**0.10**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Bays	0.200	0.020	5	**0.10**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Delta	0.200	0.020	5	**0.10**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Lower Sacramento River	0.200	0.020	5	**0.10**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Middle Sacramento River	0.200	0.020	5	**0.10**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Stony Creek	0.200	0.020	5	**0.10**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.020	5	**0.10**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.100	0.020	5	**0.10**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.100	0.020	5	**0.10**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in Stony Creek	0.100	0.020	5	**0.10**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.100	0.020	5	**0.10**	**L**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Flow Conditions	0.150	Diversion into Central Delta	0.050	0.025	4	**0.10**	**L**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Flow Conditions	0.150	Reverse Flow Conditions	0.050	0.025	4	**0.10**	**L**
Thomes Creek	0.13	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.050	Redd disturbance	1.000	0.10	1.00	**0.10**	**L**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Water Quality	0.050	Stony Creek	0.100	0.024	4	**0.10**	**L**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Putah Creek	0.12	Adult Immigration and Holding	0.200	Water Temperature	0.050	Putah Creek	0.400	0.048	2	**0.10**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Lower Sacramento River	0.200	0.02	4	**0.09**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Middle Sacramento River	0.200	0.02	4	**0.09**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.150	Reverse Flow Conditions	0.025	0.015	6	**0.09**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Middle Sacramento River	0.150	0.02	5	**0.09**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Middle Sacramento River	0.150	0.02	5	**0.09**	**L**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Passage Impediments/Barriers	0.350	Sacramento Deep Water Ship Channel	0.025	0.021	4	**0.08**	**L**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Passage Impediments/Barriers	0.350	Suisun Marsh Salinity Control Structure	0.025	0.021	4	**0.08**	**L**
Thomes Creek	0.13	Spawning	**0.25**	Physical Habitat Alteration	0.050	Limited Instream Gravel Supply	0.500	0.08	1	**0.08**	**L**
Beegum Creek	0.13	Spawning	**0.25**	Physical Habitat Alteration	0.050	Limited Instream Gravel Supply	0.500	0.08	1	**0.08**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.025	Bays	0.400	0.040	2	**0.08**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in Beegum Creek	0.100	0.01	7	**0.08**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.01	7	**0.08**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.01	7	**0.08**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the upper Sacramento River	0.100	0.01	7	**0.08**	**L**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Hatchery Effects	0.025	Bays	0.300	0.025	3	**0.07**	**L**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Bays	0.050	0.01	7	**0.07**	**L**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.024	3	**0.07**	**L**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.300	Sacramento Deep Water Ship Channel	0.010	0.014	5	**0.07**	**L**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.300	Suisun Marsh Salinity Control Structure	0.010	0.014	5	**0.07**	**L**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.300	Sutter Bypass - Tisdale Weir	0.010	0.014	5	**0.07**	**L**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.300	Yolo Bypass - Freemont Weir	0.010	0.014	5	**0.07**	**L**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Contra Costa Power Plant	0.050	0.010	7	**0.07**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Unscreened Diversions in the middle Sacramento River	0.050	0.010	7	**0.07**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Pittsburg Power Plant	0.050	0.010	7	**0.07**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.01	6	**0.07**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.01	6	**0.07**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in Thomes Creek	0.100	0.01	6	**0.07**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Bays	0.100	0.01	6	**0.07**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Beegum Creek	0.050	0.01	6	**0.07**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.050	0.01	6	**0.07**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in Beegum Creek	0.100	0.01	6	**0.07**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban, Heavy Metals in the Bays	0.100	0.01	6	**0.07**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.050	0.01	5	**0.07**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Upper Sacramento River	0.050	0.01	5	**0.07**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.03	2	**0.06**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.010	Delta	0.600	0.03	2	**0.06**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Bays	0.100	0.01	5	**0.06**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Thomes Creek	0.100	0.01	5	**0.06**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Delta	0.100	0.01	5	**0.06**	**L**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Hatchery Effects	0.025	Putah Creek	0.200	0.017	3	**0.05**	**L**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Passage Impediments/Barriers	0.025	Montecello Dam	0.200	0.017	3	**0.05**	**L**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.200	0.017	3	**0.05**	**L**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.017	3	**0.05**	**L**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Loss of Tidal Marsh Habitat	0.025	Bays	0.300	0.025	2	**0.05**	**L**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Harvest/Angling Impacts	0.100	Bays	0.050	0.012	4	**0.05**	**L**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Harvest/Angling Impacts	0.100	Ocean	0.050	0.012	4	**0.05**	**L**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in th Delta	0.200	0.024	2	**0.05**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Delta	0.100	0.01	4	**0.05**	**L**
Putah Creek	0.12	Spawning	0.375	Flow Conditions	0.200	Flow Fluctuations	0.050	0.045	1	**0.05**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.02	2	**0.04**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.010	Bays	0.400	0.02	2	**0.04**	**L**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Entrainment	0.025	Contra Costa Power Plant	0.100	0.008	5	**0.04**	**L**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Entrainment	0.025	Individual Diversions in the Delta	0.100	0.008	5	**0.04**	**L**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Entrainment	0.025	Pittsburg Power Plant	0.100	0.008	5	**0.04**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.030	Bays	0.050	0.01	5	**0.04**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.030	Clear Creek	0.050	0.01	5	**0.04**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Beegum Creek	0.050	0.01	6	**0.03**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Upper Sacramento River	0.050	0.01	5	**0.03**	**L**
Putah Creek	0.12	Spawning	0.375	Barrier	0.250	Redd superimposition, competition for habitat, hybridization/genetic integrity	0.025	0.028	1	**0.03**	**L**
Putah Creek	0.12	Embryo Incubation	0.150	Harvest/Angling Impacts	0.050	Redd disturbance	0.275	0.025	1.00	**0.02**	**L**
Putah Creek	0.12	Spawning	0.375	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	0.075	0.017	1	**0.02**	**L**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Passage Impediments/Barriers	0.025	Tributary Barriers	0.050	0.004	3	**0.01**	**L**
Putah Creek	0.12	Spawning	0.375	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	0.050	0.011	1	**0.01**	**L**
Putah Creek	0.12	Spawning	0.375	Water Temperature	0.050	Putah Creek	0.050	0.011	1	**0.01**	**L**

Northwestern California Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Putah Creek	0.12	Spawning	0.375	Water Quality	0.050	Putah Creek	0.025	0.006	1	**0.01**	**L**
Putah Creek	0.12	Embryo Incubation	0.150	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	0.050	0.005	1	**0.00**	**L**
Putah Creek	0.12	Embryo Incubation	0.150	Water Quality	0.050	Water Pollution	0.050	0.005	1.00	**0.00**	**L**

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
San Joaquin River	0.15	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.400	Friant Dam	0.500	0.900	5	**4.500**	**VH**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.350	Bellota Weir	0.375	0.748	5	**3.741**	**VH**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.350	Flash Board Dams	0.375	0.748	5	**3.741**	**VH**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Flow Conditions	0.250	Flow Dependent Habitat Availability in the San Joaquin River	0.500	0.750	4	**3.000**	**VH**
Tuolumne River	0.16	Spawning	0.35	Spawning Habitat Availability	0.500	Habitat Suitability	1.000	2.800	1	**2.800**	**VH**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.300	Flow Dependent Habitat Availability in the Calaveras River	0.500	0.855	3	**2.565**	**VH**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.350	La Grange	0.500	0.560	4	**2.240**	**VH**
Stanislaus River	0.18	Spawning	0.35	Physical Habitat Alteration	0.350	Limited Instream Gravel Supply	1.000	2.205	1	**2.205**	**VH**
Stanislaus River	0.18	Spawning	0.35	Spawning Habitat Availability	0.350	Habitat Suitability	1.000	2.205	1	**2.205**	**VH**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.350	Don Pedro	0.350	0.392	5	**1.960**	**VH**
Merced River	0.16	Spawning	0.30	Spawning Habitat Availability	0.400	Habitat Suitability	1.000	1.920	1	**1.920**	**VH**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	Goodwin Dam	0.350	0.378	5	**1.890**	**VH**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Flow Conditions	0.250	Changes in Hydrology	0.300	0.450	4	**1.800**	**VH**
Calaveras River	0.19	Embryo Incubation	**0.20**	Flow Conditions	0.450	Flow Fluctuations	1.000	1.710	1	**1.710**	**VH**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Flow Conditions	0.300	Low flows limiting attraction into the Calaveras Rvier	1.000	1.710	1	**1.710**	**VH**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.200	Flow Dependent Habitat Availability in Merced River	0.350	0.336	5	**1.680**	**VH**
Tuolumne River	0.16	Spawning	0.35	Physical Habitat Alteration	0.300	Limited Instream Gravel Supply	1.000	1.680	1	**1.680**	**VH**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	New Melones	0.300	0.324	5	**1.620**	**VH**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.300	Changes in Hydrology	0.300	0.513	3	**1.539**	**VH**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.350	Stockton Deep Water Ship Channel	0.150	0.299	5	**1.496**	**VH**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Water Quality	0.150	Ag, Urban in the San Joaquin River	0.550	0.495	3	**1.485**	**VH**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.300	Camanche Dam	0.440	0.297	5	**1.485**	**VH**
Merced River	0.16	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	Crocker Huffman	0.300	0.288	5	**1.440**	**VH**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Flow Conditions	0.350	Low flows limiting attraction into the Stanislaus River	0.550	0.693	2	**1.386**	**VH**

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
San Joaquin River	0.15	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.400	Mendota Pool	0.150	0.270	5	**1.350**	**VH**
San Joaquin River	0.15	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.400	Sack Dam	0.150	0.270	5	**1.350**	**VH**
San Joaquin River	0.15	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.400	Stockton Deep Water Ship Channel	0.150	0.270	5	**1.350**	**VH**
Stanislaus River	0.18	Embryo Incubation	**0.20**	Flow Conditions	0.600	Flow Fluctuations	0.600	1.296	1	**1.296**	**VH**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.175	Mokelumne River	0.650	0.427	3	**1.280**	**VH**
Stanislaus River	0.18	Spawning	0.35	Flow Conditions	0.200	Flow Fluctuations	1.000	1.260	1	**1.260**	**VH**
San Joaquin River	0.15	Adult Immigration and Holding	0.30	Water Quality	0.200	Ag, Urban in the San Joaquin River	0.700	0.630	2	**1.260**	**VH**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Water Temperature	0.150	San Joaquin River	0.700	0.630	2	**1.260**	**VH**
Mokelumne River	0.15	Spawning	0.40	Barrier	0.200	Competition for spawning habitat	1.000	1.200	1	**1.200**	**VH**
Mokelumne River	0.15	Spawning	0.40	Hatchery Effects	0.200	Redd superimposition, competition for habitat, Genetic Integrity	1.000	1.200	1	**1.200**	**VH**
Merced River	0.16	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	McSwain Dam	0.250	0.240	5	**1.200**	**VH**
Mokelumne River	0.15	Spawning	0.40	Spawning Habitat Availability	0.200	Habitat Suitability	1.000	1.200	1	**1.200**	**VH**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Passage Impediments/Barriers	0.175	Bellota Weir	0.400	0.399	3	**1.197**	**VH**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Passage Impediments/Barriers	0.175	New Hogan Dam	0.400	0.399	3	**1.197**	**VH**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Water Quality	0.150	Ag, Urban in the Calaveras River	0.700	0.599	2	**1.197**	**VH**
Tuolumne River	0.16	Embryo Incubation	**0.20**	Flow Conditions	0.600	Flow Fluctuations	0.600	1.152	1	**1.152**	**VH**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.300	Pardee Reservoir Dam	0.340	0.230	5	**1.148**	**VH**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Flow Conditions	0.350	Low Flows - attraction, migratory cues in Stanislaus River	0.450	0.567	2	**1.134**	**VH**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Flow Dependent Habitat Availability in the Stanislaus River	0.400	0.225	5	**1.125**	**VH**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.200	San Joaquin River	0.450	0.360	3	**1.080**	**VH**
Merced River	0.16	Adult Immigration and Holding	0.20	Flow Conditions	0.300	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in San Joaquin River	0.550	0.528	2	**1.056**	**VH**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.300	Reverse Flow Conditions	0.200	0.342	3	**1.026**	**VH**

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.150	San Joaquin River	0.500	0.338	3	**1.013**	**VH**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.125	Calaveras River	0.700	0.499	2	**0.998**	**VH**
Mokelumne River	0.15	Embryo Incubation	**0.20**	Flow Conditions	0.325	Flow Fluctuations	1.000	0.975	1	**0.975**	**VH**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	Tulloch Dam	0.180	0.194	5	**0.972**	**VH**
Merced River	0.16	Embryo Incubation	**0.20**	Flow Conditions	0.550	Flow Fluctuations	0.550	0.968	1	**0.968**	**VH**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.200	Flow Dependent Habitat Availability in the San Joaquin River	0.200	0.192	5	**0.960**	**VH**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.200	Reverse Flow Conditions	0.200	0.192	5	**0.960**	**VH**
Merced River	0.16	Spawning	0.30	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply	1.000	0.960	1	**0.960**	**VH**
Merced River	0.16	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	New Exchequer Dam	0.200	0.192	5	**0.960**	**VH**
Merced River	0.16	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	Stockton Deep Water Ship Channel	0.200	0.192	5	**0.960**	**VH**
Calaveras River	0.19	Embryo Incubation	**0.20**	Water Temperature	0.250	Water temperature in the Calaveras River	1.000	0.950	1	**0.950**	**VH**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Water Quality	0.100	Ag, Urban in the Calaveras River	0.550	0.314	3	**0.941**	**VH**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.200	Flow Dependent Habitat Availability in the Mokelumne River	0.400	0.300	3	**0.900**	**VH**
San Joaquin River	0.15	Adult Immigration and Holding	0.30	Flow Conditions	0.200	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in San Joaquin River	1.000	0.900	1	**0.900**	**VH**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Flow Conditions	0.250	Reverse Flow Conditions	0.150	0.225	4	**0.900**	**VH**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Flow Dependent Habitat Availability in the Tuolumne River	0.350	0.175	5	**0.875**	**VH**
Merced River	0.16	Adult Immigration and Holding	0.20	Flow Conditions	0.300	Low Flows - attraction, migratory cues in the Merced River	0.450	0.432	2	**0.864**	**VH**
Calaveras River	0.19	Spawning	0.20	Spawning Habitat Availability	0.225	Habitat Suitability	1.000	0.855	1	**0.855**	**VH**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Changes in Hydrology	0.300	0.169	5	**0.844**	**VH**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Loss of Riparian Habitat and Instream Cover	0.100	San Joaquin River	0.700	0.420	2	**0.840**	**VH**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.200	Tuolumne River	0.350	0.280	3	**0.840**	**VH**
Mokelumne River	0.15	Embryo Incubation	**0.20**	Water Temperature	0.275	Water temperature in the Mokelumne River	1.000	0.825	1	**0.825**	**VH**

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	Stockton Deep Water Ship Channel	0.150	0.162	5	**0.810**	**VH**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in th Delta	0.300	0.270	3	**0.810**	**VH**
Merced River	0.16	Adult Immigration and Holding	0.20	Water Temperature	0.200	Merced River	0.400	0.256	3	**0.768**	**VH**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Water Temperature	0.200	San Joaquin River	0.400	0.256	3	**0.768**	**VH**
Merced River	0.16	Adult Immigration and Holding	0.20	Water Temperature	0.200	San Joaquin River	0.400	0.256	3	**0.768**	**VH**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Water Temperature	0.200	Tuolumne River	0.400	0.256	3	**0.768**	**VH**
Calaveras River	0.19	Spawning	0.20	Barrier	0.200	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.760	1	**0.760**	**VH**
Calaveras River	0.19	Spawning	0.20	Flow Conditions	0.200	Flow Fluctuations	1.000	0.760	1	**0.760**	**VH**
Calaveras River	0.19	Spawning	0.20	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply	1.000	0.760	1	**0.760**	**VH**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.350	0.252	3	**0.756**	**VH**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Riparian Habitat and Instream Cover	0.150	San Joaquin River	0.350	0.252	3	**0.756**	**VH**
San Joaquin River	0.15	Spawning	0.20	Spawning Habitat Availability	0.250	Habitat Suitability	1.000	0.750	1	**0.750**	**VH**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Water Quality	0.150	Ag, Urban in the San Joaquin River	0.450	0.243	3	**0.729**	**VH**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.200	Changes in Hydrology	0.150	0.144	5	**0.720**	**VH**
Merced River	0.16	Spawning	0.30	Flow Conditions	0.150	Flow Fluctuations	1.000	0.720	1	**0.720**	**VH**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Water Quality	0.100	Ag, Urban in the San Joaquin River	0.400	0.180	4	**0.720**	**VH**
Merced River	0.16	Spawning	0.30	Water Temperature	0.150	Water temperature in the Merced River	1.000	0.720	1	**0.720**	**VH**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Flow Conditions	0.200	Low Flows - attraction, migratory cues in Tuolumne River	0.550	0.352	2	**0.704**	**VH**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Entrainment	0.075	Jones and Banks Pumping Plants	0.500	0.141	5	**0.703**	**VH**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Loss of Natural River Morphology	0.100	Calaveras River	0.600	0.342	2	**0.684**	**VH**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Water Temperature	0.100	Calaveras River	0.600	0.342	2	**0.684**	**VH**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Flow Conditions	0.300	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in the Mokelumne River	1.000	0.675	1	**0.675**	**VH**

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.200	Changes in Hydrology	0.300	0.225	3	0.675	VH
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.200	Reverse Flow Conditions	0.300	0.225	3	0.675	VH
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Jones and Banks Pumping Plants	0.450	0.108	6	0.648	VH
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.100	San Joaquin River	0.450	0.216	3	0.648	VH
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Riparian Habitat and Instream Cover	0.150	Merced River	0.300	0.216	3	0.648	VH
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in th Delta	0.400	0.216	3	0.648	VH
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Predation	0.075	Predation in the Delta	0.500	0.214	3	0.641	VH
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.150	Delta	0.300	0.203	3	0.608	VH
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Entrainment	0.050	Jones and Banks Pumping Plants	0.400	0.120	5	0.600	VH
San Joaquin River	0.15	Spawning	0.20	Barrier	0.200	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.600	1	0.600	VH
Mokelumne River	0.15	Spawning	0.40	Flow Conditions	0.100	Flow Fluctuations	1.000	0.600	1	0.600	VH
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Loss of Floodplain Habitat	0.050	Delta	0.500	0.150	4	0.600	VH
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Loss of Floodplain Habitat	0.050	San Joaquin River	0.500	0.150	4	0.600	VH
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Loss of Tidal Marsh Habitat	0.050	Bays	0.500	0.150	4	0.600	VH
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Loss of Tidal Marsh Habitat	0.050	Delta	0.500	0.150	4	0.600	VH
Mokelumne River	0.15	Spawning	0.40	Physical Habitat Alteration	0.100	Limited Instream Gravel Supply	1.000	0.600	1	0.600	VH
Mokelumne River	0.15	Spawning	0.40	Water Temperature	0.100	Water temperature in the Mokelumne River	1.000	0.600	1	0.600	VH
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Passage Impediments/Barriers	0.175	Tributary Barriers	0.200	0.200	3	0.599	H
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Flow Conditions	0.200	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in San Joaquin River	0.450	0.288	2	0.576	H
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Water Quality	0.150	Ag, Urban in the San Joaquin River	0.400	0.192	3	0.576	H
Calaveras River	0.19	Embryo Incubation	**0.20**	Harvest/Angling Impacts	0.150	Redd disturbance	1.000	0.570	1.00	0.570	H
Tuolumne River	0.16	Spawning	0.35	Flow Conditions	0.100	Flow Fluctuations	1.000	0.560	1	0.560	H
Tuolumne River	0.16	Spawning	0.35	Water Temperature	0.100	Water temperature in the Tuolumne River	1.000	0.560	1	0.560	H
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Jones and Banks Pumping Plants	0.400	0.090	6	0.540	H

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.100	Stanislaus River	0.400	0.180	3	**0.540**	**H**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Predation	0.075	Predation in the Delta	0.400	0.180	3	**0.540**	**H**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Predation	0.075	Predation in the San Joaquin River	0.400	0.180	3	**0.540**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in th Delta	0.300	0.135	4	**0.540**	**H**
San Joaquin River	0.15	Adult Immigration and Holding	0.30	Water Quality	0.200	DO, Ag, Urban, Heavy Metals in th Delta	0.300	0.270	2	**0.540**	**H**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Water Temperature	0.150	Delta	0.300	0.270	2	**0.540**	**H**
San Joaquin River	0.15	Adult Immigration and Holding	0.30	Water Temperature	0.100	San Joaquin River	0.600	0.270	2	**0.540**	**H**
San Joaquin River	0.15	Spawning	0.20	Physical Habitat Alteration	0.175	Limited Instream Gravel Supply	1.000	0.525	1	**0.525**	**H**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Calaveras River	0.450	0.128	4	**0.513**	**H**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Predation	0.075	Predation in the Calaveras River	0.400	0.171	3	**0.513**	**H**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Calaveras River	0.600	0.171	3	**0.513**	**H**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in th Delta	0.300	0.171	3	**0.513**	**H**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in th Delta	0.300	0.257	2	**0.513**	**H**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.300	Stockton Deep Water Ship Channel	0.150	0.101	5	**0.506**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Floodplain Habitat	0.100	Merced River	0.350	0.168	3	**0.504**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Floodplain Habitat	0.100	San Joaquin River	0.350	0.168	3	**0.504**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Natural River Morphology	0.100	Delta	0.350	0.168	3	**0.504**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Natural River Morphology	0.100	San Joaquin River	0.350	0.168	3	**0.504**	**H**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Water Quality	0.150	Ag, Urban in the Tuolumne River	0.350	0.168	3	**0.504**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.100	Merced River	0.350	0.168	3	**0.504**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Flow Dependent Habitat Availability in the San Joaquin River	0.200	0.100	5	**0.500**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Reverse Flow Conditions	0.200	0.100	5	**0.500**	**H**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Jones and Banks Pumping Plants	0.350	0.100	5	**0.499**	**H**

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Calaveras River	0.19	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.350	New Hogan Dam	0.050	0.100	5	**0.499**	**H**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.350	Suisun Marsh Salinity Control Structure	0.050	0.100	5	**0.499**	**H**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.175	Delta	0.250	0.164	3	**0.492**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.200	Diversion into Central Delta	0.100	0.096	5	**0.480**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Predation	0.050	Predation in the Merced River	0.500	0.120	4	**0.480**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.200	Delta	0.200	0.160	3	**0.480**	**H**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Mokelumne River	0.525	0.118	4	**0.473**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.100	San Joaquin River	0.350	0.158	3	**0.473**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.100	Stanislaus River	0.350	0.158	3	**0.473**	**H**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Loss of Natural River Morphology	0.100	Delta	0.400	0.228	2	**0.456**	**H**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Water Temperature	0.100	Delta	0.400	0.228	2	**0.456**	**H**
San Joaquin River	0.15	Spawning	0.20	Flow Conditions	0.150	Flow Fluctuations	1.000	0.450	1	**0.450**	**H**
Mokelumne River	0.15	Embryo Incubation	**0.20**	Harvest/Angling Impacts	0.150	Redd disturbance	1.000	0.450	1.00	**0.450**	**H**
San Joaquin River	0.15	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.400	Suisun Marsh Salinity Control Structure	0.050	0.090	5	**0.450**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Predation	0.050	Predation in the Stanislaus River	0.500	0.113	4	**0.450**	**H**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the San Joaquin River	0.500	0.150	3	**0.450**	**H**
Mokelumne River	0.15	Embryo Incubation	**0.20**	Water Quality	0.150	Water Pollution	1.000	0.450	1.00	**0.450**	**H**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.100	Mokelumne River	0.600	0.225	2	**0.450**	**H**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.350	Stockton Deep Water Ship Channel	0.100	0.112	4	**0.448**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Passage Impediments/Barriers	0.050	Crocker Huffman	0.450	0.108	4	**0.432**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Floodplain Habitat	0.100	Delta	0.300	0.144	3	**0.432**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Natural River Morphology	0.100	Merced River	0.300	0.144	3	**0.432**	**H**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Water Temperature	0.100	Delta	0.400	0.144	3	**0.432**	**H**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Water Temperature	0.100	San Joaquin River	0.400	0.144	3	**0.432**	**H**

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Individual Diversions in the Calaveras River	0.300	0.086	5	**0.428**	**H**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.125	Delta	0.300	0.214	2	**0.428**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Flow Dependent Habitat Availability in the San Joaquin River	0.150	0.084	5	**0.422**	**H**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.210	2	**0.420**	**H**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Passage Impediments/Barriers	0.050	Friant Dam	0.700	0.210	2	**0.420**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Water Quality	0.075	Ag, Urban in the San Joaquin River	0.350	0.105	4	**0.420**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Jones and Banks Pumping Plants	0.350	0.070	6	**0.420**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.100	San Joaquin River	0.350	0.140	3	**0.420**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.100	Tuolumne River	0.350	0.140	3	**0.420**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.100	Delta	0.350	0.140	3	**0.420**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.100	San Joaquin River	0.350	0.140	3	**0.420**	**H**
San Joaquin River	0.15	Embryo Incubation	**0.10**	Flow Conditions	0.275	Flow Fluctuations	1.000	0.413	1	**0.413**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.150	Stanislaus River	0.200	0.135	3	**0.405**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.100	Delta	0.300	0.135	3	**0.405**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.100	Delta	0.300	0.135	3	**0.405**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.100	San Joaquin River	0.300	0.135	3	**0.405**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.100	Delta	0.300	0.135	3	**0.405**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.100	San Joaquin River	0.300	0.135	3	**0.405**	**H**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Water Quality	0.150	Ag, Urban, Heavy Metals in the Bays	0.150	0.135	3	**0.405**	**H**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Delta	0.350	0.100	4	**0.399**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the San Joaquin River	0.400	0.096	4	**0.384**	**H**
Merced River	0.16	Adult Immigration and Holding	0.20	Water Quality	0.100	Ag, Urban in the San Joaquin River	0.400	0.128	3	**0.384**	**H**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Water Temperature	0.200	Delta	0.200	0.128	3	**0.384**	**H**

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Merced River	0.16	Adult Immigration and Holding	0.20	Water Temperature	0.200	Delta	0.200	0.128	3	**0.384**	**H**
Calaveras River	0.19	Embryo Incubation	**0.20**	Water Quality	0.100	Water Pollution	1.000	0.380	1.00	**0.380**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Changes in Hydrology	0.150	0.075	5	**0.375**	**H**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.100	Delta	0.500	0.188	2	**0.375**	**H**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.100	Mokelumne River	0.500	0.188	2	**0.375**	**H**
San Joaquin River	0.15	Embryo Incubation	**0.10**	Water Quality	0.250	Water Pollution	1.000	0.375	1.00	**0.375**	**H**
San Joaquin River	0.15	Embryo Incubation	**0.10**	Water Temperature	0.250	Water temperature in the San Joaquin River	1.000	0.375	1	**0.375**	**H**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Stanislaus River	0.400	0.072	5	**0.360**	**H**
San Joaquin River	0.15	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	San Joaquin River	0.400	0.090	4	**0.360**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.100	Delta	0.300	0.120	3	**0.360**	**H**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Loss of Natural River Morphology	0.050	San Joaquin River	0.600	0.180	2	**0.360**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.100	Tuolumne River	0.300	0.120	3	**0.360**	**H**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Loss of Riparian Habitat and Instream Cover	0.100	Delta	0.300	0.180	2	**0.360**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Predation	0.075	Predation in the San Joaquin River	0.300	0.090	4	**0.360**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Predation	0.075	Predation in the Tuolumne River	0.300	0.090	4	**0.360**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the San Joaquin River	0.400	0.090	4	**0.360**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Water Quality	0.100	Ag, Urban in the Stanislaus River	0.200	0.090	4	**0.360**	**H**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in th Delta	0.250	0.120	3	**0.360**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Water Quality	0.075	DO, Ag, Urban, Heavy Metals in th Delta	0.300	0.090	4	**0.360**	**H**
San Joaquin River	0.15	Adult Immigration and Holding	0.30	Water Temperature	0.100	Delta	0.400	0.180	2	**0.360**	**H**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Loss of Riparian Habitat and Instream Cover	0.050	Calaveras River	0.600	0.171	2	**0.342**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.168	2	**0.336**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Passage Impediments/Barriers	0.050	McSwain Dam	0.350	0.084	4	**0.336**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Water Quality	0.050	Ag, Urban in the San Joaquin River	0.350	0.084	4	**0.336**	**H**

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Merced River	0.16	Adult Immigration and Holding	0.20	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in th Delta	0.350	0.112	3	**0.336**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the San Joaquin River	0.400	0.080	4	**0.320**	**H**
Stanislaus River	0.18	Spawning	0.35	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.315	1	**0.315**	**H**
Stanislaus River	0.18	Spawning	0.35	Water Quality	0.050	Water quality in Stanislaus River	1.000	0.315	1	**0.315**	**H**
Stanislaus River	0.18	Spawning	0.35	Water Temperature	0.050	Water temperature in the Stanislaus River	1.000	0.315	1	**0.315**	**H**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Delta	0.350	0.079	4	**0.315**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.158	2	**0.315**	**H**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Entrainment	0.050	Individual Diversions in the Delta	0.200	0.060	5	**0.300**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Diversions in the San Joaquin River	0.250	0.050	6	**0.300**	**M**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Entrainment	0.050	Individual Diversions in the San Joaquin River	0.200	0.060	5	**0.300**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Don Pedro	0.500	0.100	3	**0.300**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	La Grange	0.500	0.100	3	**0.300**	**M**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Flow Conditions	0.250	Diversion into Central Delta	0.050	0.075	4	**0.300**	**M**
Mokelumne River	0.15	Spawning	0.40	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.300	1	**0.300**	**M**
Mokelumne River	0.15	Embryo Incubation	**0.20**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.300	1	**0.300**	**M**
Mokelumne River	0.15	Spawning	0.40	Water Quality	0.050	Water quality in the Mokelumne River	1.000	0.300	1	**0.300**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.100	Delta	0.400	0.150	2	**0.300**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Goodwin Dam	0.330	0.074	4	**0.297**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	New Melones	0.330	0.074	4	**0.297**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Tulloch Dam	0.330	0.074	4	**0.297**	**M**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Individual Diversions in the San Joaquin River	0.200	0.048	6	**0.288**	**M**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Tidal Marsh Habitat	0.050	Delta	0.600	0.144	2	**0.288**	**M**

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.072	4	**0.288**	**M**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the San Joaquin River	0.400	0.072	4	**0.288**	**M**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in th Delta	0.300	0.072	4	**0.288**	**M**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.100	Delta	0.200	0.096	3	**0.288**	**M**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Individual Diversions in the Delta	0.200	0.057	5	**0.285**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Entrainment	0.075	Individual Diversions in the Mokelumne River	0.200	0.056	5	**0.281**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Reverse Flow Conditions	0.100	0.056	5	**0.281**	**M**
Merced River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Merced River	0.350	0.056	5	**0.280**	**M**
Tuolumne River	0.16	Spawning	0.35	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.280	1	**0.280**	**M**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Tuolumne River	0.350	0.056	5	**0.280**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.140	2	**0.280**	**M**
Tuolumne River	0.16	Spawning	0.35	Water Quality	0.050	Water quality in Tuolumne River	1.000	0.280	1	**0.280**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Diversions in the San Joaquin River	0.200	0.045	6	**0.270**	**M**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Hatchery Effects	0.025	Delta	0.600	0.090	3	**0.270**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.100	Stanislaus River	0.200	0.090	3	**0.270**	**M**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Predation	0.075	Predation in the Bays	0.200	0.090	3	**0.270**	**M**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.090	3	**0.270**	**M**
San Joaquin River	0.15	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the San Joaquin River	0.400	0.090	3	**0.270**	**M**
San Joaquin River	0.15	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Delta	0.300	0.068	4	**0.270**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.050	Delta	0.600	0.135	2	**0.270**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.068	4	**0.270**	**M**

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Water Temperature	0.100	Mokelumne River	0.600	0.135	2	**0.270**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.131	2	**0.263**	**M**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.086	3	**0.257**	**M**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Water Quality	0.100	Ag, Urban, Heavy Metals in the Bays	0.150	0.086	3	**0.257**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Predation	0.050	Predation in the Delta	0.450	0.084	3	**0.253**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Predation	0.050	Predation in the Mokelumne River	0.450	0.084	3	**0.253**	**M**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Mokelumne River	0.750	0.084	3	**0.253**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Diversion into Central Delta	0.100	0.050	5	**0.250**	**M**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Water Quality	0.150	Ag, Urban in the Stanislaus River	0.150	0.081	3	**0.243**	**M**
Merced River	0.16	Spawning	0.30	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.240	1	**0.240**	**M**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Loss of Natural River Morphology	0.050	Delta	0.400	0.120	2	**0.240**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Predation	0.075	Predation in the Bays	0.200	0.060	4	**0.240**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Predation	0.075	Predation in the Delta	0.200	0.060	4	**0.240**	**M**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Predation	0.050	Predation in the San Joaquin River	0.250	0.060	4	**0.240**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Water Quality	0.075	Ag, Urban in the Tuolumne River	0.200	0.060	4	**0.240**	**M**
Merced River	0.16	Spawning	0.30	Water Quality	0.050	Water quality in Merced River	1.000	0.240	1	**0.240**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Diversions in the Delta	0.200	0.040	6	**0.240**	**M**
Merced River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	San Joaquin River	0.300	0.048	5	**0.240**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.050	Delta	0.600	0.120	2	**0.240**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.060	4	**0.240**	**M**
Merced River	0.16	Adult Immigration and Holding	0.20	Water Quality	0.100	Ag, Urban in the Merced River	0.250	0.080	3	**0.240**	**M**
Merced River	0.16	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	Suisun Marsh Salinity Control Structure	0.050	0.048	5	**0.240**	**M**

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
San Joaquin River	0.15	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.350	0.079	3	**0.236**	**M**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Loss of Floodplain Habitat	0.025	Delta	0.800	0.114	2	**0.228**	**M**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Loss of Riparian Habitat and Instream Cover	0.050	Delta	0.400	0.114	2	**0.228**	**M**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	San Joaquin River	0.250	0.045	5	**0.225**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.050	Mokelumne River	0.600	0.113	2	**0.225**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.050	Mokelumne River	0.600	0.113	2	**0.225**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.050	Delta	0.600	0.113	2	**0.225**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Camanche Dam	0.300	0.056	4	**0.225**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Woodbridge Dam	0.300	0.056	4	**0.225**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Predation	0.050	Predation in the San Joaquin River	0.250	0.056	4	**0.225**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in the Mokelumne River	0.400	0.075	3	**0.225**	**M**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Water Quality	0.100	Ag, Urban in the Mokelumne River	0.500	0.113	2	**0.225**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in th Delta	0.400	0.075	3	**0.225**	**M**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in th Delta	0.500	0.113	2	**0.225**	**M**
San Joaquin River	0.15	Spawning	0.20	Water Quality	0.075	Water quality in the San Joaquin River	1.000	0.225	1	**0.225**	**M**
San Joaquin River	0.15	Spawning	0.20	Water Temperature	0.075	Water temperature in the San Joaquin River	1.000	0.225	1	**0.225**	**M**
Stanislaus River	0.18	Embryo Incubation	**0.20**	Water Temperature	0.250	Water Temperature in the Stanislaus River	0.250	0.225	1	**0.225**	**M**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.350	Suisun Marsh Salinity Control Structure	0.050	0.056	4	**0.224**	**M**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the San Joaquin River	0.350	0.056	4	**0.224**	**M**
Merced River	0.16	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the San Joaquin River	0.350	0.056	4	**0.224**	**M**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Individual Diversions in the Merced River	0.150	0.036	6	**0.216**	**M**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Water Temperature	0.100	Stanislaus River	0.200	0.072	3	**0.216**	**M**

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.054	4	**0.216**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.050	Delta	0.350	0.070	3	**0.210**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.050	San Joaquin River	0.350	0.070	3	**0.210**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Diversions in the Delta	0.150	0.034	6	**0.203**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Diversions in the Stanislaus River	0.150	0.034	6	**0.203**	**M**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	San Joaquin River	0.250	0.040	5	**0.200**	**M**
Merced River	0.16	Embryo Incubation	**0.20**	Water Temperature	0.250	Water temperature in the Merced River	0.250	0.200	1	**0.200**	**M**
Tuolumne River	0.16	Embryo Incubation	**0.20**	Water Temperature	0.250	Water Temperature in the Tuolumne River	0.250	0.200	1	**0.200**	**M**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Invasive Species/Food Web Disruption	0.025	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.100	2	**0.200**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.175	Bays	0.100	0.066	3	**0.197**	**M**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Tidal Marsh Habitat	0.050	Bays	0.400	0.096	2	**0.192**	**M**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.200	0.048	4	**0.192**	**M**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Water Quality	0.050	Ag, Urban in the Merced River	0.200	0.048	4	**0.192**	**M**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.048	4	**0.192**	**M**
Merced River	0.16	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.048	4	**0.192**	**M**
Calaveras River	0.19	Spawning	0.20	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.190	1	**0.190**	**M**
Calaveras River	0.19	Embryo Incubation	**0.20**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.190	1	**0.190**	**M**
Calaveras River	0.19	Spawning	0.20	Water Quality	0.050	Water quality in the Calaveras River	1.000	0.190	1	**0.190**	**M**
Calaveras River	0.19	Spawning	0.20	Water Temperature	0.050	Water temperature in the Calaveras River	1.000	0.190	1	**0.190**	**M**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Delta	0.200	0.036	5	**0.180**	**M**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.200	0.060	3	**0.180**	**M**

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Diversions in the Tuolumne River	0.150	0.030	6	**0.180**	**M**
San Joaquin River	0.15	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Bays	0.200	0.045	4	**0.180**	**M**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.090	2	**0.180**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.050	Tuolumne River	0.300	0.060	3	**0.180**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.050	Bays	0.400	0.090	2	**0.180**	**M**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Passage Impediments/Barriers	0.050	Tributary Barriers	0.300	0.090	2	**0.180**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.200	0.045	4	**0.180**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Water Quality	0.100	Ag, Urban, Heavy Metals in the Bays	0.100	0.045	4	**0.180**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Water Quality	0.075	Ag, Urban, Heavy Metals in the Bays	0.150	0.045	4	**0.180**	**M**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Water Temperature	0.100	Delta	0.400	0.090	2	**0.180**	**M**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.400	0.057	3	**0.171**	**L**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Bays	0.150	0.043	4	**0.171**	**L**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Loss of Tidal Marsh Habitat	0.025	Delta	0.600	0.086	2	**0.171**	**L**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.300	Suisun Marsh Salinity Control Structure	0.050	0.034	5	**0.169**	**L**
San Joaquin River	0.15	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.250	0.056	3	**0.169**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Mokelumne River	0.600	0.056	3	**0.169**	**L**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Delta	0.200	0.032	5	**0.160**	**L**
Merced River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Delta	0.200	0.032	5	**0.160**	**L**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.050	Bays	0.400	0.080	2	**0.160**	**L**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.200	0.040	4	**0.160**	**L**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Entrainment	0.050	Contra Costa Power Plant	0.100	0.030	5	**0.150**	**L**

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Entrainment	0.050	Pittsburg Power Plant	0.100	0.030	5	**0.150**	**L**
San Joaquin River	0.15	Spawning	0.20	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.150	1	**0.150**	**L**
San Joaquin River	0.15	Spawning	0.20	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.150	1	**0.150**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.050	Delta	0.400	0.075	2	**0.150**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.050	Delta	0.400	0.075	2	**0.150**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.050	Bays	0.400	0.075	2	**0.150**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Pardee Reservoir Dam	0.200	0.038	4	**0.150**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Tributary Barriers	0.200	0.038	4	**0.150**	**L**
San Joaquin River	0.15	Embryo Incubation	**0.10**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.150	1	**0.150**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Individual Diversions in the Delta	0.100	0.024	6	**0.144**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.072	2	**0.144**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Passage Impediments/Barriers	0.050	New Exchequer Dam	0.150	0.036	4	**0.144**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Predation	0.050	Predation in the Delta	0.150	0.036	4	**0.144**	**L**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Stanislaus River	0.200	0.036	4	**0.144**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.150	0.036	4	**0.144**	**L**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Contra Costa Power Plant	0.100	0.029	5	**0.143**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Entrainment	0.075	Contra Costa Power Plant	0.100	0.028	5	**0.141**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Entrainment	0.075	Individual Diversions in the Delta	0.100	0.028	5	**0.141**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Entrainment	0.075	Pittsburg Power Plant	0.100	0.028	5	**0.141**	**L**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Diversion into Central Delta	0.050	0.028	5	**0.141**	**L**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.068	2	**0.135**	**L**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Predation	0.050	Predation in the Delta	0.150	0.034	4	**0.135**	**L**

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Predation	0.075	Predation in the Bays	0.100	0.043	3	**0.128**	**L**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.300	0.043	3	**0.128**	**L**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Calaveras River	0.300	0.043	3	**0.128**	**L**
Merced River	0.16	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Merced River	0.200	0.032	4	**0.128**	**L**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Tuolumne River	0.200	0.032	4	**0.128**	**L**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.060	2	**0.120**	**L**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Loss of Tidal Marsh Habitat	0.025	Bays	0.400	0.057	2	**0.114**	**L**
San Joaquin River	0.15	Embryo Incubation	**0.10**	Hatchery Effects	0.075	Density dependent impacts - Redd superimposition, fungus	1.000	0.113	1	**0.113**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.056	2	**0.113**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.200	0.038	3	**0.113**	**L**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	Suisun Marsh Salinity Control Structure	0.020	0.022	5	**0.108**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Predation	0.050	Predation in the Bays	0.100	0.024	4	**0.096**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Merced River	0.100	0.024	4	**0.096**	**L**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.150	0.024	4	**0.096**	**L**
Merced River	0.16	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.150	0.024	4	**0.096**	**L**
Calaveras River	0.19	Spawning	0.20	Hatchery Effects	0.025	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.095	1	**0.095**	**L**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Bays	0.100	0.018	5	**0.090**	**L**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Hatchery Effects	0.025	Bays	0.200	0.030	3	**0.090**	**L**
San Joaquin River	0.15	Juvenile Rearing and Outmigration	0.40	Hatchery Effects	0.025	San Joaquin River	0.200	0.030	3	**0.090**	**L**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Bays	0.100	0.023	4	**0.090**	**L**

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
San Joaquin River	0.15	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Ocean	0.100	0.023	4	**0.090**	**L**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Predation	0.050	Predation in the Bays	0.100	0.023	4	**0.090**	**L**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Stanislaus River	0.100	0.023	4	**0.090**	**L**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.100	0.029	3	**0.086**	**L**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Invasive Species/Food Web Disruption	0.025	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.043	2	**0.086**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.028	3	**0.084**	**L**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Bays	0.100	0.016	5	**0.080**	**L**
Merced River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Bays	0.100	0.016	5	**0.080**	**L**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Ocean	0.100	0.016	5	**0.080**	**L**
Merced River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Ocean	0.100	0.016	5	**0.080**	**L**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Tuolumne River	0.100	0.020	4	**0.080**	**L**
San Joaquin River	0.15	Embryo Incubation	**0.10**	Harvest/Angling Impacts	0.050	Redd disturbance	1.000	0.075	1.00	**0.075**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Contra Costa Power Plant	0.050	0.012	6	**0.072**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Pittsburg Power Plant	0.050	0.012	6	**0.072**	**L**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.100	0.018	4	**0.072**	**L**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Pittsburg Power Plant	0.050	0.014	5	**0.071**	**L**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Contra Costa Power Plant	0.050	0.011	6	**0.068**	**L**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Pittsburg Power Plant	0.050	0.011	6	**0.068**	**L**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.300	Woodbridge Dam	0.020	0.014	5	**0.068**	**L**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.023	3	**0.068**	**L**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Contra Costa Power Plant	0.050	0.010	6	**0.060**	**L**

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Pittsburg Power Plant	0.050	0.010	6	**0.060**	**L**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Ocean	0.050	0.014	4	**0.057**	**L**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Loss of Floodplain Habitat	0.025	Calaveras River	0.200	0.029	2	**0.057**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Predation	0.050	Predation in the Bays	0.100	0.019	3	**0.056**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Passage Impediments/Barriers	0.050	Tributary Barriers	0.050	0.012	4	**0.048**	**L**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Ocean	0.050	0.009	5	**0.045**	**L**
Merced River	0.16	Embryo Incubation	**0.20**	Water Quality	0.100	Water Pollution	0.100	0.032	1.00	**0.032**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.009	3	**0.028**	**L**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Ocean	0.025	0.006	4	**0.023**	**L**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.050	0.006	3	**0.017**	**L**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Bays	0.025	0.003	4	**0.010**	**L**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Delta	0.025	0.003	4	**0.010**	**L**
Stanislaus River	0.18	Embryo Incubation	**0.20**	Harvest/Angling Impacts	0.050	Redd disturbance	0.050	0.009	1.00	**0.009**	**L**
Stanislaus River	0.18	Embryo Incubation	**0.20**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	0.050	0.009	1	**0.009**	**L**
Stanislaus River	0.18	Embryo Incubation	**0.20**	Water Quality	0.050	Water Pollution	0.050	0.009	1.00	**0.009**	**L**
Tuolumne River	0.16	Embryo Incubation	**0.20**	Harvest/Angling Impacts	0.050	Redd disturbance	0.050	0.008	1.00	**0.008**	**L**
Merced River	0.16	Embryo Incubation	**0.20**	Harvest/Angling Impacts	0.050	Redd disturbance	0.050	0.008	1.00	**0.008**	**L**
Tuolumne River	0.16	Embryo Incubation	**0.20**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	0.050	0.008	1	**0.008**	**L**
Merced River	0.16	Embryo Incubation	**0.20**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	0.050	0.008	1	**0.008**	**L**
Tuolumne River	0.16	Embryo Incubation	**0.20**	Water Quality	0.050	Water Pollution	0.050	0.008	1.00	**0.008**	**L**
Tuolumne River	0.16	Spawning	0.35	Barrier	0.000	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.000	1	**0.000**	
Merced River	0.16	Spawning	0.30	Barrier	0.000	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.000	1	**0.000**	

Southern Sierra Nevada Steelhead Diversity Group Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Tuolumne River	0.16	Spawning	0.35	Hatchery Effects	0.000	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.000	1	**0.000**	
Merced River	0.16	Spawning	0.30	Hatchery Effects	0.000	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.000	1	**0.000**	
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Bays	0.000	0.000	4	**0.000**	
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.000	Bays	0.000	0.000	4	**0.000**	
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.025	Bays	0.000	0.000	3	**0.000**	
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.025	Calaveras River	0.000	0.000	3	**0.000**	
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Delta	0.000	0.000	4	**0.000**	
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.000	Delta	0.000	0.000	4	**0.000**	
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.025	Delta	0.000	0.000	3	**0.000**	
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.000	Merced River	0.000	0.000	4	**0.000**	
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	San Joaquin River	0.000	0.000	4	**0.000**	
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	San Joaquin River	0.000	0.000	4	**0.000**	
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.000	San Joaquin River	0.000	0.000	4	**0.000**	
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Stanislaus River	0.000	0.000	4	**0.000**	
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Tuolumne River	0.000	0.000	4	**0.000**	
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Tributary Barriers	0.000	0.000	4	**0.000**	
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Tributary Barriers	0.000	0.000	3	**0.000**	

American River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
American River	0.06	Spawning	0.40	Barrier	0.450	Historical spawning habitat blocked	1.000	1.080	1	**1.080**	**VH**
American River	0.06	Adult Immigration and Holding	0.10	Passage Impediments/Barriers	0.500	Nimbus/Folsom Dams	0.980	0.294	3	**0.882**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.200	American River	0.700	0.294	3	**0.882**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Predation	0.150	Predation in the American River	0.600	0.189	4	**0.756**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.150	American River	0.750	0.236	3	**0.709**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	American River	0.500	0.105	5	**0.525**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	American River	0.700	0.147	3	**0.441**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Loss of Tidal Marsh Habitat	0.050	Delta	0.800	0.084	5	**0.420**	**VH**
American River	0.06	Spawning	0.40	Hatchery Effects	0.150	Competition for habitat, Genetic Integrity	1.000	0.360	1	**0.360**	**VH**
American River	0.06	Embryo Incubation	**0.15**	Flow Conditions	0.375	Flow Fluctuations	1.000	0.338	1	**0.338**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.200	Delta	0.250	0.105	3	**0.315**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Lower Sacramento River	0.300	0.063	5	**0.315**	**VH**
American River	0.06	Spawning	0.40	Physical Habitat Alteration	0.125	Limited Instream Gravel Supply	1.000	0.300	1	**0.300**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in the Delta	0.275	0.058	5	**0.289**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Jones and Banks Pumping Plants	0.275	0.058	5	**0.289**	**VH**
American River	0.06	Adult Immigration and Holding	0.10	Water Temperature	0.200	American River	0.800	0.096	3	**0.288**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in the lower Sacramento River	0.250	0.053	5	**0.263**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.600	0.063	4	**0.252**	**VH**
American River	0.06	Spawning	0.40	Spawning Habitat Availability	0.100	Habitat Suitability	1.000	0.240	1	**0.240**	**VH**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Changes in Hydrology	0.450	0.047	5	**0.236**	**H**
American River	0.06	Adult Immigration and Holding	0.10	Harvest/Angling Impacts	0.100	American River	0.750	0.045	5	**0.225**	**H**
American River	0.06	Embryo Incubation	**0.15**	Water Temperature	0.250	Water Temperature in the American River	1.000	0.225	1	**0.225**	**H**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Predation	0.150	Predation in the Delta	0.150	0.047	4	**0.189**	**H**

American River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
American River	0.06	Juvenile Rearing and Outmigration	0.35	Predation	0.150	Predation in the lower Sacramento River	0.150	0.047	4	**0.189**	**H**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Flow Dependent Habitat Availability in the American River	0.350	0.037	5	**0.184**	**H**
American River	0.06	Spawning	0.40	Flow Conditions	0.075	Flow Fluctuations	1.000	0.180	1	**0.180**	**H**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Hatchery Effects	0.050	American River	0.400	0.042	4	**0.168**	**H**
American River	0.06	Adult Immigration and Holding	0.10	Flow Conditions	0.150	Low Flows - attraction, migratory cues in the American River	0.800	0.072	2	**0.144**	**H**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.150	0.047	3	**0.142**	**H**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Hatchery Effects	0.050	Delta	0.300	0.032	4	**0.126**	**H**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Delta	0.200	0.042	3	**0.126**	**H**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Predation	0.150	Predation in the Bays	0.100	0.032	4	**0.126**	**H**
American River	0.06	Spawning	0.40	Water Temperature	0.050	American River	1.000	0.120	1	**0.120**	**H**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Invasive Species/Food Web Disruption	0.040	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.059	2	**0.118**	**H**
American River	0.06	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.125	Redd disturbance	1.000	0.113	1.00	**0.113**	**H**
American River	0.06	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.113	1	**0.113**	**H**
American River	0.06	Embryo Incubation	**0.15**	Water Quality	0.125	Water Pollution	1.000	0.113	1.00	**0.113**	**H**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Contra Costa Power Plant	0.100	0.021	5	**0.105**	**H**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Pittsburg Power Plant	0.100	0.021	5	**0.105**	**H**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Hatchery Effects	0.050	Lower Sacramento River	0.250	0.026	4	**0.105**	**H**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Delta	0.100	0.021	5	**0.105**	**H**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Loss of Tidal Marsh Habitat	0.050	Bays	0.200	0.021	5	**0.105**	**H**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.100	0.032	3	**0.095**	**M**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the American River	0.200	0.021	4	**0.084**	**M**
American River	0.06	Spawning	0.40	Harvest/Angling Impacts	0.030	Recreational, Poaching, Angler Impacts	1.000	0.072	1	**0.072**	**M**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Lower Sacramento River	0.100	0.021	3	**0.063**	**M**

American River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
American River	0.06	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.050	0.016	4	**0.063**	**M**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.150	0.016	4	**0.063**	**M**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.200	Lower Sacramento River	0.050	0.021	3	**0.063**	**M**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Water Quality	0.010	Ag, Urban in the lower Sacramento River	0.650	0.014	4	**0.055**	**M**
American River	0.06	Adult Immigration and Holding	0.10	Water Temperature	0.200	Lower Sacramento River	0.150	0.018	3	**0.054**	**M**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Diversion into Central Delta	0.100	0.011	5	**0.053**	**M**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Invasive Species/Food Web Disruption	0.040	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.025	2	**0.050**	**M**
American River	0.06	Spawning	0.40	Water Quality	0.020	American River	1.000	0.048	1	**0.048**	**M**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Passage Impediments/Barriers	0.010	Nimbus/Folsom Dam	0.900	0.019	2	**0.038**	**M**
American River	0.06	Adult Immigration and Holding	0.10	Flow Conditions	0.150	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.200	0.018	2	**0.036**	**M**
American River	0.06	Adult Immigration and Holding	0.10	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.100	0.006	5	**0.030**	**M**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Flow Dependent Habitat Availability in the lower Sacramento River	0.050	0.005	5	**0.026**	**M**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Reverse Flow Conditions	0.050	0.005	5	**0.026**	**M**
American River	0.06	Adult Immigration and Holding	0.10	Water Quality	0.030	Ag, Urban in the lower Sacramento River	0.400	0.007	3	**0.022**	**M**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Hatchery Effects	0.050	Bays	0.050	0.005	4	**0.021**	**M**
American River	0.06	Adult Immigration and Holding	0.10	Short-term Inwater Construction	0.020	Sedimentation, turbidity, acoustic effects, hazardous spills in the American River	0.400	0.005	4	**0.019**	**L**
American River	0.06	Adult Immigration and Holding	0.10	Water Temperature	0.200	Delta	0.050	0.006	3	**0.018**	**L**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Water Quality	0.010	DO, Ag, Urban, Heavy Metals in th Delta	0.200	0.004	4	**0.017**	**L**
American River	0.06	Adult Immigration and Holding	0.10	Water Quality	0.030	Ag, Urban in the American River	0.300	0.005	3	**0.016**	**L**
American River	0.06	Adult Immigration and Holding	0.10	Water Quality	0.030	DO, Ag, Urban, Heavy Metals in th Delta	0.300	0.005	3	**0.016**	**L**

American River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
American River	0.06	Adult Immigration and Holding	0.10	Harvest/Angling Impacts	0.100	Bays	0.050	0.003	5	**0.015**	**L**
American River	0.06	Adult Immigration and Holding	0.10	Harvest/Angling Impacts	0.100	Delta	0.050	0.003	5	**0.015**	**L**
American River	0.06	Adult Immigration and Holding	0.10	Harvest/Angling Impacts	0.100	Ocean	0.050	0.003	5	**0.015**	**L**
American River	0.06	Adult Immigration and Holding	0.10	Short-term Inwater Construction	0.020	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.004	4	**0.014**	**L**
American River	0.06	Adult Immigration and Holding	0.10	Short-term Inwater Construction	0.020	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.002	4	**0.010**	**L**
American River	0.06	Adult Immigration and Holding	0.10	Passage Impediments/Barriers	0.500	Sacramento Deep Water Ship Channel	0.010	0.003	3	**0.009**	**L**
American River	0.06	Adult Immigration and Holding	0.10	Passage Impediments/Barriers	0.500	Suisun Marsh Salinity Control Structure	0.010	0.003	3	**0.009**	**L**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Water Quality	0.010	Ag, Urban in the American River	0.100	0.002	4	**0.008**	**L**
American River	0.06	Adult Immigration and Holding	0.10	Short-term Inwater Construction	0.020	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.100	0.001	4	**0.005**	**L**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Passage Impediments/Barriers	0.010	Tributary Barriers	0.100	0.002	2	**0.004**	**L**
American River	0.06	Juvenile Rearing and Outmigration	0.35	Water Quality	0.010	Ag, Urban, Heavy Metals in the Bays	0.050	0.001	4	**0.004**	**L**

Antelope Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Antelope Creek	0.700	0.58	4	**2.31**	**VH**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Agricultural Diversion Dam(s) in Antelope Creek	0.600	0.45	5	**2.25**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Individual or Terminal Diversions and loss of channel connectivity in Antelope Creek	0.500	0.32	7	**2.21**	**VH**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in Antelope Creek	0.600	0.36	3	**1.08**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Lower Sacramento River	0.350	0.24	4	**0.94**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.350	0.24	4	**0.94**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.350	0.24	4	**0.94**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Delta	0.300	0.20	4	**0.81**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Antelope Creek	0.300	0.20	4	**0.81**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.300	0.20	4	**0.81**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the Delta	0.300	0.16	5	**0.79**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the lower Sacramento River	0.300	0.16	5	**0.79**	**VH**
Antelope Creek	0.12	Embryo Incubation	**0.15**	Water Quality	0.400	Turbidity, sedimentation in Antelope Creek	1.000	0.72	1.00	**0.72**	**VH**
Antelope Creek	0.12	Spawning	**0.25**	Hatchery Effects	0.225	Stocked trout fishery in upper Antelope drainage - competition for habitat, genetic integrity	1.000	0.68	1	**0.68**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the middle Sacramento River	0.250	0.13	5	**0.66**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in Antelope Creek	0.600	0.13	5	**0.63**	**VH**
Antelope Creek	0.12	Spawning	**0.25**	Physical Habitat Alteration	0.200	Gravel embeddedness and fines	1.000	0.60	1	**0.60**	**VH**
Antelope Creek	0.12	Spawning	**0.25**	Water Quality	0.200	Turbidity, Sedimentation in Antelope Creek	1.000	0.60	1	**0.60**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Diversion into Central Delta	0.300	0.09	6	**0.57**	**VH**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.300	0.09	6	**0.54**	**VH**
Antelope Creek	0.12	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.300	Sedimentation, turbidity, physical disturbance	1.000	0.54	1.00	**0.54**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Middle Sacramento River	0.200	0.13	4	**0.54**	**VH**

Antelope Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Delta	0.200	0.13	4	**0.54**	**VH**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Antelope Creek	0.200	0.13	4	**0.54**	**VH**
Antelope Creek	0.12	Spawning	**0.25**	Spawning Habitat Availability	0.175	Habitat Availability	1.000	0.53	1	**0.53**	**H**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Individual Diversions in the Delta	0.100	0.06	7	**0.44**	**H**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Individual Diversions in the lower Sacramento River	0.100	0.06	7	**0.44**	**H**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Individual Diversions in the middle Sacramento River	0.100	0.06	7	**0.44**	**H**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Jones and Banks Pumping Plants	0.100	0.06	7	**0.44**	**H**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Antelope Creek	0.150	0.10	4	**0.40**	**H**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Middle Sacramento River	0.150	0.10	4	**0.40**	**H**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Middle Sacramento River	0.150	0.10	4	**0.40**	**H**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Changes in Hydrology	0.200	0.06	6	**0.38**	**H**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Reverse Flow Conditions	0.200	0.06	6	**0.38**	**H**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.100	0.08	5	**0.38**	**H**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.100	0.08	5	**0.38**	**H**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.100	0.08	5	**0.38**	**H**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.08	5	**0.38**	**H**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.200	0.12	3	**0.36**	**H**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.12	3	**0.36**	**H**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Antelope Creek	0.200	0.06	6	**0.36**	**H**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.07	5	**0.34**	**H**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	0.800	0.17	2	**0.34**	**H**

Antelope Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Lower Sacramento River	0.400	0.08	4	**0.34**	**H**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Delta	0.100	0.08	4	**0.33**	**H**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Lower Sacramento River	0.100	0.08	4	**0.33**	**H**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Middle Sacramento River	0.100	0.08	4	**0.33**	**H**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.06	5	**0.32**	**H**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.06	5	**0.32**	**H**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.200	0.06	5	**0.30**	**M**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.200	0.06	5	**0.30**	**M**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Antelope Creek	0.200	0.06	5	**0.30**	**M**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Bay	0.200	0.06	5	**0.30**	**M**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.200	0.06	5	**0.30**	**M**
Antelope Creek	0.12	Embryo Incubation	**0.15**	Water Temperature	0.165	Water Temperature in Antelope Creek	1.000	0.30	1.00	**0.30**	**M**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.06	5	**0.28**	**M**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the Bays	0.100	0.05	5	**0.26**	**M**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Middle Sacramento River	0.300	0.06	4	**0.25**	**M**
Antelope Creek	0.12	Embryo Incubation	**0.15**	Flow Conditions	0.125	Flow Fluctuations	1.000	0.23	1.00	**0.23**	**M**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.125	0.04	6	**0.23**	**M**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.125	0.04	6	**0.23**	**M**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.125	0.04	6	**0.23**	**M**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.125	0.04	6	**0.23**	**M**
Antelope Creek	0.12	Spawning	**0.25**	Harvest/Angling Impacts	0.075	Recreational, Poaching, Angler Impacts	1.000	0.23	1	**0.23**	**M**

Antelope Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.05	5	**0.23**	**M**
Antelope Creek	0.12	Spawning	**0.25**	Water Temperature	0.075	Water Temperature in Antelope Creek	1.000	0.23	1	**0.23**	**M**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Contra Costa Power Plant	0.050	0.03	7	**0.22**	**M**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.150	Pittsburg Power Plant	0.050	0.03	7	**0.22**	**M**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.04	5	**0.21**	**M**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.030	Delta	0.300	0.04	5	**0.19**	**M**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.030	Lower Sacramento River	0.300	0.04	5	**0.19**	**M**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in Antelope Creek	0.100	0.03	6	**0.19**	**M**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.03	6	**0.19**	**M**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.03	6	**0.19**	**M**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.03	5	**0.17**	**L**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Antelope Creek	0.200	0.04	4	**0.17**	**L**
Antelope Creek	0.12	Spawning	**0.25**	Flow Conditions	0.050	Flow Fluctuations	1.000	0.15	1	**0.15**	**L**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in Antelope Creek	0.050	0.03	5	**0.13**	**L**
Antelope Creek	0.12	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in Antelope Creek	0.100	0.02	5	**0.11**	**L**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Antelope Creek	0.100	0.02	5	**0.11**	**L**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.02	5	**0.11**	**L**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.100	0.02	5	**0.11**	**L**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.100	0.02	5	**0.11**	**L**

Antelope Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.100	0.02	5	**0.11**	**L**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.100	0.02	5	**0.11**	**L**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.030	Middle Sacramento River	0.150	0.02	5	**0.09**	**L**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Dam(s)	0.200	0.04	2	**0.08**	**L**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Delta	0.100	0.02	4	**0.08**	**L**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.030	Antelope Creek	0.100	0.01	5	**0.06**	**L**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.030	Bays	0.100	0.01	5	**0.06**	**L**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.03	2	**0.05**	**L**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.010	Delta	0.600	0.03	2	**0.05**	**L**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.02	2	**0.03**	**L**
Antelope Creek	0.12	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.010	Bays	0.400	0.02	2	**0.03**	**L**
Antelope Creek	0.12	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.010	Redd disturbance	1.000	0.02	1.00	**0.02**	**L**

Auburn/Coon Creek Drainage Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Passage Impediments/Barriers	0.850	Impediments/Barriers in the Auburn Ravine and Coon Creek drainage	0.990	2.356	3	**7.07**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Spawning	0.30	Passage Impediments/Barriers	0.350	Impediments/Barriers in the Auburn Ravine and Coon Creek drainage	1.000	0.735	1	**0.74**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Entrainment	0.200	Individual Diversions in the Auburn Ravine and Coon Creek drainage	0.450	0.126	5	**0.63**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Flow Conditions	0.150	Flow Dependent Habitat Availability in the Auburn Ravine and Coon Creek drainage	0.600	0.126	5	**0.63**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Flow Conditions	0.100	Low Flows - attraction, migratory cues in the Auburn Ravine and Coon Creek drainage	0.900	0.252	2	**0.50**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Water Quality	0.100	Ag, Urban in the Auburn Ravine and Coon Creek drainage	0.800	0.112	4	**0.45**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Spawning	0.30	Flow Conditions	0.200	Flow Fluctuations	1.000	0.420	1	**0.42**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Loss of Natural River Morphology	0.125	Auburn Ravine and Coon Creek drainage	0.800	0.140	3	**0.42**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Loss of Riparian Habitat and Instream Cover	0.125	Auburn Ravine and Coon Creek drainage	0.800	0.140	3	**0.42**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Water Temperature	0.100	Auburn Ravine and Coon Creek drainage	0.900	0.126	3	**0.38**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Predation	0.100	Predation in the Auburn Ravine and Coon Creek drainage	0.650	0.091	4	**0.36**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Embryo Incubation	**0.10**	Flow Conditions	0.450	Flow Fluctuations	1.000	0.315	1	**0.32**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Entrainment	0.200	Individual Diversions in the Delta	0.200	0.056	5	**0.28**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Entrainment	0.200	Jones and Banks Pumping Plants	0.200	0.056	5	**0.28**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Embryo Incubation	**0.10**	Water Temperature	0.350	Water Temperature in the Auburn Ravine and Coon Creek drainage	1.000	0.245	1	**0.25**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Spawning	0.30	Hatchery Effects	0.100	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.210	1	**0.21**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Spawning	0.30	Physical Habitat Alteration	0.100	Limited Instream Gravel Supply	1.000	0.210	1	**0.21**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Spawning	0.30	Spawning Habitat Availability	0.100	Habitat Suitability	1.000	0.210	1	**0.21**	**VH**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Water Temperature	0.020	Auburn Ravine and Coon Creek drainage	0.800	0.045	3	**0.13**	**VH**

Auburn/Coon Creek Drainage Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Flow Conditions	0.150	Changes in Delta Hydrology	0.125	0.026	5	**0.13**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Flow Conditions	0.150	Diversion into Central Delta	0.125	0.026	5	**0.13**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Passage Impediments/Barriers	0.050	Impediments/Barriers in the Auburn Ravine and Coon Creek drainage	0.900	0.063	2	**0.13**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Predation	0.100	Predation in the Delta	0.200	0.028	4	**0.11**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Flow Conditions	0.150	Reverse Flow Conditions	0.100	0.021	5	**0.11**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Spawning	0.30	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.105	1	**0.11**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Spawning	0.30	Water Quality	0.050	Auburn Ravine and Coon Creek drainage	1.000	0.105	1	**0.11**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Spawning	0.30	Water Temperature	0.050	Auburn Ravine and Coon Creek drainage	1.000	0.105	1	**0.11**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Harvest/Angling Impacts	0.010	Auburn Ravine and Coon Creek drainage	0.650	0.018	5	**0.09**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Loss of Natural River Morphology	0.125	Delta	0.150	0.026	3	**0.08**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Loss of Riparian Habitat and Instream Cover	0.125	Lower Sacramento River	0.150	0.026	3	**0.08**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the Auburn Ravine and Coon Creek drainage	0.650	0.018	4	**0.07**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Entrainment	0.200	Contra Costa Power Plant	0.050	0.014	5	**0.07**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Entrainment	0.200	Individual Diversions in the lower Sacramento River	0.050	0.014	5	**0.07**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Entrainment	0.200	Pittsburg Power Plant	0.050	0.014	5	**0.07**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Water Quality	0.010	Ag, Urban in the Auburn Ravine and Coon Creek drainage	0.800	0.022	3	**0.07**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Loss of Tidal Marsh Habitat	0.010	Delta	0.900	0.013	5	**0.06**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Flow Conditions	0.100	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in the lower Sacramento River	0.100	0.028	2	**0.06**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Predation	0.100	Predation in the lower Sacramento River	0.100	0.014	4	**0.06**	**H**

Auburn/Coon Creek Drainage Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.100	0.014	4	**0.06**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in th Delta	0.100	0.014	4	**0.06**	**H**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Flow Conditions	0.150	Flow Dependent Habitat Availability in the lower Sacramento River	0.050	0.011	5	**0.05**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Embryo Incubation	**0.10**	Harvest/Angling Impacts	0.075	Redd disturbance	1.000	0.053	1.00	**0.05**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Embryo Incubation	**0.10**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.053	1	**0.05**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Loss of Floodplain Habitat	0.010	Lower Sacramento River	0.550	0.008	5	**0.04**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Passage Impediments/Barriers	0.850	Sacramento Deep Water Ship Channel	0.005	0.012	3	**0.04**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Passage Impediments/Barriers	0.850	Suisun Marsh Salinity Control Structure	0.005	0.012	3	**0.04**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Embryo Incubation	**0.10**	Water Quality	0.050	Water Pollution	1.000	0.035	1.00	**0.04**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the Auburn Ravine and Coon Creek drainage	0.600	0.008	4	**0.03**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Loss of Floodplain Habitat	0.010	Auburn Ravine and Coon Creek drainage	0.400	0.006	5	**0.03**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Predation	0.100	Predation in the Bays	0.050	0.007	4	**0.03**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Loss of Natural River Morphology	0.125	Lower Sacramento River	0.050	0.009	3	**0.03**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Loss of Riparian Habitat and Instream Cover	0.125	Delta	0.050	0.009	3	**0.03**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.900	0.013	2	**0.03**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Hatchery Effects	0.010	Auburn Ravine and Coon Creek drainage	0.400	0.006	4	**0.02**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Hatchery Effects	0.010	Delta	0.400	0.006	4	**0.02**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.006	4	**0.02**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Water Temperature	0.100	Delta	0.050	0.007	3	**0.02**	**M**

Auburn/Coon Creek Drainage Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Water Temperature	0.100	Lower Sacramento River	0.050	0.007	3	**0.02**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.004	4	**0.02**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Water Temperature	0.020	Delta	0.100	0.006	3	**0.02**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Water Temperature	0.020	Lower Sacramento River	0.100	0.006	3	**0.02**	**M**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Harvest/Angling Impacts	0.010	Delta	0.100	0.003	5	**0.01**	**L**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Harvest/Angling Impacts	0.010	Lower Sacramento River	0.100	0.003	5	**0.01**	**L**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Harvest/Angling Impacts	0.010	Ocean	0.100	0.003	5	**0.01**	**L**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Passage Impediments/Barriers	0.050	Tributary Barriers	0.100	0.007	2	**0.01**	**L**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Hatchery Effects	0.010	Lower Sacramento River	0.200	0.003	4	**0.01**	**L**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.100	0.003	4	**0.01**	**L**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Water Quality	0.010	Ag, Urban in the lower Sacramento River	0.100	0.003	3	**0.01**	**L**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Water Quality	0.010	DO, Ag, Urban, Heavy Metals in th Delta	0.100	0.003	3	**0.01**	**L**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Harvest/Angling Impacts	0.010	Bays	0.050	0.001	5	**0.01**	**L**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Loss of Tidal Marsh Habitat	0.010	Bays	0.100	0.001	5	**0.01**	**L**
Auburn Ravine and Coon Creek drainage	0.07	Adult Immigration and Holding	0.40	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.050	0.001	4	**0.01**	**L**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.100	0.001	4	**0.01**	**L**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Loss of Floodplain Habitat	0.010	Delta	0.050	0.001	5	**0.00**	**L**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.100	0.001	2	**0.00**	**L**
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Hatchery Effects	0.010	Bays	0.000	0.000	4	**0.00**	

Auburn/Coon Creek Drainage Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.000	0.000	4	**0.00**	
Auburn Ravine and Coon Creek drainage	0.07	Juvenile Rearing and Outmigration	0.20	Water Quality	0.100	Ag, Urban, Heavy Metals in the Bays	0.000	0.000	4	**0.00**	

Battle Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.26	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	North Fork Dams	0.325	0.74	7	**5.18**	**VH**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	South Fork Dams	0.325	0.74	7	**5.18**	**VH**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Temperature	0.175	Battle Creek	0.550	0.63	5	**3.13**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Hatchery Effects	0.125	Battle Creek - Coleman - Competition for habitat and food	0.350	0.40	6	**2.39**	**VH**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Red Bluff Diversion Dam	0.150	0.34	7	**2.39**	**VH**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Flow Conditions	0.200	Low Flows - attraction, migratory cues in Battle Creek	0.400	0.52	4	**2.08**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the Delta	0.300	0.34	6	**2.05**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in Battle Creek	0.250	0.23	8	**1.82**	**VH**
Battle Creek	0.26	Spawning	0.25	Barriers	0.250	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	1.63	1	**1.63**	**VH**
Battle Creek	0.26	Spawning	0.25	Flow Conditions	0.250	Low instream flows per FERC license	1.000	1.63	1	**1.63**	**VH**
Battle Creek	0.26	Spawning	0.25	Hatchery Effects	0.250	Coleman - competition for habitat, genetic integrity	1.000	1.63	1	**1.63**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Delta	0.350	0.32	5	**1.59**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Delta	0.350	0.32	5	**1.59**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Delta	0.350	0.32	5	**1.59**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Jones and Banks Pumping Plants	0.200	0.18	8	**1.46**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Lower Sacramento River	0.300	0.27	5	**1.37**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Lower Sacramento River	0.300	0.27	5	**1.37**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Lower Sacramento River	0.300	0.27	5	**1.37**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Hatchery Effects	0.125	Upper Sacramento River	0.200	0.23	6	**1.37**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the lower Sacramento River	0.200	0.23	6	**1.37**	**VH**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Flow Conditions	0.200	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.250	0.33	4	**1.30**	**VH**

Battle Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Flow Dependent Habitat Availability in Battle Creek	0.400	0.18	7	**1.27**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Ag, Urban in the lower Sacramento River	0.300	0.20	6	**1.23**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	DO, Ag, Urban, Heavy Metals in the Delta	0.300	0.20	6	**1.23**	**VH**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.375	0.24	5	**1.22**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the middle Sacramento River	0.175	0.20	6	**1.19**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Lower Sacramento River	0.350	0.24	5	**1.19**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in the Delta	0.150	0.14	8	**1.09**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in the lower Sacramento River	0.150	0.14	8	**1.09**	**VH**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in the middle Sacramento River	0.150	0.14	8	**1.09**	**VH**
Battle Creek	0.26	Embryo Incubation	**0.15**	Flow Conditions	0.275	Flow Fluctuations	1.000	1.07	1.00	**1.07**	**H**
Battle Creek	0.26	Embryo Incubation	**0.15**	Water Temperature	0.275	Water Temperature in Battle Creek	1.000	1.07	1.00	**1.07**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.26	4	**1.04**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Hatchery Effects	0.125	Lower Sacramento River	0.150	0.17	6	**1.02**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Hatchery Effects	0.125	Middle Sacramento River	0.150	0.17	6	**1.02**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Delta	0.300	0.20	5	**1.02**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in Battle Creek	0.200	0.16	6	**0.98**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.16	6	**0.98**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.16	6	**0.98**	**H**
Battle Creek	0.26	Spawning	0.25	Spawning Habitat Availability	0.150	Habitat Suitability	1.000	0.98	1	**0.98**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Middle Sacramento River	0.200	0.18	5	**0.91**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Middle Sacramento River	0.200	0.18	5	**0.91**	**H**

Battle Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.275	0.18	5	**0.89**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in Battle Creek	0.125	0.14	6	**0.85**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.14	6	**0.82**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Sacramento Deep Water Ship Channel	0.050	0.11	7	**0.80**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Suisun Marsh Salinity Control Structure	0.050	0.11	7	**0.80**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Sutter Bypass - Tisdale Weir	0.050	0.11	7	**0.80**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Passage Impediments/Barriers	0.350	Yolo Bypass - Freemont Weir	0.050	0.11	7	**0.80**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the upper Sacramento River	0.150	0.20	4	**0.78**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.150	0.12	6	**0.73**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.12	6	**0.73**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Temperature	0.175	Lower Sacramento River	0.125	0.14	5	**0.71**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Temperature	0.175	Middle Sacramento River	0.125	0.14	5	**0.71**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Middle Sacramento River	0.150	0.14	5	**0.68**	**H**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Ocean	0.300	0.10	7	**0.68**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Hatchery Effects	0.125	Delta	0.100	0.11	6	**0.68**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the Bays	0.100	0.11	6	**0.68**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Predation	0.125	Predation in the upper Sacramento River	0.100	0.11	6	**0.68**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.11	6	**0.68**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Battle Creek	0.200	0.14	5	**0.68**	**H**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Diversion into Central Delta	0.200	0.09	7	**0.64**	**M**

Battle Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Ag, Urban, Heavy Metals in the Bays	0.150	0.10	6	**0.61**	**M**
Battle Creek	0.26	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.150	Redd disturbance	1.000	0.59	1.00	**0.59**	**M**
Battle Creek	0.26	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.59	1.00	**0.59**	**M**
Battle Creek	0.26	Embryo Incubation	**0.15**	Water Quality	0.150	Water Quality in Battle Creek	1.000	0.59	1.00	**0.59**	**M**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.175	0.11	5	**0.57**	**M**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Temperature	0.175	Delta	0.100	0.11	5	**0.57**	**M**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Temperature	0.175	Upper Sacramento River	0.100	0.11	5	**0.57**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Passage Impediments/Barriers	0.050	North Fork Dams	0.400	0.18	3	**0.55**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Passage Impediments/Barriers	0.050	South Fork Dams	0.400	0.18	3	**0.55**	**M**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.100	0.08	6	**0.49**	**M**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Quality	0.100	Urban, Heavy Metals in the upper Sacramento River	0.150	0.10	5	**0.49**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Upper Sacramento River	0.100	0.09	5	**0.46**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Upper Sacramento River	0.100	0.09	5	**0.46**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Battle Creek	0.100	0.09	5	**0.46**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Riparian Habitat and Instream Cover	0.100	Upper Sacramento River	0.100	0.09	5	**0.46**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.07	6	**0.41**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.150	0.07	6	**0.41**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Urban, Heavy Metals in the upper Sacramento River	0.100	0.07	6	**0.41**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Ag, Urban in the middle Sacramento River	0.100	0.07	6	**0.41**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Individual Diversions in the upper Sacramento River	0.050	0.05	8	**0.36**	**M**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Battle Creek	0.150	0.05	7	**0.34**	**M**

Battle Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Hatchery Effects	0.125	Bays	0.050	0.06	6	**0.34**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Middle Sacramento River	0.100	0.07	5	**0.34**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Changes in Hydrology	0.100	0.05	7	**0.32**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.05	7	**0.32**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Invasive Species/Food Web Disruption	0.025	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.16	2	**0.32**	**M**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Middle Sacramento River	0.125	0.04	7	**0.28**	**M**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Upper Sacramento River	0.125	0.04	7	**0.28**	**M**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Tidal Marsh Habitat	0.025	Delta	0.600	0.14	2	**0.27**	**L**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Passage Impediments/Barriers	0.050	Tributary Barriers	0.200	0.09	3	**0.27**	**L**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.05	6	**0.27**	**L**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Flow Dependent Habitat Availability in the middle Sacramento River	0.075	0.03	7	**0.24**	**L**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Flow Dependent Habitat Availability in the upper Sacramento River	0.075	0.03	7	**0.24**	**L**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Floodplain Habitat	0.100	Battle Creek	0.050	0.05	5	**0.23**	**L**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Natural River Morphology	0.100	Battle Creek	0.050	0.05	5	**0.23**	**L**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Bays	0.100	0.03	7	**0.23**	**L**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Delta	0.100	0.03	7	**0.23**	**L**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Harvest/Angling Impacts	0.050	Lower Sacramento River	0.100	0.03	7	**0.23**	**L**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Quality	0.075	Ag, Urban in Battle Creek	0.050	0.03	6	**0.20**	**L**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Contra Costa Power Plant	0.025	0.02	8	**0.18**	**L**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Entrainment	0.100	Pittsburg Power Plant	0.025	0.02	8	**0.18**	**L**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Loss of Tidal Marsh Habitat	0.025	Bays	0.400	0.09	2	**0.18**	**L**

Battle Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Water Temperature	0.075	Upper Sacramento River	0.050	0.03	5	**0.17**	**L**
Battle Creek	0.26	Spawning	0.25	Harvest/Angling Impacts	0.025	Recreational, Poaching, Angler Impacts	1.000	0.16	1	**0.16**	**L**
Battle Creek	0.26	Spawning	0.25	Physical Habitat Alteration	0.025	Limited Instream Gravel Supply	1.000	0.16	1	**0.16**	**L**
Battle Creek	0.26	Spawning	0.25	Water Quality	0.025	Water Quality in Battle Creek	1.000	0.16	1	**0.16**	**L**
Battle Creek	0.26	Spawning	0.25	Water Temperature	0.025	Water Temperature in Battle Creek	1.000	0.16	1	**0.16**	**L**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Flow Conditions	0.050	Reverse Flow Conditions	0.050	0.02	7	**0.16**	**L**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Invasive Species/Food Web Disruption	0.025	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.07	2	**0.14**	**L**
Battle Creek	0.26	Juvenile Rearing and Outmigration	0.35	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Battle Creek	0.050	0.02	6	**0.14**	**L**
Battle Creek	0.26	Adult Immigration and Holding	0.25	Water Quality	0.100	Battle Creek	0.025	0.02	5	**0.08**	**L**

Bear River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Bear River	0.06	Adult Immigration and Holding	0.20	Water Temperature	0.500	Bear River	0.950	0.570	4	**2.280**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.300	Flow Dependent Habitat Availability in the Bear River	0.550	0.297	6	**1.782**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.250	Bear River	0.850	0.383	4	**1.530**	**VH**
Bear River	0.06	Adult Immigration and Holding	0.20	Flow Conditions	0.450	Low Flows - attraction, migratory cues in the Bear River	0.850	0.459	3	**1.377**	**VH**
Bear River	0.06	Spawning	0.30	Flow Conditions	0.350	Flow Fluctuations	1.000	0.630	1	**0.630**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Individual Diversions in the Bear River	0.950	0.086	7	**0.599**	**VH**
Bear River	0.06	Embryo Incubation	0.20	Water Temperature	0.450	Water Temperature in the Bear River	1.000	0.540	1	**0.540**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Loss of Floodplain Habitat	0.075	Bear River	0.600	0.081	6	**0.486**	**VH**
Bear River	0.06	Embryo Incubation	0.20	Flow Conditions	0.400	Flow Fluctuations	1.000	0.480	1	**0.480**	**VH**
Bear River	0.06	Spawning	0.30	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply	1.000	0.360	1	**0.360**	**VH**
Bear River	0.06	Spawning	0.30	Spawning Habitat Availability	0.200	Habitat Suitability	1.000	0.360	1	**0.360**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.300	Changes in Delta Hydrology	0.100	0.054	6	**0.324**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.300	Diversion into Central Delta	0.100	0.054	6	**0.324**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.300	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.054	6	**0.324**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.300	Reverse Flow Conditions	0.100	0.054	6	**0.324**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Loss of Natural River Morphology	0.075	Bear River	0.600	0.081	4	**0.324**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Loss of Riparian Habitat and Instream Cover	0.075	Bear River	0.600	0.081	4	**0.324**	**VH**
Bear River	0.06	Spawning	0.30	Water Temperature	0.150	Water Temperature in the Bear River	1.000	0.270	1	**0.270**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Predation	0.050	Predation in the Bear River	0.400	0.036	5	**0.180**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Water Quality	0.025	Bear River	0.800	0.036	5	**0.180**	**VH**
Bear River	0.06	Adult Immigration and Holding	0.20	Flow Conditions	0.450	Low Flows - attraction, migratory cues in the Feather River	0.100	0.054	3	**0.162**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.300	Flow Dependent Habitat Availability in the Feather River	0.050	0.027	6	**0.162**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Loss of Floodplain Habitat	0.075	Delta	0.200	0.027	6	**0.162**	**VH**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Loss of Tidal Marsh Habitat	0.025	Delta	0.600	0.027	6	**0.162**	**VH**

Bear River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Predation	0.050	Predation in the Feather River	0.350	0.032	5	**0.158**	**H**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bear River	0.650	0.029	5	**0.146**	**H**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Loss of Tidal Marsh Habitat	0.025	Bays	0.400	0.018	6	**0.108**	**H**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Loss of Natural River Morphology	0.075	Delta	0.200	0.027	4	**0.108**	**H**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Loss of Riparian Habitat and Instream Cover	0.075	Delta	0.200	0.027	4	**0.108**	**H**
Bear River	0.06	Adult Immigration and Holding	0.20	Water Temperature	0.500	Feather River	0.040	0.024	4	**0.096**	**H**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.250	Delta	0.050	0.023	4	**0.090**	**H**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.250	Feather River	0.050	0.023	4	**0.090**	**H**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.250	Lower Sacramento River	0.050	0.023	4	**0.090**	**H**
Bear River	0.06	Adult Immigration and Holding	0.20	Water Quality	0.020	Bear River	0.900	0.022	4	**0.086**	**H**
Bear River	0.06	Adult Immigration and Holding	0.20	Flow Conditions	0.450	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.050	0.027	3	**0.081**	**H**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Loss of Floodplain Habitat	0.075	Feather River	0.100	0.014	6	**0.081**	**H**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Loss of Floodplain Habitat	0.075	Lower Sacramento River	0.100	0.014	6	**0.081**	**H**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.025	Delta	0.300	0.014	5	**0.068**	**H**
Bear River	0.06	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.020	Bear River	0.700	0.017	4	**0.067**	**H**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.025	Feather River	0.275	0.012	5	**0.062**	**H**
Bear River	0.06	Embryo Incubation	0.20	Harvest/Angling Impacts	0.050	Redd disturbance	1.000	0.060	1.00	**0.060**	**H**
Bear River	0.06	Embryo Incubation	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.060	1	**0.060**	**H**
Bear River	0.06	Embryo Incubation	0.20	Water Quality	0.050	Water Pollution in the Bear River	1.000	0.060	1.00	**0.060**	**H**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Invasive Species/Food Web Disruption	0.025	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.027	2	**0.054**	**H**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Loss of Natural River Morphology	0.075	Feather River	0.100	0.014	4	**0.054**	**H**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Loss of Natural River Morphology	0.075	Lower Sacramento River	0.100	0.014	4	**0.054**	**H**

Bear River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Loss of Riparian Habitat and Instream Cover	0.075	Feather River	0.100	0.014	4	**0.054**	**H**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Loss of Riparian Habitat and Instream Cover	0.075	Lower Sacramento River	0.100	0.014	4	**0.054**	**H**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.025	Bear River	0.200	0.009	5	**0.045**	**M**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.025	Lower Sacramento River	0.200	0.009	5	**0.045**	**M**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Predation	0.050	Predation in the Delta	0.100	0.009	5	**0.045**	**M**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Predation	0.050	Predation in the lower Sacramento River	0.100	0.009	5	**0.045**	**M**
Bear River	0.06	Spawning	0.30	Barrier	0.025	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.045	1	**0.045**	**M**
Bear River	0.06	Spawning	0.30	Harvest/Angling Impacts	0.025	Recreational, Poaching, Angler Impacts	1.000	0.045	1	**0.045**	**M**
Bear River	0.06	Spawning	0.30	Hatchery Effects	0.025	Redd superimposition, competition for habitat, genetic integrity	1.000	0.045	1	**0.045**	**M**
Bear River	0.06	Spawning	0.30	Water Quality	0.025	Water Quality in the Bear River	1.000	0.045	1	**0.045**	**M**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Invasive Species/Food Web Disruption	0.025	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.018	2	**0.036**	**M**
Bear River	0.06	Adult Immigration and Holding	0.20	Water Temperature	0.500	Lower Sacramento River	0.010	0.006	4	**0.024**	**M**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Predation	0.050	Predation in the Bays	0.050	0.005	5	**0.023**	**M**
Bear River	0.06	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.005	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bear River	0.750	0.005	5	**0.023**	**M**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.100	0.005	5	**0.023**	**M**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Feather River	0.100	0.005	5	**0.023**	**M**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.100	0.005	5	**0.023**	**M**
Bear River	0.06	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.020	Yolo Bypass - Freemont Weir	0.200	0.005	4	**0.019**	**M**
Bear River	0.06	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.005	Bear River	0.600	0.004	5	**0.018**	**M**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Jones and Banks Pumping Plants	0.020	0.002	7	**0.013**	**M**

Bear River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.050	0.002	5	**0.011**	**M**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Water Quality	0.025	Ag, Urban in the lower Sacramento River	0.050	0.002	5	**0.011**	**M**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Water Quality	0.025	Ag, Urban in the Feather River	0.050	0.002	5	**0.011**	**M**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Water Quality	0.025	Ag, Urban, Heavy Metals in the Bays	0.050	0.002	5	**0.011**	**M**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Water Quality	0.025	DO, Ag, Urban, Heavy Metals in th Delta	0.050	0.002	5	**0.011**	**M**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Individual Diversions in the Delta	0.010	0.001	7	**0.006**	**L**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.025	Bays	0.025	0.001	5	**0.006**	**L**
Bear River	0.06	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.020	Sacramento Deep Water Ship Channel	0.050	0.001	4	**0.005**	**L**
Bear River	0.06	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.020	Suisun Marsh Salinity Control Structure	0.050	0.001	4	**0.005**	**L**
Bear River	0.06	Adult Immigration and Holding	0.20	Water Quality	0.020	Ag, Urban in the Feather River	0.050	0.001	4	**0.005**	**L**
Bear River	0.06	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.005	Ocean	0.150	0.001	5	**0.005**	**L**
Bear River	0.06	Adult Immigration and Holding	0.20	Water Quality	0.020	Ag, Urban in the lower Sacramento River	0.040	0.001	4	**0.004**	**L**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Contra Costa Power Plant	0.005	0.000	7	**0.003**	**L**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Individual Diversions in the Feather River	0.005	0.000	7	**0.003**	**L**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Individual Diversions in the lower Sacramento River	0.005	0.000	7	**0.003**	**L**
Bear River	0.06	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Pittsburg Power Plant	0.005	0.000	7	**0.003**	**L**
Bear River	0.06	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.005	Delta	0.100	0.001	5	**0.003**	**L**
Bear River	0.06	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.005	Lower Sacramento River	0.100	0.001	5	**0.003**	**L**
Bear River	0.06	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.005	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.100	0.001	5	**0.003**	**L**
Bear River	0.06	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.005	Bays	0.050	0.000	5	**0.002**	**L**
Bear River	0.06	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.005	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.050	0.000	5	**0.002**	**L**

Bear River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Bear River	0.06	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.005	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.050	0.000	5	**0.002**	**L**
Bear River	0.06	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.005	Sedimentation, turbidity, acoustic effects, hazardous spills in the Feather River	0.050	0.000	5	**0.002**	**L**
Bear River	0.06	Adult Immigration and Holding	0.20	Water Quality	0.020	DO, Ag, Urban, Heavy Metals in th Delta	0.010	0.000	4	**0.001**	**L**
Bear River	0.06	Adult Immigration and Holding	0.20	Water Temperature	0.500	Delta	0.000	0.000	4	**0.000**	

Big Chico Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Iron Canyon, City of Chico Swimming Holes and Associated Dams	0.750	0.38	5	**1.88**	**VH**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Big Chico Creek	0.700	0.42	4	**1.68**	**VH**
Big Chico Creek	0.08	Spawning	**0.25**	Spawning Habitat Availability	0.400	Habitat Suitability	1.000	0.80	1	**0.80**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.350	0.15	4	**0.59**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Middle Sacramento River	0.350	0.15	4	**0.59**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Delta	0.300	0.13	4	**0.50**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.300	0.13	4	**0.50**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Delta	0.300	0.13	4	**0.50**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.300	0.13	4	**0.50**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Jones and Banks Pumping Plants	0.250	0.07	7	**0.49**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Delta	0.300	0.08	5	**0.42**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the lower Sacramento River	0.300	0.08	5	**0.42**	**VH**
Big Chico Creek	0.08	Spawning	**0.25**	Water Temperature	0.200	Water Temperature in Big Chico Creek	1.000	0.40	1	**0.40**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the Delta	0.200	0.06	7	**0.39**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the lower Sacramento River	0.200	0.06	7	**0.39**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the middle Sacramento River	0.200	0.06	7	**0.39**	**VH**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.300	0.06	6	**0.36**	**VH**
Big Chico Creek	0.08	Embryo Incubation	**0.15**	Water Temperature	0.300	Water Temperature in Big Chico Creek	1.000	0.36	1.00	**0.36**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the middle Sacramento River	0.250	0.07	5	**0.35**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Big Chico Creek	0.200	0.08	4	**0.34**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Middle Sacramento River	0.200	0.08	4	**0.34**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Big Chico Creek	0.200	0.08	4	**0.34**	**VH**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Middle Sacramento River	0.200	0.08	4	**0.34**	**VH**

Big Chico Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.200	0.08	4	**0.34**	**VH**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.06	5	**0.30**	**H**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.06	5	**0.30**	**H**
Big Chico Creek	0.08	Embryo Incubation	**0.15**	Watershed disturbance	0.250	Sedimentation	1.000	0.30	1.00	**0.30**	**H**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.13	2	**0.25**	**H**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Delta	0.600	0.13	2	**0.25**	**H**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.05	5	**0.25**	**H**
Big Chico Creek	0.08	Embryo Incubation	**0.15**	Flow Conditions	0.200	Flow Fluctuations	1.000	0.24	1.00	**0.24**	**H**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.400	0.08	3	**0.24**	**H**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues in the middle Sacramento River	0.400	0.08	3	**0.24**	**H**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.300	0.06	4	**0.24**	**H**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.300	0.06	4	**0.24**	**H**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.300	0.06	4	**0.24**	**H**
Big Chico Creek	0.08	Embryo Incubation	**0.15**	Water Quality	0.200	Water Quality in Big Chico Creek	1.000	0.24	1.00	**0.24**	**H**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Delta	0.100	0.06	4	**0.24**	**H**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Lower Sacramento River	0.100	0.06	4	**0.24**	**H**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Middle Sacramento River	0.100	0.06	4	**0.24**	**H**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.04	5	**0.21**	**H**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.04	5	**0.21**	**H**

Big Chico Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Big Chico Creek	0.08	Spawning	**0.25**	Barrier	0.100	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.20	1	**0.20**	**H**
Big Chico Creek	0.08	Spawning	**0.25**	Flow Conditions	0.100	Flow Fluctuations	1.000	0.20	1	**0.20**	**H**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.04	5	**0.20**	**H**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.150	0.03	6	**0.18**	**H**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.150	0.03	6	**0.18**	**H**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.150	0.03	6	**0.18**	**H**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.150	0.03	6	**0.18**	**H**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.08	2	**0.17**	**M**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Big Chico Creek	0.100	0.04	4	**0.17**	**M**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Bays	0.400	0.08	2	**0.17**	**M**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in Big Chico Creek	0.100	0.03	5	**0.14**	**M**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.03	5	**0.14**	**M**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	1.000	0.14	1	**0.14**	**M**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Big Chico Creek	0.500	0.04	4	**0.14**	**M**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Diversion into Central Delta	0.300	0.02	6	**0.13**	**M**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.050	0.03	5	**0.13**	**M**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.050	0.03	5	**0.13**	**M**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.050	0.03	5	**0.13**	**M**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues in Big Chico Creek	0.200	0.04	3	**0.12**	**M**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Big Chico Creek	0.100	0.02	6	**0.12**	**M**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Delta	0.300	0.02	5	**0.11**	**M**

Big Chico Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Lower Sacramento River	0.300	0.02	5	**0.11**	**M**
Big Chico Creek	0.08	Spawning	**0.25**	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.10	1	**0.10**	**M**
Big Chico Creek	0.08	Spawning	**0.25**	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.10	1	**0.10**	**M**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in Big Chico Creek	0.100	0.02	5	**0.10**	**M**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.100	0.02	5	**0.10**	**M**
Big Chico Creek	0.08	Spawning	**0.25**	Water Quality	0.050	Water Quality in Big Chico Creek	1.000	0.10	1	**0.10**	**M**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Contra Costa Power Plant	0.050	0.01	7	**0.10**	**M**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in Big Chico Creek	0.050	0.01	7	**0.10**	**M**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Pittsburg Power Plant	0.050	0.01	7	**0.10**	**M**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Changes in Hydrology	0.200	0.01	6	**0.08**	**M**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Reverse Flow Conditions	0.200	0.01	6	**0.08**	**M**
Big Chico Creek	0.08	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in Big Chico Creek	0.100	0.02	4	**0.08**	**L**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Bays	0.050	0.01	5	**0.07**	**L**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Big Chico Creek	0.100	0.01	5	**0.07**	**L**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.01	5	**0.07**	**L**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the lower Sacramento River	0.200	0.01	5	**0.07**	**L**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the middle Sacramento River	0.200	0.01	5	**0.07**	**L**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in Big Chico Creek	0.200	0.01	5	**0.07**	**L**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban, Heavy Metals in the Bays	0.200	0.01	5	**0.07**	**L**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	DO, Ag, Urban, Heavy Metals in the Delta	0.200	0.01	5	**0.07**	**L**
Big Chico Creek	0.08	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.050	Redd disturbance	1.000	0.06	1.00	**0.06**	**L**

Big Chico Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Lower Sacramento River	0.200	0.01	4	**0.06**	**L**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Middle Sacramento River	0.200	0.01	4	**0.06**	**L**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Middle Sacramento River	0.150	0.01	5	**0.05**	**L**
Big Chico Creek	0.08	Spawning	**0.25**	Physical Habitat Alteration	0.050	Limited Instream Gravel Supply	0.500	0.05	1	**0.05**	**L**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in Big Chico Creek	0.100	0.01	6	**0.04**	**L**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.01	6	**0.04**	**L**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.01	6	**0.04**	**L**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Bays	0.100	0.01	5	**0.04**	**L**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Big Chico Creek	0.100	0.01	5	**0.04**	**L**
Big Chico Creek	0.08	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Delta	0.100	0.01	4	**0.03**	**L**

Butte Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Butte Creek	0.800	0.39	3	**1.16**	**VH**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Butte Creek Diversion Dams and Weirs	0.600	0.16	6	**0.95**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Predation	0.150	Predation in the Delta	0.350	0.13	4	**0.51**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Delta	0.425	0.17	3	**0.50**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.400	0.16	3	**0.47**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Delta	0.425	0.16	3	**0.47**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Predation	0.150	Predation in the lower Sacramento River	0.300	0.11	4	**0.44**	**VH**
Butte Creek	0.07	Spawning	**0.25**	Spawning Habitat Availability	0.225	Habitat Availability/Suitability	1.000	0.39	1	**0.39**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.080	Butte Creek - stocked rainbow trout fishery - competition for habitat and resources	0.500	0.10	4	**0.39**	**H**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.325	0.13	3	**0.38**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.325	0.13	3	**0.38**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Predation	0.150	Predation in Butte Creek	0.250	0.09	4	**0.37**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.325	0.12	3	**0.36**	**VH**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.400	0.07	5	**0.35**	**VH**
Butte Creek	0.07	Spawning	**0.25**	Hatchery Effects	0.200	Stocked rainbow trout fishery, competition for habitat, genetic integrity	1.000	0.35	1	**0.35**	**VH**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Recreational Impacts (Summer inner tubing)	0.200	Summer inner tubing and swimming in Butte Creek	1.000	0.35	1	**0.35**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Butte Creek	0.275	0.11	3	**0.32**	**VH**
Butte Creek	0.07	Embryo Incubation	**0.15**	Flow Conditions	0.300	Flow Fluctuations	1.000	0.32	1.00	**0.32**	**VH**
Butte Creek	0.07	Spawning	**0.25**	Flow Conditions	0.175	Flow Fluctuations	1.000	0.31	1	**0.31**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Butte Creek	0.250	0.10	3	**0.29**	**VH**
Butte Creek	0.07	Embryo Incubation	**0.15**	Water Quality	0.275	Water Quality, Turbidity in Butte Creek	1.000	0.29	1.00	**0.29**	**VH**
Butte Creek	0.07	Embryo Incubation	**0.15**	Water Temperature	0.275	Water Temperature in Butte Creek	1.000	0.29	1.00	**0.29**	**VH**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Butte Creek	0.250	0.09	3	**0.28**	**H**

Butte Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the Delta	0.250	0.04	6	**0.26**	**H**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the lower Sacramento River	0.250	0.04	6	**0.26**	**H**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Jones and Banks Pumping Plants	0.250	0.04	6	**0.26**	**H**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Butte Creek	0.275	0.05	5	**0.24**	**H**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Yolo Bypass - Freemont Weir	0.150	0.04	6	**0.24**	**H**
Butte Creek	0.07	Spawning	**0.25**	Harvest/Angling Impacts	0.125	Recreational, Poaching, Angler Impacts	1.000	0.22	1	**0.22**	**H**
Butte Creek	0.07	Spawning	**0.25**	Water Temperature	0.125	Water Temperature in Butte Creek	1.000	0.22	1	**0.22**	**H**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Water Quality	0.125	Ag, Urban in Butte Creek	0.333	0.07	3	**0.22**	**H**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Water Quality	0.125	Ag, Urban in the lower Sacramento River	0.333	0.07	3	**0.22**	**H**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Water Quality	0.125	DO, Ag, Urban, Heavy Metals in the Delta	0.333	0.07	3	**0.22**	**H**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in the lower Sacramento River	0.600	0.11	2	**0.21**	**H**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in Butte Creek	0.200	0.03	6	**0.21**	**H**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.060	DO, Ag, Urban, Heavy Metals in the Delta	0.350	0.05	4	**0.21**	**H**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.375	0.05	4	**0.18**	**H**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Centerville Head Dam	0.100	0.03	6	**0.16**	**H**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.080	Delta	0.200	0.04	4	**0.16**	**H**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.080	Lower Sacramento River	0.200	0.04	4	**0.16**	**H**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.050	Delta	0.600	0.07	2	**0.15**	**H**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Predation	0.150	Predation in the Bays	0.100	0.04	4	**0.15**	**H**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.04	4	**0.15**	**H**

Butte Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.060	Ag, Urban in the lower Sacramento River	0.250	0.04	4	**0.15**	**H**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.060	Ag, Urban, Heavy Metals in the Bays	0.250	0.04	4	**0.15**	**H**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Delta	0.100	0.05	3	**0.14**	**M**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Water Temperature	0.275	Lower Sacramento River	0.100	0.05	3	**0.14**	**M**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues in Butte Creek	0.400	0.07	2	**0.14**	**M**
Butte Creek	0.07	Spawning	**0.25**	Water Quality	0.075	Water Quality, Turbidity in Butte Creek	1.000	0.13	1	**0.13**	**M**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.125	0.02	5	**0.11**	**M**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.125	0.02	5	**0.11**	**M**
Butte Creek	0.07	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.100	Redd disturbance	1.000	0.11	1.00	**0.11**	**M**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.050	Bays	0.400	0.05	2	**0.10**	**M**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Butte Creek	0.200	0.02	4	**0.10**	**M**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.275	0.02	4	**0.10**	**M**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.275	0.02	4	**0.10**	**M**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.060	Ag, Urban in Butte Creek	0.150	0.02	4	**0.09**	**M**
Butte Creek	0.07	Spawning	**0.25**	Barrier	0.050	Centerville Head Dam - Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.09	1	**0.09**	**M**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.250	0.02	4	**0.09**	**M**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Sacramento Deep Water Ship Channel	0.050	0.01	6	**0.08**	**M**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Suisun Marsh Salinity Control Structure	0.050	0.01	6	**0.08**	**M**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.150	Sutter Bypass - Tisdale Weir	0.050	0.01	6	**0.08**	**M**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.080	Bays	0.100	0.02	4	**0.08**	**M**

Butte Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Butte Creek	0.400	0.02	3	**0.07**	**M**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Butte Creek	0.200	0.02	4	**0.07**	**M**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Diversion into Central Delta	0.225	0.01	5	**0.07**	**M**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in Butte Creek	0.225	0.01	5	**0.07**	**M**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Reverse Flow Conditions	0.225	0.01	5	**0.07**	**M**
Butte Creek	0.07	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.075	0.01	5	**0.07**	**L**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.125	0.02	4	**0.06**	**L**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Delta	0.300	0.02	3	**0.06**	**L**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Lower Sacramento River	0.300	0.02	3	**0.06**	**L**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Changes in Delta Hydrology	0.175	0.01	5	**0.05**	**L**
Butte Creek	0.07	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.05	1.00	**0.05**	**L**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the lower Sacramento River	0.150	0.01	5	**0.05**	**L**
Butte Creek	0.07	Spawning	**0.25**	Physical Habitat Alteration	0.025	Limited Instream Gravel Supply	1.000	0.04	1	**0.04**	**L**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.010	Agricultural, Wildlife and Terminal Diversions	0.800	0.02	2	**0.04**	**L**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.01	2	**0.03**	**L**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Contra Costa Power Plant	0.025	0.00	6	**0.03**	**L**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Pittsburg Power Plant	0.025	0.00	6	**0.03**	**L**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.01	2	**0.02**	**L**
Butte Creek	0.07	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.010	Tributary Barriers	0.200	0.00	2	**0.01**	**L**

Calaveras River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Calaveras River	0.19	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.350	Bellota Weir	0.375	0.748	5	**3.741**	**VH**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.350	Flash Board Dams	0.375	0.748	5	**3.741**	**VH**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.300	Flow Dependent Habitat Availability in the Calaveras River	0.500	0.855	3	**2.565**	**VH**
Calaveras River	0.19	Embryo Incubation	**0.20**	Flow Conditions	0.450	Flow Fluctuations	1.000	1.710	1	**1.710**	**VH**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Flow Conditions	0.300	Low flows limiting attraction into the Calaveras Rvier	1.000	1.710	1	**1.710**	**VH**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.300	Changes in Hydrology	0.300	0.513	3	**1.539**	**VH**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.350	Stockton Deep Water Ship Channel	0.150	0.299	5	**1.496**	**VH**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Passage Impediments/Barriers	0.175	Bellota Weir	0.400	0.399	3	**1.197**	**VH**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Passage Impediments/Barriers	0.175	New Hogan Dam	0.400	0.399	3	**1.197**	**VH**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Water Quality	0.150	Ag, Urban in the Calaveras River	0.700	0.599	2	**1.197**	**VH**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.300	Reverse Flow Conditions	0.200	0.342	3	**1.026**	**VH**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.125	Calaveras River	0.700	0.499	2	**0.998**	**VH**
Calaveras River	0.19	Embryo Incubation	**0.20**	Water Temperature	0.250	Water temperature in the Calaveras River	1.000	0.950	1	**0.950**	**VH**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Water Quality	0.100	Ag, Urban in the Calaveras River	0.550	0.314	3	**0.941**	**VH**
Calaveras River	0.19	Spawning	0.20	Spawning Habitat Availability	0.225	Habitat Suitability	1.000	0.855	1	**0.855**	**VH**
Calaveras River	0.19	Spawning	0.20	Barrier	0.200	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.760	1	**0.760**	**VH**
Calaveras River	0.19	Spawning	0.20	Flow Conditions	0.200	Flow Fluctuations	1.000	0.760	1	**0.760**	**VH**
Calaveras River	0.19	Spawning	0.20	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply	1.000	0.760	1	**0.760**	**VH**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Loss of Natural River Morphology	0.100	Calaveras River	0.600	0.342	2	**0.684**	**H**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Water Temperature	0.100	Calaveras River	0.600	0.342	2	**0.684**	**H**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Predation	0.075	Predation in the Delta	0.500	0.214	3	**0.641**	**H**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Passage Impediments/Barriers	0.175	Tributary Barriers	0.200	0.200	3	**0.599**	**H**
Calaveras River	0.19	Embryo Incubation	**0.20**	Harvest/Angling Impacts	0.150	Redd disturbance	1.000	0.570	1.00	**0.570**	**H**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Calaveras River	0.450	0.128	4	**0.513**	**H**

Calaveras River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Predation	0.075	Predation in the Calaveras River	0.400	0.171	3	**0.513**	**H**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Calaveras River	0.600	0.171	3	**0.513**	**H**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in th Delta	0.300	0.171	3	**0.513**	**H**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in th Delta	0.300	0.257	2	**0.513**	**H**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Jones and Banks Pumping Plants	0.350	0.100	5	**0.499**	**H**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.350	New Hogan Dam	0.050	0.100	5	**0.499**	**H**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.350	Suisun Marsh Salinity Control Structure	0.050	0.100	5	**0.499**	**H**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Loss of Natural River Morphology	0.100	Delta	0.400	0.228	2	**0.456**	**H**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Water Temperature	0.100	Delta	0.400	0.228	2	**0.456**	**H**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Individual Diversions in the Calaveras River	0.300	0.086	5	**0.428**	**H**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.125	Delta	0.300	0.214	2	**0.428**	**H**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Delta	0.350	0.100	4	**0.399**	**M**
Calaveras River	0.19	Embryo Incubation	**0.20**	Water Quality	0.100	Water Pollution	1.000	0.380	1.00	**0.380**	**M**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Loss of Riparian Habitat and Instream Cover	0.050	Calaveras River	0.600	0.171	2	**0.342**	**M**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Individual Diversions in the Delta	0.200	0.057	5	**0.285**	**M**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.086	3	**0.257**	**M**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Water Quality	0.100	Ag, Urban, Heavy Metals in the Bays	0.150	0.086	3	**0.257**	**M**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Loss of Floodplain Habitat	0.025	Delta	0.800	0.114	2	**0.228**	**M**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Loss of Riparian Habitat and Instream Cover	0.050	Delta	0.400	0.114	2	**0.228**	**M**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Invasive Species/Food Web Disruption	0.025	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.100	2	**0.200**	**M**
Calaveras River	0.19	Spawning	0.20	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.190	1	**0.190**	**M**
Calaveras River	0.19	Embryo Incubation	**0.20**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.190	1	**0.190**	**M**

Calaveras River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Calaveras River	0.19	Spawning	0.20	Water Quality	0.050	Water quality in the Calaveras River	1.000	0.190	1	**0.190**	**M**
Calaveras River	0.19	Spawning	0.20	Water Temperature	0.050	Water temperature in the Calaveras River	1.000	0.190	1	**0.190**	**M**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.400	0.057	3	**0.171**	**M**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Bays	0.150	0.043	4	**0.171**	**M**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Loss of Tidal Marsh Habitat	0.025	Delta	0.600	0.086	2	**0.171**	**M**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Contra Costa Power Plant	0.100	0.029	5	**0.143**	**L**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Predation	0.075	Predation in the Bays	0.100	0.043	3	**0.128**	**L**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.300	0.043	3	**0.128**	**L**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Calaveras River	0.300	0.043	3	**0.128**	**L**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Loss of Tidal Marsh Habitat	0.025	Bays	0.400	0.057	2	**0.114**	**L**
Calaveras River	0.19	Spawning	0.20	Hatchery Effects	0.025	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.095	1	**0.095**	**L**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.100	0.029	3	**0.086**	**L**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Invasive Species/Food Web Disruption	0.025	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.043	2	**0.086**	**L**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Pittsburg Power Plant	0.050	0.014	5	**0.071**	**L**
Calaveras River	0.19	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Ocean	0.050	0.014	4	**0.057**	**L**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Loss of Floodplain Habitat	0.025	Calaveras River	0.200	0.029	2	**0.057**	**L**
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.025	Bays	0.000	0.000	3	**0.000**	
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.025	Calaveras River	0.000	0.000	3	**0.000**	
Calaveras River	0.19	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.025	Delta	0.000	0.000	3	**0.000**	

Clear Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.21	Spawning	0.4	Physical Habitat Alteration	0.250	Limited Instream Gravel Supply	1.000	2.10	1	**2.10**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Red Bluff Diversion Dam	0.410	0.34	6	**2.07**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Temperature	0.300	Clear Creek	0.400	0.50	4	**2.02**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Whiskeytown Dam	0.355	0.30	6	**1.79**	**VH**
Clear Creek	0.21	Spawning	0.4	Spawning Habitat Availability	0.200	Habitat Suitability	1.000	1.68	1	**1.68**	**VH**
Clear Creek	0.21	Spawning	0.4	Water Temperature	0.200	Water Temperature in Clear Creek	1.000	1.68	1	**1.68**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.350	0.29	5	**1.47**	**VH**
Clear Creek	0.21	Spawning	0.4	Flow Conditions	0.150	Flow Fluctuations	1.000	1.26	1	**1.26**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Flow Conditions	0.250	Low Flows - attraction, migratory cues in Clear Creek	0.400	0.42	3	**1.26**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Delta	0.300	0.25	5	**1.26**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.350	0.29	4	**1.18**	**VH**
Clear Creek	0.21	Embryo Incubation	**0.15**	Water Quality	0.350	Sedimentation in Clear Creek	1.000	1.10	1.00	**1.10**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Flow Dependent Habitat Availability in Clear Creek	0.450	0.18	6	**1.06**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Lower Sacramento River	0.250	0.21	5	**1.05**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the Delta	0.250	0.16	6	**0.98**	**VH**
Clear Creek	0.21	Embryo Incubation	**0.15**	Flow Conditions	0.300	Flow Fluctuations	1.000	0.95	1.00	**0.95**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Clear Creek	0.200	0.17	5	**0.84**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Clear Creek	0.200	0.17	5	**0.84**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Delta	0.200	0.17	5	**0.84**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Middle Sacramento River	0.200	0.17	5	**0.84**	**VH**
Clear Creek	0.21	Spawning	0.4	Barriers	0.100	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.84	1	**0.84**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the lower Sacramento River	0.200	0.13	6	**0.79**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the middle Sacramento River	0.200	0.13	6	**0.79**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the upper Sacramento River	0.200	0.13	6	**0.79**	**VH**

Clear Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.21	Embryo Incubation	**0.15**	Water Temperature	0.250	Water Temperature in Clear Creek	1.000	0.79	1.00	**0.79**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Quality	0.150	Ag, Urban in the lower Sacramento River	0.200	0.13	6	**0.76**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Quality	0.150	Clear Creek	0.200	0.13	6	**0.76**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Delta	0.200	0.13	6	**0.76**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Temperature	0.300	Delta	0.150	0.19	4	**0.76**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Temperature	0.300	Lower Sacramento River	0.150	0.19	4	**0.76**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Temperature	0.300	Middle Sacramento River	0.150	0.19	4	**0.76**	**VH**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Temperature	0.300	Upper Sacramento River	0.150	0.19	4	**0.76**	**VH**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Clear Creek	0.200	0.17	4	**0.67**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.200	0.17	4	**0.67**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Middle Sacramento River	0.200	0.17	4	**0.67**	**H**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Flow Conditions	0.250	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.200	0.21	3	**0.63**	**H**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Flow Conditions	0.250	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.21	3	**0.63**	**H**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Flow Conditions	0.250	Low Flows - attraction, migratory cues in the upper Sacramento River	0.200	0.21	3	**0.63**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Upper Sacramento River	0.150	0.13	5	**0.63**	**H**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Quality	0.150	Ag, Urban in the middle Sacramento River	0.150	0.09	6	**0.57**	**H**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Quality	0.150	Urban, Heavy Metals in the upper Sacramento River	0.150	0.09	6	**0.57**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in the Delta	0.175	0.06	8	**0.51**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in the lower Sacramento River	0.175	0.06	8	**0.51**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in the middle Sacramento River	0.175	0.06	8	**0.51**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Jones and Banks Pumping Plants	0.175	0.06	8	**0.51**	**H**

Clear Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.21	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Ocean	0.350	0.07	7	**0.51**	**H**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Yolo Bypass - Freemont Weir	0.100	0.08	6	**0.50**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Diversion into Central Delta	0.200	0.08	6	**0.47**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Lower Sacramento River	0.350	0.09	5	**0.46**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.160	Middle Sacramento River	0.100	0.08	5	**0.42**	**H**
Clear Creek	0.21	Spawning	0.4	Water Quality	0.050	Water Quality in Clear Creek	1.000	0.42	1	**0.42**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in Clear Creek	0.100	0.07	6	**0.39**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Middle Sacramento River	0.300	0.08	5	**0.39**	**H**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Bay	0.100	0.06	6	**0.38**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Tributary Barriers	0.700	0.18	2	**0.37**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in Clear Creek	0.100	0.04	8	**0.29**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Individual Diversions in the upper Sacramento River	0.100	0.04	8	**0.29**	**H**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Clear Creek	0.200	0.04	7	**0.29**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Clear Creek	0.200	0.05	5	**0.26**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.05	5	**0.26**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.05	5	**0.26**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.200	0.05	5	**0.26**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Urban, Heavy Metals in the upper Sacramento River	0.200	0.05	5	**0.26**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.200	0.05	5	**0.26**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.200	0.05	5	**0.26**	**H**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in Clear Creek	0.200	0.05	5	**0.26**	**H**

Clear Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Clear Creek	0.200	0.05	5	**0.26**	**H**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Sacramento Deep Water Ship Channel	0.050	0.04	6	**0.25**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Suisun Marsh Salinity Control Structure	0.050	0.04	6	**0.25**	**M**
Clear Creek	0.21	Spawning	0.4	Harvest/Angling Impacts	0.030	Recreational, Poaching, Angler Impacts	1.000	0.25	1	**0.25**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Changes in Hydrology	0.100	0.04	6	**0.24**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Reverse Flow Conditions	0.100	0.04	6	**0.24**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.030	Delta	0.300	0.05	5	**0.24**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.160	Upper Sacramento River	0.050	0.04	5	**0.21**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.04	5	**0.21**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.04	5	**0.21**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.200	0.04	5	**0.21**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Predation	0.125	Predation in the Bays	0.050	0.03	6	**0.20**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.04	5	**0.20**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Passage Impediments/Barriers	0.200	Sutter Bypass - Tisdale Weir	0.035	0.03	6	**0.18**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.160	Upper Sacramento River	0.050	0.04	4	**0.17**	**M**
Clear Creek	0.21	Spawning	0.4	Hatchery Effects	0.020	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.17	1	**0.17**	**M**
Clear Creek	0.21	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.050	Redd disturbance	1.000	0.16	1.00	**0.16**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.030	Lower Sacramento River	0.200	0.03	5	**0.16**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.030	Middle Sacramento River	0.200	0.03	5	**0.16**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.030	Upper Sacramento River	0.200	0.03	5	**0.16**	**M**

Clear Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Whiskeytown Dam	0.300	0.08	2	**0.16**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Clear Creek	0.150	0.03	5	**0.16**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.03	5	**0.16**	**M**
Clear Creek	0.21	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.16	1.00	**0.16**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Contra Costa Power Plant	0.050	0.02	8	**0.15**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Entrainment	0.070	Pittsburg Power Plant	0.050	0.02	8	**0.15**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Delta	0.100	0.02	7	**0.15**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Lower Sacramento River	0.100	0.02	7	**0.15**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Middle Sacramento River	0.100	0.02	7	**0.15**	**M**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Upper Sacramento River	0.100	0.02	7	**0.15**	**M**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.100	0.03	5	**0.13**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.100	0.03	5	**0.13**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Delta	0.100	0.03	5	**0.13**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Flow Dependent Habitat Availability in the lower Sacramento River	0.050	0.02	6	**0.12**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Flow Dependent Habitat Availability in the middle Sacramento River	0.050	0.02	6	**0.12**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.075	Flow Dependent Habitat Availability in the upper Sacramento River	0.050	0.02	6	**0.12**	**L**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.100	0.02	5	**0.11**	**L**
Clear Creek	0.21	Adult Immigration and Holding	0.2	Harvest/Angling Impacts	0.050	Bays	0.050	0.01	7	**0.07**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.050	0.01	5	**0.07**	**L**

Clear Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.050	Upper Sacramento River	0.050	0.01	5	**0.07**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.03	2	**0.06**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.010	Delta	0.600	0.03	2	**0.06**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.02	2	**0.04**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.010	Bays	0.400	0.02	2	**0.04**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.030	Bays	0.050	0.01	5	**0.04**	**L**
Clear Creek	0.21	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.030	Clear Creek	0.050	0.01	5	**0.04**	**L**

Cottonwood/Beegum Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Beegum Creek	0.600	0.49	5	**2.44**	**VH**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	RBDD	0.550	0.36	5	**1.79**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Delta	0.300	0.20	5	**1.02**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.300	0.20	5	**1.02**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Delta	0.300	0.20	5	**1.02**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.300	0.20	5	**1.02**	**VH**
Beegum Creek	0.13	Spawning	**0.25**	Spawning Habitat Availability	0.300	Habitat Suitability	1.000	0.98	1	**0.98**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.275	0.19	5	**0.94**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.275	0.19	5	**0.94**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Beegum Creek	0.250	0.17	5	**0.85**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the Delta	0.200	0.09	8	**0.73**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the lower Sacramento River	0.200	0.09	8	**0.73**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the middle Sacramento River	0.200	0.09	8	**0.73**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Jones and Banks Pumping Plants	0.200	0.09	8	**0.73**	**VH**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.300	0.10	7	**0.68**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Delta	0.250	0.11	6	**0.68**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the lower Sacramento River	0.250	0.11	6	**0.68**	**VH**
Beegum Creek	0.13	Embryo Incubation	**0.15**	Watershed disturbance	0.350	Sedimentation	1.000	0.68	1.00	**0.68**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Middle Sacramento River	0.200	0.14	5	**0.68**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Beegum Creek	0.200	0.14	5	**0.68**	**VH**
Beegum Creek	0.13	Spawning	**0.25**	Flow Conditions	0.200	Flow Fluctuations	1.000	0.65	1	**0.65**	**VH**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.250	0.16	4	**0.65**	**VH**

Cottonwood/Beegum Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in Beegum Creek	0.250	0.16	4	**0.65**	**VH**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the middle Sacramento River	0.250	0.16	4	**0.65**	**VH**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the Upper Sacramento River	0.250	0.16	4	**0.65**	**VH**
Beegum Creek	0.13	Spawning	**0.25**	Water Temperature	0.200	Water Temperature in Beegum Creek	1.000	0.65	1	**0.65**	**VH**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the middle Sacramento River	0.200	0.09	6	**0.55**	**VH**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	Yolo Bypass - Freemont Weir	0.150	0.10	5	**0.49**	**VH**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.250	0.08	6	**0.49**	**VH**
Beegum Creek	0.13	Embryo Incubation	**0.15**	Flow Conditions	0.225	Flow Fluctuations	1.000	0.44	1.00	**0.44**	**H**
Beegum Creek	0.13	Embryo Incubation	**0.15**	Water Quality	0.225	Water Quality in Beegum Creek	1.000	0.44	1.00	**0.44**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the upper Sacramento River	0.150	0.07	6	**0.41**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.07	6	**0.41**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.07	6	**0.41**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.20	2	**0.41**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Delta	0.600	0.20	2	**0.41**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Delta	0.100	0.08	5	**0.41**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Lower Sacramento River	0.100	0.08	5	**0.41**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Middle Sacramento River	0.100	0.08	5	**0.41**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Upper Sacramento River	0.100	0.08	5	**0.41**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.07	6	**0.39**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.07	6	**0.39**	**H**

Cottonwood/Beegum Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.200	0.07	6	**0.39**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.200	0.07	6	**0.39**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the upper Sacramento River	0.200	0.07	6	**0.39**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Beegum Creek	0.100	0.07	5	**0.34**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Upper Sacramento River	0.100	0.07	5	**0.34**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Middle Sacramento River	0.100	0.07	5	**0.34**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Upper Sacramento River	0.100	0.07	5	**0.34**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Middle Sacramento River	0.100	0.07	5	**0.34**	**H**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Upper Sacramento River	0.100	0.07	5	**0.34**	**H**
Beegum Creek	0.13	Spawning	**0.25**	Barrier	0.100	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.33	1	**0.33**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	Sacramento Deep Water Ship Channel	0.100	0.07	5	**0.33**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	Suisun Marsh Salinity Control Structure	0.100	0.07	5	**0.33**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.200	Sutter Bypass - Tisdale Weir	0.100	0.07	5	**0.33**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.150	0.05	6	**0.29**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.05	6	**0.29**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.150	0.05	6	**0.29**	**H**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.125	0.04	7	**0.28**	**M**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.125	0.04	7	**0.28**	**M**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.125	0.04	7	**0.28**	**M**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Upper Sacramento River	0.125	0.04	7	**0.28**	**M**

Cottonwood/Beegum Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Beegum Creek	0.500	0.06	5	**0.28**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in Beegum Creek	0.100	0.05	6	**0.27**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.05	6	**0.27**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.14	2	**0.27**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Bays	0.400	0.14	2	**0.27**	**M**
Beegum Creek	0.13	Embryo Incubation	**0.15**	Water Temperature	0.125	Water Temperature in Beegum Creek	1.000	0.24	1.00	**0.24**	**M**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.100	0.03	7	**0.23**	**M**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Beegum Creek	0.100	0.03	7	**0.23**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	1.000	0.23	1	**0.23**	**M**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in Beegum Creek	0.100	0.03	6	**0.20**	**M**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in Beegum Creek	0.100	0.03	6	**0.20**	**M**
Beegum Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the Bay	0.100	0.03	6	**0.20**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Contra Costa Power Plant	0.050	0.02	8	**0.18**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in Beegum Creek	0.050	0.02	8	**0.18**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the upper Sacramento River	0.050	0.02	8	**0.18**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Pittsburg Power Plant	0.050	0.02	8	**0.18**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Delta	0.250	0.03	6	**0.17**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the lower Sacramento River	0.250	0.03	6	**0.17**	**M**
Beegum Creek	0.13	Spawning	**0.25**	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.16	1	**0.16**	**M**
Beegum Creek	0.13	Spawning	**0.25**	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.16	1	**0.16**	**M**
Beegum Creek	0.13	Spawning	**0.25**	Water Quality	0.050	Water Quality in Beegum Creek	1.000	0.16	1	**0.16**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Changes in Hydrology	0.200	0.02	7	**0.16**	**M**

Cottonwood/Beegum Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Diversion into Central Delta	0.200	0.02	7	**0.16**	**M**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Reverse Flow Conditions	0.200	0.02	7	**0.16**	**M**
Beegum Creek	0.13	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.075	Redd disturbance	1.000	0.15	1.00	**0.15**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Lower Sacramento River	0.200	0.02	6	**0.14**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Middle Sacramento River	0.200	0.02	6	**0.14**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Upper Sacramento River	0.200	0.02	6	**0.14**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Bays	0.050	0.02	6	**0.14**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.02	6	**0.14**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the middle Sacramento River	0.200	0.02	6	**0.14**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the upper Sacramento River	0.200	0.02	6	**0.14**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Lower Sacramento River	0.200	0.02	5	**0.11**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	DO, Ag, Urban, Heavy Metals in the Delta	0.150	0.02	6	**0.10**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Middle Sacramento River	0.150	0.02	5	**0.09**	**L**
Beegum Creek	0.13	Spawning	**0.25**	Physical Habitat Alteration	0.050	Limited Instream Gravel Supply	0.500	0.08	1	**0.08**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in Beegum Creek	0.100	0.01	7	**0.08**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.01	7	**0.08**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.01	7	**0.08**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the upper Sacramento River	0.100	0.01	7	**0.08**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Bays	0.100	0.01	6	**0.07**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Beegum Creek	0.050	0.01	6	**0.07**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.050	0.01	6	**0.07**	**L**

Cottonwood/Beegum Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in Beegum Creek	0.100	0.01	6	**0.07**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban, Heavy Metals in the Bays	0.100	0.01	6	**0.07**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Delta	0.100	0.01	5	**0.06**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Beegum Creek	0.050	0.01	6	**0.03**	**L**
Beegum Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Upper Sacramento River	0.050	0.01	5	**0.03**	**L**

Cow Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stresor Category
Cow Creek	0.3	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Impediments/Barriers in Cow Creek	0.86	2.322	6	**13.932**	**VH**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Temperature	**0.300**	Cow Creek	0.95	2.565	4	**10.260**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Entrainment	0.250	Individual Unscreened Diversions in Cow Creek	0.4	0.900	8	**7.200**	**VH**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Flow Conditions	**0.250**	Low Flows - attraction, migratory cues in Cow Creek	0.75	1.688	4	**6.750**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.150	Cow Creek	0.6	0.810	5	**4.050**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.150	Cow Creek	0.75	1.013	4	**4.050**	**VH**
Cow Creek	0.3	Spawning	0.3	Passage Impediments/Barriers	0.400	Redd superimposition, competition for habitat, hybridization/genetic integrity	1	3.600	1	**3.600**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Entrainment	0.250	Jones and Banks Pumping Plants	0.2	0.450	8	**3.600**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.100	Cow Creek	0.8	0.720	5	**3.600**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Flow Dependent Habitat Availability in Cow Creek	0.5	0.450	7	**3.150**	**VH**
Cow Creek	0.3	Spawning	0.3	Hatchery Effects	0.300	Stocked trout fishery in upper Cow Creek - competition for habitat, genetic integrity	1	2.700	1	**2.700**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in Cow Creek	0.4	0.360	6	**2.160**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the upper Sacramento River	0.4	0.360	6	**2.160**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.150	Upper Sacramento River	0.3	0.405	5	**2.025**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Entrainment	0.250	Individual Unscreened Diversions in the Delta	0.1	0.225	8	**1.800**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Entrainment	0.250	Individual Unscreened Diversions in the middle Sacramento River	0.1	0.225	8	**1.800**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.150	Cow Creek	0.2	0.270	5	**1.350**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.2	0.270	5	**1.350**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.150	Middle Sacramento River	0.2	0.270	5	**1.350**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.150	Delta	0.2	0.270	5	**1.350**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Changes in Hydrology	0.2	0.180	7	**1.260**	**VH**
Cow Creek	0.3	Embryo Incubation	**0.10**	Water Quality	0.325	Water Quality in Cow Creek	1.00	0.975	1.00	**0.975**	**VH**

Cow Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stresor Category
Cow Creek	0.3	Embryo Incubation	**0.10**	Water Temperature	0.325	Water Temperature in Cow Creek	1.00	0.975	1	**0.975**	**VH**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.050**	Upper Sacramento River	0.3	0.135	7	**0.945**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Entrainment	0.250	Contra Costa Power Plant	0.05	0.113	8	**0.900**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Entrainment	0.250	Individual Unscreened Diversions in the lower Sacramento River	0.05	0.113	8	**0.900**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Entrainment	0.250	Individual Unscreened Diversions in the upper Sacramento River	0.05	0.113	8	**0.900**	**VH**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Entrainment	0.250	Pittsburg Power Plant	0.05	0.113	8	**0.900**	**VH**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Flow Conditions	**0.250**	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.1	0.225	4	**0.900**	**VH**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Flow Conditions	**0.250**	Low Flows - attraction, migratory cues in the middle Sacramento River	0.1	0.225	4	**0.900**	**VH**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Flow Conditions	**0.250**	Low Flows - attraction, migratory cues in the upper Sacramento River	0.1	0.225	4	**0.900**	**VH**
Cow Creek	0.3	Spawning	0.3	Physical Habitat Alteration	0.100	Limited Instream Gravel Supply	1	0.900	1	**0.900**	**VH**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.050**	Sedimentation, turbidity, acoustic effects, hazardous spills in Cow Creek	0.4	0.180	5	**0.900**	**VH**
Cow Creek	0.3	Spawning	0.3	Water Temperature	0.100	Water Temperature in Cow Creek	1	0.900	1	**0.900**	**VH**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Red Bluff Diversion Dam	0.05	0.135	6	**0.810**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Passage Impediments/Barriers	0.050	Impediments/Barriers in Cow Creek	0.9	0.405	2	**0.810**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.050**	Middle Sacramento River	0.25	0.113	7	**0.788**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.150	Delta	0.1	0.135	5	**0.675**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.150	Upper Sacramento River	0.1	0.135	5	**0.675**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Quality	**0.050**	Cow Creek	0.3	0.135	5	**0.675**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Quality	**0.050**	Urban, Heavy Metals in the upper Sacramento River	0.3	0.135	5	**0.675**	**H**

Cow Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stresor Category
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Flow Dependent Habitat Availability in the upper Sacramento River	0.1	0.090	7	**0.630**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.050**	Cow Creek	0.2	0.090	7	**0.630**	**H**
Cow Creek	0.3	Embryo Incubation	**0.10**	Flow Conditions	0.200	Flow Fluctuations	1	0.600	1	**0.600**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.050**	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.25	0.113	5	**0.563**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.150	Middle Sacramento River	0.1	0.135	4	**0.540**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.150	Upper Sacramento River	0.1	0.135	4	**0.540**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the middle Sacramento River	0.1	0.090	6	**0.540**	**H**
Cow Creek	0.3	Spawning	0.3	Flow Conditions	0.050	Flow Fluctuations	1	0.450	1	**0.450**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.050**	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.2	0.090	5	**0.450**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Quality	**0.050**	Ag, Urban in the middle Sacramento River	0.2	0.090	5	**0.450**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.100	Middle Sacramento River	0.1	0.090	5	**0.450**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.05	0.068	5	**0.338**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.150	Middle Sacramento River	0.05	0.068	5	**0.338**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Temperature	**0.300**	Middle Sacramento River	0.03	0.081	4	**0.324**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Diversion into Central Delta	0.05	0.045	7	**0.315**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Flow Dependent Habitat Availability in the lower Sacramento River	0.05	0.045	7	**0.315**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Flow Dependent Habitat Availability in the middle Sacramento River	0.05	0.045	7	**0.315**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Reverse Flow Conditions	0.05	0.045	7	**0.315**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.050**	Delta	0.1	0.045	7	**0.315**	**H**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.050**	Lower Sacramento River	0.1	0.045	7	**0.315**	**H**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.05	0.068	4	**0.270**	**M**

Cow Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stresor Category
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the lower Sacramento River	0.05	0.045	6	**0.270**	**M**
Cow Creek	0.3	Spawning	0.3	Water Quality	0.030	Water Quality in Cow Creek	1	0.270	1	**0.270**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in Cow Creek	0.45	0.041	6	**0.243**	**M**
Cow Creek	0.3	Embryo Incubation	**0.10**	Harvest/Angling Impacts	0.075	Redd disturbance	1.00	0.225	1.00	**0.225**	**M**
Cow Creek	0.3	Embryo Incubation	**0.10**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1	0.225	1	**0.225**	**M**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Quality	**0.050**	Ag, Urban in the lower Sacramento River	0.1	0.045	5	**0.225**	**M**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Quality	**0.050**	DO, Ag, Urban, Heavy Metals in th Delta	0.1	0.045	5	**0.225**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.100	Upper Sacramento River	0.05	0.045	5	**0.225**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the Delta	0.04	0.036	6	**0.216**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Ag, Urban in Cow Creek	0.35	0.032	6	**0.189**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.100	Lower Sacramento River	0.04	0.036	5	**0.180**	**M**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Sacramento Deep Water Ship Channel	0.01	0.027	6	**0.162**	**M**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Suisun Marsh Salinity Control Structure	0.01	0.027	6	**0.162**	**M**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Sutter Bypass - Tisdale Weir	0.01	0.027	6	**0.162**	**M**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Yolo Bypass - Freemont Weir	0.01	0.027	6	**0.162**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Urban, Heavy Metals in the upper Sacramento River	0.3	0.027	6	**0.162**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Ag, Urban in the middle Sacramento River	0.3	0.027	6	**0.162**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.8	0.072	2	**0.144**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Tidal Marsh Habitat	0.010	Delta	0.8	0.072	2	**0.144**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Delta	0.3	0.027	5	**0.135**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Middle Sacramento River	0.3	0.027	5	**0.135**	**M**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.25	0.023	6	**0.135**	**M**

Cow Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stresor Category
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.2	0.018	6	**0.108**	**M**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Temperature	**0.300**	Lower Sacramento River	0.01	0.027	4	**0.108**	**M**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Temperature	**0.300**	Upper Sacramento River	0.01	0.027	4	**0.108**	**M**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.050**	Bays	0.03	0.014	7	**0.095**	**M**
Cow Creek	0.3	Spawning	0.3	Harvest/Angling Impacts	0.010	Recreational, Poaching, Angler Impacts	1	0.090	1	**0.090**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Passage Impediments/Barriers	0.050	Tributary Barriers	0.1	0.045	2	**0.090**	**L**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.050**	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.04	0.018	5	**0.090**	**L**
Cow Creek	0.3	Spawning	0.3	Spawning Habitat Availability	0.010	Habitat Suitability	1	0.090	1	**0.090**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Lower Sacramento River	0.15	0.014	5	**0.068**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Upper Sacramento River	0.15	0.014	5	**0.068**	**L**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.050**	Ocean	0.02	0.009	7	**0.063**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Ag, Urban in the lower Sacramento River	0.1	0.009	6	**0.054**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the Bays	0.01	0.009	6	**0.054**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Cow Creek	0.1	0.009	5	**0.045**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.100	Delta	0.01	0.009	5	**0.045**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.2	0.018	2	**0.036**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Tidal Marsh Habitat	0.010	Bays	0.2	0.018	2	**0.036**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.05	0.005	6	**0.027**	**L**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.050**	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.01	0.005	5	**0.023**	**L**
Cow Creek	0.3	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.050**	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.01	0.005	5	**0.023**	**L**

Cow Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stresor Category
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.04	0.004	6	**0.022**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	DO, Ag, Urban, Heavy Metals in th Delta	0.04	0.004	6	**0.022**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.01	0.001	6	**0.005**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Ag, Urban, Heavy Metals in the Bays	0.01	0.001	6	**0.005**	**L**
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Bays	0	0.000	5		
Cow Creek	0.3	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0	0.000	4		
Cow Creek	0.3	Adult Immigration and Holding	0.3	Water Temperature	**0.300**	Delta	0	0.000	4		

Deer Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Agricultural Diversion Dam(s) in Deer Creek	0.600	0.49	5	**2.44**	**VH**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Deer Creek	0.700	0.57	4	**2.28**	**VH**
Deer Creek	0.13	Embryo Incubation	**0.15**	Water Quality	0.665	Turbidity, sedimentation, hazardous spills (HWY 32) in Deer Creek	1.000	1.30	1.00	**1.30**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Lower Sacramento River	0.350	0.25	4	**1.02**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.350	0.25	4	**1.02**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Middle Sacramento River	0.350	0.25	4	**1.02**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.350	0.25	4	**1.02**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Middle Sacramento River	0.350	0.25	4	**1.02**	**VH**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.150	Deer Creek	0.400	0.20	5	**0.98**	**VH**
Deer Creek	0.13	Spawning	**0.25**	Hatchery Effects	0.275	Put-and-take rainbow trout fishery in upper Deer Creek, Genetic Integrity	1.000	0.89	1	**0.89**	**VH**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues in Deer Creek	0.600	0.29	3	**0.88**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Delta	0.300	0.22	4	**0.87**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the Delta	0.300	0.17	5	**0.85**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the lower Sacramento River	0.300	0.17	5	**0.85**	**VH**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.400	0.13	6	**0.78**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the middle Sacramento River	0.250	0.14	5	**0.71**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban, Hazardous Spills (Hwy 32) in Deer Creek	0.600	0.14	5	**0.68**	**VH**
Deer Creek	0.13	Spawning	**0.25**	Spawning Habitat Availability	0.200	Habitat Availability	1.000	0.65	1	**0.65**	**VH**
Deer Creek	0.13	Spawning	**0.25**	Water Quality	0.200	Turbidity, Sedimentation, Hazardous Spills (Hwy 32) in Deer Creek	1.000	0.65	1	**0.65**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Diversion into Central Delta	0.300	0.10	6	**0.61**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Middle Sacramento River	0.200	0.15	4	**0.58**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Delta	0.200	0.15	4	**0.58**	**VH**

Deer Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.200	0.15	4	**0.58**	**VH**
Deer Creek	0.13	Spawning	**0.25**	Physical Habitat Alteration	0.175	Gravel embeddedness and fines	1.000	0.57	1	**0.57**	**VH**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.050	Deer Creek	0.450	0.10	5	**0.51**	**H**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Deer Creek	0.150	0.11	4	**0.44**	**H**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Changes in Hydrology	0.200	0.07	6	**0.41**	**H**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Reverse Flow Conditions	0.200	0.07	6	**0.41**	**H**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.100	0.08	5	**0.41**	**H**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.100	0.08	5	**0.41**	**H**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.100	0.08	5	**0.41**	**H**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.08	5	**0.41**	**H**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Deer Creek	0.200	0.07	6	**0.39**	**H**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.150	Ag, Urban in the lower Sacramento River	0.150	0.07	5	**0.37**	**H**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.150	Ag, Urban in the middle Sacramento River	0.150	0.07	5	**0.37**	**H**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Bay	0.150	0.07	5	**0.37**	**H**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Delta	0.150	0.07	5	**0.37**	**H**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	0.800	0.18	2	**0.36**	**H**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Lower Sacramento River	0.400	0.09	4	**0.36**	**H**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.07	5	**0.34**	**H**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.07	5	**0.34**	**H**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Delta	0.100	0.08	4	**0.33**	**H**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Lower Sacramento River	0.100	0.08	4	**0.33**	**H**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Middle Sacramento River	0.100	0.08	4	**0.33**	**H**

Deer Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.050	Individual Diversions in the Delta	0.200	0.05	7	**0.32**	**H**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.050	Individual Diversions in the lower Sacramento River	0.200	0.05	7	**0.32**	**H**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.050	Individual Diversions in the middle Sacramento River	0.200	0.05	7	**0.32**	**H**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.050	Jones and Banks Pumping Plants	0.200	0.05	7	**0.32**	**H**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.200	0.10	3	**0.29**	**M**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.10	3	**0.29**	**M**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Deer Creek	0.100	0.07	4	**0.29**	**M**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Deer Creek	0.100	0.07	4	**0.29**	**M**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the Bays	0.100	0.06	5	**0.28**	**M**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Middle Sacramento River	0.300	0.07	4	**0.27**	**M**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.05	5	**0.24**	**M**
Deer Creek	0.13	Embryo Incubation	**0.15**	Flow Conditions	0.125	Flow Fluctuations	1.000	0.24	1.00	**0.24**	**M**
Deer Creek	0.13	Spawning	**0.25**	Water Temperature	0.075	Water Temperature in Deer Creek	1.000	0.24	1	**0.24**	**M**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.05	5	**0.23**	**M**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in Deer Creek	0.100	0.03	6	**0.20**	**M**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.03	6	**0.20**	**M**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.03	6	**0.20**	**M**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.04	5	**0.20**	**M**

Deer Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.100	0.03	6	**0.20**	**M**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.100	0.03	6	**0.20**	**M**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.100	0.03	6	**0.20**	**M**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.100	0.03	6	**0.20**	**M**
Deer Creek	0.13	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.20	1.00	**0.20**	**M**
Deer Creek	0.13	Embryo Incubation	**0.15**	Water Temperature	0.100	Water Temperature in Deer Creek	1.000	0.20	1.00	**0.20**	**M**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Deer Creek	0.200	0.05	4	**0.18**	**M**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.050	Delta	0.150	0.03	5	**0.17**	**M**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.050	Lower Sacramento River	0.150	0.03	5	**0.17**	**M**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.050	Middle Sacramento River	0.150	0.03	5	**0.17**	**M**
Deer Creek	0.13	Spawning	**0.25**	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.16	1	**0.16**	**L**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.03	5	**0.16**	**L**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.050	Individual Diversions in Deer Creek	0.100	0.02	7	**0.16**	**L**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in Deer Creek	0.050	0.03	5	**0.14**	**L**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.02	5	**0.12**	**L**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.050	Bays	0.100	0.02	5	**0.11**	**L**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Deer Creek	0.100	0.02	5	**0.11**	**L**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.02	5	**0.11**	**L**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.100	0.02	5	**0.11**	**L**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.100	0.02	5	**0.11**	**L**

Deer Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.100	0.02	5	**0.11**	**L**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.100	0.02	5	**0.11**	**L**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Dam(s)	0.200	0.05	2	**0.09**	**L**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Delta	0.100	0.02	4	**0.09**	**L**
Deer Creek	0.13	Spawning	**0.25**	Flow Conditions	0.025	Flow Fluctuations	1.000	0.08	1	**0.08**	**L**
Deer Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Deer Creek	0.100	0.02	5	**0.08**	**L**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.050	Contra Costa Power Plant	0.050	0.01	7	**0.08**	**L**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.050	Pittsburg Power Plant	0.050	0.01	7	**0.08**	**L**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.03	2	**0.05**	**L**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.010	Delta	0.600	0.03	2	**0.05**	**L**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.02	2	**0.04**	**L**
Deer Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.010	Bays	0.400	0.02	2	**0.04**	**L**
Deer Creek	0.13	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.010	Redd disturbance	1.000	0.02	1.00	**0.02**	**L**

Dry Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.450	Impediments/Barriers in the Dry Creek drainage	0.900	0.567	3	1.701	VH
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Water Quality	0.200	Ag, Urban in the Dry Creek drainage	0.700	0.294	4	1.176	VH
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.150	Dry Creek drainage	0.800	0.252	3	0.756	VH
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.100	Flow Dependent Habitat Availability in the Dry Creek drainage	0.600	0.126	5	0.630	VH
Dry Creek drainage (Sacramento Region)	0.07	Spawning	0.40	Barrier	0.200	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.560	1	0.560	VH
Dry Creek drainage (Sacramento Region)	0.07	Spawning	0.40	Spawning Habitat Availability	0.200	Habitat Suitability	1.000	0.560	1	0.560	VH
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Water Temperature	0.150	Dry Creek drainage	0.750	0.158	3	0.473	VH
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Flow Conditions	0.200	Low Flows - attraction, migratory cues in the Dry Creek drainage	0.800	0.224	2	0.448	VH
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Loss of Natural River Morphology	0.100	Dry Creek drainage	0.700	0.147	3	0.441	VH
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Loss of Riparian Habitat and Instream Cover	0.100	Dry Creek drainage	0.700	0.147	3	0.441	VH
Dry Creek drainage (Sacramento Region)	0.07	Spawning	0.40	Physical Habitat Alteration	0.150	Limited Instream Gravel Supply	1.000	0.420	1	0.420	VH
Dry Creek drainage (Sacramento Region)	0.07	Spawning	0.40	Water Quality	0.150	Dry Creek drainage	1.000	0.420	1	0.420	VH
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Water Quality	0.100	Ag, Urban in the Dry Creek drainage	0.850	0.119	3	0.357	VH
Dry Creek drainage (Sacramento Region)	0.07	Spawning	0.40	Flow Conditions	0.100	Flow Fluctuations	1.000	0.280	1	0.280	VH
Dry Creek drainage (Sacramento Region)	0.07	Spawning	0.40	Water Temperature	0.100	Dry Creek drainage	1.000	0.280	1	0.280	VH
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Dry Creek drainage	0.600	0.063	4	0.252	VH
Dry Creek drainage (Sacramento Region)	0.07	Embryo Incubation	**0.10**	Water Quality	0.350	Water Pollution	1.000	0.245	1.00	0.245	VH
Dry Creek drainage (Sacramento Region)	0.07	Embryo Incubation	**0.10**	Water Temperature	0.350	Water Temperature in the Dry Creek drainage	1.000	0.245	1	0.245	VH
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.100	Changes in Hydrology	0.200	0.042	5	0.210	VH
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Dry Creek drainage	0.700	0.049	4	0.196	VH

Dry Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Dry Creek drainage	0.500	0.035	5	0.175	H
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Water Quality	0.200	Ag, Urban in the lower Sacramento River	0.100	0.042	4	0.168	H
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Water Quality	0.200	Ag, Urban, Heavy Metals in the Bays	0.100	0.042	4	0.168	H
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Water Quality	0.200	DO, Ag, Urban, Heavy Metals in th Delta	0.100	0.042	4	0.168	H
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.150	Lower Sacramento River	0.150	0.047	3	0.142	H
Dry Creek drainage (Sacramento Region)	0.07	Embryo Incubation	**0.10**	Flow Conditions	0.200	Flow Fluctuations	1.000	0.140	1	0.140	H
Dry Creek drainage (Sacramento Region)	0.07	Spawning	0.40	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.140	1	0.140	H
Dry Creek drainage (Sacramento Region)	0.07	Spawning	0.40	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.140	1	0.140	H
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Loss of Natural River Morphology	0.100	Delta	0.200	0.042	3	0.126	H
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Loss of Riparian Habitat and Instream Cover	0.100	Lower Sacramento River	0.200	0.042	3	0.126	H
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Water Temperature	0.150	Lower Sacramento River	0.200	0.042	3	0.126	H
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Flow Conditions	0.200	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in the lower Sacramento River	0.200	0.056	2	0.112	H
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.100	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.021	5	0.105	H
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Entrainment	0.020	Jones and Banks Pumping Plants	0.400	0.017	6	0.101	H
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Predation	0.020	Predation in the Dry Creek drainage	0.600	0.025	4	0.101	H
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.450	Sacramento Deep Water Ship Channel	0.050	0.032	3	0.095	H
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.450	Suisun Marsh Salinity Control Structure	0.050	0.032	3	0.095	H
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Loss of Tidal Marsh Habitat	0.010	Delta	0.900	0.019	5	0.095	H
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.200	0.021	4	0.084	H

Dry Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Loss of Floodplain Habitat	0.020	Lower Sacramento River	0.400	0.017	5	**0.084**	**H**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Entrainment	0.020	Individual Diversions in the Delta	0.300	0.013	6	**0.076**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Delta	0.200	0.014	5	**0.070**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.020	Dry Creek drainage	0.400	0.017	4	**0.067**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Loss of Natural River Morphology	0.100	Lower Sacramento River	0.100	0.021	3	**0.063**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Loss of Riparian Habitat and Instream Cover	0.100	Delta	0.100	0.021	3	**0.063**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Loss of Floodplain Habitat	0.020	Delta	0.300	0.013	5	**0.063**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Loss of Floodplain Habitat	0.020	Dry Creek drainage	0.300	0.013	5	**0.063**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.100	Diversion into Central Delta	0.050	0.011	5	**0.053**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.100	Reverse Flow Conditions	0.050	0.011	5	**0.053**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Ocean	0.150	0.011	5	**0.053**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.020	Delta	0.300	0.013	4	**0.050**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.150	Delta	0.050	0.016	3	**0.047**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.011	4	**0.042**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.100	0.011	4	**0.042**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.100	0.014	3	**0.042**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.900	0.019	2	**0.038**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Lower Sacramento River	0.100	0.007	5	**0.035**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Embryo Incubation	**0.10**	Harvest/Angling Impacts	0.050	Redd disturbance	1.000	0.035	1.00	**0.035**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Embryo Incubation	**0.10**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.035	1	**0.035**	**M**

Dry Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.020	Lower Sacramento River	0.200	0.008	4	**0.034**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Predation	0.020	Predation in the Delta	0.200	0.008	4	**0.034**	**M**
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.100	0.007	4	**0.028**	**L**
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.100	0.007	4	**0.028**	**L**
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.100	0.007	4	**0.028**	**L**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Entrainment	0.020	Individual Diversions in the Dry Creek drainage	0.100	0.004	6	**0.025**	**L**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Entrainment	0.020	Individual Diversions in the lower Sacramento River	0.100	0.004	6	**0.025**	**L**
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in th Delta	0.050	0.007	3	**0.021**	**L**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Passage Impediments/Barriers	0.010	Impediments/Barriers in the Dry Creek drainage	0.500	0.011	2	**0.021**	**L**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Passage Impediments/Barriers	0.010	Tributary Barriers	0.500	0.011	2	**0.021**	**L**
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Bays	0.050	0.004	5	**0.018**	**L**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.020	Bays	0.100	0.004	4	**0.017**	**L**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Predation	0.020	Predation in the Bays	0.100	0.004	4	**0.017**	**L**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Predation	0.020	Predation in the lower Sacramento River	0.100	0.004	4	**0.017**	**L**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Entrainment	0.020	Contra Costa Power Plant	0.050	0.002	6	**0.013**	**L**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Entrainment	0.020	Pittsburg Power Plant	0.050	0.002	6	**0.013**	**L**
Dry Creek drainage (Sacramento Region)	0.07	Adult Immigration and Holding	0.20	Water Temperature	0.050	Delta	0.050	0.004	3	**0.011**	**L**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Loss of Tidal Marsh Habitat	0.010	Bays	0.100	0.002	5	**0.011**	**L**
Dry Creek drainage (Sacramento Region)	0.07	Juvenile Rearing and Outmigration	0.30	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.100	0.002	2	**0.004**	**L**

Feather River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Feather River	0.10	Adult Immigration and Holding	0.150	Passage Impediments/Barriers	0.400	Fish Barrier/Oroville Dam	0.850	0.51	4	**2.04**	**VH**
Feather River	0.10	Spawning	0.350	Barrier	0.300	Fish Barrier Dam/Oroville Dam - Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	1.05	1	**1.05**	**VH**
Feather River	0.10	Spawning	0.350	Hatchery Effects	0.200	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.70	1	**0.70**	**VH**
Feather River	0.10	Spawning	0.350	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply	1.000	0.70	1	**0.70**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.400	0.21	3	**0.63**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Predation	0.125	Predation in the Delta	0.350	0.15	4	**0.61**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Floodplain Habitat	0.125	Delta	0.425	0.19	3	**0.56**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Natural River Morphology	0.150	Delta	0.350	0.18	3	**0.55**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.350	0.18	3	**0.55**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Predation	0.125	Predation in the Feather River	0.300	0.13	4	**0.53**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.325	0.17	3	**0.51**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Natural River Morphology	0.150	Feather River	0.300	0.16	3	**0.47**	**VH**
Feather River	0.10	Adult Immigration and Holding	0.150	Harvest/Angling Impacts	0.150	Ocean	0.400	0.09	5	**0.45**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Predation	0.125	Predation in the lower Sacramento River	0.250	0.11	4	**0.44**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Riparian Habitat and Instream Cover	0.150	Feather River	0.275	0.14	3	**0.43**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Floodplain Habitat	0.125	Lower Sacramento River	0.325	0.14	3	**0.43**	**VH**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Water Quality	0.075	DO, Ag, Urban, Heavy Metals in the Delta	0.350	0.09	4	**0.37**	**VH**
Feather River	0.10	Spawning	0.350	Spawning Habitat Availability	0.100	Habitat Suitability	1.000	0.35	1	**0.35**	**VH**
Feather River	0.10	Spawning	0.350	Water Temperature	0.100	Water Temperature	1.000	0.35	1	**0.35**	**VH**
Feather River	0.10	Adult Immigration and Holding	0.150	Water Temperature	0.150	Feather River	0.500	0.11	3	**0.34**	**H**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Floodplain Habitat	0.125	Feather River	0.250	0.11	3	**0.33**	**H**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Water Temperature	0.075	Feather River	0.400	0.11	3	**0.32**	**H**
Feather River	0.10	Adult Immigration and Holding	0.150	Harvest/Angling Impacts	0.150	Feather River	0.275	0.06	5	**0.31**	**H**

Feather River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Entrainment	0.050	Individual Diversions in the Delta	0.250	0.04	6	**0.26**	**H**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Entrainment	0.050	Individual Diversions in the lower Sacramento River	0.250	0.04	6	**0.26**	**H**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Entrainment	0.050	Jones and Banks Pumping Plants	0.250	0.04	6	**0.26**	**H**
Feather River	0.10	Adult Immigration and Holding	0.150	Flow Conditions	0.125	Low Flows - attraction, migratory cues in the Feather River	0.700	0.13	2	**0.26**	**H**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.375	0.07	4	**0.26**	**H**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Water Quality	0.075	Ag, Urban in the lower Sacramento River	0.250	0.07	4	**0.26**	**H**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Water Quality	0.075	Ag, Urban, Heavy Metals in the Bays	0.250	0.07	4	**0.26**	**H**
Feather River	0.10	Embryo Incubation	0.125	Flow Conditions	0.200	Flow Fluctuations, Flooding	1.000	0.25	1.00	**0.25**	**H**
Feather River	0.10	Embryo Incubation	0.125	Harvest/Angling Impacts	0.200	Redd disturbance	1.000	0.25	1.00	**0.25**	**H**
Feather River	0.10	Embryo Incubation	0.125	Short-term Inwater Construction	0.200	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.25	1.00	**0.25**	**H**
Feather River	0.10	Embryo Incubation	0.125	Water Quality	0.200	Water Pollution	1.000	0.25	1.00	**0.25**	**H**
Feather River	0.10	Embryo Incubation	0.125	Water Temperature	0.200	Water Temperature in the Feather River	1.000	0.25	1.00	**0.25**	**H**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Water Temperature	0.075	Delta	0.300	0.08	3	**0.24**	**H**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Water Temperature	0.075	Lower Sacramento River	0.300	0.08	3	**0.24**	**H**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.11	2	**0.21**	**H**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Tidal Marsh Habitat	0.050	Delta	0.600	0.11	2	**0.21**	**H**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.05	4	**0.21**	**H**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Entrainment	0.050	Individual Diversions in the Feather River	0.200	0.04	6	**0.21**	**H**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Flow Conditions	0.050	Diversion into Central Delta	0.225	0.04	5	**0.20**	**M**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Flow Conditions	0.050	Flow Dependent Habitat Availability in the Feather River	0.225	0.04	5	**0.20**	**M**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Flow Conditions	0.050	Reverse Flow Conditions	0.225	0.04	5	**0.20**	**M**
Feather River	0.10	Spawning	0.350	Flow Conditions	0.050	Flow Fluctuations	1.000	0.18	1	**0.18**	**M**
Feather River	0.10	Spawning	0.350	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.18	1	**0.18**	**M**

Feather River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Passage Impediments/Barriers	0.025	Fish Barrier/Oroville Dam	1.000	0.09	2	**0.18**	**M**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Predation	0.125	Predation in the Bays	0.100	0.04	4	**0.18**	**M**
Feather River	0.10	Adult Immigration and Holding	0.150	Water Temperature	0.150	Delta	0.250	0.06	3	**0.17**	**M**
Feather River	0.10	Adult Immigration and Holding	0.150	Water Temperature	0.150	Lower Sacramento River	0.250	0.06	3	**0.17**	**M**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Water Quality	0.075	Ag, Urban in the Feather River	0.150	0.04	4	**0.16**	**M**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Flow Conditions	0.050	Changes in Delta Hydrology	0.175	0.03	5	**0.15**	**M**
Feather River	0.10	Adult Immigration and Holding	0.150	Water Quality	0.100	Ag, Urban in the Feather River	0.333	0.05	3	**0.15**	**M**
Feather River	0.10	Adult Immigration and Holding	0.150	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.333	0.05	3	**0.15**	**M**
Feather River	0.10	Adult Immigration and Holding	0.150	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.333	0.05	3	**0.15**	**M**
Feather River	0.10	Adult Immigration and Holding	0.150	Harvest/Angling Impacts	0.150	Delta	0.125	0.03	5	**0.14**	**M**
Feather River	0.10	Adult Immigration and Holding	0.150	Harvest/Angling Impacts	0.150	Lower Sacramento River	0.125	0.03	5	**0.14**	**M**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.07	2	**0.14**	**M**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Loss of Tidal Marsh Habitat	0.050	Bays	0.400	0.07	2	**0.14**	**M**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Feather River	0.200	0.04	4	**0.14**	**M**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Flow Conditions	0.050	Flow Dependent Habitat Availability in the lower Sacramento River	0.150	0.03	5	**0.13**	**L**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Hatchery Effects	0.025	Feather River	0.375	0.03	4	**0.13**	**L**
Feather River	0.10	Adult Immigration and Holding	0.150	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.275	0.03	4	**0.12**	**L**
Feather River	0.10	Adult Immigration and Holding	0.150	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.275	0.03	4	**0.12**	**L**
Feather River	0.10	Adult Immigration and Holding	0.150	Passage Impediments/Barriers	0.400	Sacramento Deep Water Ship Channel	0.050	0.03	4	**0.12**	**L**
Feather River	0.10	Adult Immigration and Holding	0.150	Passage Impediments/Barriers	0.400	Suisun Marsh Salinity Control Structure	0.050	0.03	4	**0.12**	**L**
Feather River	0.10	Adult Immigration and Holding	0.150	Passage Impediments/Barriers	0.400	Yolo Bypass - Freemont Weir	0.050	0.03	4	**0.12**	**L**

Feather River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Hatchery Effects	0.025	Lower Sacramento River	0.325	0.03	4	**0.11**	**L**
Feather River	0.10	Adult Immigration and Holding	0.150	Flow Conditions	0.125	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.300	0.06	2	**0.11**	**L**
Feather River	0.10	Adult Immigration and Holding	0.150	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.250	0.03	4	**0.11**	**L**
Feather River	0.10	Adult Immigration and Holding	0.150	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills in the Feather River	0.200	0.02	4	**0.09**	**L**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.125	0.02	4	**0.09**	**L**
Feather River	0.10	Adult Immigration and Holding	0.150	Harvest/Angling Impacts	0.150	Bays	0.075	0.02	5	**0.08**	**L**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Hatchery Effects	0.025	Delta	0.175	0.02	4	**0.06**	**L**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Hatchery Effects	0.025	Bays	0.125	0.01	4	**0.04**	**L**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Entrainment	0.050	Contra Costa Power Plant	0.025	0.00	6	**0.03**	**L**
Feather River	0.10	Juvenile Rearing and Outmigration	0.350	Entrainment	0.050	Pittsburg Power Plant	0.025	0.00	6	**0.03**	**L**

Merced River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Merced River	0.16	Spawning	0.30	Spawning Habitat Availability	0.400	Habitat Suitability	1.000	1.920	1	**1.920**	**VH**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.200	Flow Dependent Habitat Availability in Merced River	0.350	0.336	5	**1.680**	**VH**
Merced River	0.16	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	Crocker Huffman	0.300	0.288	5	**1.440**	**VH**
Merced River	0.16	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	McSwain Dam	0.250	0.240	5	**1.200**	**VH**
Merced River	0.16	Adult Immigration and Holding	0.20	Flow Conditions	0.300	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in San Joaquin River	0.550	0.528	2	**1.056**	**VH**
Merced River	0.16	Embryo Incubation	**0.20**	Flow Conditions	0.550	Flow Fluctuations	0.550	0.968	1	**0.968**	**VH**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.200	Flow Dependent Habitat Availability in the San Joaquin River	0.200	0.192	5	**0.960**	**VH**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.200	Reverse Flow Conditions	0.200	0.192	5	**0.960**	**VH**
Merced River	0.16	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	New Exchequer Dam	0.200	0.192	5	**0.960**	**VH**
Merced River	0.16	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	Stockton Deep Water Ship Channel	0.200	0.192	5	**0.960**	**VH**
Merced River	0.16	Spawning	0.30	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply	1.000	0.960	1	**0.960**	**VH**
Merced River	0.16	Adult Immigration and Holding	0.20	Flow Conditions	0.300	Low Flows - attraction, migratory cues in the Merced River	0.450	0.432	2	**0.864**	**VH**
Merced River	0.16	Adult Immigration and Holding	0.20	Water Temperature	0.200	Merced River	0.400	0.256	3	**0.768**	**VH**
Merced River	0.16	Adult Immigration and Holding	0.20	Water Temperature	0.200	San Joaquin River	0.400	0.256	3	**0.768**	**VH**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.350	0.252	3	**0.756**	**VH**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Riparian Habitat and Instream Cover	0.150	San Joaquin River	0.350	0.252	3	**0.756**	**VH**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.200	Changes in Hydrology	0.150	0.144	5	**0.720**	**VH**
Merced River	0.16	Spawning	0.30	Flow Conditions	0.150	Flow Fluctuations	1.000	0.720	1	**0.720**	**VH**
Merced River	0.16	Spawning	0.30	Water Temperature	0.150	Water temperature in the Merced River	1.000	0.720	1	**0.720**	**VH**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Jones and Banks Pumping Plants	0.450	0.108	6	**0.648**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Riparian Habitat and Instream Cover	0.150	Merced River	0.300	0.216	3	**0.648**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.100	San Joaquin River	0.450	0.216	3	**0.648**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Floodplain Habitat	0.100	Merced River	0.350	0.168	3	**0.504**	**H**

Merced River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Floodplain Habitat	0.100	San Joaquin River	0.350	0.168	3	**0.504**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Natural River Morphology	0.100	Delta	0.350	0.168	3	**0.504**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Natural River Morphology	0.100	San Joaquin River	0.350	0.168	3	**0.504**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.100	Merced River	0.350	0.168	3	**0.504**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Flow Conditions	0.200	Diversion into Central Delta	0.100	0.096	5	**0.480**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Predation	0.050	Predation in the Merced River	0.500	0.120	4	**0.480**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Floodplain Habitat	0.100	Delta	0.300	0.144	3	**0.432**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Natural River Morphology	0.100	Merced River	0.300	0.144	3	**0.432**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Passage Impediments/Barriers	0.050	Crocker Huffman	0.450	0.108	4	**0.432**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the San Joaquin River	0.400	0.096	4	**0.384**	**H**
Merced River	0.16	Adult Immigration and Holding	0.20	Water Quality	0.100	Ag, Urban in the San Joaquin River	0.400	0.128	3	**0.384**	**H**
Merced River	0.16	Adult Immigration and Holding	0.20	Water Temperature	0.200	Delta	0.200	0.128	3	**0.384**	**H**
Merced River	0.16	Adult Immigration and Holding	0.20	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in th Delta	0.350	0.112	3	**0.336**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.168	2	**0.336**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Passage Impediments/Barriers	0.050	McSwain Dam	0.350	0.084	4	**0.336**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Water Quality	0.050	Ag, Urban in the San Joaquin River	0.350	0.084	4	**0.336**	**H**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Individual Diversions in the San Joaquin River	0.200	0.048	6	**0.288**	**M**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Water Temperature	0.100	Delta	0.200	0.096	3	**0.288**	**M**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Tidal Marsh Habitat	0.050	Delta	0.600	0.144	2	**0.288**	**M**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.072	4	**0.288**	**M**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in th Delta	0.300	0.072	4	**0.288**	**M**
Merced River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Merced River	0.350	0.056	5	**0.280**	**M**
Merced River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	San Joaquin River	0.300	0.048	5	**0.240**	**M**

Merced River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Merced River	0.16	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	Suisun Marsh Salinity Control Structure	0.050	0.048	5	**0.240**	**M**
Merced River	0.16	Adult Immigration and Holding	0.20	Water Quality	0.100	Ag, Urban in the Merced River	0.250	0.080	3	**0.240**	**M**
Merced River	0.16	Spawning	0.30	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.240	1	**0.240**	**M**
Merced River	0.16	Spawning	0.30	Water Quality	0.050	Water quality in Merced River	1.000	0.240	1	**0.240**	**M**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Predation	0.050	Predation in the San Joaquin River	0.250	0.060	4	**0.240**	**M**
Merced River	0.16	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the San Joaquin River	0.350	0.056	4	**0.224**	**M**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Individual Diversions in the Merced River	0.150	0.036	6	**0.216**	**M**
Merced River	0.16	Embryo Incubation	**0.20**	Water Temperature	0.250	Water temperature in the Merced River	0.250	0.200	1	**0.200**	**M**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Loss of Tidal Marsh Habitat	0.050	Bays	0.400	0.096	2	**0.192**	**M**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.200	0.048	4	**0.192**	**M**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Water Quality	0.050	Ag, Urban in the Merced River	0.200	0.048	4	**0.192**	**M**
Merced River	0.16	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.048	4	**0.192**	**M**
Merced River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Delta	0.200	0.032	5	**0.160**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Individual Diversions in the Delta	0.100	0.024	6	**0.144**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.072	2	**0.144**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Passage Impediments/Barriers	0.050	New Exchequer Dam	0.150	0.036	4	**0.144**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Predation	0.050	Predation in the Delta	0.150	0.036	4	**0.144**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.150	0.036	4	**0.144**	**L**
Merced River	0.16	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Merced River	0.200	0.032	4	**0.128**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Predation	0.050	Predation in the Bays	0.100	0.024	4	**0.096**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Merced River	0.100	0.024	4	**0.096**	**L**

Merced River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Merced River	0.16	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.150	0.024	4	**0.096**	**L**
Merced River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Bays	0.100	0.016	5	**0.080**	**L**
Merced River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Ocean	0.100	0.016	5	**0.080**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Contra Costa Power Plant	0.050	0.012	6	**0.072**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Entrainment	0.050	Pittsburg Power Plant	0.050	0.012	6	**0.072**	**L**
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Passage Impediments/Barriers	0.050	Tributary Barriers	0.050	0.012	4	**0.048**	**L**
Merced River	0.16	Embryo Incubation	**0.20**	Water Quality	0.100	Water Pollution	0.100	0.032	1.00	**0.032**	**L**
Merced River	0.16	Embryo Incubation	**0.20**	Harvest/Angling Impacts	0.050	Redd disturbance	0.050	0.008	1.00	**0.008**	**L**
Merced River	0.16	Embryo Incubation	**0.20**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	0.050	0.008	1	**0.008**	**L**
Merced River	0.16	Spawning	0.30	Barrier	0.000	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.000	1	**0.000**	
Merced River	0.16	Spawning	0.30	Hatchery Effects	0.000	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.000	1	**0.000**	
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.000	Bays	0.000	0.000	4	**0.000**	
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.000	Delta	0.000	0.000	4	**0.000**	
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.000	Merced River	0.000	0.000	4	**0.000**	
Merced River	0.16	Juvenile Rearing and Outmigration	0.30	Hatchery Effects	0.000	San Joaquin River	0.000	0.000	4	**0.000**	

Mill Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Agricultural Diversion Dam(s) in Mill Creek	0.600	0.49	5	**2.44**	**VH**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Mill Creek	0.700	0.57	4	**2.28**	**VH**
Mill Creek	0.13	Embryo Incubation	**0.15**	Water Quality	0.665	Turbidity and sedimentation in Mill Creek	1.000	1.30	1.00	**1.30**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Lower Sacramento River	0.350	0.25	4	**1.02**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Lower Sacramento River	0.350	0.25	4	**1.02**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Middle Sacramento River	0.350	0.25	4	**1.02**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Lower Sacramento River	0.350	0.25	4	**1.02**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Middle Sacramento River	0.350	0.25	4	**1.02**	**VH**
Mill Creek	0.13	Spawning	**0.25**	Hatchery Effects	0.275	Stocked trout fishery in upper Mill Creek drainage competition for habitat, Genetic Integrity	1.000	0.89	1	**0.89**	**VH**
Mill Creek	0.13	Spawning	**0.25**	Water Quality	0.275	Turbidity and Sedimentation in Mill Creek	1.000	0.89	1	**0.89**	**VH**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues in Mill Creek	0.600	0.29	3	**0.88**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Delta	0.300	0.22	4	**0.87**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the Delta	0.300	0.17	5	**0.85**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the lower Sacramento River	0.300	0.17	5	**0.85**	**VH**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.400	0.13	6	**0.78**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the middle Sacramento River	0.250	0.14	5	**0.71**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Diversion into Central Delta	0.300	0.10	6	**0.61**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Middle Sacramento River	0.200	0.15	4	**0.58**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Delta	0.200	0.15	4	**0.58**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Delta	0.200	0.15	4	**0.58**	**VH**
Mill Creek	0.13	Spawning	**0.25**	Physical Habitat Alteration	0.175	Gravel embeddedness and fines	1.000	0.57	1	**0.57**	**VH**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.10	5	**0.49**	**VH**

Mill Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the Delta	0.200	0.06	7	**0.45**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the lower Sacramento River	0.200	0.06	7	**0.45**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in the middle Sacramento River	0.200	0.06	7	**0.45**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Jones and Banks Pumping Plants	0.200	0.06	7	**0.45**	**VH**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.160	Mill Creek	0.150	0.11	4	**0.44**	**H**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Changes in Hydrology	0.200	0.07	6	**0.41**	**H**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Reverse Flow Conditions	0.200	0.07	6	**0.41**	**H**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.100	0.08	5	**0.41**	**H**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.100	0.08	5	**0.41**	**H**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.100	0.08	5	**0.41**	**H**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.08	5	**0.41**	**H**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.08	5	**0.41**	**H**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.250	0.08	5	**0.41**	**H**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.250	0.08	5	**0.41**	**H**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.250	0.08	5	**0.41**	**H**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Mill Creek	0.200	0.07	6	**0.39**	**H**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in the Bay	0.150	0.07	5	**0.37**	**H**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	0.800	0.18	2	**0.36**	**H**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Lower Sacramento River	0.400	0.09	4	**0.36**	**H**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.07	5	**0.34**	**H**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.07	5	**0.34**	**H**

Mill Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.13	Spawning	**0.25**	Harvest/Angling Impacts	0.100	Recreational, Poaching, Angler Impacts	1.000	0.33	1	**0.33**	**H**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.07	5	**0.33**	**H**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Delta	0.100	0.08	4	**0.33**	**H**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Lower Sacramento River	0.100	0.08	4	**0.33**	**H**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.250	Middle Sacramento River	0.100	0.08	4	**0.33**	**H**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.200	0.10	3	**0.29**	**H**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.150	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.10	3	**0.29**	**H**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.160	Mill Creek	0.100	0.07	4	**0.29**	**H**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.160	Mill Creek	0.100	0.07	4	**0.29**	**H**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in the Bays	0.100	0.06	5	**0.28**	**M**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Middle Sacramento River	0.300	0.07	4	**0.27**	**M**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.05	5	**0.24**	**M**
Mill Creek	0.13	Embryo Incubation	**0.15**	Flow Conditions	0.125	Flow Fluctuations	1.000	0.24	1.00	**0.24**	**M**
Mill Creek	0.13	Spawning	**0.25**	Water Temperature	0.075	Water Temperature in Mill Creek	1.000	0.24	1	**0.24**	**M**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.05	5	**0.23**	**M**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.200	0.05	5	**0.23**	**M**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.200	0.05	5	**0.23**	**M**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban in Mill Creek	0.200	0.05	5	**0.23**	**M**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.200	0.05	5	**0.23**	**M**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.200	0.05	5	**0.23**	**M**

Mill Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Individual Diversions in Mill Creek	0.100	0.03	7	**0.22**	**M**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in Mill Creek	0.100	0.03	6	**0.20**	**M**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.03	6	**0.20**	**M**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.075	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.03	6	**0.20**	**M**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.030	Delta	0.300	0.04	5	**0.20**	**M**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.030	Lower Sacramento River	0.300	0.04	5	**0.20**	**M**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.100	0.03	6	**0.20**	**M**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.100	0.03	6	**0.20**	**M**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.100	0.03	6	**0.20**	**M**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.100	0.03	6	**0.20**	**M**
Mill Creek	0.13	Embryo Incubation	**0.15**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.20	1.00	**0.20**	**M**
Mill Creek	0.13	Embryo Incubation	**0.15**	Water Temperature	0.100	Water Temperature in Mill Creek	1.000	0.20	1.00	**0.20**	**M**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Mill Creek	0.200	0.05	4	**0.18**	**M**
Mill Creek	0.13	Spawning	**0.25**	Flow Conditions	0.050	Flow Fluctuations	1.000	0.16	1	**0.16**	**L**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in Mill Creek	0.100	0.03	5	**0.16**	**L**
Mill Creek	0.13	Spawning	**0.25**	Spawning Habitat Availability	0.050	Habitat Suitability	1.000	0.16	1	**0.16**	**L**
Mill Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Mill Creek	0.100	0.03	5	**0.16**	**L**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.125	Predation in Mill Creek	0.050	0.03	5	**0.14**	**L**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Mill Creek	0.100	0.02	5	**0.11**	**L**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.02	5	**0.11**	**L**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Contra Costa Power Plant	0.050	0.02	7	**0.11**	**L**

Mill Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.070	Pittsburg Power Plant	0.050	0.02	7	**0.11**	**L**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.030	Middle Sacramento River	0.150	0.02	5	**0.10**	**L**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Dam(s)	0.200	0.05	2	**0.09**	**L**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.050	Delta	0.100	0.02	4	**0.09**	**L**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.030	Bays	0.100	0.01	5	**0.07**	**L**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.030	Mill Creek	0.100	0.01	5	**0.07**	**L**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.03	2	**0.05**	**L**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.010	Delta	0.600	0.03	2	**0.05**	**L**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.02	2	**0.04**	**L**
Mill Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.010	Bays	0.400	0.02	2	**0.04**	**L**
Mill Creek	0.13	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.010	Redd disturbance	1.000	0.02	1.00	**0.02**	**L**

Mokelumne River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.300	Camanche Dam	0.440	0.297	5	**1.485**	**VH**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.175	Mokelumne River	0.650	0.427	3	**1.280**	**VH**
Mokelumne River	0.15	Spawning	0.40	Barrier	0.200	Competition for spawning habitat	1.000	1.200	1	**1.200**	**VH**
Mokelumne River	0.15	Spawning	0.40	Hatchery Effects	0.200	Redd superimposition, competition for habitat, Genetic Integrity	1.000	1.200	1	**1.200**	**VH**
Mokelumne River	0.15	Spawning	0.40	Spawning Habitat Availability	0.200	Habitat Suitability	1.000	1.200	1	**1.200**	**VH**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.300	Pardee Reservoir Dam	0.340	0.230	5	**1.148**	**VH**
Mokelumne River	0.15	Embryo Incubation	**0.20**	Flow Conditions	0.325	Flow Fluctuations	1.000	0.975	1	**0.975**	**VH**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.200	Flow Dependent Habitat Availability in the Mokelumne River	0.400	0.300	3	**0.900**	**VH**
Mokelumne River	0.15	Embryo Incubation	**0.20**	Water Temperature	0.275	Water temperature in the Mokelumne River	1.000	0.825	1	**0.825**	**VH**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Entrainment	0.075	Jones and Banks Pumping Plants	0.500	0.141	5	**0.703**	**VH**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.200	Changes in Hydrology	0.300	0.225	3	**0.675**	**VH**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.200	Reverse Flow Conditions	0.300	0.225	3	**0.675**	**VH**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Flow Conditions	0.300	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in the Mokelumne River	1.000	0.675	1	**0.675**	**VH**
Mokelumne River	0.15	Spawning	0.40	Flow Conditions	0.100	Flow Fluctuations	1.000	0.600	1	**0.600**	**VH**
Mokelumne River	0.15	Spawning	0.40	Physical Habitat Alteration	0.100	Limited Instream Gravel Supply	1.000	0.600	1	**0.600**	**VH**
Mokelumne River	0.15	Spawning	0.40	Water Temperature	0.100	Water temperature in the Mokelumne River	1.000	0.600	1	**0.600**	**VH**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.300	Stockton Deep Water Ship Channel	0.150	0.101	5	**0.506**	**VH**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.175	Delta	0.250	0.164	3	**0.492**	**H**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Mokelumne River	0.525	0.118	4	**0.473**	**H**
Mokelumne River	0.15	Embryo Incubation	**0.20**	Harvest/Angling Impacts	0.150	Redd disturbance	1.000	0.450	1.00	**0.450**	**H**
Mokelumne River	0.15	Embryo Incubation	**0.20**	Water Quality	0.150	Water Pollution	1.000	0.450	1.00	**0.450**	**H**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.100	Mokelumne River	0.600	0.225	2	**0.450**	**H**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.100	Delta	0.500	0.188	2	**0.375**	**H**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.100	Mokelumne River	0.500	0.188	2	**0.375**	**H**

Mokelumne River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Delta	0.350	0.079	4	**0.315**	**H**
Mokelumne River	0.15	Spawning	0.40	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.300	1	**0.300**	**H**
Mokelumne River	0.15	Embryo Incubation	**0.20**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.300	1	**0.300**	**H**
Mokelumne River	0.15	Spawning	0.40	Water Quality	0.050	Water quality in the Mokelumne River	1.000	0.300	1	**0.300**	**H**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.100	Delta	0.400	0.150	2	**0.300**	**H**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Entrainment	0.075	Individual Diversions in the Mokelumne River	0.200	0.056	5	**0.281**	**H**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Water Temperature	0.100	Mokelumne River	0.600	0.135	2	**0.270**	**H**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.131	2	**0.263**	**H**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Predation	0.050	Predation in the Delta	0.450	0.084	3	**0.253**	**H**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Predation	0.050	Predation in the Mokelumne River	0.450	0.084	3	**0.253**	**H**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Mokelumne River	0.750	0.084	3	**0.253**	**H**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.050	Mokelumne River	0.600	0.113	2	**0.225**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.050	Mokelumne River	0.600	0.113	2	**0.225**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.050	Delta	0.600	0.113	2	**0.225**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Camanche Dam	0.300	0.056	4	**0.225**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Woodbridge Dam	0.300	0.056	4	**0.225**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in the Mokelumne River	0.400	0.075	3	**0.225**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in th Delta	0.400	0.075	3	**0.225**	**M**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Water Quality	0.100	Ag, Urban in the Mokelumne River	0.500	0.113	2	**0.225**	**M**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in th Delta	0.500	0.113	2	**0.225**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.175	Bays	0.100	0.066	3	**0.197**	**M**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Water Temperature	0.100	Delta	0.400	0.090	2	**0.180**	**M**

Mokelumne River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Mokelumne River	0.600	0.056	3	**0.169**	**M**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.300	Suisun Marsh Salinity Control Structure	0.050	0.034	5	**0.169**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.050	Delta	0.400	0.075	2	**0.150**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.050	Delta	0.400	0.075	2	**0.150**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.050	Bays	0.400	0.075	2	**0.150**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Pardee Reservoir Dam	0.200	0.038	4	**0.150**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Tributary Barriers	0.200	0.038	4	**0.150**	**M**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Entrainment	0.075	Contra Costa Power Plant	0.100	0.028	5	**0.141**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Entrainment	0.075	Individual Diversions in the Delta	0.100	0.028	5	**0.141**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Entrainment	0.075	Pittsburg Power Plant	0.100	0.028	5	**0.141**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.056	2	**0.113**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.200	0.038	3	**0.113**	**L**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Bays	0.100	0.023	4	**0.090**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.028	3	**0.084**	**L**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.023	3	**0.068**	**L**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.300	Woodbridge Dam	0.020	0.014	5	**0.068**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Predation	0.050	Predation in the Bays	0.100	0.019	3	**0.056**	**L**
Mokelumne River	0.15	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.009	3	**0.028**	**L**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Ocean	0.025	0.006	4	**0.023**	**L**
Mokelumne River	0.15	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.050	0.006	3	**0.017**	**L**

Putah Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Putah Creek	0.12	Adult Immigration and Holding	0.200	Passage Impediments/Barriers	0.350	Solano Dam	0.550	0.462	4	**1.848**	**VH**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Passage Impediments/Barriers	0.350	Montecello Dam	0.400	0.336	4	**1.344**	**VH**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Flow Conditions	0.150	Flow Dependent Habitat Availability in Putah Creek	0.600	0.297	4	**1.188**	**VH**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Flow Conditions	0.400	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Putah Creek	1.000	0.960	1	**0.960**	**VH**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Water Temperature	0.150	Putah Creek	0.750	0.371	2	**0.743**	**VH**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Harvest/Angling Impacts	0.100	Putah Creek	0.750	0.180	4	**0.720**	**VH**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Loss of Floodplain Habitat	0.150	Putah Creek	0.700	0.347	2	**0.693**	**VH**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Flow Conditions	0.150	Changes in Hydrology	0.300	0.149	4	**0.594**	**VH**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Predation	0.100	Predation in Putah Creek	0.550	0.182	3	**0.545**	**VH**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Loss of Natural River Morphology	0.100	Putah Creek	0.700	0.231	2	**0.462**	**VH**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Loss of Riparian Habitat and Instream Cover	0.100	Putah Creek	0.700	0.231	2	**0.462**	**VH**
Putah Creek	0.12	Embryo Incubation	0.150	Flow Conditions	0.550	Flow Fluctuations	0.375	0.371	1	**0.371**	**VH**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Water Quality	0.075	Ag, Urban in Putah Creek	0.500	0.124	3	**0.371**	**VH**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.173	2	**0.347**	**VH**
Putah Creek	0.12	Spawning	0.375	Physical Habitat Alteration	0.150	Limited Instream Gravel Supply	0.450	0.304	1	**0.304**	**VH**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Predation	0.100	Predation in the Delta	0.300	0.099	3	**0.297**	**VH**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Loss of Floodplain Habitat	0.150	Delta	0.300	0.149	2	**0.297**	**VH**
Putah Creek	0.12	Spawning	0.375	Spawning Habitat Availability	0.200	Habitat Suitability	0.325	0.293	1	**0.293**	**H**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Water Temperature	0.150	Delta	0.250	0.124	2	**0.248**	**H**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Water Quality	0.075	DO, Ag, Urban, Heavy Metals in th Delta	0.300	0.074	3	**0.223**	**H**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Loss of Natural River Morphology	0.100	Delta	0.300	0.099	2	**0.198**	**H**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Loss of Riparian Habitat and Instream Cover	0.100	Delta	0.300	0.099	2	**0.198**	**H**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Water Quality	0.050	Ag, Urban in Putah Creek	0.800	0.096	2	**0.192**	**H**

Putah Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Entrainment	0.025	Jones and Banks Pumping Plants	0.450	0.037	5	**0.186**	**H**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Passage Impediments/Barriers	0.025	Solano Dam	0.750	0.062	3	**0.186**	**H**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Predation	0.100	Predation in the Bays	0.150	0.050	3	**0.149**	**H**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in Putah Creek	0.600	0.050	3	**0.149**	**H**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Water Quality	0.075	Ag, Urban, Heavy Metals in the Bays	0.200	0.050	3	**0.149**	**H**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.074	2	**0.149**	**H**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Harvest/Angling Impacts	0.100	Delta	0.150	0.036	4	**0.144**	**H**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Putah Creek	0.400	0.048	3	**0.144**	**H**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.400	0.048	3	**0.144**	**H**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Water Temperature	0.050	Delta	0.600	0.072	2	**0.144**	**H**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Hatchery Effects	0.025	Delta	0.500	0.041	3	**0.124**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Loss of Tidal Marsh Habitat	0.025	Delta	0.700	0.058	2	**0.116**	**M**
Putah Creek	0.12	Embryo Incubation	0.150	Water Temperature	0.300	Water Temperature in Putah Creek	0.200	0.108	1	**0.108**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Entrainment	0.025	Individual Diversions in Putah Creek	0.250	0.021	5	**0.103**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Flow Conditions	0.150	Diversion into Central Delta	0.050	0.025	4	**0.099**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Flow Conditions	0.150	Reverse Flow Conditions	0.050	0.025	4	**0.099**	**M**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Water Temperature	0.050	Putah Creek	0.400	0.048	2	**0.096**	**M**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Passage Impediments/Barriers	0.350	Sacramento Deep Water Ship Channel	0.025	0.021	4	**0.084**	**M**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Passage Impediments/Barriers	0.350	Suisun Marsh Salinity Control Structure	0.025	0.021	4	**0.084**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Hatchery Effects	0.025	Bays	0.300	0.025	3	**0.074**	**M**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.024	3	**0.072**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Hatchery Effects	0.025	Putah Creek	0.200	0.017	3	**0.050**	**M**

Putah Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Passage Impediments/Barriers	0.025	Montecello Dam	0.200	0.017	3	**0.050**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.200	0.017	3	**0.050**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Short-term Inwater Construction	0.025	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.200	0.017	3	**0.050**	**M**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Loss of Tidal Marsh Habitat	0.025	Bays	0.300	0.025	2	**0.050**	**M**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Harvest/Angling Impacts	0.100	Bays	0.050	0.012	4	**0.048**	**L**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Harvest/Angling Impacts	0.100	Ocean	0.050	0.012	4	**0.048**	**L**
Putah Creek	0.12	Adult Immigration and Holding	0.200	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in th Delta	0.200	0.024	2	**0.048**	**L**
Putah Creek	0.12	Spawning	0.375	Flow Conditions	0.200	Flow Fluctuations	0.050	0.045	1	**0.045**	**L**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Entrainment	0.025	Contra Costa Power Plant	0.100	0.008	5	**0.041**	**L**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Entrainment	0.025	Individual Diversions in the Delta	0.100	0.008	5	**0.041**	**L**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Entrainment	0.025	Pittsburg Power Plant	0.100	0.008	5	**0.041**	**L**
Putah Creek	0.12	Spawning	0.375	Barrier	0.250	Redd superimposition, competition for habitat, hybridization/genetic integrity	0.025	0.028	1	**0.028**	**L**
Putah Creek	0.12	Embryo Incubation	0.150	Harvest/Angling Impacts	0.050	Redd disturbance	0.275	0.025	1.00	**0.025**	**L**
Putah Creek	0.12	Spawning	0.375	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	0.075	0.017	1	**0.017**	**L**
Putah Creek	0.12	Juvenile Rearing and Outmigration	0.275	Passage Impediments/Barriers	0.025	Tributary Barriers	0.050	0.004	3	**0.012**	**L**
Putah Creek	0.12	Spawning	0.375	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	0.050	0.011	1	**0.011**	**L**
Putah Creek	0.12	Spawning	0.375	Water Temperature	0.050	Putah Creek	0.050	0.011	1	**0.011**	**L**
Putah Creek	0.12	Spawning	0.375	Water Quality	0.050	Putah Creek	0.025	0.006	1	**0.006**	**L**
Putah Creek	0.12	Embryo Incubation	0.150	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	0.050	0.005	1	**0.005**	**L**
Putah Creek	0.12	Embryo Incubation	0.150	Water Quality	0.050	Water Pollution	0.050	0.005	1.00	**0.005**	**L**

Sacramento River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	0.26	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Keswick Dam	0.525	0.82	7	**5.73**	**VH**
Sacramento River	0.26	Spawning	0.3	Barrier/Genetics	0.450	Keswick/Shasta Dam	1.000	3.51	1	**3.51**	**VH**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Red Bluff Diversion Dam	0.300	0.47	7	**3.28**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Natural Morphologic Function	0.160	Loss of Natural Morphologic Function in the lower Sacramento River	0.350	0.58	4	**2.33**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Floodplain Habitat	0.160	Loss of Floodplain Habitat in the Delta	0.300	0.50	4	**2.00**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Floodplain Habitat	0.160	Loss of Floodplain Habitat in the lower Sacramento River	0.300	0.50	4	**2.00**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Natural Morphologic Function	0.160	Loss of Natural Morphologic Function in the Delta	0.300	0.50	4	**2.00**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Riparian Habitat and Instream Cover	0.160	Loss of Riparian Habitat and Instream Cover in the Delta	0.300	0.50	4	**2.00**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Riparian Habitat and Instream Cover	0.160	Loss of Riparian Habitat and Instream Cover in the lower Sacramento River	0.300	0.50	4	**2.00**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Predation in the Delta	0.250	0.39	5	**1.95**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Predation in the lower Sacramento River	0.250	0.39	5	**1.95**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the upper Sacramento River	0.400	0.37	5	**1.87**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Non-site specific and structure (GCID, RBDD) related in the middle Sacramento River	0.225	0.35	5	**1.76**	**VH**
Sacramento River	0.26	Spawning	0.3	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply in upper Sacramento River	1.000	1.56	1	**1.56**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the middle Sacramento River	0.300	0.28	5	**1.40**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Non-site specific and structure (ACID) related in the upper Sacramento River	0.175	0.27	5	**1.37**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Floodplain Habitat	0.160	Loss of Floodplain Habitat in the middle Sacramento River	0.200	0.33	4	**1.33**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Floodplain Habitat	0.160	Loss of Floodplain Habitat in the upper Sacramento River	0.200	0.33	4	**1.33**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Natural Morphologic Function	0.160	Loss of Natural Morphologic Function in the upper Sacramento River	0.200	0.33	4	**1.33**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Riparian Habitat and Instream Cover	0.160	Loss of Riparian Habitat and Instream Cover in the middle Sacramento River	0.200	0.33	4	**1.33**	**VH**

Sacramento River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Riparian Habitat and Instream Cover	0.160	Loss of Riparian Habitat and Instream Cover in the upper Sacramento River	0.200	0.33	4	**1.33**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Individual Diversions in the Delta	0.200	0.15	7	**1.02**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Individual Diversions in the lower Sacramento River	0.200	0.15	7	**1.02**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Individual Diversions in the middle Sacramento River	0.200	0.15	7	**1.02**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Jones and Banks Pumping Plants	0.200	0.15	7	**1.02**	**VH**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Natural Morphologic Function	0.160	Loss of Natural Morphologic Function in the middle Sacramento River	0.150	0.25	4	**1.00**	**H**
Sacramento River	0.26	Embryo Incubation	0.15	Flow Conditions	0.225	Flow Fluctuations in upper Sacramento River	1.000	0.88	1	**0.88**	**H**
Sacramento River	0.26	Embryo Incubation	0.15	Water Quality	0.225	Water Pollution in upper Sacramento River	1.000	0.88	1	**0.88**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Water Temperature	0.050	Delta	0.400	0.21	4	**0.83**	**H**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Ocean	0.350	0.14	6	**0.82**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Predation	0.150	Predation in the Bay	0.100	0.16	5	**0.78**	**H**
Sacramento River	0.26	Spawning	0.3	Flow Conditions	0.100	Flow Fluctuations in upper Sacramento River	1.000	0.78	1	**0.78**	**H**
Sacramento River	0.26	Spawning	0.3	Harvest/Angling Impacts	0.100	Upper Sacramento River	1.000	0.78	1	**0.78**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.300	0.16	5	**0.78**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.300	0.16	5	**0.78**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	Urban, Heavy Metals in the upper Sacramento River	0.300	0.16	5	**0.78**	**H**
Sacramento River	0.26	Embryo Incubation	0.15	Water Temperature	0.200	Water Temperature in upper Sacramento River	1.000	0.78	1	**0.78**	**H**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.250	0.15	5	**0.73**	**H**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.15	5	**0.73**	**H**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.250	0.15	5	**0.73**	**H**

Sacramento River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.275	0.14	5	**0.72**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.275	0.14	5	**0.72**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.275	0.14	5	**0.72**	**H**
Sacramento River	0.26	Embryo Incubation	0.15	Harvest/Angling Impacts	0.175	Redd disturbance in upper Sacramento River	1.000	0.68	1.00	**0.68**	**H**
Sacramento River	0.26	Embryo Incubation	0.15	Short-term Inwater Construction	0.175	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.68	1	**0.68**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Water Temperature	0.050	Lower Sacramento River	0.300	0.16	4	**0.62**	**H**
Sacramento River	0.26	Spawning	0.3	Spawning Habitat Availability	0.075	Habitat Suitability in in upper Sacramento River	1.000	0.59	1	**0.59**	**H**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Water Quality	0.125	DO, Ag, Urban, Heavy Metals in the Delta	0.300	0.15	4	**0.59**	**H**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Water Temperature	0.125	Lower Sacramento River	0.400	0.20	3	**0.59**	**H**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Water Temperature	0.125	Middle Sacramento River	0.400	0.20	3	**0.59**	**H**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Changes in Delta Hydrology	0.300	0.09	6	**0.56**	**M**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Reverse Flow Conditions in the Delta	0.300	0.09	6	**0.56**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Yolo Bypass-Freemont Weir	0.050	0.08	7	**0.55**	**M**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Individual Diversions in the upper Sacramento River	0.100	0.07	7	**0.51**	**M**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Diversion into Central Delta	0.250	0.08	6	**0.47**	**M**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the Bays	0.100	0.09	5	**0.47**	**M**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the Delta	0.100	0.09	5	**0.47**	**M**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Hatchery Effects	0.090	Competition, Predation in the lower Sacramento River	0.100	0.09	5	**0.47**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.150	0.09	5	**0.44**	**M**

Sacramento River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Water Temperature	0.050	Middle Sacramento River	0.200	0.10	4	**0.42**	**M**
Sacramento River	0.26	Spawning	0.3	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in upper Sacramento River	1.000	0.39	1	**0.39**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Water Quality	0.125	Ag, Urban in the lower Sacramento River	0.200	0.10	4	**0.39**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Water Quality	0.125	Ag, Urban in the middle Sacramento River	0.200	0.10	4	**0.39**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Water Quality	0.125	Urban, Heavy Metals in the upper Sacramento River	0.200	0.10	4	**0.39**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.333	0.13	3	**0.39**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues in Middle Sacramento River	0.333	0.13	3	**0.39**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues in Upper Sacramento River	0.333	0.13	3	**0.39**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Sacramento Deep Water Ship Channel	0.035	0.05	7	**0.38**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Suisun Marsh Salinity Control Structure	0.035	0.05	7	**0.38**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Sutter Bypass - Tisdale Weir	0.035	0.05	7	**0.38**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Upper Sacramento River	0.150	0.06	6	**0.35**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.150	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.06	5	**0.29**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Bays	0.125	0.05	6	**0.29**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Delta	0.125	0.05	6	**0.29**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.125	0.05	6	**0.29**	**M**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.125	0.05	6	**0.29**	**M**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.05	5	**0.26**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Contra Costa Power Plant	0.050	0.04	7	**0.25**	**L**

Sacramento River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Entrainment	0.070	Pittsburg Power Plant	0.050	0.04	7	**0.25**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.090	0.05	5	**0.23**	**L**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	ACID Dam	0.020	0.03	7	**0.22**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Water Temperature	0.050	Upper Sacramento River	0.100	0.05	4	**0.21**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.075	0.04	5	**0.20**	**L**
Sacramento River	0.26	Spawning	0.3	Water Temperature	0.025	Upper Sacramento River	1.000	0.20	1	**0.20**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Invasive species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, water hyacinth etc. in the Delta	0.800	0.08	2	**0.17**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Tidal Marsh Habitat	0.010	Loss of Tidal Marsh Habitat in the Delta	0.800	0.08	2	**0.17**	**L**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Water Temperature	0.125	Delta	0.100	0.05	3	**0.15**	**L**
Sacramento River	0.26	Adult Immigration and Holding	0.15	Water Temperature	0.125	Upper Sacramento River	0.100	0.05	3	**0.15**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Passage Impediments/Barriers	0.010	Keswick Dam	0.400	0.04	3	**0.12**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Flow Dependent Habitat Availability in the lower Sacramento River	0.050	0.02	6	**0.09**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Flow Dependent Habitat Availability in the middle Sacramento River	0.050	0.02	6	**0.09**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Flow Conditions	0.030	Flow Dependent Habitat Availability in the upper Sacramento River	0.050	0.02	6	**0.09**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Passage Impediments/Barriers	0.010	ACID Dam	0.300	0.03	3	**0.09**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Passage Impediments/Barriers	0.010	Tributary Barriers	0.300	0.03	3	**0.09**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Invasive species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, water hyacinth etc. in the Bays	0.200	0.02	2	**0.04**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Loss of Tidal Marsh Habitat	0.010	Loss of Tidal Marsh Habitat in the Bays	0.200	0.02	2	**0.04**	**L**
Sacramento River	0.26	Juvenile Rearing and Outmigration	0.4	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.010	0.01	5	**0.03**	**L**

San Joaquin River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
San Joaquin Rive	0.15	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.400	Friant Dam	0.500	0.900	5	**4.500**	**VH**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Flow Conditions	0.250	Flow Dependent Habitat Availability in the San Joaquin River	0.500	0.750	4	**3.000**	**VH**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Flow Conditions	0.250	Changes in Hydrology	0.300	0.450	4	**1.800**	**VH**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Water Quality	0.150	Ag, Urban in the San Joaquin River	0.550	0.495	3	**1.485**	**VH**
San Joaquin Rive	0.15	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.400	Mendota Pool	0.150	0.270	5	**1.350**	**VH**
San Joaquin Rive	0.15	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.400	Sack Dam	0.150	0.270	5	**1.350**	**VH**
San Joaquin Rive	0.15	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.400	Stockton Deep Water Ship Channel	0.150	0.270	5	**1.350**	**VH**
San Joaquin Rive	0.15	Adult Immigration and Holding	0.30	Water Quality	0.200	Ag, Urban in the San Joaquin River	0.700	0.630	2	**1.260**	**VH**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Water Temperature	0.150	San Joaquin River	0.700	0.630	2	**1.260**	**VH**
San Joaquin Rive	0.15	Adult Immigration and Holding	0.30	Flow Conditions	0.200	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in San Joaquin River	1.000	0.900	1	**0.900**	**VH**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Flow Conditions	0.250	Reverse Flow Conditions	0.150	0.225	4	**0.900**	**VH**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Loss of Riparian Habitat and Instream Cover	0.100	San Joaquin River	0.700	0.420	2	**0.840**	**VH**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in th Delta	0.300	0.270	3	**0.810**	**VH**
San Joaquin Rive	0.15	Spawning	0.20	Spawning Habitat Availability	0.250	Habitat Suitability	1.000	0.750	1	**0.750**	**VH**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Entrainment	0.050	Jones and Banks Pumping Plants	0.400	0.120	5	**0.600**	**VH**
San Joaquin Rive	0.15	Spawning	0.20	Barrier	0.200	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.600	1	**0.600**	**VH**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Loss of Floodplain Habitat	0.050	Delta	0.500	0.150	4	**0.600**	**VH**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Loss of Floodplain Habitat	0.050	San Joaquin River	0.500	0.150	4	**0.600**	**VH**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Loss of Tidal Marsh Habitat	0.050	Bays	0.500	0.150	4	**0.600**	**VH**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Loss of Tidal Marsh Habitat	0.050	Delta	0.500	0.150	4	**0.600**	**VH**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Predation	0.075	Predation in the Delta	0.400	0.180	3	**0.540**	**H**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Predation	0.075	Predation in the San Joaquin River	0.400	0.180	3	**0.540**	**H**

San Joaquin River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
San Joaquin Rive	0.15	Adult Immigration and Holding	0.30	Water Quality	0.200	DO, Ag, Urban, Heavy Metals in th Delta	0.300	0.270	2	**0.540**	**H**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Water Temperature	0.150	Delta	0.300	0.270	2	**0.540**	**H**
San Joaquin Rive	0.15	Adult Immigration and Holding	0.30	Water Temperature	0.100	San Joaquin River	0.600	0.270	2	**0.540**	**H**
San Joaquin Rive	0.15	Spawning	0.20	Physical Habitat Alteration	0.175	Limited Instream Gravel Supply	1.000	0.525	1	**0.525**	**H**
San Joaquin Rive	0.15	Spawning	0.20	Flow Conditions	0.150	Flow Fluctuations	1.000	0.450	1	**0.450**	**H**
San Joaquin Rive	0.15	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.400	Suisun Marsh Salinity Control Structure	0.050	0.090	5	**0.450**	**H**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the San Joaquin River	0.500	0.150	3	**0.450**	**H**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.210	2	**0.420**	**H**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Passage Impediments/Barriers	0.050	Friant Dam	0.700	0.210	2	**0.420**	**H**
San Joaquin Rive	0.15	Embryo Incubation	**0.10**	Flow Conditions	0.275	Flow Fluctuations	1.000	0.413	1	**0.413**	**H**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Water Quality	0.150	Ag, Urban, Heavy Metals in the Bays	0.150	0.135	3	**0.405**	**H**
San Joaquin Rive	0.15	Embryo Incubation	**0.10**	Water Quality	0.250	Water Pollution	1.000	0.375	1.00	**0.375**	**H**
San Joaquin Rive	0.15	Embryo Incubation	**0.10**	Water Temperature	0.250	Water temperature in the San Joaquin River	1.000	0.375	1	**0.375**	**H**
San Joaquin Rive	0.15	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	San Joaquin River	0.400	0.090	4	**0.360**	**H**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Loss of Natural River Morphology	0.050	San Joaquin River	0.600	0.180	2	**0.360**	**H**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Loss of Riparian Habitat and Instream Cover	0.100	Delta	0.300	0.180	2	**0.360**	**H**
San Joaquin Rive	0.15	Adult Immigration and Holding	0.30	Water Temperature	0.100	Delta	0.400	0.180	2	**0.360**	**H**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Entrainment	0.050	Individual Diversions in the Delta	0.200	0.060	5	**0.300**	**M**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Entrainment	0.050	Individual Diversions in the San Joaquin River	0.200	0.060	5	**0.300**	**M**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Flow Conditions	0.250	Diversion into Central Delta	0.050	0.075	4	**0.300**	**M**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Hatchery Effects	0.025	Delta	0.600	0.090	3	**0.270**	**M**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Predation	0.075	Predation in the Bays	0.200	0.090	3	**0.270**	**M**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.090	3	**0.270**	**M**
San Joaquin Rive	0.15	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the San Joaquin River	0.400	0.090	3	**0.270**	**M**

San Joaquin River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
San Joaquin Rive	0.15	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Delta	0.300	0.068	4	**0.270**	**M**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Loss of Natural River Morphology	0.050	Delta	0.400	0.120	2	**0.240**	**M**
San Joaquin Rive	0.15	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.350	0.079	3	**0.236**	**M**
San Joaquin Rive	0.15	Spawning	0.20	Water Quality	0.075	Water quality in the San Joaquin River	1.000	0.225	1	**0.225**	**M**
San Joaquin Rive	0.15	Spawning	0.20	Water Temperature	0.075	Water temperature in the San Joaquin River	1.000	0.225	1	**0.225**	**M**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.200	0.060	3	**0.180**	**M**
San Joaquin Rive	0.15	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Bays	0.200	0.045	4	**0.180**	**M**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.090	2	**0.180**	**M**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Passage Impediments/Barriers	0.050	Tributary Barriers	0.300	0.090	2	**0.180**	**M**
San Joaquin Rive	0.15	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.250	0.056	3	**0.169**	**M**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Entrainment	0.050	Contra Costa Power Plant	0.100	0.030	5	**0.150**	**L**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Entrainment	0.050	Pittsburg Power Plant	0.100	0.030	5	**0.150**	**L**
San Joaquin Rive	0.15	Spawning	0.20	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.150	1	**0.150**	**L**
San Joaquin Rive	0.15	Spawning	0.20	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.150	1	**0.150**	**L**
San Joaquin Rive	0.15	Embryo Incubation	**0.10**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.150	1	**0.150**	**L**
San Joaquin Rive	0.15	Embryo Incubation	**0.10**	Hatchery Effects	0.075	Density dependent impacts - Redd superimposition, fungus	1.000	0.113	1	**0.113**	**L**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Hatchery Effects	0.025	Bays	0.200	0.030	3	**0.090**	**L**
San Joaquin Rive	0.15	Juvenile Rearing and Outmigration	0.40	Hatchery Effects	0.025	San Joaquin River	0.200	0.030	3	**0.090**	**L**
San Joaquin Rive	0.15	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Ocean	0.100	0.023	4	**0.090**	**L**
San Joaquin Rive	0.15	Embryo Incubation	**0.10**	Harvest/Angling Impacts	0.050	Redd disturbance	1.000	0.075	1.00	**0.075**	**L**

Stanislaus River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Stanislaus River	0.18	Spawning	0.35	Physical Habitat Alteration	0.350	Limited Instream Gravel Supply	1.000	2.205	1	**2.205**	**VH**
Stanislaus River	0.18	Spawning	0.35	Spawning Habitat Availability	0.350	Habitat Suitability	1.000	2.205	1	**2.205**	**VH**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	Goodwin Dam	0.350	0.378	5	**1.890**	**VH**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	New Melones	0.300	0.324	5	**1.620**	**VH**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Flow Conditions	0.350	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in San Joaquin River	0.550	0.693	2	**1.386**	**VH**
Stanislaus River	0.18	Embryo Incubation	**0.20**	Flow Conditions	0.600	Flow Fluctuations	0.600	1.296	1	**1.296**	**VH**
Stanislaus River	0.18	Spawning	0.35	Flow Conditions	0.200	Flow Fluctuations	1.000	1.260	1	**1.260**	**VH**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Flow Conditions	0.350	Low flows limiting attraction into the Stanislaus River	0.450	0.567	2	**1.134**	**VH**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Flow Dependent Habitat Availability in the Stanislaus River	0.400	0.225	5	**1.125**	**VH**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.150	San Joaquin River	0.500	0.338	3	**1.013**	**VH**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	Tulloch Dam	0.180	0.194	5	**0.972**	**VH**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Changes in Hydrology	0.300	0.169	5	**0.844**	**VH**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	Stockton Deep Water Ship Channel	0.150	0.162	5	**0.810**	**VH**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Water Quality	0.150	Ag, Urban in the San Joaquin River	0.450	0.243	3	**0.729**	**VH**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Water Quality	0.100	Ag, Urban in the San Joaquin River	0.400	0.180	4	**0.720**	**VH**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in th Delta	0.400	0.216	3	**0.648**	**VH**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.150	Delta	0.300	0.203	3	**0.608**	**VH**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Jones and Banks Pumping Plants	0.400	0.090	6	**0.540**	**VH**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.100	Stanislaus River	0.400	0.180	3	**0.540**	**VH**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in th Delta	0.300	0.135	4	**0.540**	**VH**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.100	San Joaquin River	0.350	0.158	3	**0.473**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.100	Stanislaus River	0.350	0.158	3	**0.473**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Predation	0.050	Predation in the Stanislaus River	0.500	0.113	4	**0.450**	**H**

Stanislaus River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Water Temperature	0.100	Delta	0.400	0.144	3	**0.432**	**H**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Water Temperature	0.100	San Joaquin River	0.400	0.144	3	**0.432**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Flow Dependent Habitat Availability in the San Joaquin River	0.150	0.084	5	**0.422**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.150	Stanislaus River	0.200	0.135	3	**0.405**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.100	Delta	0.300	0.135	3	**0.405**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.100	Delta	0.300	0.135	3	**0.405**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.100	San Joaquin River	0.300	0.135	3	**0.405**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.100	Delta	0.300	0.135	3	**0.405**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.100	San Joaquin River	0.300	0.135	3	**0.405**	**H**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Stanislaus River	0.400	0.072	5	**0.360**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the San Joaquin River	0.400	0.090	4	**0.360**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Water Quality	0.100	Ag, Urban in the Stanislaus River	0.200	0.090	4	**0.360**	**H**
Stanislaus River	0.18	Spawning	0.35	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.315	1	**0.315**	**H**
Stanislaus River	0.18	Spawning	0.35	Water Quality	0.050	Water quality in Stanislaus River	1.000	0.315	1	**0.315**	**H**
Stanislaus River	0.18	Spawning	0.35	Water Temperature	0.050	Water temperature in the Stanislaus River	1.000	0.315	1	**0.315**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.158	2	**0.315**	**H**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Goodwin Dam	0.330	0.074	4	**0.297**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	New Melones	0.330	0.074	4	**0.297**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Tulloch Dam	0.330	0.074	4	**0.297**	**M**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the San Joaquin River	0.400	0.072	4	**0.288**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Reverse Flow Conditions	0.100	0.056	5	**0.281**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Diversions in the San Joaquin River	0.200	0.045	6	**0.270**	**M**

Stanislaus River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.100	Stanislaus River	0.200	0.090	3	**0.270**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.050	Delta	0.600	0.135	2	**0.270**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.068	4	**0.270**	**M**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Water Quality	0.150	Ag, Urban in the Stanislaus River	0.150	0.081	3	**0.243**	**M**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	San Joaquin River	0.250	0.045	5	**0.225**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Predation	0.050	Predation in the San Joaquin River	0.250	0.056	4	**0.225**	**M**
Stanislaus River	0.18	Embryo Incubation	**0.20**	Water Temperature	0.250	Water Temperature in the Stanislaus River	0.250	0.225	1	**0.225**	**M**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Water Temperature	0.100	Stanislaus River	0.200	0.072	3	**0.216**	**M**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.054	4	**0.216**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Diversions in the Delta	0.150	0.034	6	**0.203**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Diversions in the Stanislaus River	0.150	0.034	6	**0.203**	**M**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Delta	0.200	0.036	5	**0.180**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.050	Bays	0.400	0.090	2	**0.180**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.200	0.045	4	**0.180**	**M**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Water Quality	0.100	Ag, Urban, Heavy Metals in the Bays	0.100	0.045	4	**0.180**	**M**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Stanislaus River	0.200	0.036	4	**0.144**	**L**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Diversion into Central Delta	0.050	0.028	5	**0.141**	**L**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.068	2	**0.135**	**L**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Predation	0.050	Predation in the Delta	0.150	0.034	4	**0.135**	**L**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.300	Suisun Marsh Salinity Control Structure	0.020	0.022	5	**0.108**	**L**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Bays	0.100	0.018	5	**0.090**	**L**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Predation	0.050	Predation in the Bays	0.100	0.023	4	**0.090**	**L**

Stanislaus River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Stanislaus River	0.100	0.023	4	**0.090**	**L**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.100	0.018	4	**0.072**	**L**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Contra Costa Power Plant	0.050	0.011	6	**0.068**	**L**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Pittsburg Power Plant	0.050	0.011	6	**0.068**	**L**
Stanislaus River	0.18	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Ocean	0.050	0.009	5	**0.045**	**L**
Stanislaus River	0.18	Embryo Incubation	**0.20**	Harvest/Angling Impacts	0.050	Redd disturbance	0.050	0.009	1.00	**0.009**	**L**
Stanislaus River	0.18	Embryo Incubation	**0.20**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	0.050	0.009	1	**0.009**	**L**
Stanislaus River	0.18	Embryo Incubation	**0.20**	Water Quality	0.050	Water Pollution	0.050	0.009	1.00	**0.009**	**L**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Bays	0.000	0.000	4	**0.000**	**L**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Delta	0.000	0.000	4	**0.000**	**L**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	San Joaquin River	0.000	0.000	4	**0.000**	**L**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Stanislaus River	0.000	0.000	4	**0.000**	**L**
Stanislaus River	0.18	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Tributary Barriers	0.000	0.000	4	**0.000**	**L**

Stony Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Stony Creek	0.16	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.300	Black Butte Dam	0.960	1.382	5	**6.912**	**VH**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.075	North Diversion Dam	0.500	0.150	3	**0.450**	**VH**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Water Temperature	0.300	Stony Creek	0.500	0.720	4	**2.880**	**VH**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Flow Conditions	0.250	Low Flows - attraction, migratory cues in Stony Creek	0.600	0.720	3	**2.160**	**VH**
Stony Creek	0.16	Spawning	0.35	Barrier	0.300	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	1.680	1	**1.680**	**VH**
Stony Creek	0.16	Spawning	0.35	Spawning Habitat Availability	0.300	Habitat Suitability	1.000	1.680	1	**1.680**	**VH**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.150	Flow Dependent Habitat Availability in Stony Creek	0.450	0.270	6	**1.620**	**VH**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.150	Stony Creek	0.600	0.360	4	**1.440**	**VH**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Water Temperature	0.300	Delta	0.200	0.288	4	**1.152**	**VH**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Water Temperature	0.300	Lower Sacramento River	0.200	0.288	4	**1.152**	**VH**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.150	Diversion into Central Delta	0.250	0.150	6	**0.900**	**VH**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.150	Delta	0.350	0.210	4	**0.840**	**VH**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Flow Conditions	0.250	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.200	0.240	3	**0.720**	**VH**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Flow Conditions	0.250	Low Flows - attraction, migratory cues in the middle Sacramento River	0.200	0.240	3	**0.720**	**VH**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.300	0.180	4	**0.720**	**VH**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Ocean	0.400	0.096	6	**0.576**	**VH**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Water Temperature	0.300	Middle Sacramento River	0.100	0.144	4	**0.576**	**VH**
Stony Creek	0.16	Spawning	0.35	Flow Conditions	0.100	Flow Fluctuations	1.000	0.560	1	**0.560**	**VH**
Stony Creek	0.16	Spawning	0.35	Physical Habitat Alteration	0.100	Limited Instream Gravel Supply	1.000	0.560	1	**0.560**	**VH**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.150	Changes in Hydrology	0.150	0.090	6	**0.540**	**VH**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Predation	0.075	Predation in the Delta	0.350	0.105	5	**0.525**	**VH**
Stony Creek	0.16	Embryo Incubation	**0.10**	Water Quality	0.325	Water Quality in Stony Creek	1.000	0.520	1.00	**0.520**	**VH**

Stony Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Stony Creek	0.16	Embryo Incubation	**0.10**	Water Temperature	0.325	Water Temperature in Stony Creek	1.000	0.520	1	**0.520**	**VH**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Jones and Banks Pumping Plants	0.350	0.070	7	**0.490**	**VH**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.150	Stony Creek	0.200	0.120	4	**0.480**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.150	Delta	0.200	0.120	4	**0.480**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.075	Tributary Barriers	0.500	0.150	3	**0.450**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.075	Delta	0.350	0.105	4	**0.420**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.075	Delta	0.350	0.105	4	**0.420**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in th Delta	0.400	0.080	5	**0.400**	**H**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in th Delta	0.400	0.096	4	**0.384**	**H**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.072	5	**0.360**	**H**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.072	5	**0.360**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.150	Middle Sacramento River	0.150	0.090	4	**0.360**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.075	Lower Sacramento River	0.300	0.090	4	**0.360**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Unscreened Diversions in the Delta	0.250	0.050	7	**0.350**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.075	Lower Sacramento River	0.275	0.083	4	**0.330**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.075	Stony Creek	0.275	0.083	4	**0.330**	**H**
Stony Creek	0.16	Embryo Incubation	**0.10**	Flow Conditions	0.200	Flow Fluctuations	1.000	0.320	1	**0.320**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.060	5	**0.300**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.060	5	**0.300**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.300	0.060	5	**0.300**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Predation	0.075	Predation in the lower Sacramento River	0.200	0.060	5	**0.300**	**H**

Stony Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Stony Creek	0.16	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Middle Sacramento River	0.200	0.048	6	**0.288**	**H**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.300	0.072	4	**0.288**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.140	2	**0.280**	**H**
Stony Creek	0.16	Spawning	0.35	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.280	1	**0.280**	**H**
Stony Creek	0.16	Spawning	0.35	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.280	1	**0.280**	**H**
Stony Creek	0.16	Spawning	0.35	Water Quality	0.050	Water Quality in Stony Creek	1.000	0.280	1	**0.280**	**H**
Stony Creek	0.16	Spawning	0.35	Water Temperature	0.050	Water Temperature in Stony Creek	1.000	0.280	1	**0.280**	**H**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.150	Flow Dependent Habitat Availability in the lower Sacramento River	0.075	0.045	6	**0.270**	**M**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Stony Creek	0.200	0.048	5	**0.240**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.075	Stony Creek	0.200	0.060	4	**0.240**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.150	Lower Sacramento River	0.100	0.060	4	**0.240**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.150	Middle Sacramento River	0.100	0.060	4	**0.240**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.075	Black Butte Dam	0.250	0.075	3	**0.225**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Predation	0.075	Predation in Stony Creek	0.150	0.045	5	**0.225**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Predation	0.075	Predation in the Bays	0.150	0.045	5	**0.225**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Predation	0.075	Predation in the middle Sacramento River	0.150	0.045	5	**0.225**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Unscreened Diversions in Stony Creek	0.150	0.030	7	**0.210**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Stony Creek	0.200	0.040	5	**0.200**	**M**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.200	0.048	4	**0.192**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.150	Flow Dependent Habitat Availability in the middle Sacramento River	0.050	0.030	6	**0.180**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.075	Middle Sacramento River	0.150	0.045	4	**0.180**	**M**

Stony Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Stony Creek	0.16	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Bays	0.100	0.024	6	**0.144**	**M**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Delta	0.100	0.024	6	**0.144**	**M**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Lower Sacramento River	0.100	0.024	6	**0.144**	**M**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Harvest/Angling Impacts	0.050	Stony Creek	0.100	0.024	6	**0.144**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Unscreened Diversions in the lower Sacramento River	0.100	0.020	7	**0.140**	**M**
Stony Creek	0.16	Embryo Incubation	**0.10**	Harvest/Angling Impacts	0.075	Redd disturbance	1.000	0.120	1.00	**0.120**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.060	2	**0.120**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.025	Delta	0.600	0.060	2	**0.120**	**M**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.100	0.024	5	**0.120**	**M**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.100	0.024	5	**0.120**	**M**
Stony Creek	0.16	Embryo Incubation	**0.10**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.120	1	**0.120**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.075	Middle Sacramento River	0.100	0.030	4	**0.120**	**M**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Bays	0.200	0.020	5	**0.100**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Delta	0.200	0.020	5	**0.100**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Lower Sacramento River	0.200	0.020	5	**0.100**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Middle Sacramento River	0.200	0.020	5	**0.100**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Stony Creek	0.200	0.020	5	**0.100**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.020	5	**0.100**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.100	0.020	5	**0.100**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in the middle Sacramento River	0.100	0.020	5	**0.100**	**L**

Stony Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban in Stony Creek	0.100	0.020	5	**0.100**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.100	0.020	5	**0.100**	**L**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Water Quality	0.050	Stony Creek	0.100	0.024	4	**0.096**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.150	Reverse Flow Conditions	0.025	0.015	6	**0.090**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.025	Bays	0.400	0.040	2	**0.080**	**L**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.300	Sacramento Deep Water Ship Channel	0.010	0.014	5	**0.072**	**L**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.300	Suisun Marsh Salinity Control Structure	0.010	0.014	5	**0.072**	**L**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.300	Sutter Bypass - Tisdale Weir	0.010	0.014	5	**0.072**	**L**
Stony Creek	0.16	Adult Immigration and Holding	0.30	Passage Impediments/Barriers	0.300	Yolo Bypass - Freemont Weir	0.010	0.014	5	**0.072**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Contra Costa Power Plant	0.050	0.010	7	**0.070**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Unscreened Diversions in the middle Sacramento River	0.050	0.010	7	**0.070**	**L**
Stony Creek	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Pittsburg Power Plant	0.050	0.010	7	**0.070**	**L**

Thomes Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Ag Diversion Dams, Braiding, Natural Channel Gradient	0.750	0.61	5	**3.05**	**VH**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Thomes Creek	0.700	0.68	4	**2.73**	**VH**
Thomes Creek	0.13	Spawning	**0.25**	Spawning Habitat Availability	0.400	Habitat Suitability	1.000	1.30	1	**1.30**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.350	0.24	4	**0.96**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Middle Sacramento River	0.350	0.24	4	**0.96**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Delta	0.300	0.20	4	**0.82**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Lower Sacramento River	0.300	0.20	4	**0.82**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Delta	0.300	0.20	4	**0.82**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.300	0.20	4	**0.82**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Jones and Banks Pumping Plants	0.250	0.11	7	**0.80**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Delta	0.300	0.14	5	**0.68**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the lower Sacramento River	0.300	0.14	5	**0.68**	**VH**
Thomes Creek	0.13	Spawning	**0.25**	Water Temperature	0.200	Water Temperature in Thomes Creek	1.000	0.65	1	**0.65**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the Delta	0.200	0.09	7	**0.64**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the lower Sacramento River	0.200	0.09	7	**0.64**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in the middle Sacramento River	0.200	0.09	7	**0.64**	**VH**
Thomes Creek	0.13	Embryo Incubation	**0.15**	Water Temperature	0.300	Water Temperature in Thomes Creek	1.000	0.59	1.00	**0.59**	**VH**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Ocean	0.300	0.10	6	**0.59**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the middle Sacramento River	0.250	0.11	5	**0.57**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Thomes Creek	0.200	0.14	4	**0.55**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Floodplain Habitat	0.150	Middle Sacramento River	0.200	0.14	4	**0.55**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Thomes Creek	0.200	0.14	4	**0.55**	**VH**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Natural River Morphology	0.150	Middle Sacramento River	0.200	0.14	4	**0.55**	**VH**

Thomes Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.200	0.14	4	**0.55**	**VH**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.10	5	**0.49**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.10	5	**0.49**	**H**
Thomes Creek	0.13	Embryo Incubation	**0.15**	Watershed disturbance	0.250	Sedimentation	1.000	0.49	1.00	**0.49**	**H**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.600	0.20	2	**0.41**	**H**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Delta	0.600	0.20	2	**0.41**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Yolo Bypass - Freemont Weir	0.100	0.08	5	**0.41**	**H**
Thomes Creek	0.13	Embryo Incubation	**0.15**	Flow Conditions	0.200	Flow Fluctuations	1.000	0.39	1.00	**0.39**	**H**
Thomes Creek	0.13	Embryo Incubation	**0.15**	Water Quality	0.200	Water Quality in Thomes Creek	1.000	0.39	1.00	**0.39**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.400	0.13	3	**0.39**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues in the middle Sacramento River	0.400	0.13	3	**0.39**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.300	0.10	4	**0.39**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in the middle Sacramento River	0.300	0.10	4	**0.39**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.300	0.10	4	**0.39**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Delta	0.100	0.10	4	**0.39**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Lower Sacramento River	0.100	0.10	4	**0.39**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Water Temperature	0.300	Middle Sacramento River	0.100	0.10	4	**0.39**	**H**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.07	5	**0.34**	**H**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.300	0.07	5	**0.34**	**H**

Thomes Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Thomes Creek	0.13	Spawning	**0.25**	Barrier	0.100	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.33	1	**0.33**	**H**
Thomes Creek	0.13	Spawning	**0.25**	Flow Conditions	0.100	Flow Fluctuations	1.000	0.33	1	**0.33**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.07	5	**0.33**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Bays	0.150	0.05	6	**0.29**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Delta	0.150	0.05	6	**0.29**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Lower Sacramento River	0.150	0.05	6	**0.29**	**H**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Middle Sacramento River	0.150	0.05	6	**0.29**	**H**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Invasive Species/Food Web Disruption	0.075	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.14	2	**0.27**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Riparian Habitat and Instream Cover	0.150	Thomes Creek	0.100	0.07	4	**0.27**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Loss of Tidal Marsh Habitat	0.075	Bays	0.400	0.14	2	**0.27**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in Thomes Creek	0.100	0.05	5	**0.23**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.200	0.05	5	**0.23**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Passage Impediments/Barriers	0.050	Tributary Barriers	1.000	0.23	1	**0.23**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Thomes Creek	0.500	0.06	4	**0.23**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Diversion into Central Delta	0.300	0.03	6	**0.20**	**M**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sacramento Deep Water Ship Channel	0.050	0.04	5	**0.20**	**M**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Suisun Marsh Salinity Control Structure	0.050	0.04	5	**0.20**	**M**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Passage Impediments/Barriers	0.250	Sutter Bypass - Tisdale Weir	0.050	0.04	5	**0.20**	**M**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Flow Conditions	0.100	Low Flows - attraction, migratory cues in Thomes Creek	0.200	0.07	3	**0.20**	**M**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Harvest/Angling Impacts	0.100	Thomes Creek	0.100	0.03	6	**0.20**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Delta	0.300	0.03	5	**0.17**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Lower Sacramento River	0.300	0.03	5	**0.17**	**M**

Thomes Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Thomes Creek	0.13	Spawning	**0.25**	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.16	1	**0.16**	**M**
Thomes Creek	0.13	Spawning	**0.25**	Hatchery Effects	0.050	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.16	1	**0.16**	**M**
Thomes Creek	0.13	Spawning	**0.25**	Water Quality	0.050	Water Quality in Thomes Creek	1.000	0.16	1	**0.16**	**M**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in Thomes Creek	0.100	0.03	5	**0.16**	**M**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Short-term Inwater Construction	0.100	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.100	0.03	5	**0.16**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Contra Costa Power Plant	0.050	0.02	7	**0.16**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Individual Diversions in Thomes Creek	0.050	0.02	7	**0.16**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Entrainment	0.100	Pittsburg Power Plant	0.050	0.02	7	**0.16**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Changes in Hydrology	0.200	0.02	6	**0.14**	**M**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Reverse Flow Conditions	0.200	0.02	6	**0.14**	**M**
Thomes Creek	0.13	Adult Immigration and Holding	**0.25**	Water Quality	0.100	Ag, Urban in Thomes Creek	0.100	0.03	4	**0.13**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Predation	0.100	Predation in the Bays	0.050	0.02	5	**0.11**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in Thomes Creek	0.100	0.02	5	**0.11**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.02	5	**0.11**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the lower Sacramento River	0.200	0.02	5	**0.11**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in the middle Sacramento River	0.200	0.02	5	**0.11**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban in Thomes Creek	0.200	0.02	5	**0.11**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	Ag, Urban, Heavy Metals in the Bays	0.200	0.02	5	**0.11**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Quality	0.025	DO, Ag, Urban, Heavy Metals in the Delta	0.200	0.02	5	**0.11**	**L**
Thomes Creek	0.13	Embryo Incubation	**0.15**	Harvest/Angling Impacts	0.050	Redd disturbance	1.000	0.10	1.00	**0.10**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Lower Sacramento River	0.200	0.02	4	**0.09**	**L**

Thomes Creek Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Middle Sacramento River	0.200	0.02	4	**0.09**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Middle Sacramento River	0.150	0.02	5	**0.09**	**L**
Thomes Creek	0.13	Spawning	**0.25**	Physical Habitat Alteration	0.050	Limited Instream Gravel Supply	0.500	0.08	1	**0.08**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in Thomes Creek	0.100	0.01	6	**0.07**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the lower Sacramento River	0.100	0.01	6	**0.07**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Flow Conditions	0.025	Flow Dependent Habitat Availability in the middle Sacramento River	0.100	0.01	6	**0.07**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Bays	0.100	0.01	5	**0.06**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Hatchery Effects	0.025	Thomes Creek	0.100	0.01	5	**0.06**	**L**
Thomes Creek	0.13	Juvenile Rearing and Outmigration	**0.35**	Water Temperature	0.025	Delta	0.100	0.01	4	**0.05**	**L**

Tuolumne River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Tuolumne River	0.16	Spawning	0.35	Spawning Habitat Availability	0.500	Habitat Suitability	1.000	2.800	1	**2.800**	**VH**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.350	La Grange	0.500	0.560	4	**2.240**	**VH**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.350	Don Pedro	0.350	0.392	5	**1.960**	**VH**
Tuolumne River	0.16	Spawning	0.35	Physical Habitat Alteration	0.300	Limited Instream Gravel Supply	1.000	1.680	1	**1.680**	**VH**
Tuolumne River	0.16	Embryo Incubation	**0.20**	Flow Conditions	0.600	Flow Fluctuations	0.600	1.152	1	**1.152**	**VH**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.200	San Joaquin River	0.450	0.360	3	**1.080**	**VH**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Flow Dependent Habitat Availability in the Tuolumne River	0.350	0.175	5	**0.875**	**VH**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.200	Tuolumne River	0.350	0.280	3	**0.840**	**VH**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Water Temperature	0.200	San Joaquin River	0.400	0.256	3	**0.768**	**VH**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Water Temperature	0.200	Tuolumne River	0.400	0.256	3	**0.768**	**VH**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Flow Conditions	0.200	Low Flows - attraction, migratory cues in Tuolumne River	0.550	0.352	2	**0.704**	**VH**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Flow Conditions	0.200	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in San Joaquin River	0.450	0.288	2	**0.576**	**VH**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Water Quality	0.150	Ag, Urban in the San Joaquin River	0.400	0.192	3	**0.576**	**VH**
Tuolumne River	0.16	Spawning	0.35	Flow Conditions	0.100	Flow Fluctuations	1.000	0.560	1	**0.560**	**VH**
Tuolumne River	0.16	Spawning	0.35	Water Temperature	0.100	Water temperature in the Tuolumne River	1.000	0.560	1	**0.560**	**VH**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Water Quality	0.150	Ag, Urban in the Tuolumne River	0.350	0.168	3	**0.504**	**VH**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Flow Dependent Habitat Availability in the San Joaquin River	0.200	0.100	5	**0.500**	**VH**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Reverse Flow Conditions	0.200	0.100	5	**0.500**	**VH**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Water Temperature	0.200	Delta	0.200	0.160	3	**0.480**	**H**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.350	Stockton Deep Water Ship Channel	0.100	0.112	4	**0.448**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Jones and Banks Pumping Plants	0.350	0.070	6	**0.420**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.100	San Joaquin River	0.350	0.140	3	**0.420**	**H**

Tuolumne River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.100	Tuolumne River	0.350	0.140	3	**0.420**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.100	Delta	0.350	0.140	3	**0.420**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.100	San Joaquin River	0.350	0.140	3	**0.420**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Water Quality	0.075	Ag, Urban in the San Joaquin River	0.350	0.105	4	**0.420**	**H**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Water Temperature	0.200	Delta	0.200	0.128	3	**0.384**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Changes in Hydrology	0.150	0.075	5	**0.375**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Floodplain Habitat	0.100	Delta	0.300	0.120	3	**0.360**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Natural River Morphology	0.100	Tuolumne River	0.300	0.120	3	**0.360**	**H**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Water Quality	0.150	DO, Ag, Urban, Heavy Metals in th Delta	0.250	0.120	3	**0.360**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Predation	0.075	Predation in the San Joaquin River	0.300	0.090	4	**0.360**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Predation	0.075	Predation in the Tuolumne River	0.300	0.090	4	**0.360**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Water Quality	0.075	DO, Ag, Urban, Heavy Metals in th Delta	0.300	0.090	4	**0.360**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the San Joaquin River	0.400	0.080	4	**0.320**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Diversions in the San Joaquin River	0.250	0.050	6	**0.300**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Don Pedro	0.500	0.100	3	**0.300**	**H**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	La Grange	0.500	0.100	3	**0.300**	**H**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Tuolumne River	0.350	0.056	5	**0.280**	**M**
Tuolumne River	0.16	Spawning	0.35	Harvest/Angling Impacts	0.050	Recreational, Poaching, Angler Impacts	1.000	0.280	1	**0.280**	**M**
Tuolumne River	0.16	Spawning	0.35	Water Quality	0.050	Water quality in Tuolumne River	1.000	0.280	1	**0.280**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.700	0.140	2	**0.280**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Flow Conditions	0.125	Diversion into Central Delta	0.100	0.050	5	**0.250**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Diversions in the Delta	0.200	0.040	6	**0.240**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.050	Delta	0.600	0.120	2	**0.240**	**M**

Tuolumne River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Predation	0.075	Predation in the Bays	0.200	0.060	4	**0.240**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Predation	0.075	Predation in the Delta	0.200	0.060	4	**0.240**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.060	4	**0.240**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Water Quality	0.075	Ag, Urban in the Tuolumne River	0.200	0.060	4	**0.240**	**M**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Passage Impediments/Barriers	0.350	Suisun Marsh Salinity Control Structure	0.050	0.056	4	**0.224**	**M**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the San Joaquin River	0.350	0.056	4	**0.224**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.050	Delta	0.350	0.070	3	**0.210**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.050	San Joaquin River	0.350	0.070	3	**0.210**	**M**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	San Joaquin River	0.250	0.040	5	**0.200**	**M**
Tuolumne River	0.16	Embryo Incubation	**0.20**	Water Temperature	0.250	Water Temperature in the Tuolumne River	0.250	0.200	1	**0.200**	**M**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.300	0.048	4	**0.192**	**M**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Individual Diversions in the Tuolumne River	0.150	0.030	6	**0.180**	**L**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Riparian Habitat and Instream Cover	0.050	Tuolumne River	0.300	0.060	3	**0.180**	**L**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Water Quality	0.075	Ag, Urban, Heavy Metals in the Bays	0.150	0.045	4	**0.180**	**L**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Delta	0.200	0.032	5	**0.160**	**L**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Loss of Tidal Marsh Habitat	0.050	Bays	0.400	0.080	2	**0.160**	**L**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.200	0.040	4	**0.160**	**L**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Tuolumne River	0.200	0.032	4	**0.128**	**L**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.300	0.060	2	**0.120**	**L**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.150	0.024	4	**0.096**	**L**
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Bays	0.100	0.016	5	**0.080**	**L**

Tuolumne River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Tuolumne River	0.16	Adult Immigration and Holding	0.20	Harvest/Angling Impacts	0.050	Ocean	0.100	0.016	5	**0.080**	**L**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Tuolumne River	0.100	0.020	4	**0.080**	**L**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Contra Costa Power Plant	0.050	0.010	6	**0.060**	**L**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Entrainment	0.050	Pittsburg Power Plant	0.050	0.010	6	**0.060**	**L**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Bays	0.025	0.003	4	**0.010**	**L**
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Delta	0.025	0.003	4	**0.010**	**L**
Tuolumne River	0.16	Embryo Incubation	**0.20**	Harvest/Angling Impacts	0.050	Redd disturbance	0.050	0.008	1.00	**0.008**	**L**
Tuolumne River	0.16	Embryo Incubation	**0.20**	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	0.050	0.008	1	**0.008**	**L**
Tuolumne River	0.16	Embryo Incubation	**0.20**	Water Quality	0.050	Water Pollution	0.050	0.008	1.00	**0.008**	**L**
Tuolumne River	0.16	Spawning	0.35	Barrier	0.000	Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.000	1	**0.000**	
Tuolumne River	0.16	Spawning	0.35	Hatchery Effects	0.000	Redd superimposition, competition for habitat, Genetic Integrity	1.000	0.000	1	**0.000**	
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	San Joaquin River	0.000	0.000	4	**0.000**	
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Hatchery Effects	0.025	Tuolumne River	0.000	0.000	4	**0.000**	
Tuolumne River	0.16	Juvenile Rearing and Outmigration	0.25	Passage Impediments/Barriers	0.050	Tributary Barriers	0.000	0.000	3	**0.000**	

Upper Sacramento Tributaries Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Impediments/Barriers in the Upper Sacramento Tributaries	0.76	1.231	6	**7.387**	**VH**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Temperature	**0.250**	Upper Sacramento Tributaries	0.95	1.283	4	**5.130**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.200	Upper Sacramento Tributaries	0.8	0.864	5	**4.320**	**VH**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Flow Conditions	**0.200**	Low Flows - attraction, migratory cues in the Upper Sacramento Tributaries	0.75	0.810	4	**3.240**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Entrainment	0.150	Individual Unscreened Diversions in the Upper Sacramento Tributaries	0.4	0.324	8	**2.592**	**VH**
Upper Sacramento Tributaries	0.18	Spawning	0.3	Barriers	0.400	Redd superimposition, competition for habitat, hybridization/genetic integrity	1	2.160	1	**2.160**	**VH**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Red Bluff Diversion Dam	0.2	0.324	6	**1.944**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Flow Dependent Habitat Availability in the Upper Sacramento Tributaries	0.5	0.270	7	**1.890**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.100	Upper Sacramento Tributaries	0.75	0.405	4	**1.620**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the upper Sacramento River	0.4	0.216	6	**1.296**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the Upper Sacramento Tributaries	0.4	0.216	6	**1.296**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Entrainment	0.150	Jones and Banks Pumping Plants	0.2	0.162	8	**1.296**	**VH**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Quality	**0.150**	Upper Sacramento Tributaries	0.3	0.243	5	**1.215**	**VH**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Quality	**0.150**	Urban, Heavy Metals in the upper Sacramento River	0.3	0.243	5	**1.215**	**VH**

Upper Sacramento Tributaries Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Passage Impediments/Barriers	0.200	Impediments/Barriers in the Upper Sacramento Tributaries	0.5	0.540	2	**1.080**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Passage Impediments/Barriers	0.200	Tributary Barriers	0.5	0.540	2	**1.080**	**VH**
Upper Sacramento Tributaries	0.18	Spawning	0.3	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply	1	1.080	1	**1.080**	**VH**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.090**	Upper Sacramento River	0.3	0.146	7	**1.021**	**VH**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.090**	Middle Sacramento River	0.25	0.122	7	**0.851**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.050	Upper Sacramento Tributaries	0.6	0.162	5	**0.810**	**VH**
Upper Sacramento Tributaries	0.18	Spawning	0.3	Spawning Habitat Availability	0.150	Habitat Suitability	1	0.810	1	**0.810**	**VH**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Quality	**0.150**	Ag, Urban in the middle Sacramento River	0.2	0.162	5	**0.810**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Changes in Hydrology	0.2	0.108	7	**0.756**	**VH**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.090**	Upper Sacramento Tributaries	0.2	0.097	7	**0.680**	**VH**
Upper Sacramento Tributaries	0.18	Embryo Incubation	**0.10**	Water Temperature	0.375	Water Temperature in the Upper Sacramento Tributaries	1.00	0.675	1	**0.675**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Entrainment	0.150	Individual Unscreened Diversions in the Delta	0.1	0.081	8	**0.648**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Entrainment	0.150	Individual Unscreened Diversions in the middle Sacramento River	0.1	0.081	8	**0.648**	**VH**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.200	Middle Sacramento River	0.1	0.108	5	**0.540**	**H**

Upper Sacramento Tributaries Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Upper Sacramento Tributaries	0.18	Spawning	0.3	Water Temperature	0.100	Water Temperature in the Upper Sacramento Tributaries	1	0.540	1	**0.540**	**H**
Upper Sacramento Tributaries	0.18	Embryo Incubation	**0.10**	Water Quality	0.275	Water Quality in the Upper Sacramento Tributaries	1.00	0.495	1.00	**0.495**	**H**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Flow Conditions	**0.200**	Low Flows - attraction, migratory cues in the middle Sacramento River	0.1	0.108	4	**0.432**	**H**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Flow Conditions	**0.200**	Low Flows - attraction, migratory cues in the upper Sacramento River	0.1	0.108	4	**0.432**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.050	Upper Sacramento River	0.3	0.081	5	**0.405**	**H**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Quality	**0.150**	Ag, Urban in the lower Sacramento River	0.1	0.081	5	**0.405**	**H**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Quality	**0.150**	DO, Ag, Urban, Heavy Metals in th Delta	0.1	0.081	5	**0.405**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Flow Dependent Habitat Availability in the upper Sacramento River	0.1	0.054	7	**0.378**	**H**
Upper Sacramento Tributaries	0.18	Embryo Incubation	**0.10**	Flow Conditions	0.200	Flow Fluctuations	1	0.360	1	**0.360**	**H**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.090**	Delta	0.1	0.049	7	**0.340**	**H**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.090**	Lower Sacramento River	0.1	0.049	7	**0.340**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the middle Sacramento River	0.1	0.054	6	**0.324**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Entrainment	0.150	Contra Costa Power Plant	0.05	0.041	8	**0.324**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Entrainment	0.150	Individual Unscreened Diversions in the lower Sacramento River	0.05	0.041	8	**0.324**	**H**

Upper Sacramento Tributaries Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Entrainment	0.150	Individual Unscreened Diversions in the upper Sacramento River	0.05	0.041	8	**0.324**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Entrainment	0.150	Pittsburg Power Plant	0.05	0.041	8	**0.324**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.050	Lower Sacramento River	0.2	0.054	5	**0.270**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.050	Middle Sacramento River	0.2	0.054	5	**0.270**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.050	Upper Sacramento Tributaries	0.2	0.054	5	**0.270**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.050	Delta	0.2	0.054	5	**0.270**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.200	Upper Sacramento River	0.05	0.054	5	**0.270**	**H**
Upper Sacramento Tributaries	0.18	Spawning	0.3	Flow Conditions	0.050	Flow Fluctuations	1	0.270	1	**0.270**	**H**
Upper Sacramento Tributaries	0.18	Spawning	0.3	Water Quality	0.050	Water Quality in the Upper Sacramento Tributaries	1	0.270	1	**0.270**	**H**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Flow Conditions	**0.200**	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in lower Sacramento River	0.05	0.054	4	**0.216**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.100	Middle Sacramento River	0.1	0.054	4	**0.216**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.100	Upper Sacramento River	0.1	0.054	4	**0.216**	**H**
Upper Sacramento Tributaries	0.18	Spawning	0.3	Hatchery Effects	0.040	Redd superimposition, competition for habitat, Genetic Integrity	1	0.216	1	**0.216**	**H**

Upper Sacramento Tributaries Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.200	Lower Sacramento River	0.04	0.043	5	**0.216**	**H**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Diversion into Central Delta	0.05	0.027	7	**0.189**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Flow Dependent Habitat Availability in the lower Sacramento River	0.05	0.027	7	**0.189**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Flow Dependent Habitat Availability in the middle Sacramento River	0.05	0.027	7	**0.189**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Flow Conditions	0.100	Reverse Flow Conditions	0.05	0.027	7	**0.189**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the lower Sacramento River	0.05	0.027	6	**0.162**	**M**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Temperature	**0.250**	Middle Sacramento River	0.03	0.041	4	**0.162**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the Upper Sacramento Tributaries	0.45	0.024	6	**0.146**	**M**
Upper Sacramento Tributaries	0.18	Embryo Incubation	**0.10**	Harvest/Angling Impacts	0.075	Redd disturbance	1.00	0.135	1.00	**0.135**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Floodplain Habitat	0.050	Delta	0.1	0.027	5	**0.135**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.050	Upper Sacramento River	0.1	0.027	5	**0.135**	**M**
Upper Sacramento Tributaries	0.18	Embryo Incubation	**0.10**	Short-term Inwater Construction	0.075	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1	0.135	1	**0.135**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the Delta	0.04	0.022	6	**0.130**	**M**

Upper Sacramento Tributaries Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Ag, Urban in the Upper Sacramento Tributaries	0.35	0.019	6	**0.113**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.100	Lower Sacramento River	0.05	0.027	4	**0.108**	**M**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.010**	Sedimentation, turbidity, acoustic effects, hazardous spills in the Upper Sacramento Tributaries	0.4	0.022	5	**0.108**	**M**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.090**	Bays	0.03	0.015	7	**0.102**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Delta	0.3	0.016	6	**0.097**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Middle Sacramento River	0.3	0.016	6	**0.097**	**M**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Sacramento Deep Water Ship Channel	0.01	0.016	6	**0.097**	**M**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Suisun Marsh Salinity Control Structure	0.01	0.016	6	**0.097**	**M**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Sutter Bypass - Tisdale Weir	0.01	0.016	6	**0.097**	**M**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Passage Impediments/Barriers	**0.300**	Yolo Bypass - Freemont Weir	0.01	0.016	6	**0.097**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Urban, Heavy Metals in the upper Sacramento River	0.3	0.016	6	**0.097**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Ag, Urban in the middle Sacramento River	0.3	0.016	6	**0.097**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Delta	0.8	0.043	2	**0.086**	**M**

Upper Sacramento Tributaries Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Tidal Marsh Habitat	0.010	Delta	0.8	0.043	2	**0.086**	**M**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.010**	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.3	0.016	5	**0.081**	**M**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the middle Sacramento River	0.25	0.014	6	**0.081**	**M**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Harvest/Angling Impacts	**0.090**	Ocean	0.02	0.010	7	**0.068**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.050	Lower Sacramento River	0.05	0.014	5	**0.068**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Natural River Morphology	0.050	Middle Sacramento River	0.05	0.014	5	**0.068**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.010**	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.25	0.014	5	**0.068**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the upper Sacramento River	0.2	0.011	6	**0.065**	**L**
Upper Sacramento Tributaries	0.18	Spawning	0.3	Harvest/Angling Impacts	0.010	Recreational, Poaching, Angler Impacts	1	0.054	1	**0.054**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Temperature	0.200	Delta	0.01	0.011	5	**0.054**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Temperature	**0.250**	Lower Sacramento River	0.01	0.014	4	**0.054**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Temperature	**0.250**	Upper Sacramento River	0.01	0.014	4	**0.054**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Lower Sacramento River	0.15	0.008	6	**0.049**	**L**

Upper Sacramento Tributaries Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Upper Sacramento River	0.15	0.008	6	**0.049**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Upper Sacramento Tributaries	0.1	0.005	6	**0.032**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Predation	0.100	Predation in the Bays	0.01	0.005	6	**0.032**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Ag, Urban in the lower Sacramento River	0.1	0.005	6	**0.032**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Invasive Species/Food Web Disruption	0.010	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.2	0.011	2	**0.022**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Tidal Marsh Habitat	0.010	Bays	0.2	0.011	2	**0.022**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.05	0.003	6	**0.016**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.04	0.002	6	**0.013**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	DO, Ag, Urban, Heavy Metals in th Delta	0.04	0.002	6	**0.013**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.010**	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.04	0.002	5	**0.011**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Short-term Inwater Construction	0.010	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.01	0.001	6	**0.003**	**L**
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Water Quality	0.010	Ag, Urban, Heavy Metals in the Bays	0.01	0.001	6	**0.003**	**L**
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.010**	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.01	0.001	5	**0.003**	**L**

Upper Sacramento Tributaries Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Hatchery Effects	0.010	Bays	0	0.000	6		
Upper Sacramento Tributaries	0.18	Juvenile Rearing and Outmigration	0.3	Loss of Riparian Habitat and Instream Cover	0.100	Delta	0	0.000	4		
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Short-term Inwater Construction	**0.010**	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0	0.000	5		
Upper Sacramento Tributaries	0.18	Adult Immigration and Holding	0.3	Water Temperature	**0.250**	Delta	0	0.000	4		

Yuba River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Yuba River	0.11	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Englebright Dam	0.650	0.43	5	**2.15**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Natural River Morphology	0.150	Yuba River	0.350	0.25	4	**0.98**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Riparian Habitat and Instream Cover	0.150	Yuba River	0.350	0.25	4	**0.98**	**VH**
Yuba River	0.11	Spawning	0.275	Barrier	0.300	Englebright Dam - Redd superimposition, competition for habitat, hybridization/genetic integrity	1.000	0.91	1	**0.91**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Floodplain Habitat	0.125	Delta	0.375	0.22	4	**0.88**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Predation in the Delta	0.300	0.18	5	**0.88**	**VH**
Yuba River	0.11	Embryo Incubation	0.15	Flow Conditions	0.525	Flow Fluctuations, Flood Events	1.000	0.87	1.00	**0.87**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Riparian Habitat and Instream Cover	0.150	Delta	0.300	0.21	4	**0.84**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Predation in the Yuba River	0.250	0.15	5	**0.73**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Natural River Morphology	0.150	Delta	0.250	0.18	4	**0.70**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Natural River Morphology	0.150	Lower Sacramento River	0.250	0.18	4	**0.70**	**VH**
Yuba River	0.11	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Daguerre Point Dam	0.200	0.13	5	**0.66**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Individual Diversions in the Yuba River and DPD	0.250	0.09	7	**0.61**	**VH**
Yuba River	0.11	Spawning	0.275	Hatchery Effects	0.200	Redd superimposition, competition for habitat, genetic integrity	1.000	0.61	1	**0.61**	**VH**
Yuba River	0.11	Spawning	0.275	Physical Habitat Alteration	0.200	Limited Instream Gravel Supply	1.000	0.61	1	**0.61**	**VH**
Yuba River	0.11	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Ocean	0.400	0.10	6	**0.59**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Predation in the Feather River	0.200	0.12	5	**0.58**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Predation in the lower Sacramento River	0.200	0.12	5	**0.58**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Floodplain Habitat	0.125	Lower Sacramento River	0.250	0.15	4	**0.58**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Riparian Habitat and Instream Cover	0.150	Lower Sacramento River	0.200	0.14	4	**0.56**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Individual Diversions in the Delta	0.200	0.07	7	**0.49**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Individual Diversions in the lower Sacramento River	0.200	0.07	7	**0.49**	**VH**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Jones and Banks Pumping Plants	0.200	0.07	7	**0.49**	**VH**

Yuba River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Floodplain Habitat	0.125	Yuba River	0.200	0.12	4	**0.47**	**VH**
Yuba River	0.11	Spawning	0.275	Spawning Habitat Availability	0.150	Habitat Suitability	1.000	0.45	1	**0.45**	**H**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Natural River Morphology	0.150	Feather River	0.150	0.11	4	**0.42**	**H**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Riparian Habitat and Instream Cover	0.150	Feather River	0.150	0.11	4	**0.42**	**H**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Water Temperature	0.075	Delta	0.300	0.11	4	**0.42**	**H**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Water Temperature	0.075	Feather River	0.300	0.11	4	**0.42**	**H**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Water Temperature	0.075	Lower Sacramento River	0.300	0.11	4	**0.42**	**H**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Floodplain Habitat	0.125	Feather River	0.175	0.10	4	**0.41**	**H**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.350	0.08	5	**0.41**	**H**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Water Quality	0.050	DO, Ag, Urban, Heavy Metals in the Delta	0.350	0.08	5	**0.41**	**H**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Flow Conditions	0.050	Flow Dependent Habitat Availability in the Yuba River	0.225	0.05	6	**0.32**	**H**
Yuba River	0.11	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Yuba River	0.200	0.05	6	**0.30**	**H**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.250	0.06	5	**0.29**	**H**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Water Quality	0.050	Ag, Urban in the lower Sacramento River	0.250	0.06	5	**0.29**	**H**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Water Quality	0.050	Ag, Urban, Heavy Metals in the Bays	0.250	0.06	5	**0.29**	**H**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Flow Conditions	0.050	Diversion into Central Delta	0.200	0.05	6	**0.28**	**H**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Flow Conditions	0.050	Reverse Flow Conditions	0.200	0.05	6	**0.28**	**H**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, water hyacinth, etc. in the Delta	0.600	0.14	2	**0.28**	**H**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Tidal Marsh Habitat	0.050	Delta	0.600	0.14	2	**0.28**	**H**
Yuba River	0.11	Adult Immigration and Holding	0.15	Water Temperature	0.125	Feather River	0.300	0.06	4	**0.25**	**H**
Yuba River	0.11	Adult Immigration and Holding	0.15	Water Temperature	0.125	Lower Sacramento River	0.300	0.06	4	**0.25**	**H**

Yuba River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Individual Diversions in the Feather River	0.100	0.04	7	**0.25**	**H**
Yuba River	0.11	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Delta	0.225	0.05	5	**0.23**	**H**
Yuba River	0.11	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the lower Sacramento River	0.225	0.05	5	**0.23**	**H**
Yuba River	0.11	Spawning	0.275	Flow Conditions	0.075	Flow Fluctuations	1.000	0.23	1	**0.23**	**H**
Yuba River	0.11	Adult Immigration and Holding	0.15	Water Temperature	0.125	Delta	0.275	0.06	4	**0.23**	**H**
Yuba River	0.11	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues in the Yuba River	0.450	0.07	3	**0.22**	**M**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Flow Conditions	0.050	Changes in Delta Hydrology	0.150	0.04	6	**0.21**	**M**
Yuba River	0.11	Embryo Incubation	0.15	Harvest/Angling Impacts	0.125	Redd disturbance	1.000	0.21	1.00	**0.21**	**M**
Yuba River	0.11	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bay	0.200	0.04	5	**0.21**	**M**
Yuba River	0.11	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Yuba River	0.200	0.04	5	**0.21**	**M**
Yuba River	0.11	Embryo Incubation	0.15	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills, physical disturbance	1.000	0.21	1.00	**0.21**	**M**
Yuba River	0.11	Embryo Incubation	0.15	Water Quality	0.125	Water Pollution above Daguerre Point Dam	1.000	0.21	1.00	**0.21**	**M**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Hatchery Effects	0.025	Feather River	0.350	0.04	5	**0.20**	**M**
Yuba River	0.11	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues in the Feather River	0.400	0.07	3	**0.20**	**M**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Invasive Species/Food Web Disruption	0.050	Asian clam, A. aspera, Microcystis, etc. in the Bays	0.400	0.09	2	**0.19**	**M**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Loss of Tidal Marsh Habitat	0.050	Bays	0.400	0.09	2	**0.19**	**M**
Yuba River	0.11	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Delta	0.125	0.03	6	**0.19**	**M**
Yuba River	0.11	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Lower Sacramento River	0.125	0.03	6	**0.19**	**M**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Flow Conditions	0.050	Flow Dependent Habitat Availability in the lower Sacramento River	0.125	0.03	6	**0.18**	**M**

Yuba River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Feather River	0.150	0.04	5	**0.18**	**M**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Yuba River	0.150	0.04	5	**0.18**	**M**
Yuba River	0.11	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Sacramento Deep Water Ship Channel	0.050	0.03	5	**0.17**	**M**
Yuba River	0.11	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Suisun Marsh Salinity Control Structure	0.050	0.03	5	**0.17**	**M**
Yuba River	0.11	Adult Immigration and Holding	0.15	Passage Impediments/Barriers	0.400	Yolo Bypass - Freemont Weir	0.050	0.03	5	**0.17**	**M**
Yuba River	0.11	Adult Immigration and Holding	0.15	Water Quality	0.100	Ag, Urban in the Feather River	0.250	0.04	4	**0.17**	**M**
Yuba River	0.11	Adult Immigration and Holding	0.15	Water Quality	0.100	Ag, Urban in the lower Sacramento River	0.250	0.04	4	**0.17**	**M**
Yuba River	0.11	Adult Immigration and Holding	0.15	Water Quality	0.100	DO, Ag, Urban, Heavy Metals in the Delta	0.250	0.04	4	**0.17**	**M**
Yuba River	0.11	Adult Immigration and Holding	0.15	Water Quality	0.100	Yuba River	0.250	0.04	4	**0.17**	**M**
Yuba River	0.11	Embryo Incubation	0.15	Water Temperature	0.100	Water Temperature above Daguerre Point Dam	1.000	0.17	1.00	**0.17**	**M**
Yuba River	0.11	Adult Immigration and Holding	0.15	Short-term Inwater Construction	0.125	Sedimentation, turbidity, acoustic effects, hazardous spills in the Feather River	0.150	0.03	5	**0.15**	**L**
Yuba River	0.11	Spawning	0.275	Water Temperature	0.050	Water Temperature in the Yuba River	1.000	0.15	1	**0.15**	**L**
Yuba River	0.11	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Bays	0.100	0.02	6	**0.15**	**L**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Hatchery Effects	0.025	Lower Sacramento River	0.250	0.03	5	**0.15**	**L**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Hatchery Effects	0.025	Yuba River	0.250	0.03	5	**0.15**	**L**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Predation	0.125	Predation in the Bay	0.050	0.03	5	**0.15**	**L**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Flow Conditions	0.050	Flow Dependent Habitat Availability in the Feather River	0.100	0.02	6	**0.14**	**L**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Passage Impediments/Barriers	0.025	Daguerre Point Dam	0.600	0.07	2	**0.14**	**L**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Water Temperature	0.075	Yuba River	0.100	0.04	4	**0.14**	**L**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Short-term Inwater Construction	0.050	Sedimentation, turbidity, acoustic effects, hazardous spills in the Bays	0.100	0.02	5	**0.12**	**L**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Water Quality	0.050	Ag, Urban in the Feather River	0.100	0.02	5	**0.12**	**L**

Yuba River Steelhead Stressor Matrix

Population	Pop Weight (0-1) Sum to 1	Life Stage	Life Stage Weight (0-1) Sum to 1	Primary Stressor Category	Primary Stressor Weight (0-1) Sum to 1	Specific Stressor	Specific Stressor Weight (0-1) Sum to 1	Composite Weight (X100)	# of Specific Stressors	Normalized Weight (Composite * # of specific stressors)	Overall Stressor Category
Yuba River	0.11	Adult Immigration and Holding	0.15	Water Temperature	0.125	Yuba River	0.125	0.03	4	**0.10**	**L**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Passage Impediments/Barriers	0.025	Englebright Dam	0.400	0.05	2	**0.09**	**L**
Yuba River	0.11	Spawning	0.275	Harvest/Angling Impacts	0.025	Recreational, Poaching, Angler Impacts	1.000	0.08	1	**0.08**	**L**
Yuba River	0.11	Adult Immigration and Holding	0.15	Flow Conditions	0.100	Low Flows - attraction, migratory cues AND Flood Flows - non-natal area attraction in Lower Sacramento River	0.150	0.02	3	**0.07**	**L**
Yuba River	0.11	Adult Immigration and Holding	0.15	Harvest/Angling Impacts	0.150	Feather River	0.050	0.01	6	**0.07**	**L**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Contra Costa Power Plant	0.025	0.01	7	**0.06**	**L**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Entrainment	0.075	Pittsburg Power Plant	0.025	0.01	7	**0.06**	**L**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Hatchery Effects	0.025	Delta	0.100	0.01	5	**0.06**	**L**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Water Quality	0.050	Yuba River	0.050	0.01	5	**0.06**	**L**
Yuba River	0.11	Juvenile Rearing and Outmigration	0.425	Hatchery Effects	0.025	Bays	0.050	0.01	5	**0.03**	**L**

APPENDIX C

Central Valley Technical Recovery Team Reports

Technical Recovery Team Members

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The Central Valley Technical Recovery Team has published five reports that provide scientific guidance for planning the recovery of listed Chinook salmon and steelhead in the Central Valley. Those five reports appear in this appendix in the following order:

- Population structure of threatened and endangered Chinook salmon ESU in California's Central Valley basin.
- Historical population structure of Central Valley steelhead and its alteration by dams.
- Monitoring and research needed to manage the recovery of threatened and endangered Chinook and steelhead in the Sacramento-San Joaquin basin.
- Framework for assessing viability of threatened and endangered Chinook salmon and steelhead in the Sacramento-San Joaquin Basin.
- Directed connectivity among fish populations in a riverine network.

NOAA Technical Memorandum NMFS

This TM series is used for documentation and timely communication of preliminary results, interim reports, or special purpose information. The TMs have not received complete formal review, editorial control, or detailed editing.

APRIL 2004

POPULATION STRUCTURE OF THREATENED AND ENDANGERED CHINOOK SALMON ESUs IN CALIFORNIA'S CENTRAL VALLEY BASIN

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NOAA-TM-NMFS-SWFSC-360

U. S. DEPARTMENT OF COMMERCE
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National Marine Fisheries Service
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Abstract

This report describes the historical structure of spring- and winter-run chinook salmon populations in the Sacramento-San Joaquin watershed based on historical distributional information, geography, hydrography, ecology, population genetics, life history information, and trends in abundance. For the purposes of technical recovery planning, there are potentially two levels of organization within the evolutionarily significant unit (ESU) that are of interest: populations and population groups. In future documents, we will describe ESU viability goals in terms of viable independent populations spread among population groups that will maintain the evolutionary potential and ensure the persistence of the ESU.

We divided the spring-run chinook salmon ESU into four geographic groups. Members of the groups inhabit similar environments, according to a principle components analysis of environmental variables. The groups are southern Cascades, northern Sierra, southern Sierra, and Coast Range. There were historically at least 18 independent populations of spring-run chinook salmon spread among these four groups, plus an additional seven spring-run chinook salmon populations that may have been strongly influenced by an adjacent population. Three of the 18 independent spring-run chinook salmon populations are extant (Mill, Deer and Butte Creek populations). Several of the seven dependent populations still have intermittent runs of spring-run chinook salmon, including Big Chico, Antelope, and Beegum creeks.

The winter-run chinook salmon ESU historically contained at least four independent populations. These populations all spawned in the southern Cascades, and have been extirpated from their historic spawning areas. The single extant population of winter-run chinook salmon spawns in habitat outside of this range (spawning below Keswick Dam on the floor of the Central Valley), and was founded by some unknown combination of fish from the original populations. The distribution and diversity of winter- and spring-run chinook salmon has been strongly altered by habitat modifications, especially the placement of impassable dams at low elevations throughout the Central Valley basin.

1 Introduction

1.1 Background

A major goal of the Central Valley Technical Recovery Team (TRT) is production of criteria that describe viable salmonid populations in terms of abundance, productivity, diversity and spatial structure (McElhany et al., 2000) for listed evolutionarily significant units (ESUs) in the Central Valley [1]. These viability factors can be assessed at various levels of biological organization, ranging from independent populations, through population groups experiencing similar environments and sharing life history traits, to the ESU. Viability assessments and viability criteria therefore require definition of population structure.

In this document, we delineate the historical population structure of the listed evolutionarily significant units of chinook salmon [2] in the Central Valley domain (Plate 1), based on available evidence. We seek to describe the historical structure of ESUs because we are relatively certain that these structures were viable, i.e., capable of persisting for long periods of time. An ESU may not need to be at its historical levels of abundance, productivity, diversity and spatial structure in order to be viable, but the further it is from its historical structure, the less likely it is to be viable. We describe the population structure in terms of geographically-based population groups composed of independent and dependent populations.

Population groups are components of an ESU that partition genetic diversity. These groups might share common life history traits (e.g., early run timing cued to snow melt) or reside in the same region (e.g., a certain mountain range with environmental conditions different from other regions with the ESU boundaries). Identifying these population groups may be useful for several reasons. The first is that such groups represent genetic diversity within the ESU, and maintenance of this diversity is important for ESU persistence (McElhany et al., 2000). Second, if it is necessary or desirable to reintroduce salmonids to areas where they were extirpated, it would be best to use a founder from the same group.

Population groups are composed of independent and dependent populations. In this report, we follow the independent population definition of McElhany et al. (2000):

> An independent population is any collection of one or more local breeding units whose population dynamics or extinction risk over a 100-year time period is not substantially altered by exchanges of individuals with other populations.

The focus on breeding units suggests that we define the boundaries of salmon populations by watershed boundaries, since salmon have high fidelity to the watershed where they were born. In most (but not all) cases, ESUs will be composed of multiple independent populations. Note that under *current* conditions, a population need not be viable to be considered independent.

1.2 Processes creating population structure

Geographic and behavioral isolation are major drivers of population divergence (Mayr, 1993; Barlow, 1995). Anadromous salmonids have a strong propensity to return to their natal stream upon maturation (Candy and Beacham, 2000; Hard and Heard, 1999; Pascual and Quinn, 1995; Quinn and Fresh, 1984; Quinn et al., 1991), and this homing isolates breeding groups. Isolation of breeding groups allows adaptation to local environmental conditions, creating phenotypic divergence and further reinforcing isolation (Healey and Prince, 1995; Quinn et al., 2001). The behavior and life history of winter-run chinook salmon and spring-run chinook salmon, in combination with the structure of the Central Valley stream network, make these mechanisms especially strong in our study area.

The life history of spring-run chinook salmon allows for exploitation of high-elevation spawning and rearing habitats. To reach these habitats, chinook salmon must migrate during high flow periods in the spring— later in the summer and fall, stream flows are too low for fish to pass higher gradient reaches. Once spring-run chinook salmon reach elevations high enough to maintain suitably cool water temperatures, they hold over the summer in pools. When temperatures drop in the fall, they move out of the pools (sometimes back downstream) and spawn. The low stream flows during the fall spawning season prevent fall-run chinook salmon from spawning with spring-run chinook salmon. Furthermore, eggs and juveniles of spring-run chinook salmon experience cooler waters than fall-run chinook salmon, which delays maturation such that some (possibly large) fraction of the juveniles do not emigrate from high elevation rearing areas until a full year of life has passed.

Winter-run chinook salmon, like spring-run chinook salmon, used to spawn at high elevations, but were restricted to the spring-fed headwaters of the southern Cascades. Winter-run chinook salmon were reproductively isolated from sympatric populations of spring-run chinook salmon because of their different spawning times.

[1] The endangered Sacramento River winter-run chinook salmon, threatened Central Valley spring-run chinook salmon and threatened Central Valley steelhead.

[2] Steelhead population structure will be described in a separate document.

Historically, winter-run chinook salmon entered freshwater in the winter and reached headwater areas in the spring. Rather than hold over the summer, as spring-run chinook salmon do, winter-run chinook salmon spawn during the summer (which isolates them reproductively from sympatric spring-run chinook salmon populations). This strategy is only successful in spring-fed streams with adequate summer flows and relatively low water temperatures. Fry emerge from the gravel in the late summer, and begin emigrating from upriver areas as water temperatures become suitable in the fall, entering the ocean the following spring.

The high elevation spawning areas used by spring-run and winter-run chinook salmon are isolated from each other by large distances, and during the summer, by low flows and high temperatures. Our initial assumption, on the basis of the isolation of spawning groups in different tributaries, and in the absence of other information, is that major basins (i.e., tributaries to the Sacramento and San Joaquin rivers) historically supported at least one independent population, and that larger basins may have supported several independent populations. In the following section, we review various kinds of information that might allow us to refine this hypothesis.

2 Conceptual approach to identifying populations

As discussed in the preceding section, population structure arises through isolation of breeding groups and adaptation to local conditions, which further reduces their tendency to breed with other groups. Clues to population structure therefore come from information about the physical isolation of spawning groups, environmental differences between habitats used by spawning groups, and evidence of reproductive isolation in the form of phenotypic and genotypic differences between populations. In this section, we discuss in detail the types of information that might provide insight into the population structure of Pacific salmonids.

2.1 Geography

We expect that the internal structure of an ESU will be related to the geography of that ESU because salmon usually spawn in their natal streams. The amount of straying between basins is inversely related to the distance between the basins (Candy and Beacham, 2000; Hard and Heard, 1999; Pascual and Quinn, 1995; Quinn and Fresh, 1984; Quinn et al., 1991). Geographic analysis can therefore provide insight into the population structure of Central Valley winter-run and spring-run chinook salmon. In order to more carefully examine the hypothesis that major basins supported at least one independent population, we considered the distances between watersheds (as the fish swims) that historically supported spawning and rearing of spring-run chinook salmon (as reported by Yoshiyama et al. (1996)). In the absence of detailed information on the distribution of spawners for most streams, we identified the intersection of streams and the 500 m elevation contour line, assuming that most spring-run chinook salmon spawning and rearing occurred above this elevation (Yoshiyama et al., 1996).

In addition to the spatial arrangement of basins, the basin size provides some information on whether a basin could have supported an independent population. Population ecology theory tells us that, due to demographic and environmental stochasticity, populations below a critical minimum size are unlikely to persist without immigration (Goodman, 1987). Because carrying capacity is related to habitat area, it is therefore plausible that watersheds smaller than some critical size are unable to support independent populations of chinook salmon. Currens et al. (2002) found that in the Puget Sound, the smallest watershed containing an independent population of chinook salmon is the Nooksack River, with an area of 477 km^2. The largest watershed containing a single independent population is the upper Skagit River basin, with an area of 2600 km^2; larger watersheds contained at least two independent populations. The Puget Sound results are of limited utility for the Central Valley due to the significant environmental differences between the regions, but nonetheless, provide a standard for comparison.

2.2 Migration rates

The extent to which adults move between sites affects the degree of reproductive isolation and, therefore, demographic independence between sites. Migration rate can be estimated in two ways: direct observation based on mark-recapture, and indirect inference based on population genetics. Mark-recapture estimates depend on few assumptions, but migrants may not necessarily contribute equally to reproduction (Tallman and Healey, 1994), and the estimates might vary over time. Genetic approaches are sensitive only to successful reproduction and integrate over longer time scales, but are dependent on several assumptions that are frequently violated in real studies.

2.3 Genetic attributes

The existence of genetic differences between reasonably large and stable populations indicates that these populations are independent, because low rates of gene flow between populations will rapidly erase such differences. There are many considerations that should be kept in mind when interpreting the results of population genetics studies, and these are described in detail Appendix A.

2.4 Patterns of life history and phenotypic characteristics

Chinook salmon have a remarkably flexible life history and variable phenotypes, and much variation has been observed among populations (Adkison, 1995; Healey, 1994; Healey and Prince, 1995). Some of this among-population variability is heritable, presumably reflecting adaptation to local conditions (Healey and Prince, 1995; Quinn et al., 2000, 2001) (although genetic drift and phenotypic plasticity lead to differences among populations (Adkison, 1995)). Because local adaptation is easily overcome by immigration, phenotypic differences between populations indicate that the populations are independent of one another, or at least that the selective environments of the populations are different.

2.5 Environmental and habitat characteristics

The distribution of lotic organisms is determined in part by their adaptation to their physical habitat "template," which is in turn created by biogeoclimatic processes (Poff and Ward, 1990). The life history characteristics that promote survival under one template may preclude survival under another, if the other template exceeds the tolerance or behavioral range of the organism. Poff and Ward (1990) emphasize substratum, thermal regime and streamflow pattern as minimal representations of the physical habitat template. Streams that differ markedly in these attributes are more likely to harbor populations that are independent of one another, because gene flow would be selected against. Chinook salmon have flexible life histories that can be tuned by adaptation to local conditions, presumably leading to optimal timing of adult entry to freshwater, migration to spawning areas, spawning, emergence, migration to rearing habitat, and emigration to the sea (but all within the constraints of development). Figure 1 illustrates some of the complex interactions among environmental effects and salmon life history events.

There is relatively abundant information on various aspects of the environment inhabited by chinook salmon in the Central Valley. In this report, we examine floristic ecoregions, geology, elevation, stream flow (magnitude, seasonal patterns, and interannual variation), and air temperature (a proxy for water temperature). There are strong correlations among these variables, leading us to use principle components analysis (PCA) to reduce the dimensionality of the information. PCA results can be potentially helpful in identifying population groups sharing similar environments (especially if they form discrete clusters) and in quantifying the similarity of environments experienced by different putative independent populations.

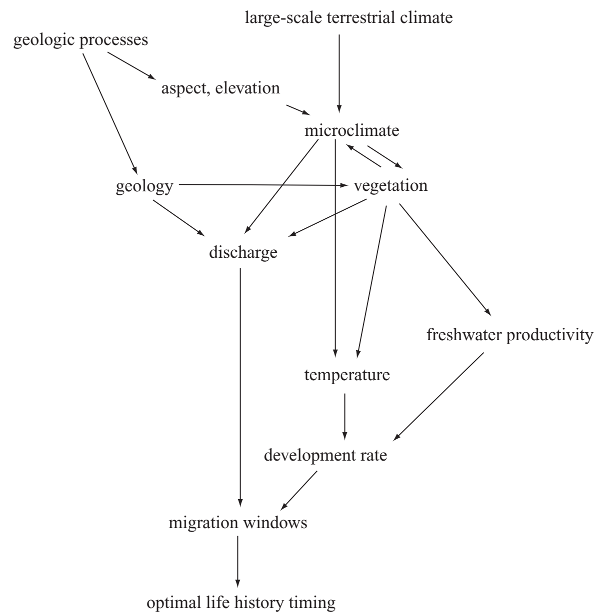

Figure 1. A simplified conceptual model of how aspects of the environment interact to influence the optimal timing of life history events such as spawning and juvenile emigration. Arrows indicate direct effects of one variable on another.

2.5.1 Ecoregional setting

Because the distribution of plants is controlled by climate, geology, and hydrology (among other factors), floristic regions are useful indicators of biogeography. Streams in different floristic ecoregions likely present chinook salmon with different selective environments, leading to local adaptation and reduction in gene flow between populations in different ecoregions.

2.5.2 Geology

Geology acts in several ways to determine characteristics of the environment faced by migrating and rearing salmon. Geologic processes determine many physical aspects of watersheds, including rock types, slope, aspect, and elevation. The interaction of these physical attributes with large-scale climate patterns determines the supply of water and sediments to stream channels on shorter time scales, and the nature of the stream channels themselves at longer timescales. We therefore expect that areas with different geological histories present salmonids with different selective regimes. However, geological attributes important to salmon habitats can be highly variable within as well as among different types of rock, depending on the extent of weathering and fracturing, particular chemical composition, and other factors.

2.5.3 Elevation

Except at extremes, elevation has little or no direct effect on organisms, but it strongly affects temperature and precipitation, and has been shown to be a primary determinant of ecological variability (Kratz et al., 1991). The elevation profile of a basin is therefore a useful proxy for streamflow and temperature. The effects of stream flow and temperature are discussed below.

2.5.4 Hydrography and thermal regime

By itself, stream flow variability has direct effects on stream-dwelling organisms as well as indirect effects on structural attributes of streams, and is therefore a useful indicator of environmental variability in lotic systems (Poff and Ward, 1989). Flow and temperature are often related in streams, and exert interacting effects on salmonids. The pattern of flow and temperature variation in rivers sets windows of opportunities for various stages of the salmonid life cycle, which combined with the developmental limits of salmonids, dictates when certain life history events and transitions must occur.

Fish that migrate to headwaters for spawning (e.g., Central Valley spring-run chinook salmon) tend to take advantage of high flows in the spring and summer while valley- floor spawners that migrate shorter distances tend to delay migration until after the peak flows (Healey, 1991). Adult upstream migration is thought to be blocked by temperatures above 21°C (McCullough, 1999), and temperatures below this level can stress fish, increasing their susceptibility to disease (Berman, 1990) and elevating their metabolism (Brett, 1979). The summer must be spent at high elevations to avoid negative impacts from high temperatures on egg viability (Hinze, 1959). Spawning can occur only when temperatures drop to acceptable levels (Murray and Beacham, 1987). The initiation of spawning is thought to be strongly influenced by temperature; spawning has been observed over a wide range of temperatures (2.2°C-18.9°C) but spawning of chinook salmon typically occurs below 13.9 °C (McCullough, 1999). Temperature controls the development rate of eggs in the gravel and the size of emerging alevins (Beer and Anderson, 1997; McCullough, 1999), and high temperatures reduce survival of eggs (Alderice and Velsen, 1978). Alevins must leave the gravel before scouring spring floods occur, or risk high rates of mortality (Montgomery et al., 1996; Beer and Anderson, 2001). Successful smolt emigration can occur only when temperatures are suitable (Brett, 1979). It is unlikely that chinook adapted to the hydrographic and thermal regime of a certain river can reproduce as effectively in a different stream with a substantially different regime.

Support for these ideas comes from comparing the results of model predictions and the observed pattern of adult migration and juvenile emergence in Mill Creek (Figure 2). Adults must move into the streams prior to the onset of high summer temperatures (> 21 °C) (Stage I in Figure 2). The adults hold over the summer either far upstream or in cool water refugia where the temperatures are below 16°C (Stage II in Figure 2). Cool water refugia are often several degrees cooler than the river temperature so fish might also hold over at lower elevations. If the fish are exposed to higher temperatures in this stage, high prespawning mortality is likely which can impact population productivity. Since temperatures above 14°C are generally lethal to the eggs, spawning should only begin below this level. We assume for illustration that spawning occurs between 12° and 14°C. Because isotherms move from high to low elevations in the autumn, the beginning of spawning can be protracted, beginning in August at the high elevations and in late October at low elevations (Stage III in Figure 2). However, as a result of the non-linear relationship between egg development and temperature, the pattern of fry emergence with elevation does not necessarily match the pattern of spawning with elevation (Beer and Anderson, 2001). Because eggs deposited at lower elevations would experience higher incubation temperatures than eggs deposited at higher elevations, the low elevation fry could in fact emerge prior to high elevation fry that spawned two months earlier. The result is likely to protract the fry emergence period, with fish emerging at all elevations over the winter and spring. This is the pattern observed for spring-run chinook salmon in Mill, Deer and Butte creeks (Figure 24). A model-derived pattern of

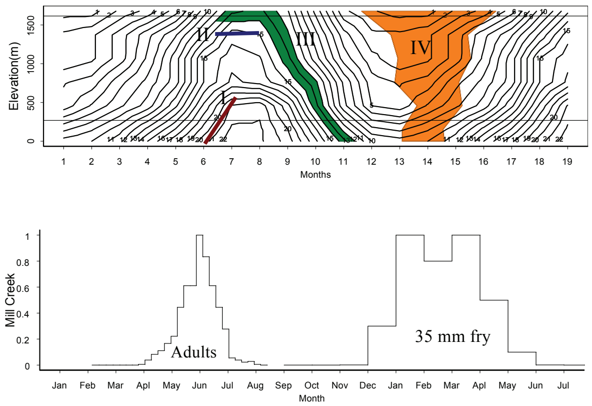

Figure 2. Effect of temperature on timing of spawning migration and fry emergence. Upper Panel shows the isotherm (°C) contours representative of northern Sierra Nevada streams. Line I depicts the thermal boundary for upstream adult migration. Line II depicts the thermally derived elevation where adults can safely hold prior to spawning, Area III depicts the 12 and 14°C isotherms, which are assumed to identify the spawning temperatures. IV depicts the resulting fry emergence distribution. Lower Panel: the relative upstream migrations of spring chinook adults and downstream migrations of 35 mm fry in Mill Creek.

emergence for fish spawning between 12° and 14°C is illustrated as Stage IV in Figure 2 using an egg development model (Beer and Anderson, 1997)[3]. Area IV depicts the fry emergence between maximum alevin weight and absorption of the yolk-sack. The observed patterns of adult immigration into Mill Creek in the spring and the downstream capture of their offspring as 35 mm fry eight months later (lower panel of Figure 2) comport with the modeled spawning and emergence pattern.

While there are reasonable flow data for Central Valley streams, water temperature data are not widely available. Studies have found that stream temperatures are closely related to air temperature. Langan et al. (2001) determined that the stream temperature from the Girnock burn in Scotland was 0.8°C warmer than the air temperature over a range 0° to 14°C. Mohseni et al. (1998) determined the air-water relationship from hundreds of streams could be described by an S-shaped function in which the river is warmer at air temperatures near freezing and is cooler than the air above 20°C. In between the extremes, water and air temperatures are essentially linearly related. Therefore, air temperature, in a linear function or S-function, can be used to estimate the water temperature and to a first approximation the water temperature is about equal to the air temperature. We therefore use the air temperature climatology to explore temporal and spatial variation in the thermal regimes at large scales.

[3] Available at http://www.cbr.washington.edu/egg_growth

2.6 Population dynamics

Abundance data can be used to explore the degree to which demographic trajectories of two groups of fish are independent of one another. All else being equal, the less correlated time series of abundance are between two groups of fish, the less likely they are to be part of the same population. Complicating the interpretation of correlations in abundance is the potentially confounding influence of correlated environmental variation. When groups of fish that are in close proximity are not correlated in abundance over time, it is likely that they are not linked demographically. The reverse is not always the case–when correlations in abundance between groups of fish are detected, more work is needed to rule out confounding sources of correlation.

2.7 Synthesis and decision making

2.7.1 Population groups

Other TRTs have identified groups of salmon within large (in the spatial sense) ESUs sharing common life history characteristics, environments, and genetics. It is assumed that conservation of the ESU depends on conservation of these groups becasue it is in these groups that significant genentic variation is contained. In the case of the Central Valley, such population groups might be defined largely on the basis of common environmental characteristics, because most populations are extirpated (making genetic analysis difficult) and run-timing differences were partitioned in the delineation of ESUs. We initially identified historical population groups through a qualitative analysis of geography, hydrography, and ecoregional information. The TRT quickly reached consensus on these groups, probably because the different types of information all seemed to point to the same conclusion. We performed a quantitative analysis (principle components analysis) of a wider suite of environmental information to check the reasonableness of the qualitative assessment.

2.7.2 Independent populations

The TRT followed a three-step process to identify independent populations:

1. identify watersheds that historically contained spawning groups of spring-run chinook salmon or winter-run chinook salmon.

2. group together watersheds within a critical dispersal distance (50 km) and in the same ecoregion to produce a list of hypothesized independent populations.

3. examine any other available data to test the population hypotheses.

3 Review of data

In the case of Central Valley spring-run chinook salmon and winter-run chinook salmon, we have at least some data on all of the above-described categories except direct estimates of migration rates among populations, although for many basins, only basic geographic and environmental information are available. In this section, we review the available data and discuss its implications for population structure. In the final sections of the report we list the independent populations of spring-run chinook salmon and winter-run chinook salmon and discuss how the data support the delineations.

3.1 Historical distribution

Yoshiyama et al. (1996) reviewed a variety of historical information, including reports by early fisheries scientists, journals of miners and explorers, and ethnographic sources, to reconstruct the historical distribution of spring-run chinook salmon and winter-run chinook salmon in the Central Valley. Plates 2 and 3 summarize this information. Spring-run chinook salmon appear to have occurred in all rivers with drainages reaching the crest of the Sierra Nevada (except for the Kern River) or southern Cascades, as well as some other streams draining the coast range and southern Klamath Mountains (Plate 2). With few exceptions, these watersheds have extensive areas above the 500 m elevation contour. Winter-run chinook salmon spawned only in the larger spring-fed streams of the southern Cascades region[4](Plate 3).

3.2 Geography

3.2.1 Distance among basins

We assume that most spawning of spring-run chinook salmon and winter-run chinook salmon occurred above 500 m elevation, and that the straying rate between spawning areas is inversely proportional to the distance along the streams separating the areas. Plate 4 shows the points where spring-run chinook salmon and winter-run chinook salmon streams cross the 500 m elevation contour. Figure 3 shows a neighbor-joining tree constructed from the distances among 500 m points. Distances to nearest neighbors among tributaries to San Joaquin and lower Sacramento rivers are longer than those of the upper Sacramento River.

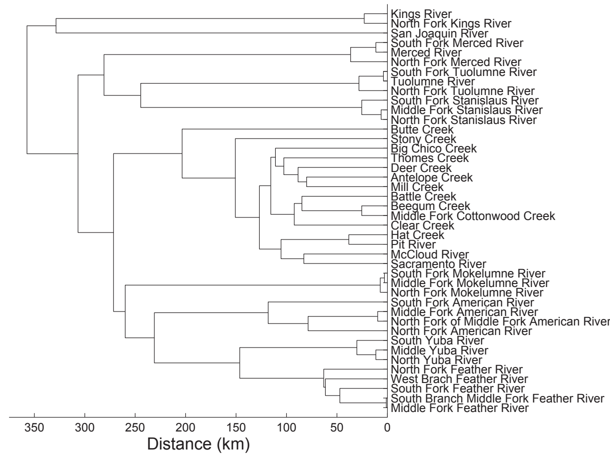

Figure 3. Neighbor-joining tree, based on distance along streams between 500 m elevation points, of watersheds that historically contained spring-run chinook salmon.

If distance between areas was the only information available, populations can be identified from Figure 3 by examining the population groups that form below a critical migration distance (x_c). Following the Interior Columbia Basin Technical Recovery Team (2003) and Quinn and Fresh (1984), we set x_c to 50 km, beyond which populations are probably independent. Other values of x_c might be reasonable, so we examined the sensitivity of the results to different values of x_c (Figure 4). The number of populations identified declines roughly exponentially with increasing x_c.

3.2.2 Basin size

Figure 5 shows the size of all basins in the Central Valley that historically supported spawning of spring- and winter-run chinook salmon, according to Yoshiyama et al. (1996). Of watersheds with extant spring-run chinook salmon spawning groups, Butte Creek is the largest at over 2000 km^2, although much of this area is of very low elevation. Deer and Mill creeks are 563 km^2 and 342 km^2, respectively. If we assume that the Puget Sound chinook salmon results (Currens et al., 2002) are roughly applica-

[4]CDFG suggested in several memos to their files (cited in Yoshiyama et al. (1996)) that winter-run chinook salmon were found in the Calaveras River, but given the lack of suitable spawning and rearing habitat in this low-elevation, rain-driven basin, it is most likely that the fish observed in the winter in the Calaveras were late-fall-run chinook salmon (Yoshiyama et al,1996).

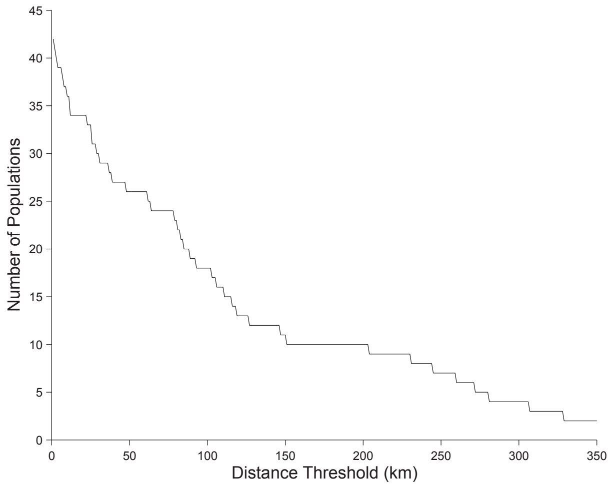

Figure 4. The number of population groups separated by dispersal distances. Distance measure is distance between 500 m elevation along the stream route.

ble to the Central Valley, then most river basins identified in Plate 2 contained at least one independent population, and most of the larger basins (e.g., Feather, American, Yuba, Stanislaus, Merced, Tuolumne, middle-upper San Joaquin rivers) may have contained two or more. As a rule of thumb, we assumed watersheds with an area > 500 km^2 to be capable of supporting independent populations, if other environmental attributes seemed suitable (especially the magnitude and variability of summer flow).

Other proxies for habitat area are available. Spring-run chinook salmon spawners are more directly limited by the amount of cool-water holding and spawning habitat than watershed area (although these measures are roughly correlated in the Central Valley). Cool-water habitat might be better measured by mean annual discharge or by the amount of high-elevation habitat. Figure 6 shows the relationship between elevation and area for watersheds that historically contained spring-run chinook salmon. Figure 7 shows the mean annual discharge rate for streams that historically supported spring-run chinook salmon or winter-run chinook salmon.

3.3 Population genetics

In this subsection we discuss the principle refereed papers and agency reports that provide molecular genetic data on Central Valley chinook salmon populations. Earlier works are cited in some of these papers. The results are structured by data type. Subsequently, we present a synthesis of these results and discuss their implications for the via-

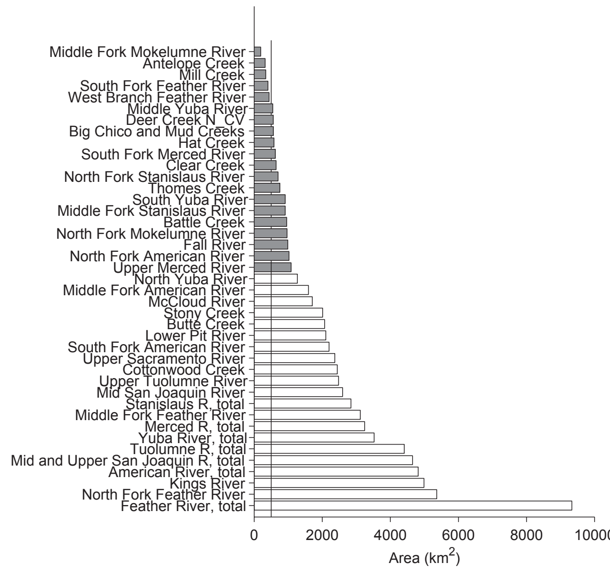

Figure 5. Area of Sacramento-San Joaquin watersheds that currently or historically contained spawning groups of spring-run chinook salmon, according to Yoshiyama et al. (1996). The vertical line marks 500 km^2.

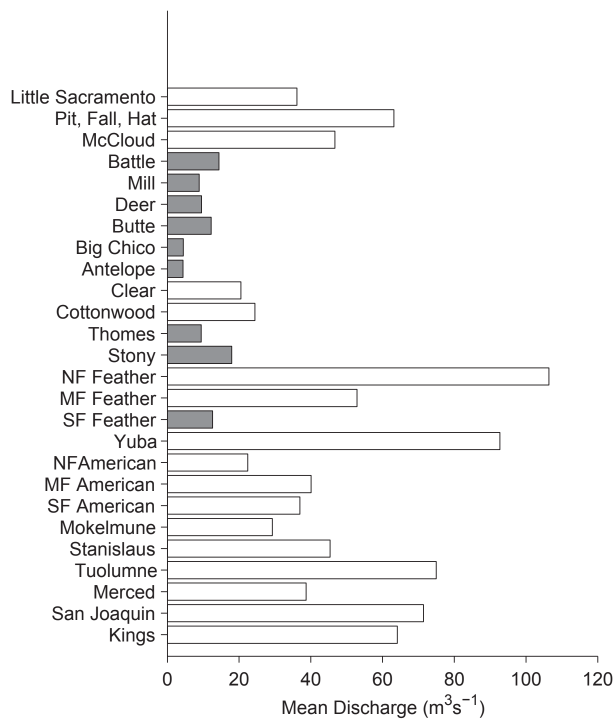

Figure 7. Mean annual discharge rate of Central Valley watersheds historically known to contain spring-run chinook salmon or winter-run chinook salmon.

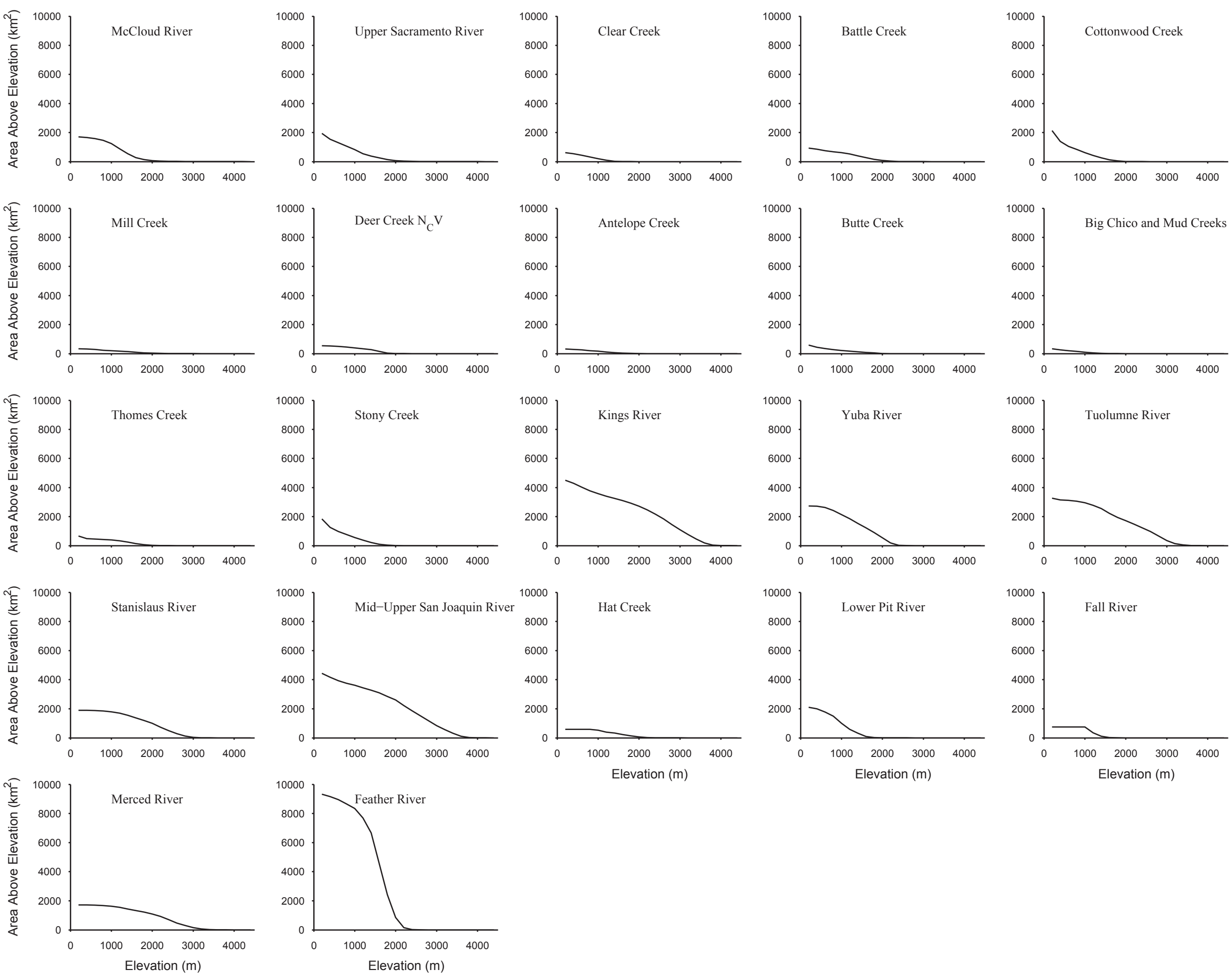

Figure 6. Area-elevation relationships of Central Valley watersheds historically known to contain spring-run chinook salmon or winter-run chinook salmon.

bility of Central Valley chinook salmon. See Appendix A for background information on population genetics.

3.3.1 Allozyme studies

Waples et al. (2004) examined patterns of genetic and life history diversity in 118 chinook salmon populations from British Columbia to California. The genetic data were derived from variation at 32 polymorphic allozyme loci. This comprehensive survey included 10 samples from the Central Valley representing fall, late-fall, spring, and winter runs. A salient feature of this study was that all Central Valley populations constituted a single taxonomic entity genetically distinct from all other populations, including those geographically proximate along the coast or in the Klamath/Trinity drainage (see Figures 8 and 9). This result indicates a more recent derivation of life history forms within the Central Valley or a greater recent gene flow rate among the Central Valley run types. Similar separation of Central Valley chinook from coastal populations was shown by Gall et al. (1991) using 47 polymorphic loci. An extension of the Waples et al. (2004) dataset has been used to show relationships among Central Valley chinook (Figure 10)[5]. Fall, late-fall, and Feather River spring-run chinook salmon formed one cluster, as did winter-run fish. Allele frequencies in Spring-run chinook salmon from Deer Creek, Butte Creek, Feather River hatchery, and Yuba River were not significantly different from each other.

3.3.2 Major histocompatibility complex (MHC) genes

Kim et al. (1999) describe results for MHC Class II exon variation among nine samples of spawning adults drawn from the Sacramento River (winter run (1991, N=18; 1992, N=27; 1993, N=9; 1994, N=23; 1995, N=33), spring run from the main stem (1995, N=13), spring run from Butte creek (1995, N=13), fall run (1993, N=19), and late fall run (1995, N=20)). The fish were taken at either the Red Bluff diversion dam or the Keswick dam. Four alleles were observed to be segregating at this locus. Figure 11 is a phenogram based on neighbor joining of Nei's genetic distance. The figure reveals the relationships among the samples with main clusters of winter-run chinook salmon samples, fall- and late-fall-run chinook salmon, and the spring-run chinook salmon samples. While the 1991 through 1994 winter-run chinook salmon samples show a high degree of temporal stability, the 1995 sample does not. The authors argue that this sample may

[5] D. Teel, NWFSC, Seattle, WA, unpublished data.

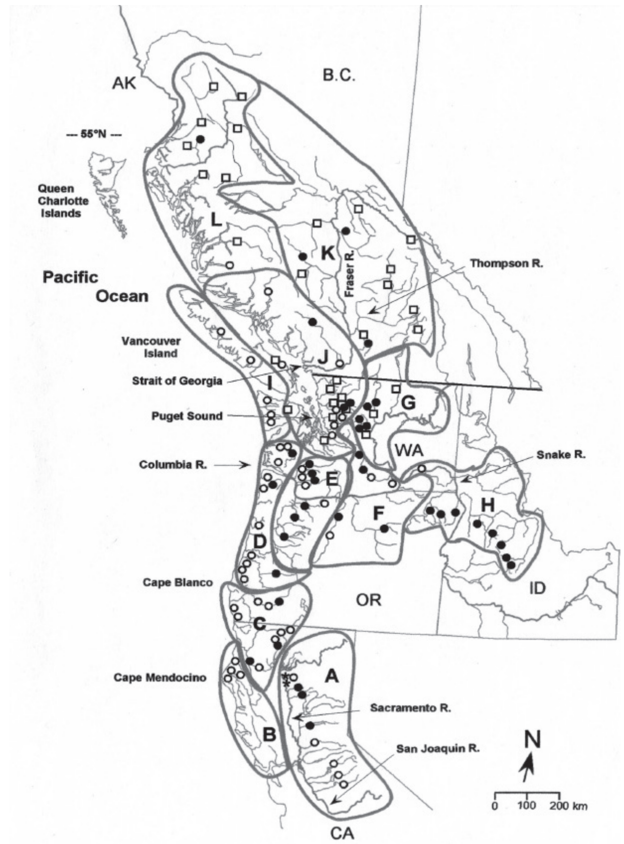

Figure 8. Populations sampled for genetic and life history data in Waples et al. (2004). Populations are coded by adult run time: closed circle = spring; open square = summer; open circle = fall; asterisk = winter. Twelve geographical provinces (A-L) used in the analysis of genetic and life history data are outlined in bold.

have some admixture with spring-run chinook salmon. The limited number of populations sampled and the use of a single locus would urge some caution in drawing strong conclusions from these data.

3.3.3 Microsatellites

Banks et al. (2000) used 10 microsatellite loci to examine the distribution of genetic variation within and among 41 wild and hatchery populations of Central Valley chinook salmon from 1991 to 1997, including representatives of winter, spring, fall and late fall runs. The number of loci examined in each of the 41 populations ranged from five to 10 loci. After initial genotyping of all individuals they adjusted their data sets in three ways. First, individuals were removed from the data set if they were missing one of five loci or two of eight or nine loci. Second, the four

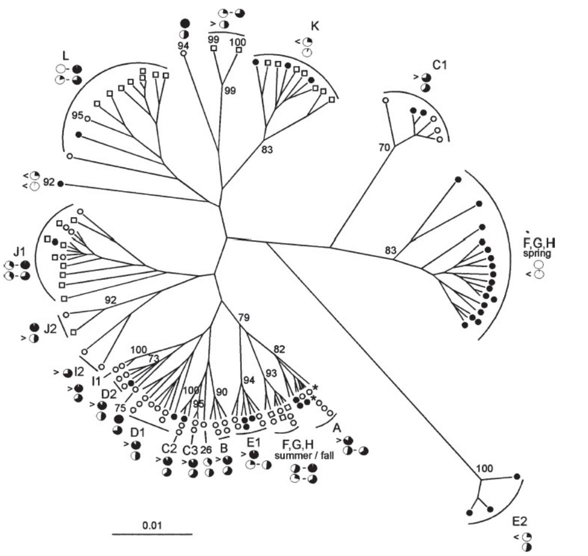

Figure 9. UPGMA phenogram of genetic distances (Cavalli-Sforza and Edwards) among 118 chinook salmon populations. Bold letters and numbers indicate provinces and areas, respectively, identified in Figure 8. Population symbols indicate adult run timing: closed circle = spring; open square = summer; open circle = fall; asterisk = winter. Genetic outliers (populations not closely affiliated with other nearby populations) are identified by their population identification number next to their symbol. Pie diagrams show the range of other life history trait values (upper: percent subyearling smolts; lower: marine harvest rate). Numbers at branch points indicate bootstrap support > 70%. Strong bootstrap support also exists for branch points within some labeled clusters but is not shown. From Waples et al. (2004).

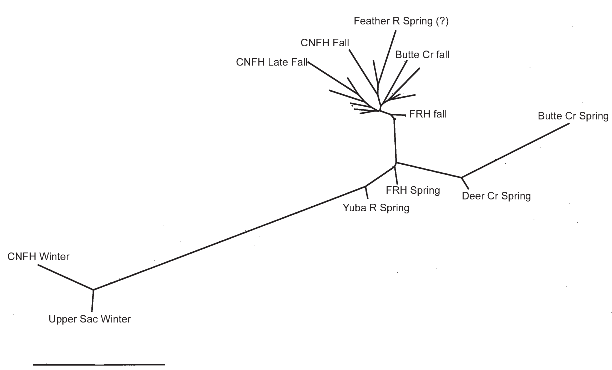

Figure 10. Neighbor joining tree (Cavalli-Sforza and Edwards chord distances) for Central Valley chinook populations, based on 24 polymorphic allozyme loci (unpublished data from D. Teel, NWFSC). Unlabeled branches are various fall-run chinook populations. CNFH = Coleman National Fish Hatchery; FRH = Feather River hatchery.

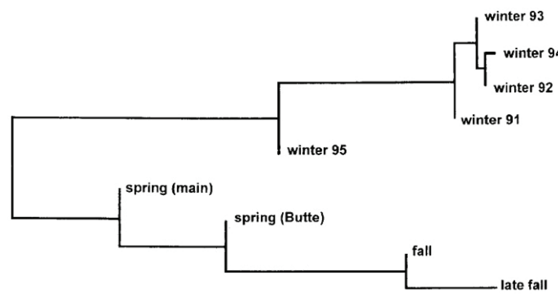

Figure 11. Phenogram based on Nei's genetic distance (D) demonstrating the relationships of Central Valley chinook runs.

populations from Butte, Mill, and Deer that involved juveniles were adjusted for apparent relatedness of individual genotypes. This procedure involved determining apparent full siblings and replacing them with putative parental genotypes. Third, winter run samples from 1991 through 1995 were determined to be admixtures of winter run and spring run. The suspect individuals were removed from the data set. After these adjustments were made, sample sizes varied from 11 to 144 with a mean of 64 individuals per population. An unweighted pair group method with arithmetic mean (UPGMA) dendrogram based on Cavalli-Sforza and Edwards chord distances from five loci showing the relationships of the 41 populations is shown in Figure 12. Four principle groupings are shown, winter run, Mill and Deer creek spring run, Butte creek spring run, and fall and late-fall. The three collections over two years of Upper Sacramento late fall run fish cluster closest to each other suggesting that they may constitute a distinct lineage.

While allele frequencies of spring-run chinook salmon in Deer, Mill, and Butte creeks appear statistically different from fall, late-fall, or winter-run populations, spring-run chinook salmon in the Feather and Yuba were not shown to be differentiated from fall-run chinook salmon by the allozyme data from Teel et al. (unpublished data) or the microsatellite data in Banks et al. (2000). A more detailed examination of putative spring-run chinook salmon adults using 12 microsatellite loci was conducted by Hedgecock (2002). Putative spring run hatchery samples from 1994, 1995, 1996 and 1999 and wild fish from 1996 and 2000 in the Feather were compared to Feather River fall run hatchery fish from 1995 and 1996, wild fish from Butte and Deer creeks, and a composite fall run sample from multiple locations. Eleven of fifteen pairwise comparisons among putative Feather River spring run samples were not significantly different from zero where only one

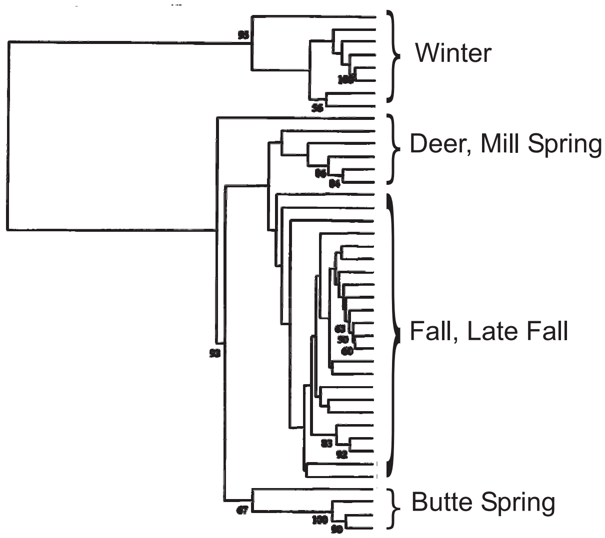

Figure 12. UPGMA dendrogram of Cavalli-Sforza and Edwards chord distances based on 5 microsatellite loci. Numbers at branch points indicate bootstrap percentages. Figure adapted from Banks et al. (2000).

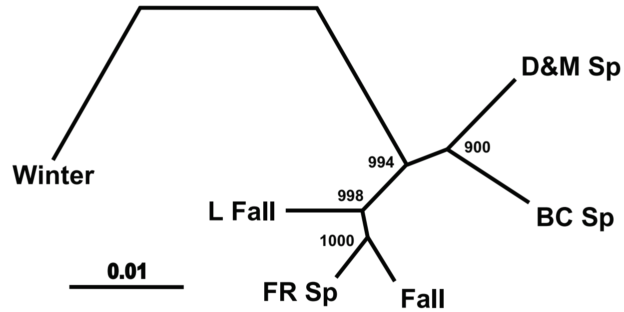

Figure 13. Neighbor joining tree (Cavalli-Sforza and Edwards chord distances) for Central Valley chinook populations, based on 12 microsatellite loci. D&M = Deer and Mill Creek; BC = Butte Creek; FR = Feather River; Sp= spring chinook; L Fall = late-fall chinook; Winter = winter-run chinook salmon. The tree was constructed using Cavalli-Sforza and Edwards measure of genetic distance and the unweighted pair-group method arithmetic averaging. The numbers at branch points indicate the number of times that these neighbors were joined together in 1000 bootstrap samples.

of twelve pairwise comparisons of these six samples with the two Feather River hatchery samples were not significantly different from zero. It should be pointed out that all but one of these twelve pairwise comparisons have F_{ST} values less than 0.01 (i.e., they are very similar). Also, the 1995 fall run hatchery sample is significantly different from the composite fall run sample and the F_{ST} for this comparison exceeds that for nine of the twelve comparisons between putative spring run and fall run samples within the Feather River. This latter point underscores how tenuous the significance levels are in these comparisons. That being said, all of these putative spring-run samples in the Feather River show a very close genetic similarity with the fall-run fish and little similarity to spring-run fish from Butte, Mill, or Deer creeks. In fact tagging studies of hatchery fish in the Feather River hatchery show that progeny from spring- and fall-run matings can return at either time and progeny from fall-run matings have been used in subsequent spring-run matings and vice versa (California Department of Fish and Game, 1998). Hedgecock (2002) show an UPGMA tree that combines related populations into six major groupings of Central Valley chinook salmon (Figure 13).

Williamson and May (2003) developed new microsatellite markers with more alleles per locus than those used previously in the Central Valley and used them to look for differences between fall-run chinook salmon from the Sacramento basin and fall-run chinook salmon from the San Joaquin basin. They used seven loci to examine variation within and among spawning adults from 23 samplings across three years, including four hatcheries and nine natural spawning populations. Seventeen to 75 alleles per locus were found supporting the view that a large amount of variation is present within these populations. However, limited differentiation was observed among the populations, far less than observed for chinook salmon in other regions of north America.

3.3.4 mtDNA

Nielsen et al. (1997) present data on the distribution of seven mitochondrial haplotypes among fall (nine locations, 479 individuals), late-fall (two locations, 56 individuals), spring (two locations, 113 individuals), and winter (one location, 46 individuals) runs of chinook salmon from 1992-1995. Fall- and late-fall-run fish revealed one rare and four common haplotypes. Of the four common haplotypes in fall-run fish, three were found in spring-run fish and only one in winter-run fish. The missing haplotype in the spring-run fish is the least common among the fall- and late-fall-run fish. Winter-run fish showed one rare haplotype as well. Nielsen et al. (1997) question whether several of the samples (1994 Deer Creek and both Butte Creek samples) were actually spring-run fish. If not, then the spring run may only possess two of the common fall and late-fall haplotypes. These results support the view of winter-run fish being differentiated from the other runs, and that Deer Creek spring-run chinook salmon are genetically distinct from spring-run chinook salmon in Butte Creek and the Feather River.

3.3.5 Synthesis and conclusions

How are we to interpret the above results? Each of the described studies suffers from various weaknesses in experimental design and violates several of the assumptions discussed in Appendix A. One common theme among many of the studies is probable violation of the sampling accuracy assumption. Whenever a juvenile sample is taken, there is the possibility of overlap of some run types and an overrepresentation of only a few families. Samples taken at weirs and fish ladders may represent multiple spawning populations. It is also doubtful that today's distribution of genetic variation within and among extant populations of chinook salmon in the Central Valley is very similar to the distribution 50, let alone 200, years ago. Nevertheless, a synthesis of the extant genetic data reveals the following picture.

1. Central Valley chinook salmon, including all run types, represent a separate lineage from other chinook salmon, specifically from California coastal chinook salmon (Waples et al., 2004).

2. Within the Central Valley and its currently available natural spawning habitat and hatcheries, there are four principle groupings that might form the basis of separate meta-population structures: (1) all winter-run chinook salmon, (2) Butte Creek spring-run chinook salmon, (3) Deer and Mill Creek spring-run chinook salmon, and (4) fall-, late-fall-, and Feather/Yuba spring-run chinook. The fourth group is represented by at least a dozen discrete spawning areas (i.e., major rivers). The first three groups are perilously close to extirpation since the first group (winter-run chinook salmon) is represented by only a single natural population and one hatchery population, the second (Butte Creek spring-run chinook salmon) is supported by a single spawning area and the third (Deer and Mill creek spring-run chinook salmon) is represented by just two discrete spawning areas. The data in Banks et al. (2000) suggest that the late fall run represents a fifth lineage.

3. Fall-run chinook salmon populations and spring-run chinook salmon in the Feather and Yuba rivers are very similar genetically to each other, probably because of the extensive movement of eggs among facilities and smolts to downstream areas (Williamson and May (2003), Teel, unpublished data; Hedgecock (2002)). This movement has included trucking of smolts downstream and transport of eggs from one hatchery to another. While the phenotype for early entrance into freshwater still persists in the Yuba and Feather rivers, the mixing of gametes of these fish with fall run fish has almost certainly led to homogenization of these runs. The genetic results from Hedgecock (2002), the existence of springtime freshwater entry, and the possible segregational natural spawning of spring-run fish in the Feather River system suggest that rescue of a spring run in the Feather may be possible, even though there has been extensive introgression of the fall run gene pool into that of the spring run. Further, the capacity of salmonid fishes to rapidly establish different run timings may make reestablishing discrete temporal runs in rivers possible if separate spawning habitats can be made available. It is doubtful that this phenotype will persist without immediate and direct intervention to preserve the genetic basis of spring run timing.

4. No data exist and therefore no conclusions are available for spring-run chinook salmon that exist in Big Chico, Antelope, Clear, Thomes, and Beegum creeks.

3.4 Life history diversity

While CDFG has recently been collecting life history information on spring-run chinook salmon in Mill, Deer and Butte creeks, limitations in the sampling prevent assessment of whether there are significant differences among spring-run chinook salmon in these streams. Interested readers can go to Appendix B, which summarizes the available data.

3.5 Population dynamics

Time series of population abundance are available only for the extant spring-run chinook salmon spawning groups in Butte, Deer and Mill creeks and the Feather River. Given the strong genetic divergence of Butte Creek spring-run chinook salmon from the Mill and Deer groups, and the close relationship of Feather River spring-run chinook salmon to Feather River fall chinook, the main question is whether Mill Creek and Deer Creek form a single population.

Inspection of the time series of spawner abundance (Figure 14) shows that spring-run chinook salmon in Deer and Mill creeks have had roughly similar patterns of abundance, with relatively high abundance in the late 1950s and 1970s (not shown), and a recent upturn in abundance

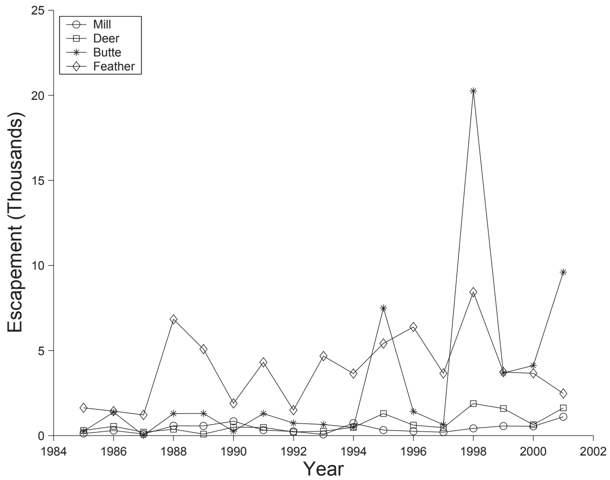

Figure 14. Estimated escapement of spring-run chinook in Mill, Deer, Butte creeks and the Feather River.

in beginning in the late 1990s. Big Chico creek has shown a similar pattern, but the extended periods of no spawners indicates that this is not an independent population. Butte Creek also had peaks of abundance around 1960, but abundance was low throughout the 1970s and the recent increase in abundance has been much larger than in the other streams. A major caveat in interpreting the spring-run chinook salmon spawning escapement data is that population estimation techniques were not standardized until the 1990s.

The population dynamics of Mill and Deer creeks can be compared quantitatively in several ways. The simplest way is to compare estimates of the parameters that describe the population time series. The simplest model that can capture the observed dynamics is the random-walk-with-drift (RWWD) model (Dennis et al., 1991). In the RWWD model, population dynamics are governed by exponential growth (drift) with random variation (the random walk). Measurement error in the population estimates can be accounted for by recasting the RWWD model as a state-space model (Lindley, 2003), which reduces the bias in estimates of the process error variation. Table 1 shows the parameter estimates of the state-space RWWD model when applied to the spawner escapement data. Parameter estimates for both populations are similar, with broadly overlapping probability intervals for parameter estimates.

A potentially more informative approach is to fit models that describe various levels of interaction among populations, and evaluate the relative performance of the models with some metric, such as Akaike's information criterion (AIC) (Burnham and Anderson, 1998). We fit three models: the simple RWWD model where Mill Creek and Deer Creek are independent, a model where there is no migration between the populations but there is correlation in the environment (expressed as covariation in the process variation), and a model where migration is allowed between the populations. The models are described in more detail in Appendix C.

The best model, in terms of AIC, is the model with no migration and uncorrelated process variation. The other models do fit the data slightly better, but not enough to justify their additional parameters. The model with correlated errors is not very compelling— AIC is higher and the estimate of the covariance is biologically insignificant. The migration model is more compelling— while it had the highest AIC (and was thus the least supported by the data), the estimates for migration rates were biologically significant, with a little more than half of the probability mass below the 0.10 migration rate thought to indicate demographic dependence (McElhany et al., 2000). In summary, the population trends in Mill and Deer creeks suggest that these populations have independent dynamics, although the evidence for independence from this analysis of population dynamics is not overwhelming.

3.6 Environmental characteristics

3.6.1 Ecoregional setting

The Sacramento-San Joaquin basin spans several major floristic ecoregions (as defined by Hickman (1993)), including the Great Central Valley, the Sierra Nevada, the southern Cascades, northwestern California, and the Modoc Plateau (Plate 5). Spring-run chinook salmon pass through the alluvial plains of the Great Valley during their migrations to and from the ocean. Spring-run chinook salmon spawning and rearing occurred mainly in the southern Cascades and the Sierra Nevada ecoregions, with some populations using basins in the Modoc plateau and northwestern California ecoregions.

3.6.2 Hydrographic variation

Precipitation generally declines from north to south along the Central Valley, but orographic effects are an extremely important source of variation in precipitation[6] (Plate 6). West-facing, high-elevation basins generally receive more total precipitation and more precipitation as snow. The basins draining into the Sacramento River are generally

[6] Precipitation climatology data obtained from The Climate Source Inc., Corvallis, OR.

Table 1. Parameter estimates for random-walk-with-drift model. Numbers in parentheses are 90% central probability intervals.

Stream	population growth rate	variance of growth rate
Deer Creek	0.112 (-0.097, 0.307)	0.346 (0.122, 0.699)
Mill Creek	0.042 (-0.200, 0.273)	0.439 (0.197, 0.730)

lower in elevation than those draining into the San Joaquin, and are more driven by rainfall than the snow-melt driven San Joaquin basin streams. Stream discharge is further influenced by the geology of the basin (shown in Plate 7). Highly fractured basalts and lavas found more commonly in the southern Cascades can store water and release it through springs, dampening variation in discharge and maintaining relatively high and cool flows during summer months.

Spring-run chinook salmon evolved in the pre-dam period, and we must therefore examine the unimpaired[7] hydrography of the Central Valley to understand how hydrographic variation might have driven population differentiation. Fortunately for the Central Valley TRT, the U. S. Army Corps of Engineers and State of California Reclamation Board estimated the unimpaired hydrography of the Central Valley as part of a comprehensive study of Central Valley hydrography (USACOE, 2002). As described by California Department of Water Resources (CDWR) (1994), "unimpaired" flow (the flow that would have occurred if dams and major diversions were not in place) was computed from various flow gauges. Prehistoric conditions were probably somewhat different, since other anthropogenic factors also influence flow, and these were not accounted for the in the calculation of unimpaired flow. Such effects include consumptive use of water by riparian vegetation that is no longer present, reduced groundwater accretion due to groundwater withdrawals, the effects of floodplains that are no longer connected to channels, and the episodic outflow from the Tulare Lake basin.

Figure 15 shows the mean monthly unimpaired discharge for 28 hydrologic units, and Figure 16 shows the month of peak discharge for these same units. In general, Sacramento River tributaries draining lower elevation basins of the southern Cascades (e.g., Sacramento Valley eastside tributaries such as Mill, Deer and Butte creeks) have peak discharges in February, and Sacramento and San Joaquin tributaries draining high elevation basins in the Sierra Nevada (e.g., Feather, Yuba, Tuolumne rivers) have peak discharges in May. Tributaries to the

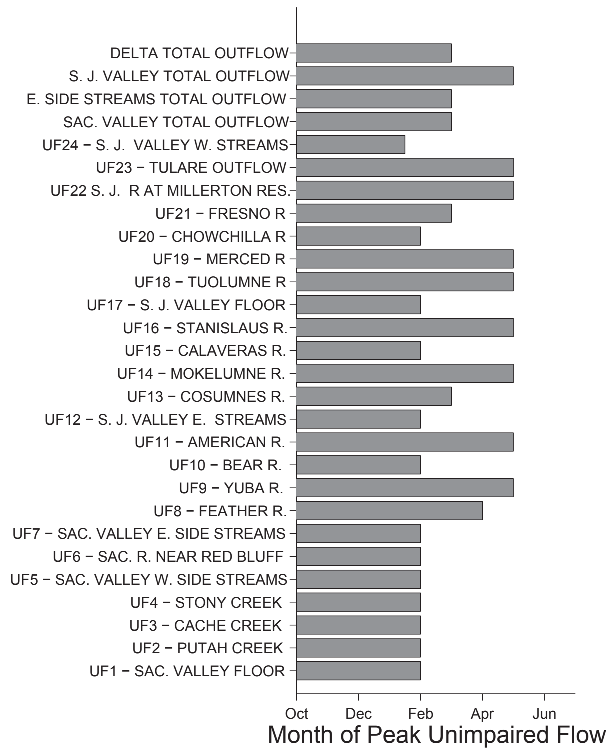

Figure 16. Month of peak discharge for the Sacramento and San Joaquin rivers and assorted tributaries, prior to development of on-stream reservoirs.

Sacramento arising in the Cascades ("Sac. Valley E. Side Streams" and "Sac. R. Near Red Bluff" in Figure 15) maintain relatively high flows with low interannual variability over the late summer compared to streams that historically supported spring-run chinook salmon in the southern Sierra (e.g., Stanislaus River).

3.6.3 Thermal variation

There are some major differences in thermal regime among Central Valley subbasins. Plate 8 shows the average high air temperature in August in the Sacramento-San Joaquin basin, Plate 9 shows the average low temperature in January, and Plate 10 shows the range between

[7]"Unimpaired" in the sense of USACOE (2002).

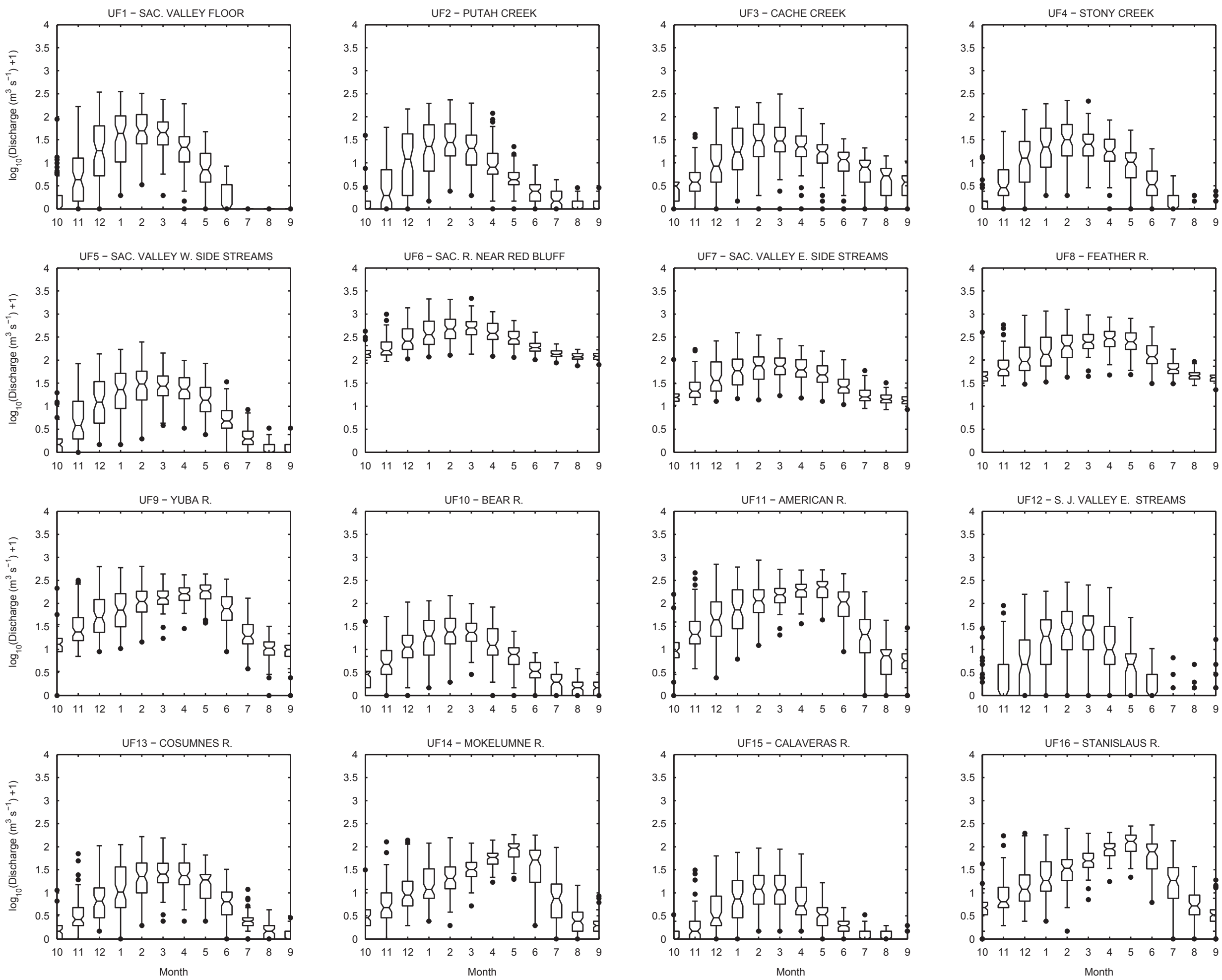

Figure 15. Estimated monthly discharge of the Sacramento and San Joaquin rivers and assorted tributaries, prior to development of on-stream reservoirs. Center of notch indicates median; notch represents standard error of median; box covers interquartile range; whiskers cover 1.5 $\times$ interquartile range; outliers are represented by dots. Year of record is water year, 1 October-30 September, and discharge is $\log_e \mathrm{m}^3\mathrm{s}^{-1}$.

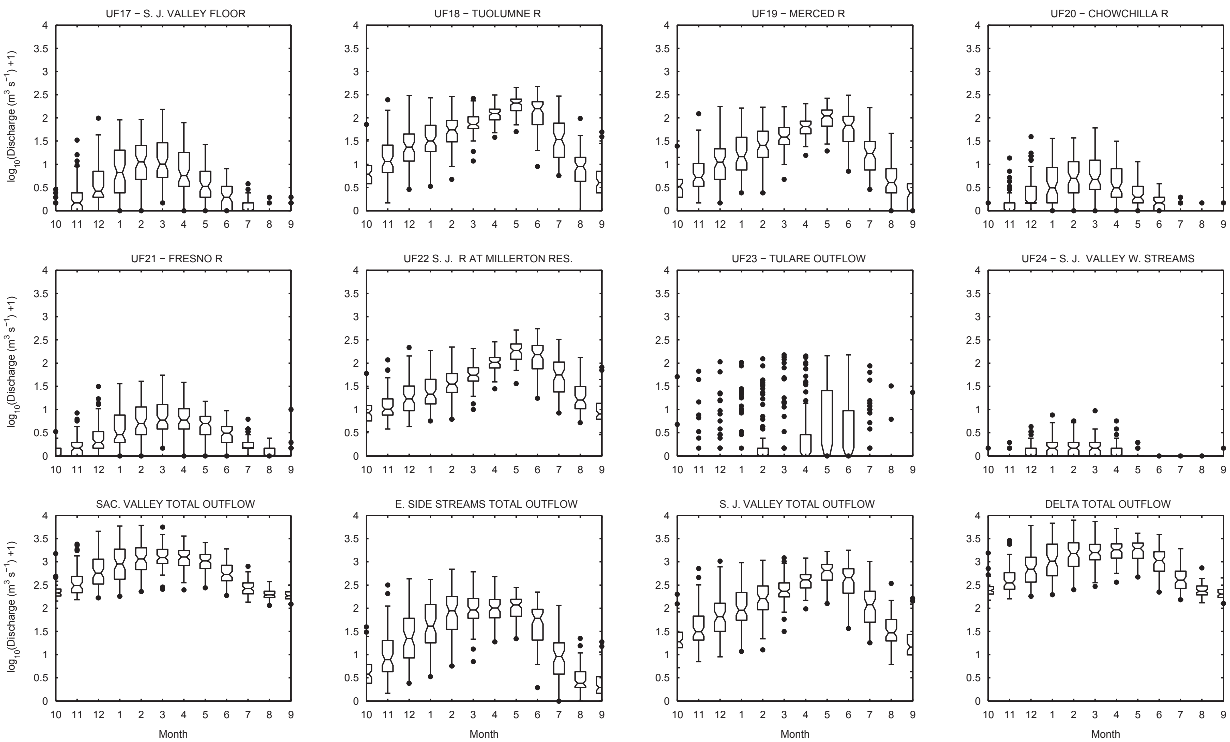

Figure 15. Continued. Estimated monthly discharge of the Sacramento and San Joaquin rivers and assorted tributaries, prior to development of on-stream reservoirs. Center of notch indicates median; notch represents standard error of median; box covers interquartile range; whiskers cover 1.5 $\times$ interquartile range; outliers are represented by dots. Year of record is water year, 1 October-30 September, and discharge is $\log_e \mathrm{m^3 s^{-1}}$.

these values[8]. Not surprisingly, temperature decreases with increasing elevation and latitude. Among drainages that historically supported spring-run chinook salmon, the Feather and Pit drainages stand out as being particularly warm in summer and highly variable over the year. This contrasts with the central and southern Sierra drainages, which are cool in the summer and show minimal seasonal variation.

3.7 Synthesis of environmental information

We conducted a principle components analysis of the environmental data described above to see how watersheds relate to each other in multivariate space and to identify common patterns of variation. The analysis is described in detail in Appendix D; the most important results are presented here.

The first two principle components, describing 55% of the variance, strongly delineate the upper Sacramento basins (southern Cascades and Coast Range drainages) from the lower Sacramento-San Joaquin basins (Sierra Nevada drainages), largely on the basis of their different geology, ecoregion, timing of peak flow, elevation, and temperature (Figure 17). The PCA does not reveal a strong split between northern and southern Sierra drainages, but with the exception of Butte Creek, the southern Cascades and Coast Range basins are well-separated. Butte Creek clusters with Coast Range streams due to its relatively low altitude and warm temperature. Some pairs of watersheds group very closely together in both the multivariate space defined by the PCA and actual geographic space, including Mill-Deer, Pit-McCloud, North and Middle Fork Feather, North and Middle Fork American, and Mokelumne-Stanislaus.

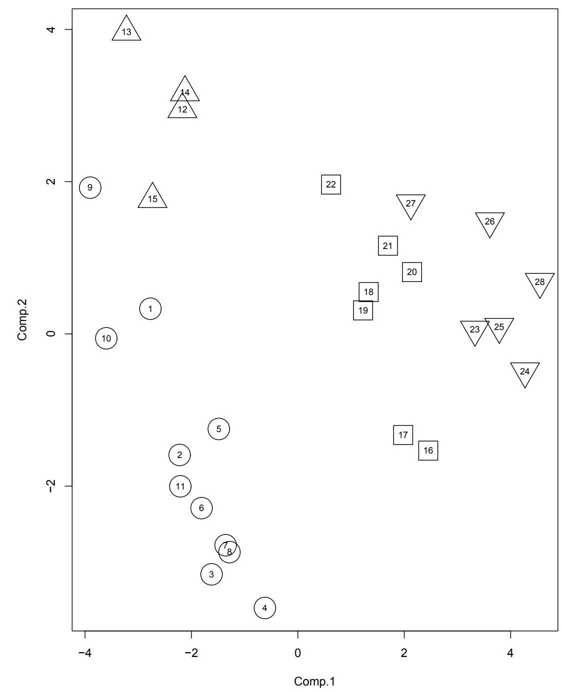

Figure 17. Principle components analysis of environmental attributes. Symbols denote regions: ◯–Southern Cascades; □–Northern Sierra; △– Coast range; ▽– Southern Sierra. Numbers indicate stream: 1–Upper Sacramento; 2–Lower Pit; 3–Fall; 4–Hat; 5–McCloud; 6–Battle; 7–Mill; 8–Deer; 9–Butte; 10–Big Chico; 11–Antelope; 12–Clear; 13–Cottonwood; 14–Thomes; 15–Stony; 16–NF Feather; 17–MF Feather 18–SF Feather; 19–WB Feather; 20–Yuba; 21–N&MF American; 22–SF American; 23–Mokelumne; 24–Stanislaus; 25–Tuolumne; 26–Merced; 27–San Joaquin; 28–Kings.

4 Structure of the Central Valley spring-run chinook ESU

In this section, we describe the structure of the Central Valley spring-run chinook salmon ESU in terms of geographic groups, independent populations, and dependent populations. Although there are differences in physical habitat among streams within the groups there are also general similarities regarding climate, topography and geology that make them useful categories for discussion of the spatial structure of Central Valley spring-run chinook. These groups should be considered in the assessment of ESU-level viability, because spatial diversity is directly related to these units, and genetic diversity is likely to be so as well.

4.1 Population groups

We initially delineated population groups on the basis of geography as defined by mountain ranges (Coast Range, southern Cascades, northern Sierra and southern Sierra) and associated thermal and hydrographic conditions (Figure 18). The geographically-based grouping is well-supported by the PCA results (Figure 17). We retained the split between the northern and southern Sierra because these basins drain into different major rivers and because although they did not form well-separated groups in multivariate space, the groups did not overlap.

[8] Temperature climatology data obtained from The Climate Source Inc., Corvallis, OR

The geology, elevation and aspect of the basins in the different groups causes hydrology to vary among the regions. Streams in the southern Cascades group are influenced by springs that maintain relatively high summer flows and lower interannual variability in summer flow. The Coast Range group encompasses streams that enter the Sacramento River from the west. These streams originate in the rain shadow of the coast range, and appear to be marginally suitable for spring-run chinook salmon under current climate conditions. These streams are strongly influenced by rainfall, with relatively small annual discharge and high interannual variability. The northern Sierra group is composed of the Feather and American River drainages, which are tributaries to the Sacramento with high annual discharge and predominately granitic geologies. Rivers in the southern Sierra group drain into the San Joaquin River (or directly into the delta, in the case of the Mokelumne River), and have hydrologies dominated by snowmelt.

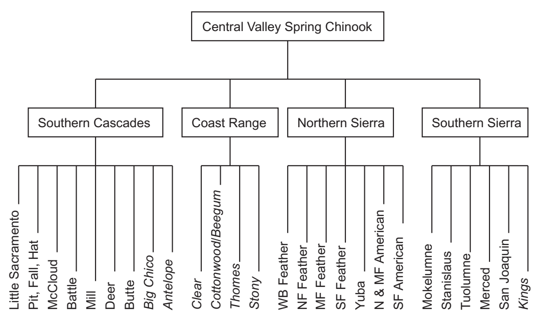

Figure 18. Historical structure of the Central Valley spring-run chinook salmon ESU. Independent populations are in regular type; dependent populations are in italics. In this figure, Mill and Deer creek spring-run chinook salmon populations are indicated as independent, although the TRT will also consider the possibility that spring-run chinook salmon in these two streams form a single population.

4.2 Independent populations

If we assume that spawning groups in different geographic groups are independent, the question then becomes which populations or groups of populations within these groupings formed independent populations. Several characteristics were used to decide whether populations were independent: distance from a basin to its nearest neighbor (at least 50km), the basin size (generally at least 500 km^2), and significant environmental differences between basins inside of the distance criterion. It is likely that historically there was significant population structure within these basins associated with various tributaries. Contemporary data on population genetics and dynamics were also used directly, where available, and indirectly to substantiate the isolation rule of thumb. Table 2 summarizes the independent and dependent populations of spring-run chinook salmon that historically existed in the Central Valley. The remainder of this section consists of discussions of these populations.

4.2.1 Little Sacramento River

The Little, or Upper, Sacramento is a spring-fed river draining Mt. Shasta. The river itself divides the volcanic southern Cascades ecoregion from the granitic northwestern California ecoregion. It is a moderate-size basin (2370 km^2), well-isolated from its nearest neighbor, the McCloud River (83 km between 500m points). It, unlike the McCloud, is not known to have supported bull trout (Moyle et al., 1982), but did support winter-run chinook salmon as well as spring-run chinook salmon (Yoshiyama et al., 1996). We concluded the the Little Sacramento was large enough and well-isolated enough to have supported an independent population of spring-run chinook salmon. Access to the Little Sacramento is presently blocked by Keswick and Shasta dams.

4.2.2 Pit River–Fall River–Hat Creek

It is not clear whether the middle Pit River itself actually supported spawning spring-run chinook salmon, but the Fall River and Hat Creek (its major tributaries) are documented to have contained spring-run chinook salmon (Yoshiyama et al., 1996). The middle and upper Pit is relatively low gradient, meandering across a flat valley floor, and is warm and turbid (Moyle et al., 1982). Large falls block access shortly above the confluence of the Fall River (Yoshiyama et al., 1996). The Fall River arises from springs at the edge of a lava field, and subsequently has a fairly large discharge of clear water. Hat Creek is similar to the Fall River. The whole region is above 500 m, and Hat Creek and the Fall River are within 50 km of each other. Based on the similarity and proximity of Hat Creek and the Fall River, and the fairly short lengths of accessible habitat within the tributaries, we decided that this area probably was occupied by a single population that had significant substructure. Access to this watershed is presently blocked by Keswick and Shasta dams.

Table 2. Historical populations of spring-run chinook salmon in the Central Valley. Criteria for independence include isolation (I), minimum basin size (S), and substantial genetic differentiation (G). See text for detailed discussion.

Independent Populations	Criteria met	Notes
Little Sacramento River	I, S	
Pit–Fall–Hat rivers	I, S	
McCloud River	I, S	only basin to support bull trout
Battle Creek	I, S	
Butte Creek	I, S, G	
Mill and Deer creeks	I, S, G	TRT will analyze as one or two populations
NF Feather River	I, S	
WB Feather River	I, S	
MF Feather River	I, S	
SF Feather River	I, S	
Yuba R	I, S	relationship between historical and current populations unknown
N & MF American River	I, S	
SF American River	I, S	
Mokelumne R	I, S	
Stanislaus River	I, S	
Tuolumne River	I, S	
Merced River	I, S	
San Joaquin River	I, S	
Dependent Populations		
Kings River		basin frequently inaccessable to anadromous fish
Big Chico, Antelope, Clear, Thomes, Cottonwood, Beegum and Stony creeks		not enough habitat to persist in isolation

4.2.3 McCloud River

The McCloud River, a spring-fed tributary to the Pit River, drains Mt. Shasta, and was swift, cold and tumultuous before hydropower development (Moyle et al., 1982). The McCloud River is the only Central Valley river known to have supported bull trout (*Salvelinus confluentus*), extirpated from the McCloud in the 1970s (Moyle et al., 1982)), and it also supported winter-run chinook salmon salmon. The area above 500 m elevation is isolated from other areas historically used by spring-run chinook salmon, being over 100 km from Hat Creek, Battle Creek, Fall River, and the mainstem Pit River. We concluded that the McCloud River was large enough and well-isolated enough to have supported an independent population of spring-run chinook salmon. Access to this watershed is now blocked by Keswick and Shasta dams.

4.2.4 Battle Creek

Battle Creek is a spring-fed stream draining Mt. Lassen, a Cascadian volcano. It is known to have supported winter-run, spring-run, and fall-run chinook salmon. Its nearest neighbors are rather distant (>80 km) west-side streams (Clear and Beegum creeks) that have quite different hydrologies and offer marginal habitat for spring-run chinook salmon. The more ecologically-similar McCloud and Little Sacramento rivers are well over 100 km away. We concluded that Battle Creek historically contained an independent population of spring-run chinook salmon. It is possible, however, that Battle Creek received significant numbers of strays from the major upper Sacramento River tributary populations. Very large numbers of spring-run chinook salmon migrated past Battle Creek, and if only a small fraction strayed into Battle Creek, this might have had a significant impact on the Battle Creek population. Presently, hydropower operations and water diversions prevent access to areas suitable for spring-run chinook salmon spawning and rearing, but there are no large impassable barriers in Battle Creek.

4.2.5 Butte Creek

Butte Creek and its spring-run chinook salmon appear to be unique. The fish are genetically distinct from spring-run chinook salmon from Mill and Deer creeks. Banks et al. (2000) and Hedgecock (2002), using microsatellites, Kim et al. (1999), using MHCII, and Teel (unpublished), using allozymes, found Butte Creek spring-run chinook salmon to be quite distinct from spring-run chinook salmon in Mill and Deer creeks as well as spring-run chinook salmon from the Feather River and other chinook salmon groups in the Central Valley. Such genetic distinctiveness indicates nearly complete isolation from other chinook populations. Butte Creek spring-run chinook salmon have an earlier spawning run timing than other extant Cascadian populations. Physically, the Butte Creek watershed is unusual for a spring-run chinook salmon stream, being low elevation (all spawning occurs below 300 m) and having rather warm summer water temperatures (exceeding 20°C in 2002 in the uppermost and coolest reach). Such warm temperatures are observed only in the lower reaches of Mill and Deer creeks. It appears that Butte Creek spring-run chinook salmon regularly survive temperatures above the incipient lethal limit reported for chinook salmon, suggesting that they may be adapted to warmer temperatures that most chinook stocks, although spring-run in Beegum Creek apparently survive in similar temperatures[9], and spring-run in the San Joaquin River were reported to do so as well (Clark, 1943; Yoshiyama et al., 2001). While the headwaters of Butte, Deer and Mill creeks are close together, Butte Creek joins the Sacramento River quite far downstream from Mill and Deer, having a long run across the valley floor. We concluded that Butte Creek contains an independent population of spring-run chinook salmon. Access to Butte Creek is presently adequate, although during drought years in recent decades, water diversions have caused the lower reaches to run dry during the spring-run chinook salmon migration period (California Department of Fish and Game, 1998).

4.2.6 Mill and Deer creeks

The question of whether Mill and Deer creeks support two independent populations or a single panmictic population of spring-run chinook salmon is a thorny one. Evidence supporting the panmictic hypothesis includes information on population genetic structure, life history, and habitat attributes. The frequencies of microsatellite alleles in Mill and Deer creeks are not significantly different (Banks et al., 2000; Hedgecock, 2002), although the small sample sizes in these studies provide limited statistical power. Habitat attributes of these adjacent basins are remarkably similar in terms of watershed area, elevation, precipitation, and geology, and the two streams clustered closely together in the PCA. Basin areas are small— the Mill Creek watershed is smaller than any watershed occupied by an independent chinook population in the Puget Sound (Currens et al., 2002). The best available information suggests that Mill and Deer creek spring-run chinook salmon populations were never very large historically; (Hanson

[9] public communication, D. Killam, CDFG, Red Bluff, CA.

et al., 1940) estimated that Mill Creek could support about 3000 and Deer Creek about 7500 spring-run chinook salmon spawners. Furthermore, large numbers of spring-run chinook salmon once migrated past Mill and Deer creeks on their way to upper Sacramento tributaries, and Mill and Deer creeks may have received significant numbers of strays, causing their dynamics to be linked to that of the up-river tributary populations.

Evidence supporting the independent populations hypothesis includes spatial isolation and population dynamics. The distance between the 500 m isopleths in Mill and Deer creeks is 89 km, longer than the 50 km cutoff used to distinguish independent chinook populations in the upper Columbia domain (Interior Columbia Basin Technical Recovery Team, 2003). The mouths of the two creeks, however, are much closer together, roughly 25 km. Analysis of contemporary spawning escapement trends supports the independence hypothesis, but not overwhelmingly so (See Appendix C for the analysis).

We could reach no conclusion as to whether Mill and Deer creeks are independent of one another, although we did conclude that spring-run chinook salmon in these streams are currently independent from other spring-run chinook salmon populations. The TRT will conduct viability analyses that consider the streams as independent populations and as a panmictic population. Given that these two streams represent a significant lineage within Central Valley chinook and are a major component of the extant ESU, we suggest that parties implementing recovery actions choose results from the more precautionary alternative.

4.2.7 North Fork Feather River

The North Fork Feather River is well-isolated from other higher-elevation areas of the Feather River, and is in the southern Cascades while the other subbasins of the Feather are in the Sierra Nevada ecoregion. The headwaters are fed by rainfall and by snowmelt from Mt.Lassen, and rocks are predominately of volcanic origin. Spring-run chinook salmon could ascend quite high in this river (Yoshiyama et al., 1996). The TRT concluded that the North Fork Feather River likely contained an independent population of spring-run chinook salmon. Access to this watershed was blocked by Oroville Dam in the 1968; habitat above Oroville is thought to be in good condition[10].

[10]E. Thiess, NOAA Fisheries SWRO, Sacramento, CA, personal communication.

4.2.8 West Branch Feather River

The West Branch of the Feather River is a tributary to the North Fork of the Feather River that drains a fairly small basin (430 km^2), but according to Yoshiyama et al. (1996), spring-run chinook salmon moved quite far up into the basin. The 500-m contour crossing of the West Branch is about 63 km from the 500-m crossing of the North Fork and 69 km from the Middle Fork of the Feather. The West Branch of the Feather River, unlike other tributaries of the Feather, is completely within the southern Cascades ecoregion. Given the large amount of the west branch that was historically used by spring-run chinook salmon, its position in the Cascades ecoregion, and its isolation from other systems, the TRT concluded that the West Branch of the Feather River contained an independent population of spring-run chinook salmon, in spite of the small area of the basin. An alternative hypothesis is that the West Branch and North Fork together supported an independent population with significant internal structure. Like other tributaries of the Feather River, access to the West Branch is presently blocked by Oroville Dam.

4.2.9 Middle Fork Feather River

The Middle Fork Feather River is a large basin (> 3000 km^2), and is quite different than the adjacent North Fork Feather River. The Middle Fork is entirely within the Sierra Nevada ecoregion, although the watershed is lower in elevation compared to more southerly Sierra basins. The Middle Fork is over 100 km from it nearest neighbor, the South Fork Feather River. Such a distance between suitable spawning and rearing environments suggests that migration between these rivers was low in demographic terms. The TRT concluded that the Middle Fork Feather River historically contained an independent population of spring-run chinook salmon. Access to this watershed is blocked by Oroville Dam.

4.2.10 South Fork Feather River

As discussed in the preceding section, the South Fork of the Feather River probably was home to an independent population of spring-run chinook salmon. Access to this watershed is blocked by Oroville Dam.

4.2.11 Yuba River

The Yuba River is a tributary to the Feather River, joining the Feather River on the floor of the Central Valley. The Yuba River basin as a whole is fairly large (3500 km^2) and well-isolated from the American and Feather rivers

(≈ 250 km and 150 km, respectively). Peak discharge in the Yuba River occurs somewhat later than in the Feather River. Within the basin, the north, middle and south forks of the Yuba River cross the 500 m elevation line within 11-37 km of each other, suggesting that some exchange among these basins was likely, but that there may have been significant structuring of the population within these tributaries. In the absence of further information, we will treat the entire Yuba River as a single independent population, while recognizing that there may have been significant population structure within the Yuba River basin. Access to much of the areas historically utilized for spawning and rearing is now blocked by Englebright Dam.

4.2.12 North and Middle Fork American River

The American River basin, as a whole, is the third largest sub-basin in the Central Valley that historically supported spring-run chinook salmon, and its spawning areas are well-isolated from the adjoining Yuba and Mokelumne rivers. Clearly, spring-run chinook salmon populations in the American River would have been independent from those in other basins; the question then is whether sub-basins within the American might have contained independent populations.

The North Fork of the American River has an area of roughly 1000 km^2 and the Middle Fork's area is about 1600 km^2. Both basins extend to the crest of the Sierra Nevada. Yoshiyama et al. (1996) documents the presence of spring-run chinook salmon in both basins. The 500-m crossings of the two rivers are only 10 km apart. Following the isolation rule of thumb, we concluded that together, the North and Middle Forks of American River supported an independent population of spring-run chinook salmon. It is possible that each of the basins may have contained independent populations. Access to these watersheds is blocked by Nimbus Dam.

4.2.13 South Fork American River

The South Fork of the American is the largest sub-basin in the American (area = 2200 km^2), and it is fairly isolated from the other American River tributaries, being about 120 km from the North and Middle forks. We concluded, from the large size and relative isolation, that the South Fork of the American River contained an independent population of spring-run chinook salmon. Access to this watershed is blocked by Nimbus Dam.

4.2.14 Mokelumne River

The Mokelumne River is unique among historical spring-run chinook salmon basins in that it drains directly into the Delta rather than into the Sacramento or San Joaquin rivers. The basin as a whole is of moderate size (2700 km^2) and it is well isolated from adjacent rivers– the Mokelumne's nearest neighbor, the American River, is about 280 km away. According to Yoshiyama et al. (1996), spring-run chinook salmon were present in the Mokelumne River, but only in the mainstem below the confluence of the various forks. The upstream limit was thought to be near the present-day location of the Electra Powerhouse (elev. 205 m). The actual amount of accessible spawning habitat was probably relatively small compared to other Sacramento and San Joaquin tributaries. We concluded that the Mokelumne River contained an independent population of spring-run chinook salmon. Access to much of this watershed is now blocked by Camanche Dam.

4.2.15 Stanislaus River

The Stanislaus River is the northernmost spring-run chinook salmon-bearing tributary to the San Joaquin River. It has an area of 2840 km^2, and is about 250 km from its nearest neighbor, the Tuolumne River. According to Yoshiyama et al. (1996), spring-run chinook salmon entered all of the forks of the Stanislaus for "considerable" distances (reaching as high as 1030 m elevation on the Middle Fork). The forks themselves enter the mainstem Stanislaus not far below the 500-m contour (distances among 500-m crossings range from 6 to 28 km). We concluded that the Stanislaus contained at least one independent population, and may have had substantial structure within the basin. Access to this watershed is presently blocked by New Melones and Tulloch dams.

4.2.16 Tuolumne River

The Tuolumne River basin has an area of nearly 4900 km^2, with much of this area at high elevation. It is 250 km from the Stanislaus River and 320 km from the Merced River. Yoshiyama et al. (1996) state that spring-run chinook salmon had access to over 80 km of the mainstem Tuolumne River, reaching nearly to the boundary of Yosemite National Park. Access to the major tributaries to the Tuolumne River, such as the Clavey River and South and Middle Forks, may have been limited by steep sections near their mouths. We concluded that the Tuolumne River contained an independent population of spring-run chinook salmon. Access to habitat suitable for spring-run chinook salmon spawning and rearing is currently blocked by La Grange and Don Pedro dams.

4.2.17 Merced River

The Merced River basin, as a whole, has an area of roughly 3250 km^2. The major tributaries join in above the 500-m contour line, suggesting little barrier to movement among spawning and rearing locations within the basin. The lowest major tributary is the North Fork, which has a substantial falls 2 km upstream from its mouth and drains a low-elevation area. According to Yoshiyama et al. (1996), spring-run chinook salmon could access at least the lower 11 km of the South Fork, and possibly significantly more if spring-run chinook salmon could pass the waterfall near Peach Tree Bar. In the mainstem, spring-run chinook salmon reached to the area of El Portal (elev. 700 m) and perhaps nearly to Yosemite Valley (Yoshiyama et al., 1996). The Merced's nearest neighbor is the Tuolumne River, over 300 km away. We concluded that the Merced River contained at least one independent population of spring-run chinook salmon, and probably had significant structure corresponding to the mainstem and South Fork. Access to habitat suitable for spring-run chinook salmon spawning and rearing is now blocked by McSwain and New Exchequer dams.

4.2.18 Middle and Upper San Joaquin River

The Middle and Upper San Joaquin basin (area above the valley floor) is a large basin (4700 km^2) and it is more than 300 km from its nearest neighbors, the Merced and Kings rivers. According to Yoshiyama et al. (1996), spring-run chinook salmon ascended as far as Mammoth Pool (elev. 1000 m), which is well below the confluence of the North, Middle and South forks. Anecdotal accounts reported by Yoshiyama et al. (1996) suggest that the population in the San Joaquin was quite large, perhaps exceeding 200,000 spawners per year. Additionally, San Joaquin spring-run chinook salmon may have been adapted to warm temperatures, like those in Butte Creek and perhaps Beegum Creek; Clark (1943) reported spring-run chinook salmon successfully holding over the summer at temperatures of 22°C. We concluded that the middle and upper San Joaquin River contained an independent population of spring-run chinook salmon. Access to habitat suitable for spring-run chinook salmon spawning and rearing is now blocked by lack of flow below Friant Dam, by Friant Dam itself, and above that, by a series of hydroelectric dams. Access to the San Joaquin had already been greatly reduced by various weirs and diversions prior to the construction of Friant Dam.

4.3 Dependent populations

In this section, we describe groups of spring-run chinook salmon that we believe were not historically independent of other populations in the Central Valley. We term them "dependent" populations because they probably would not have persisted without immigration from other streams (either because they are sink populations or part of a metapopulation). Note that dependent populations may play a role in ESU viability, and populations labeled dependent are not necessarily expendable.

4.3.1 Kings River

Yoshiyama et al. (1996) presents information indicating that spring chinook salmon spawned in the Kings River, and the Kings River basin is quite large, with substantial high-elevation areas. The Kings River drains into the Tulare Lake Basin, which in turn drains episodically into the San Joaquin basin. According to the calculations of California Department of Water Resources (CDWR) (1994), if the water storage and diversion system had not been in place during the 1921-1994 period, outflow from the Tulare Lake basin would have happened in only 38 of the 74 years, with stretches of up to 8 years without outflow. It seems that an independent population of spring-run chinook salmon would not be able to survive by spawning in the Kings River, since in many years, neither juveniles or adults could complete their migrations. However, details of the historical connection between the Kings River and San Joaquin River are not well documented (The Bay Institute, 1998), and passage for salmon may have been possible. We hypothesize that under favorable flow conditions, spring-run chinook salmon from the San Joaquin and its tributaries spawned in the Kings River, and therefore we concluded the the Kings River did not contain an independent population of spring-run chinook salmon. On the other hand, it is hard to reconcile the reports of large abundances of spring-run chinook salmon in the Kings River with its extreme isolation and its frequent inaccessibility. Perhaps, in actuality, the Kings River may have been connected to the San Joaquin basin frequently enough to support an independent spring-run chinook salmon population. Access to the Kings River is now blocked by frequently dry streambed upstream of the confluence of the Merced and San Joaquin rivers, the now-dry Tulare Lake bed, a series of irrigation weirs, and Pine Flat Dam.

4.3.2 Big Chico, Antelope, Clear, Thomes, Beegum and Stony creeks

All of these streams appear to offer habitat of marginal suitability to spring-run chinook salmon, having limited area at higher elevations and being highly dependent on rainfall. Records reviewed by Yoshiyama et al. (1996) do not suggest that spring-run chinook salmon were historically abundant in these streams. We acknowledge that the sparse historical record of fish in Beegum Creek may reflect its extreme remoteness. However, the small area of available habitat argues against the existence of an independent population.

We hypothesize that the persistence of spring-run chinook salmon population in these streams is dependent on the input of migrants from nearby streams, such as Mill, Deer and Butte creeks, and historically, spring-run chinook salmon from the extirpated populations in the upper Sacramento basin. An alternative hypothesis is that this group of streams operates as a metapopulation (Hanski and Gilpin, 1991), i.e., member populations may not be viable on their own, but migration among members of the group maintains persistence of the whole group.

The classification of these populations as dependent does not mean that they have no role to play in the persistence or recovery of the Central Valley spring-run chinook salmon ESU. If these populations are adapted to their unusual spawning and rearing habitats, they may contain a valuable genetic resource (perhaps being more tolerant of high temperatures than other spring-run chinook salmon). These habitats and populations may also serve to link other populations in ways that increase ESU viability over longer time scales.

4.4 Other spring-run chinook salmon populations

In this subsection, we discuss the status of extant spring-run chinook salmon stocks that we believe do not represent historical entities.

4.4.1 Feather River below Oroville Dam

Historically, spring-run chinook salmon probably did not spawn below the location of Oroville Dam. The dam releases cold water from its base, and this creates conditions that support an early run of chinook salmon, which are called spring-run chinook salmon by CDFG (although CDFG does not consider this population to be true spring-run chinook salmon (California Department of Fish and Game, 1998)). Presumably, this run-timing attribute is a legacy from spring-run chinook salmon populations that once spawned above Oroville Dam.

Spring-run chinook salmon currently in the Feather River are clearly independent from the spring-run chinook salmon populations in southern Cascade streams, as indicated by several genetic studies (Banks et al., 2000; Kim et al., 1999; Hedgecock, 2002). What is less clear is whether this population is independent from the Feather River Hatchery spring-run chinook salmon, or Feather River fall-run chinook.

Hedgecock (2002) found small but statistically significant allele frequency differences between Feather River spring-run chinook salmon and fall-run chinook salmon, suggesting minimal exchange between these groups (certainly much less than 10%). Hedgecock (2002) found that spring-run chinook salmon captured in the river formed a homogeneous group with spring-run chinook salmon captured in the hatchery, which suggests that the naturally-spawning population may not be independent from the hatchery spawners. California Department of Fish and Game (1998), however, reported that fish released as spring-run chinook salmon returned in the fall run at high rates, and vice-versa, suggesting that the two groups are integrated. The TRT, while perplexed by this information, believes that *F*eather River spring-run chinook salmon should be conserved because it may be all that is left of an important component of the ESU, and we will continue to consider this population in future analyses.

4.4.2 Mainstem Sacramento River, below Keswick Dam

It is highly doubtful that spring-run chinook salmon historically used the mainstem of the Sacramento River for spawning. Spring-run chinook salmon apparently began using the mainstem Sacramento River below Keswick Dam following the construction of Shasta and Keswick Dams. Recently, very few spring-run chinook salmon have been observed passing RBDD. There is no physical or obvious behavioral barrier to separate fall-run chinook from spawning with spring-run chinook below Keswick. CDFG biologists believe that serious hybridization has occurred between the runs (California Department of Fish and Game, 1998), and that spring-run chinook salmon have nearly disappeared from this stretch of the Sacramento River.

5 Structure of the Sacramento River winter-run chinook ESU

The population structure of winter-run chinook salmon was probably much simpler than that of spring-run chinook salmon. Winter-run chinook salmon were found historically only in the southern Cascades region, and the TRT found no basis for subdividing the ESU into units other than independent populations (Figure 19, Table 3). Following the logic and evidence laid out for spring-run chinook salmon in the southern Cascades region, we reached parallel conclusions: there were historically four independent populations of winter-run chinook salmon (Little Sacramento, Pit-Fall-Hat, McCloud River, and Battle Creek). The first three of these areas are blocked by Shasta and Keswick dams, and access to Battle Creek has been blocked by the Coleman National Fish Hatchery weir and various hydropower dams and diversions. Currently, there is one independent population of winter-run chinook salmon inhabiting the area of cool water between Keswick Dam and Red Bluff. Unlike spring-run chinook salmon, winter-run chinook salmon have persisted in this area due to their temporal isolation from the highly abundant fall-run chinook salmon. This area was not historically utilized by winter-run chinook salmon for spawning.

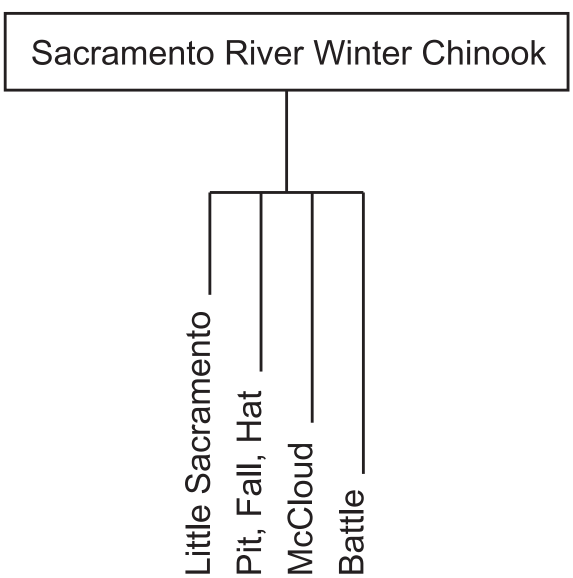

Figure 19. Historical structure of the Sacramento River winter-run chinook salmon ESU.

6 Acknowledgments

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Table 3. Historical populations of winter-run Chinook salmon in the Central Valley. Criteria for independence include isolation (I), minimum basin size (S). See text for detailed discussion.

Independent Population	Criteria met	Notes
Little Sacramento R.	I, S	
Pit–Fall–Hat Cr.	I, S	
McCloud R.	I, S	only basin to support bull trout
Battle Cr.	I, S	

A The use of population genetics for determining population structure

In this Appendix, we review common methods and concerns that should be considered in the interpretation of the results. More thorough explanations of some of this material can be found in Hallerman (2003) and references therein.

A.1 Quantitative trait loci vs. Mendelian markers

Most of the molecular markers used in population genetic studies are inherited in a simple Mendelian fashion and, with exception of the major histocompatibility complex (MHC) loci, are essentially selectively neutral. They have little or no effect on successful reproduction, and therefore the frequency of these markers does not change as a result of natural selection. Quantitative trait loci (QTLs) are those loci which code for phenotypic characters (e.g., growth rate, behavior, swimming speed, etc.). Many quantitative traits are under natural selection, and can be expected to change frequency when the population is exposed to different selective forces.

A.2 Types of molecular data

Below we discuss some of the principle types of molecular variation that have been used to gather data for chinook populations. These data come from two principle forms of analysis, separation of DNA sequences in matrices or gels (e.g., starch, agarose, acrylamide; Figure 20) or direct determination of DNA sequences (Figure 21).

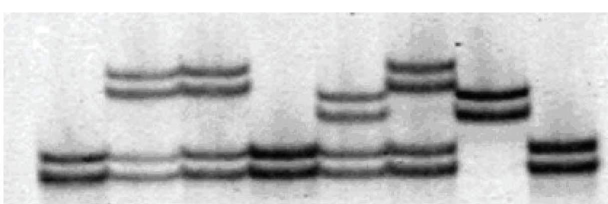

Figure 20. Microsatellite variation where each allele is portrayed by two bands, each representing one of the two strands of a DNA molecule. Vertical sets of bands are derived from single individuals. Individuals with two bands are homozygous for the same allele, receiving the same from both parents and individuals with two sets of bands are heterozygous receiving different alleles from each parent. Starting on the left side, the first individual is homozygous and the second is heterozygous, both sharing one allele in common. Three alleles are revealed on this gel.

```
Sequence 1   ...ACTGGCAAAGTCCA...
Sequence 2   ...ACTGGCAGAGTCCA...
```

Figure 21. DNA sequence variation. The principle type of DNA variation is in the sequence of nucleotides found at some location (locus) in the genome. Mutations give rise to the replacement of one of the four nucleotides (guanine - G, adenine - A, cytosine - C, and thymine - T) with another. In this case the two DNA sequences or alleles differ in having an A or a G (at point of arrow).

A.2.1 Allozymes

Allozymes are different forms of protein (usually catalytic enzymes, e.g., lactate dehydrogenase) encoded by a single Mendelian locus. Variation in DNA sequence (e.g., substitution of a G for a T) leads to changes in the DNA triplet code for the amino acids that make up enzymes. Thirty percent of these changes in amino acids involve a change in charge of the amino acid (e.g., a negatively charged amino acid is replaced with one with a neutral charge). These changes in charge may lead to the change in overall charge on the enzyme molecule. This change in charge can lead to differences in mobility in an electric field. One can detect these differences in migration by staining for specific enzymes, employing their substrate specificity.

A.2.2 MHC

The major histocompatibility complex (MHC) consists of several classes of genes that encode proteins involved in the immune response. Each class may consist of several loci. MHC genes are highly polymorphic and under intense selective pressure. MHC genes have been implicated in mate selection (Aeschlimann et al., 2003), such that individuals choose mates with divergent MHC types thereby maintaining variation at these loci in populations that go through bottlenecks. MHC variation is usually detected as sequence variation, either through direct sequencing or some form of gel separation that can detect changes in sequence rather than length of sequence (e.g., single strand conformational polymorphism, denaturing gradient (DGGE) or temperature gradient gel electrophoresis (TGGE)).

A.2.3 Microsatellites

Microsatellites are a class of repetitive DNA, consisting of variable numbers of 2-6 bp repeats (e.g., TATATATATATA). The repeating units may be simple repeats of the same unit, a complex of several repeats (e.g., TATATATA-CATCATCATCATCAT), or an interrupted sequence (e.g., TATATATATA-GAATAC-CATCATCATCAT). Surrounding the repeat are anonymous DNA sequences from which primers are designed to amplify the repeat region. These surrounding or flanking sequences evolve slowly and can often permit primers from a related taxon to amplify (e.g., chinook salmon primers will often work in cutthroat trout).

A.2.4 mtDNA

Mitochondrial DNA is found in tens to hundreds of copies in each mitochondrion and a given cell can have hundreds of mitochondria. The mitochondrial genome in fish ranges from 15 to 20 kbp (Billington and Hebert, 1991). The principle features of this type of DNA are (1) relatively strict maternal inheritance, (2) no recombination, and (3) a higher rate of mutation than most nuclear DNAs. Usually all mtDNA molecules in an individual are identical. Occasionally paternal leakage can occur and lead to sequence heteroplasmy (presence of different types of mtDNAs in the same individual) and some instances of length heteroplasmy may occur. Mitochondrial DNA molecules that differ in sequence are considered haplotypes (only one form per individual). In reality mtDNA can be thought of as a single locus that experiences no recombination. Each haplotype is a single allele at the mtDNA locus.

A.3 Allele frequencies

The principle data for use in studying populations are the frequencies of alleles at individual genetic loci. Evolutionary similarity of populations is judged based on similarities in allele frequencies, that is two populations with very dissimilar sets of frequencies for a group of loci are said to be reproductively isolated and to have been isolated for a longer time than populations with more similar allele frequencies.

A.4 Mutations and mutation rates

Changes in DNA sequence (mutations) are constantly occurring over time. Most mutations are lost from a population in the first few generations, while a few increase in frequency, even to the point of completely replacing other forms (alleles) of that sequence (allelic substitution). Different types of DNA experience substantially different rates of mutation or substitution. Mutation rate is often directly related to the number of alleles segregating in the population. For the markers used in work on chinook salmon, allozymes exhibit the lowest level of mutation, MHC and mtDNA intermediate (five to 10 times that of most nuclear genes) and microsatellites the highest (100 fold increase over allozymes).

A.5 Populations and gene pools

Populations are collections of individuals that have the potential to reproduce with each other and not to reproduce with individuals from other populations. The distinction of populations is easy to understand for fish in two lakes with no corridors for migration. The distinction is harder to draw for anadromous fish that inhabit rivers with many sub-drainages.

Gene pools consist of all of the genetic variation held by a population. In essence, a gene pool can be described by the allele frequencies of a given population over the entire genome. Gene pools under assumptive models of no selection, no immigration or selective emigration, large population size, no mutation, and random mating are expected to remain constant: one generation passes its gene pool intact on to the next generation. Obviously, reality violates many of the assumptions of the model and these violations must be weighed in interpreting the results from molecular genetic studies.

A.6 Genetic drift

A common assumption in population genetic studies is that a gene pool stays the same from generation to generation, that is, the same allele frequencies at each locus will be observed in the spawning adults each generation (or each year assuming overlapping generations). This assumption is based on having thousands of spawners that have an equal probability of mating with each and producing the same number of offspring per family. Obviously, reality shows there are uneven family sizes and often small numbers of spawners in many tributary streams. Thus, there is some variation in allele frequencies from one generation to the next, termed "genetic drift." Genetic drift is expected to be greatest for those loci with larger numbers of alleles and those populations with the smallest number of breeders.

A.7 Gene flow

While salmonid fish are noted for their fidelity to return to their natal streams (homing), they do at times stray to other streams. This straying is often called migration from one population to another and not to be confused with the migration pattern of salmonids to the ocean and back to their natal stream. There are two types of straying, emigration (out of the population) or immigration (into the population). Straying/migration is not equivalent to gene flow or introgression. It only matters for competition for habitat resources whether a fish simply enters or immigrates into a non-natal population. For that immigrant to effect evolutionary change it must leave its gametes in the non-natal population. That a non-natal fish appears in a population is not in and of itself sufficient for gene flow; however, transferring eggs from one hatchery to another likely is. We usually term this exchange of genes *gene flow* for intraspecific exchange, and *introgression* where the flow is across a species boundary from hybridization and subsequent backcross events.

A.8 Data analysis

A.8.1 Is this a single population and is it genetically stable?

There are several tests that can be done to establish the genetic integrity and genetic health of a population. The first test is whether the population is in Hardy-Weinberg equilibrium. If the mutation, selection, genetic drift, and immigration are minimal and mating is basically random, then there is an expectation of frequencies of single locus genotypes based on the allelic frequencies at that locus. Departures from Hardy-Weinberg equilibrium at multiple single loci imply deviations from the aforementioned basic assumptions. Non-random mating within the presumptive population (e.g., mating between native and out-of-basin hatchery fish or multiple sub-populations within the drainage system) is often the cause of departure from Hardy-Weinberg equilibrium.

A more sensitive measure of genetic integrity of a population is the test for linkage disequilibrium. This test examines pairs of loci at a time and seeks to determine if the observed gamete frequencies in the population fit the expected distribution of gametes based on allele frequencies. Again, departures from the basic population assumptions can be detected by linkage disequilibrium and more importantly the signature from past generational disruptions in equilibrium last for multiple generations, unlike Hardy-Weinberg equilibrium which can be returned in a single generation.

A.8.2 Are these populations reproductively isolated?

Once allele frequencies are calculated for sample sets, they can be compared to determine if the allele frequency arrays for two populations are significantly different. Alternatively, could the samples be drawn from a common population? Determination that the samples could not come from a single random mating population implies that there must be at least two populations and that they should be managed separately. There are a variety of means of testing for significantly different allele frequency arrays (Hallerman, 2003).

A.8.3 How is the diversity partitioned among the populations?

The distribution of allelic variation within and among populations can be evaluated with the genetic statistic F_{ST}. This statistic compares the levels of heterozygosity found in component populations relative to an imaginary pooled population of all the component populations. An F_{ST} of 0.07 for a pair of populations would suggest that 7% of the total variation is between the populations. Values below 0.005 are often not significant, such that the populations might not in fact be reproductively isolated.

A.8.4 Pairwise genetic distance values

Arithmetic measures of the similarity of allele frequencies between a pair of populations can be calculated using a number of different algorithms. Today most of these measures give dissimilarity measures (termed "genetic distance") rather than similarities. Thus, a pair of populations with a lower genetic distance value is considered more related than a pair of populations with a higher genetic distance value. Some common measures used today include Nei (1972, 1978), Goldstein's $(du)^2$, and Cavalli-Sforza and Edwards chord distances (1967).

A.8.5 Clustering or ordination - putting the genetic distance values together

Gaining a feel for the overall relationships for a group of populations can be accomplished by combining the information from the pairwise population comparisons into an overall graphical representation. Many approaches are available including: unweighted pair-group method using arithmetic averages (UPGMA), multidimensional scaling (MDS), principal component analysis (PCA), minimum spanning tree, neighbor joining, etc. Some of these methods ordinate the populations in two or three dimensions, some draw lines of linkage with shortest lines indicating those pairs of populations with the most similarity, while others position the populations in space without any lines linking populations.

Several methods are available to test the robustness of particular ordinations. Maximum likelihood compares probabilities for different trees to choose the best tree. Bootstrapping generates pseudo replicates of the original data set by random sampling with replacement.

A.8.6 Concerns in interpreting the results

The clarity in scoring of Mendelian loci coupled with a rich history of theoretical population genetics can lead to overconfidence in accepting the seemingly obvious conclusions from interpreting the results. However, in the following paragraphs we discuss a number of concerns or cautions that should be addressed because they may alter the meaning of the results. Most of these concerns cannot be overcome and we tend to ignore them based on assumptions that may be erroneous. There are obvious overlaps among these concerns.

A.8.7 Sampling accuracy

Assumption: The sample of fish analyzed reflect the population being examined.

Discussion: While we often use the mouths of rivers to designate major populations from one another, the complexity of each individual river will dictate how the fish that spawn in that river are broken into subsets of populations that have varying levels of gene flow among them. Temporal and spatial spawning separations may lead to reproductive isolation of populations within rivers. We need to know how a sample was taken in order to feel confident that the sample is a true reflection of the population in question? This assumption of sampling accuracy is probably often violated and the literature is rife with statements that apparently aberrant samples may be combinations of populations (e.g., "The wild population . . . from Butte Creek that may have been contaminated with a few fall-run fish" (Hedgecock et al., 2001) or "It seems likely that the spring run is mixed into the 1995 winter run because the run is most similar to spring" (Kim et al., 1999).)

A.8.8 Temporal stability

Assumption: The results for one year will be replicable in the next year.

Discussion: While evolutionary change is expected, relatively stable gene pools over several generations are a requisite to comparisons of data sets taken in different years. Admixture, low spawner, and sampling inaccuracy can lead to temporal variation that may equal spatial variation (see Williamson and May (2003)).

A.8.9 Historical reflection

Assumption: The population in the stream today is nearly the same as the population 200 years before.

Discussion: We know that populations are constantly changing due to new mutations, random drift, changes in environment, and immigration. These changes would be expected to be relatively small over 200 years. However, there have been drastic anthropogenic changes in the environment, and immigration from transplants and straying has increased many fold. Contaminants may have increased mutation rates. Small numbers of spawners in some years have led to gross change in allele frequencies from random drift.

A.8.10 Admixture

Assumption: The population has not experienced admixture of genes from other populations (e.g. transplants or straying leading to hybridization with out-of-basin stocks or other temporal runs).

Discussion: The current population is a reflection of the contributions of previous generations. Since most wild spawning goes unobserved, the number of nonnatal fish that spawn is unknown. While data suggest that hatchery fish contribute less to a gene pool, any contribution of gametes to the gene pool will alter the composition of that gene pool over time. The data for fall-run chinook salmon in the Central Valley strongly support the conclusion that admixture from transplants and straying has reduced an historical tapestry of different populations to essentially one panmictic population (Williamson and May, 2003).

A.8.11 Genetic uniqueness

Assumption: Statistical differences in molecular markers among populations are reflective of substantial gene pool differences among the populations.

Discussion: Are these fish sufficiently different from other geographically proximate runs to warrant independent status? Beyond run timing what quantitative traits distinguish one population from another such that each should be managed separately?

A.8.12 Genetic variability

Assumption: The molecular marker variability rates are reflective of the variability in important survival traits.

Discussion: Can we ascertain whether the levels of variability for a few dozen molecular markers are predictive of the genetic health of a population for 100 years?

B Life history diversity of Central Valley spring-run chinook salmon

Life history information is available for the spring-run chinook salmon spawning groups in Mill, Deer and Butte creeks. Biologists at CDFG have collected and compiled information on adult migration timing, the size distribution of spawners, the timing of juvenile emigration, and the size of juvenile emigrants. In general, periods of high flow cause gaps in the sampling, and it is likely that significant numbers of fish move during these high-flow periods. No attempt has been made to account for the effects of these gaps on the information presented here.

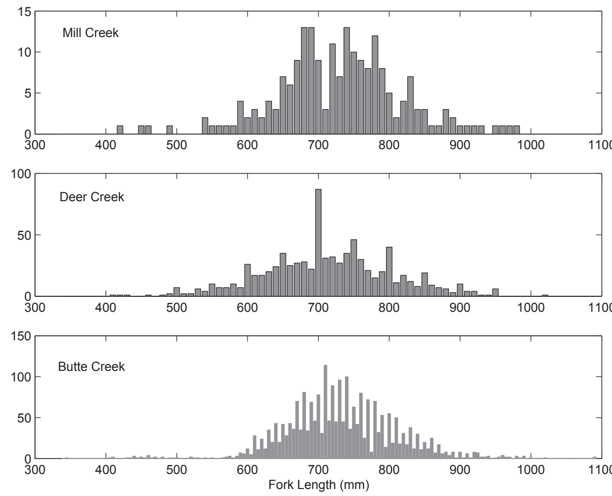

Figure 23. Size distribution of spawning adult spring-run chinook salmon in Mill, Deer and Butte creeks.

B.1 Adult migration

The Butte Creek spring-run chinook salmon enter their natal stream roughly six weeks earlier, on average, and have a more protracted migration than spring-run chinook salmon in Mill and Deer creeks (Figure 22). Run timing in Mill and Deer creeks looks quite similar. This size distribution of spawners looks quite similar in all three streams, with perhaps fewer $<$ 60 cm fish (typically two-year-old) in Butte Creek (Fig 23), although this difference may an artifact of sampling differences rather than the result of biological differences.

B.2 Juvenile emigration

In all three streams, the peak of juvenile emigration occurs in January or February (Figure 24). Emigration of young-of-the-year (YOY) juveniles appears to be somewhat later, and yearlings somewhat earlier, in Mill and Deer creeks than in Butte Creek, consistent with the latter spawning timing and colder water temperatures in Mill and Deer creeks. Figure 25 shows the size distribution of emigrants from all three streams. In October, all outmigrants are yearlings. In November, YOY begin to be observed, but only in substantial numbers in Butte Creek. YOY migrants are abundant in all three streams from December through May. In the December through April period, the modal size of migrants is constant at around 40 mm, presumably reflecting the prolonged emergence of fry from the gravel. As the outmigration season progresses, the upper tail of the distribution broadens, reflecting the growth of juveniles in areas above the traps. Modal size increases in May and June. Overall, the patterns look very similar among the streams, with only the early and prolonged emigration from Butte Creek standing out as different (and this may be an artifact of the different sampling regimes in the streams).

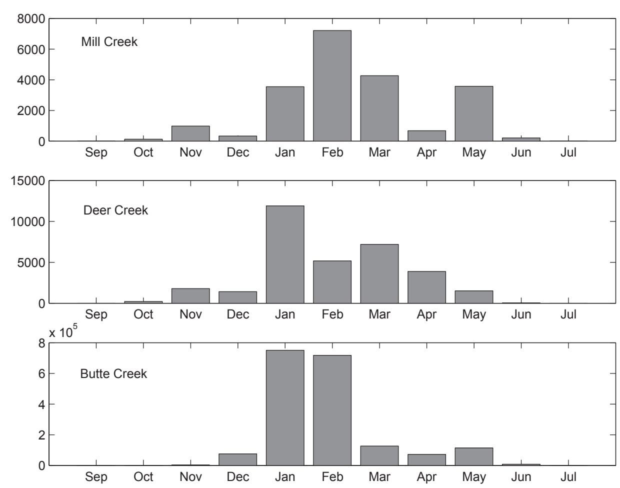

Figure 24. Mean monthly catches of juvenile spring-run chinook salmon in rotary screw traps in Mill, Deer and Butte creeks.

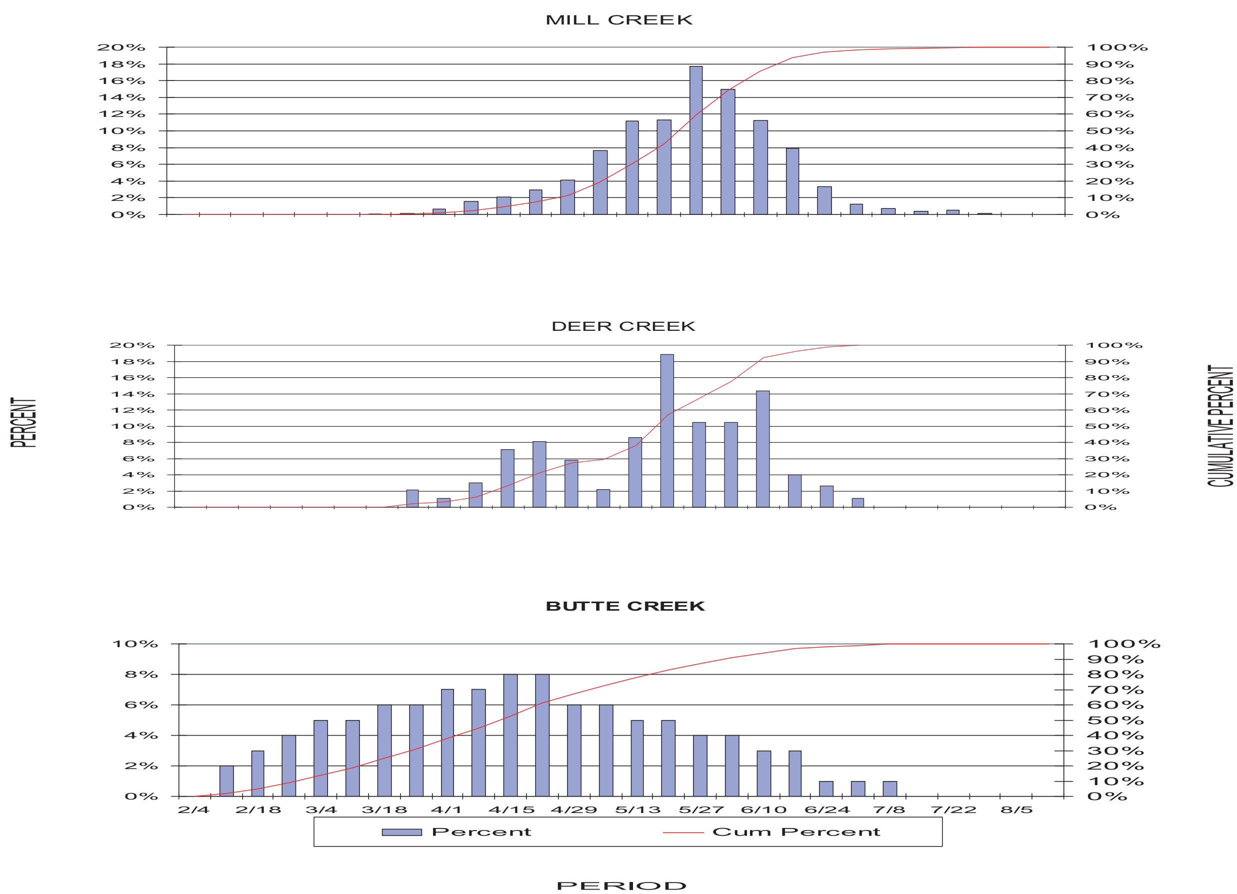

Figure 22. Weekly migration of spring-run chinook salmon into Mill, Deer and Butte creeks. Bars show the percentage of migrants migrating in that week; the line shows the cumulative percent migration.

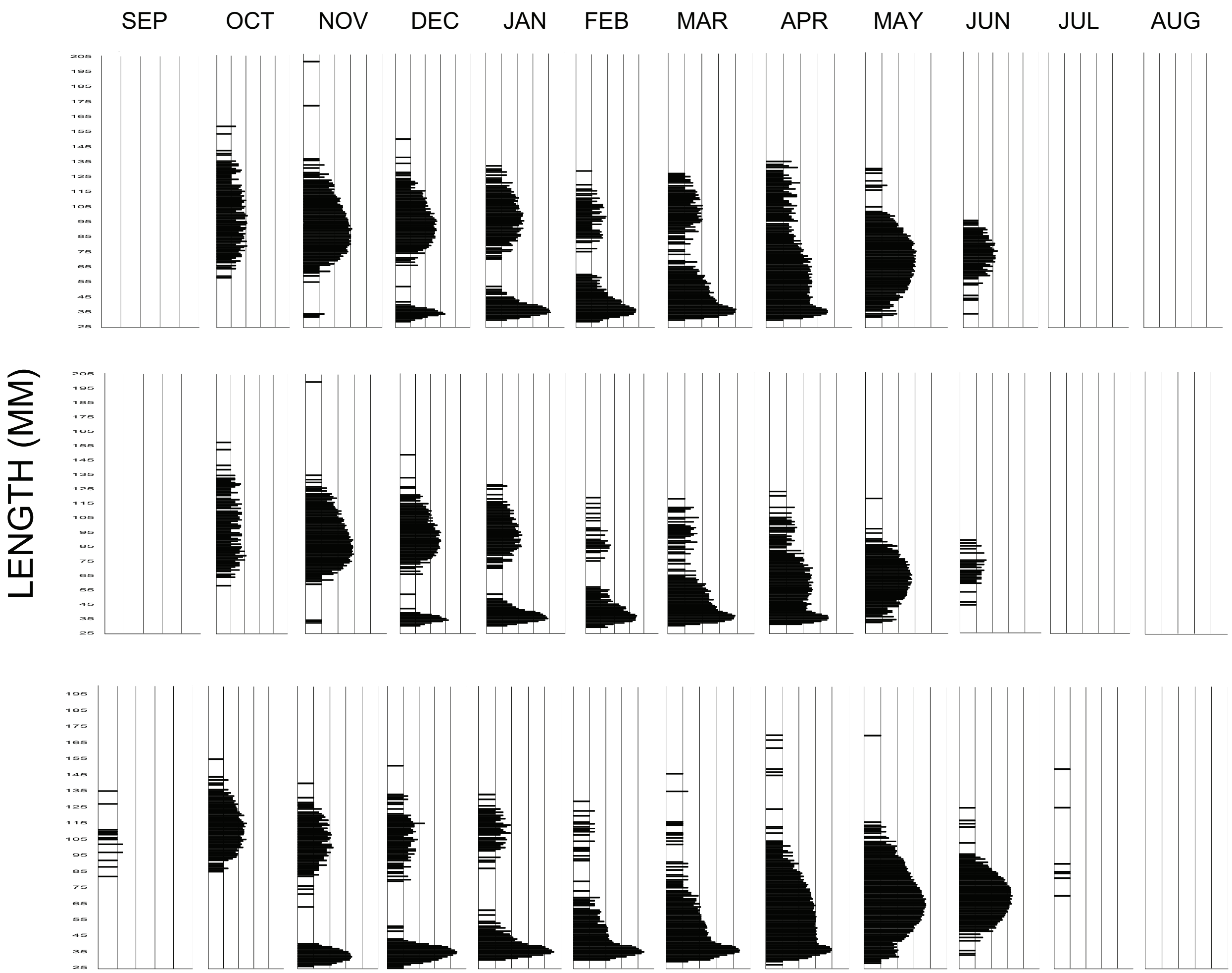

Figure 25. Size distribution of juvenile spring-run chinook salmon migrants in Mill (top), Deer (middle) and Butte (bottom) creeks. The x-axis is on the $\log_{10}$ scale. Data from C. Harvey-Arrison and T. McReynolds, CDFG.

C Population dynamics of Mill and Deer Creek spring chinook

Summary: A model comparison approach is used to test whether Mill and Deer creek spring-run chinook form a single population. Three models, based on random-walk-with-drift dynamics, are compared: completely independent dynamics, correlated process variation, and a simple metapopulation model allowing for migration between populations. According to Akaike's Information Criterion, the model ignoring correlated process variation and migration is the most parsimonious explanation for the observed time series of abundances. The metapopulation model is not implausible, however, and the estimated rates of migration are biologically significant.

C.1 Model formulations

Three hypotheses describe the possible relationship between two spawning groups:

1. completely independent dynamics

2. correlated environment causing correlations in abundance

3. migrations between populations causing correlation in abundance

These hypotheses can be tested by fitting corresponding models to population abundance data and comparing the fits with Akaike's Information Criterion (AIC) (Burnham and Anderson, 1998). The model with the lowest AIC is the most parsimonious model of the data. Three models are sketched below, corresponding to the three hypotheses above. models are cast in state-space form to account for observation error in abundance.

Let N_t denote the size of a population of chinook. Total population size is not typically measured in salmon populations, rather, only mature individuals are available for counting in freshwater. N_t is therefore estimated from a running sum of spawning escapements:

$$N_t = S_t + S_{t+1} + S_{t+2}. \tag{1}$$

The summation is taken over three years because most chinook salmon spawn by age 3 in the Central Valley. A similar approach to estimating population size from observations of breeding adults has been used in studies of a variety of vertebrates (Dennis et al., 1991; Holmes, 2001).

C.1.1 Model 1: independent populations

A state-space model for two independent populations is described by

$$\begin{aligned} N_{t+1,a} &= \alpha_a N_{t,a} + \eta_{t,a} && (2)\\ N_{t+1,b} &= \alpha_b N_{t,b} + \eta_{t,b} && (3)\\ y_{t,a} &= N_{t,a} + \epsilon_{t,a} && (4)\\ y_{t,b} &= N_{t,b} + \epsilon_{t,b}, && (5) \end{aligned}$$

where α_a is the population growth rate of population a, $\eta_{t,a}$ is a random change in population size caused by the environment, $y_{t,a}$ is the observation of population size at time t, and $\epsilon_{t,a}$ is an observation error. Both η_t and ϵ_t are assumed to be normal and independent, with means = 0 and standard deviations proportional to N_t^2. This is an approximation to lognormal errors, which could easily be used for this model but not for the migration model described below without leaving the normal linear setting (which allows use of the Kalman filter, greatly simplifying computations).

C.1.2 Model 2: correlated environment

Model 1 can be extended to incorporate correlated environmental variation simply by treating the η_ts as arising from a bivariate normal distribution with mean = 0 and with covariance Σ:

$$\Sigma = \begin{bmatrix} c_p N_{t,a}^2 & c_{a,b} N_{t,a} N_{t,b} \\ c_{a,b} N_{t,a} N_{t,b} & c_p N_{t,b}^2 \end{bmatrix}, \tag{6}$$

where c_p and c_{ab} are proportionality constants (roughly, coefficients of variation).

C.1.3 Model 3: migration between populations

Model 1 can also be extended by adding movement between populations to the state equations, creating a simple metapopulation model:

$$\begin{aligned} N_{t+1,a} &= (1-s_{ab})\alpha_a N_{t,a} + (1-s_{ab}))\eta_{t,a} && (7)\\ &\quad + s_{ba}\alpha_b N_{t,b} + s_{ba}\eta_{t,b} \\ N_{t+1,b} &= (1-s_{ba})\alpha_b N_{t,b} + (1-s_{ba})\eta_{t,b} && (8)\\ &\quad + s_{ab}\alpha_a N_{t,a} + s_{ab}\eta_{t,a}, \end{aligned}$$

where s_{ab} is the fraction of group a moving into spawning area b.

C.2 Model fitting and comparison

Maximum likelihood estimates of unknown parameters were obtained by minimizing the negative loglikelihood with the Nelder-Mead algorithm for multidimensional unconstrained minimization. Variances and probabilities were log and logit transformed, respectively, so that they would fall on the real line. The likelihood of the data was found with the Kalman filter (Harvey, 1989; Lindley, 2003). To explore the issue of parameter uncertainty, a Bayesian approach was taken by simulating from the joint posterior distribution of the parameters using the Metropolis-Hastings algorithm (Metropolis et al., 1953; Hastings, 1970).

C.3 Results and discussion

Table 4 summarizes parameter estimates and the AIC of the three models as applied to Mill (a) and Deer (b) Creek spawner data. According to AIC, Model 1 is the best approximation to the data, followed by Model 3 and Model 2. This means that there is no *need* to invoke migration between populations or correlated environments to explain the population dynamics of Mill and Deer Creek spring-run chinook salmon. AIC differences of $< 2-3$ relative to the best model, however, indicate that models 2 and 3 are not unreasonable approximations to the data. The estimate of the covariance of process errors for Model 2 is positive but small, indicating that most of the variation in population size is independent: even though the covariation is statistically significant, it is not significant in the biological sense.

According to the point estimates of the parameters of Model 3, no fish move from Mill to Deer creek, but around 9% of the production of Deer Creek returns to Mill Creek. This level of migration is biologically significant, and is near the VSP criteria of 10% migration (McElhany et al., 2000). In order to assess the precision of the estimate of s_{ba}, I computed the profile likelihood of this parameter (shown in Figure 26). According to Model 3, estimates of s_{ba} in the range of 0–0.2 would be expected from repeated observations of the system.

The uncertainty in parameter estimated is most easily conveyed with univariate and bivariate plots of parameter densities (Figure 27). Growth rate and emigration rate are positively correlated within populations, and growth rates and emigration rates are negatively correlated between populations. The probability that $s_{ab} < 0.10$ is 0.52, and the probability that $s_{ba} < 0.10$ is 0.57, i.e., it is slightly more likely than not that migration rates between Mill and Deer creeks are less than 0.10.

Table 4. Summary of parameter estimates and AIC for three models describing dynamics of two salmon populations

parameter	Model 1	Model 2	Model 3
α_a	1.15	1.16	1.04
α_b	1.12	1.12	1.19
c	0.105	0.105	0.071
c_{ab}	NA	9.54×10^{-3}	NA
s_{ab}	NA	NA	0.000
s_{ba}	NA	NA	0.107
δAIC	0	1.91	2.29

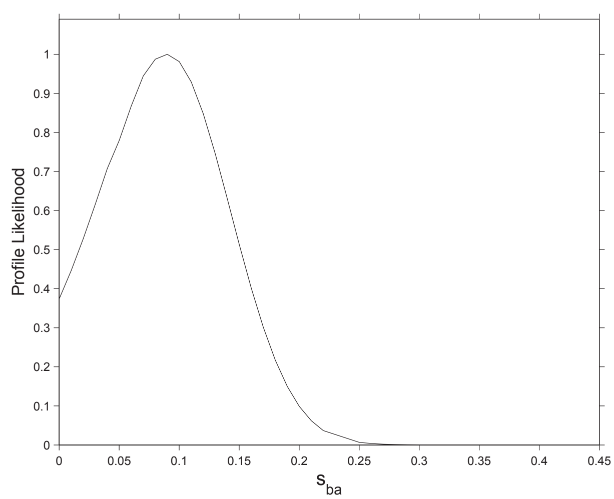

Figure 26. Profile likelihood of the migration parameter describing the fraction of fish moving from Deer to Mill Creek.

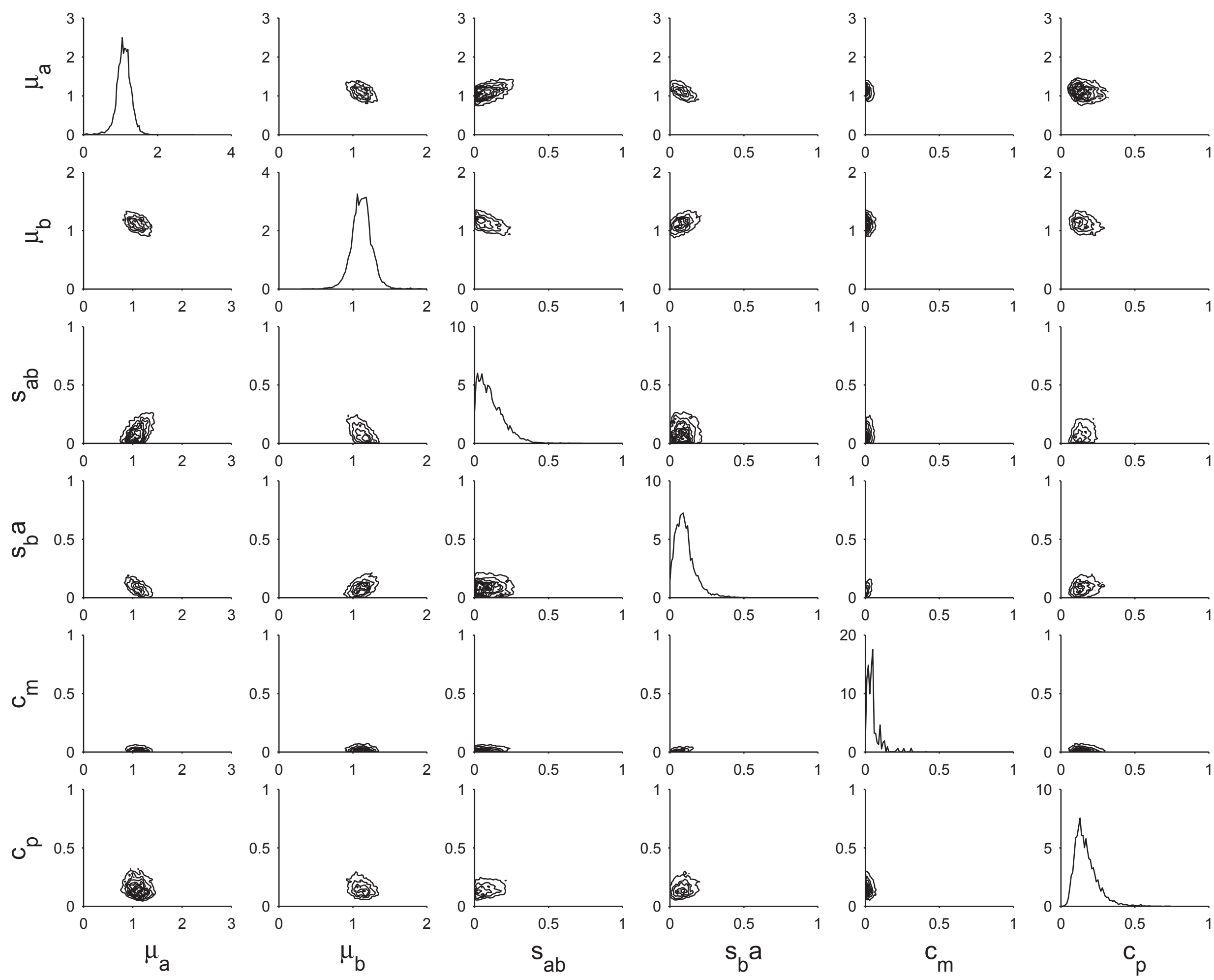

Figure 27. Marginal (on diagonal) and bivariate densities of parameter estimates.

D Multivariate analysis of spring-run Chinook watersheds in the Central Valley

The Central Valley Technical Recovery Team (TRT) is tasked with identifying the structure of historic independent populations. As part of this effort we created an initial classification scheme (see Figure 18) for spring-run chinook salmon watersheds in the Central Valley. This gestalt delineation was based loosely on the following variables: ecoregions, geology, elevation, hydrography, several climatological variables, and timing of peak flow. In order to quantitatively test whether this initial structure was valid and concordant with available environmental data, we ran a series of multivariate analyses on the watershed-level environmental data.

D.1 Methods

D.1.1 Data

We delineated watersheds across the entire Central Valley Basin, and used these polygons as the basis for extracting environmental data and constructing an *m x n* database for ordination. To complete this database we used two different types of joins in ArcInfo GIS (ArcGIS 8.3, Environmental Systems Research Institute, Redlands, CA): a spatial join between two polygon coverages; and a spatial join between one polygon coverage and one raster coverage. ArcInfo splits its data types into two main categories: vector (points, lines & polygons) and raster (a grid-cell based representation of a surface). We use the term coverage to refer to any of the three vector data-types and grid or raster interchangeably to refer to the raster data type.)

Using GIS, we first joined the watershed coverage with the other two polygon coverages: Jepson Ecoregion (Table 5), and Dominant Geology (Table 6). The output of these two joins were summarized by type by watershed. For the second join, we intersected the watershed coverage with several raster layers (Table 7). In addition to these spatial joins, the month of peak flow and the area of each watershed was added to each watershed in the database.

D.2 Data Analysis

We exported the complete database to R (Ihaka and Gentleman, 1996) for statistical analysis. We investigated the use of Non-Metric Multidimensional Scaling (NMMDS) (Shepard, 1962; Kruskal, 1964), but we chose Principal Components Analysis (PCA) (Pearson, 1901; Hotelling, 1933) for the ordination of these data because its easier conceptual underpinnings and because NMMDS lacks an analytical solution. Because PCA makes assumptions about linearity and normality, we scaled and centered the data before analysis.

We ran the PCA on the standard covariance matrix, and explored the output using 2D and 3D plots. Additionally, we produced biplots using the principal component biplot (sensu Gabriel (1971)). This type of biplot shows the descriptors on top of the 2D plots, and allows for visual interpretation of the environmental correlation within the ordination space. For example, if a certain group of watersheds are all high in granitic soil, and are in the Sierra Nevada Ecoregion, then these two vectors will show up along this axis or along this dimension in multivariate space.

While examining the initial biplots we noted several of the environmental descriptors were closely correlated in multivariate space. Because this biplot is a scaled representation of their (the descriptors) relative positions (Legendre and Legendre, 1998), we removed highly correlated ($> 80\%$) descriptors. To do this, we examined the correlation matrix prior to removing one of a correlated pair of descriptors, e.g. remove min January temp from the min annual temp and min January temp pair.

Table 5. Jepson Ecoregion Codes

Item Name	Item Definition
nwca	% (by area) Northwestern California Ecoregion
cwca	% (by area) Central Western California Ecoregion
swca	% (by area) South Western California Ecoregion
gcv	% (by area) Great Central Valley Ecoregion
cscd	% (by area) Cascade Ranges Ecoregion
modc	% (by area) Modoc Plateau Ecoregion
srnv	% (by area) Sierra Nevada Ecoregion

Table 6. Geological Type

Item Name	Item Definition
sedi	% (by area) Sedimentary
gran	% (by area) Granitic
aluv	% (by area) Alluvium
volc	% (by area) Volcanic
watr	% (by area) Water

Table 7. Raster data layers averaged over the whole watershed with units in parentheses

Item Name	Item Definition
Elev Mean	Elevation (meters)
Elev gt 500m	Summed area of elevation greater than 500m (m^2)
Mean Ann Precip	Mean annual precipitation (mm)
Mean Ann Temp	Mean annual temperature (0.1 °C)
Min Ann Temp	Minimum annual temperature (0.1 °C)
Max Ann Temp	Maximum annual temperature (0.1 °C)
Range Ann Temp	Range of annual temperature (0.1 °C)
Min Jan Temp	Minimum average January temperature (0.1 °C)
Max Aug Temp	Maximum average August temperature (0.1 °C)
Jan Aug Temp	Minimum January & maximum August temperature range (0.1 °C)

Table 8. Key to spring run watershed labels in ordination plots

Abbreviation	Stream Name
ANT	Antelope Creek
BAT	Battle Creek
BCH	Big Chico and Mud Creeks
BUT	Butte Creek
CLE	Clear Creek
COT	Cottonwood Creek
DEE	Deer Creek
FAL	Fall River
HAT	Hat Creek
KIN	Kings River
PIT	Lower Pit River
MCC	McCloud River
MER	Merced River
MSJ	Mid San Joaquin River
MAM	Middle Fork American River
MFT	Middle Fork Feather River
MIL	Mill Creek
NAM	North Fork American River
NFT	North Fork Feather River
MOK	Mokelumne River
SAM	South Fork American River
SFT	South Fork Feather River
STA	Stanislaus River
STO	Stony Creek
THO	Thomes Creek
USC	Upper Sacramento River
UTU	Upper Tuolumne River
WFT	West Branch Feather River
YUB	Yuba River

Table 9. Key to color labels in ordination plots

Item Name	Item Definition
LSSJ.NS	Lower Sacramento-San Joaquin/Northern Sierra
LSSJ.SS	Lower Sacramento-San Joaquin/Southern Sierra
US.RD	Upper Sacramento/Rain Driven
US.SF	Upper Sacramento/Spring-Fed

Table 10. Loadings (> ± 0.1) for first three principal components

Variable Name	PCA 1	PCA 2	PCA 3
Peak Flow Month	0.329	0.194	
nwca	-0.106	0.253	
gcv		0.193	-0.361
cwca			0.126
cscd	-0.200	-0.355	
modc		-0.146	-0.108
srnv	0.302	0.113	0.132
sedi	-0.145	0.347	0.159
gran	0.321	0.233	
aluv	-0.217	0.103	-0.476
volc	-0.113	-0.481	0.107
ann.precip			0.609
mean.ann.T	-0.358	0.197	
min.ann.T	-0.330	0.278	
max.ann.T	-0.368	0.103	
range.ann.T		-0.388	
elev	0.377		
area.gt500	0.152		-0.400

Table 11. Percent variance explained by the first three principal components

Component #	% Variance Explained
PCA 1	34
PCA 2	19
PCA 3	9
Cumulative Variance	62

Table 12. Potential non-independent watersheds, as determined by hierarchical clustering.

Pair #	Watershed Pair	
1	Clear Creek	Cottonwood Creek
2	Deer Creek	Mill Creek
3	Pit River	McCloud River
4	Middle Fork Feather River	North Fork Feather River
5	South Fork Feather River	West Fork Feather River
6	Middle Fork American River	North Fork American River
7	Mokulumne River	Stanislaus River
8	South Fork American River	Thomes Creek

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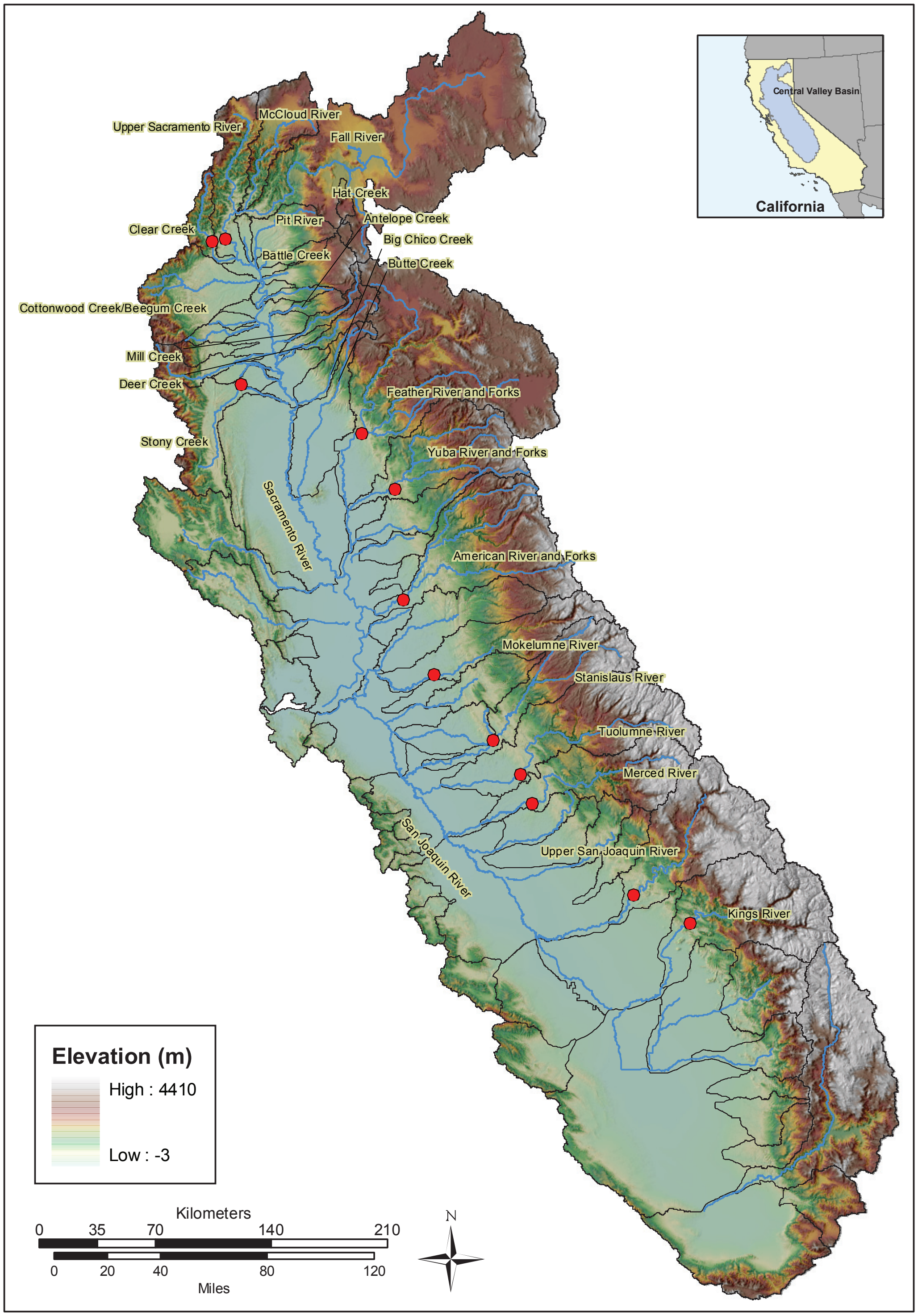

Plate 1. Map of the Central Valley basin, showing elevation, major rivers and streams (blue lines) and their associated watersheds (black lines), and major barriers to fish passage (red dots).

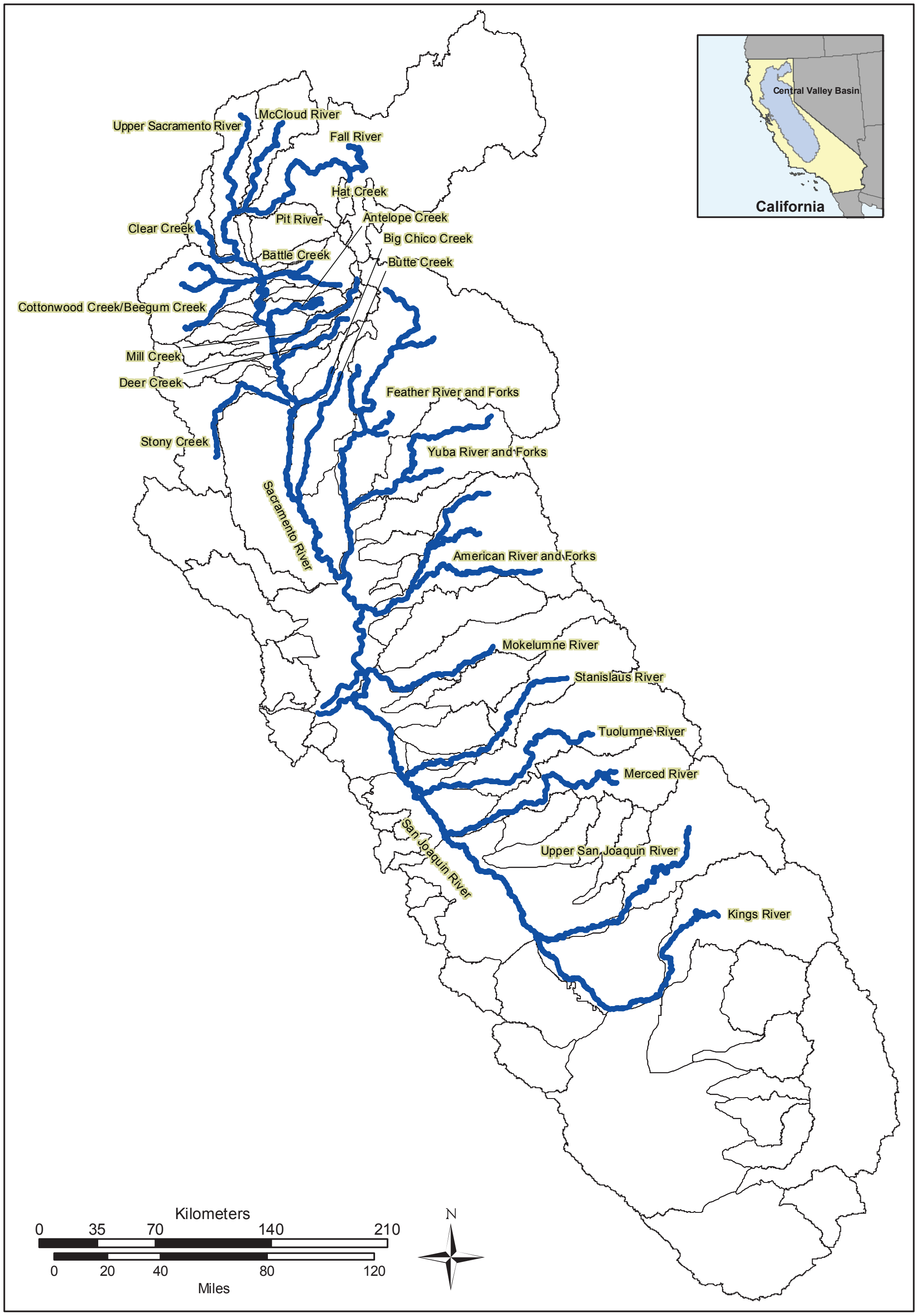

Plate 2. Historic distribution of spring-run chinook salmon in the Central Valley. Distribution information from Yoshiyama et al. (1996).

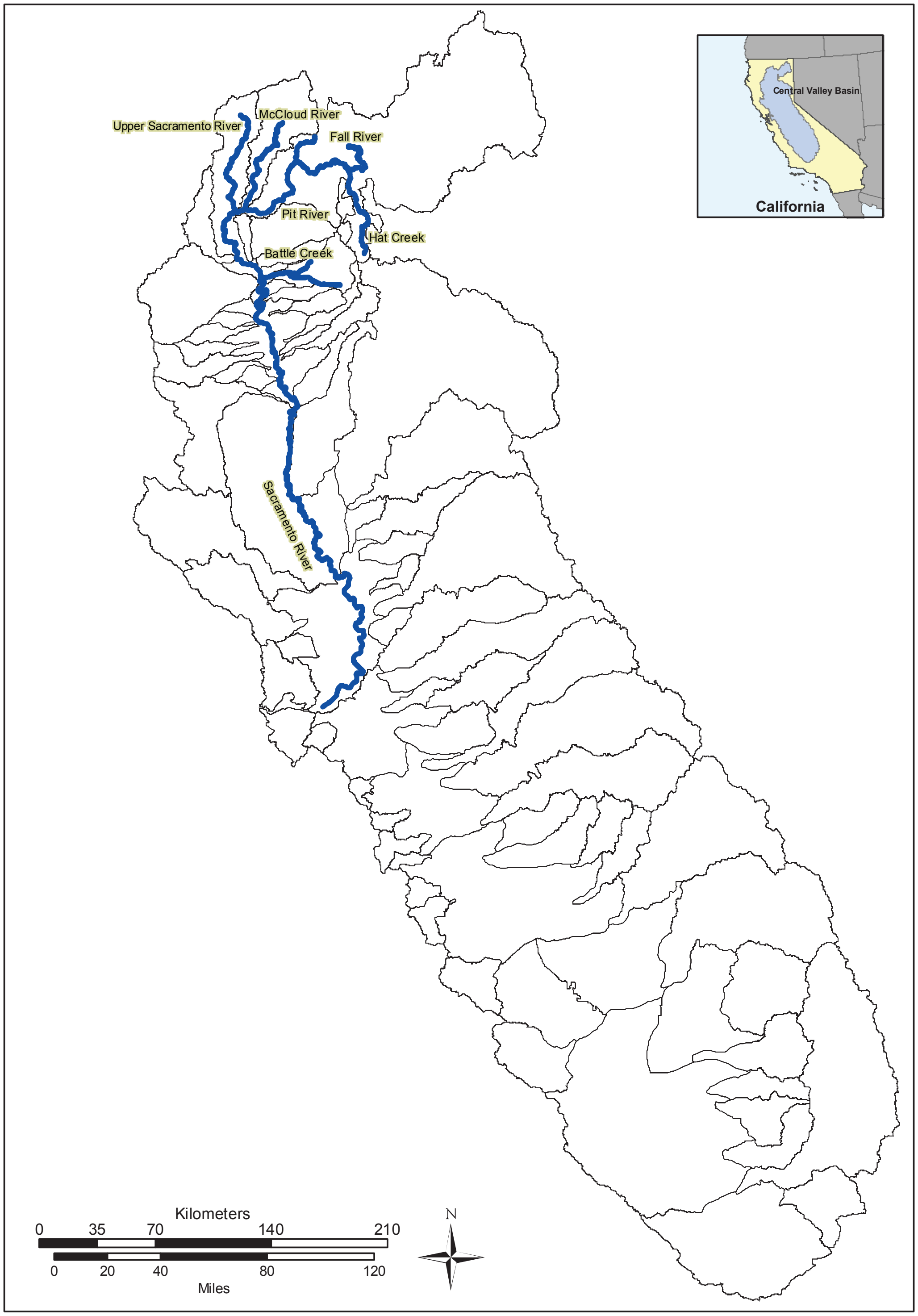

Plate 3. Historic distribution of winter-run chinook salmon in the Central Valley. Distribution information from Yoshiyama et al. (1996).

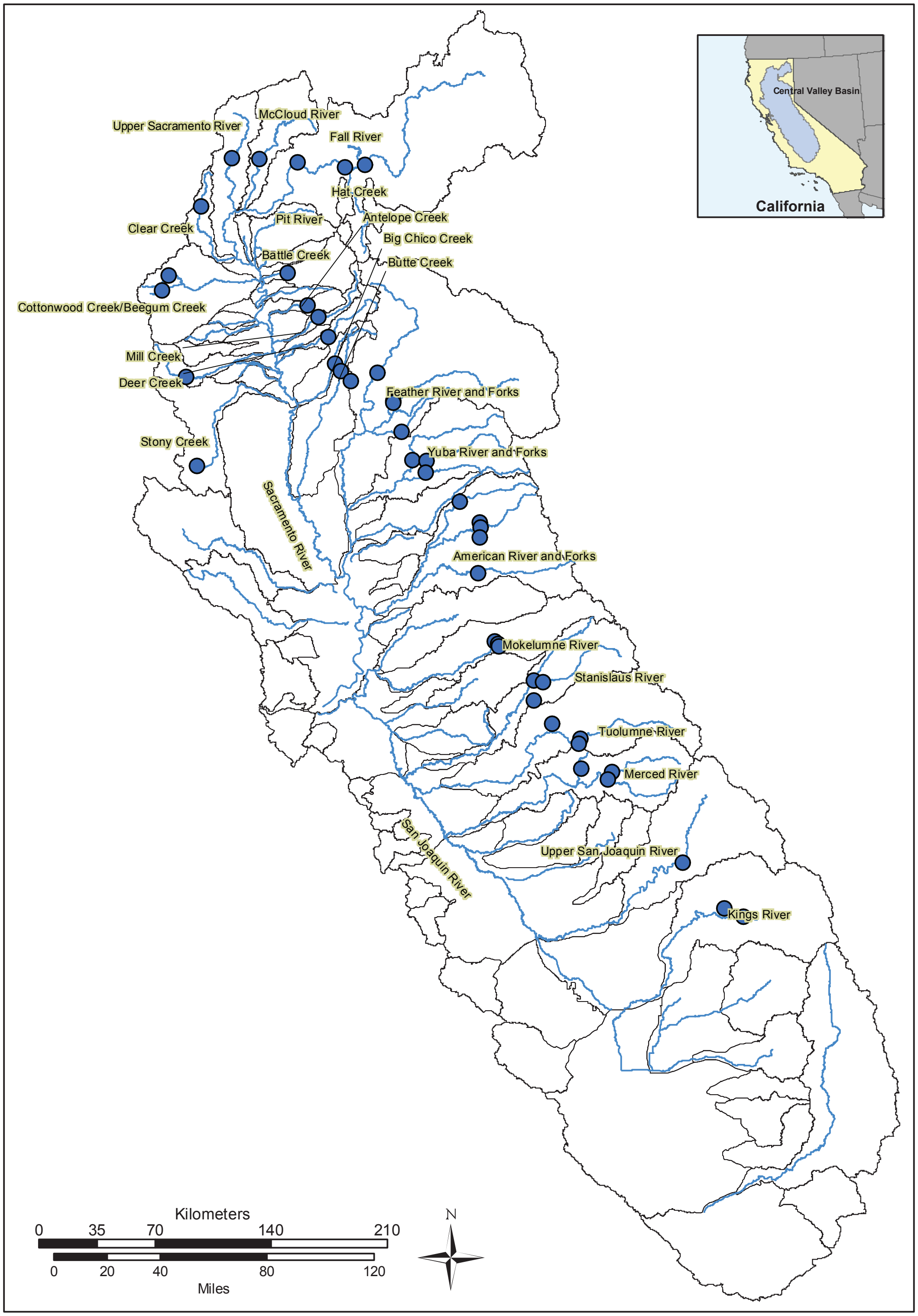

Plate 4. Points used to calculate distances among watersheds.

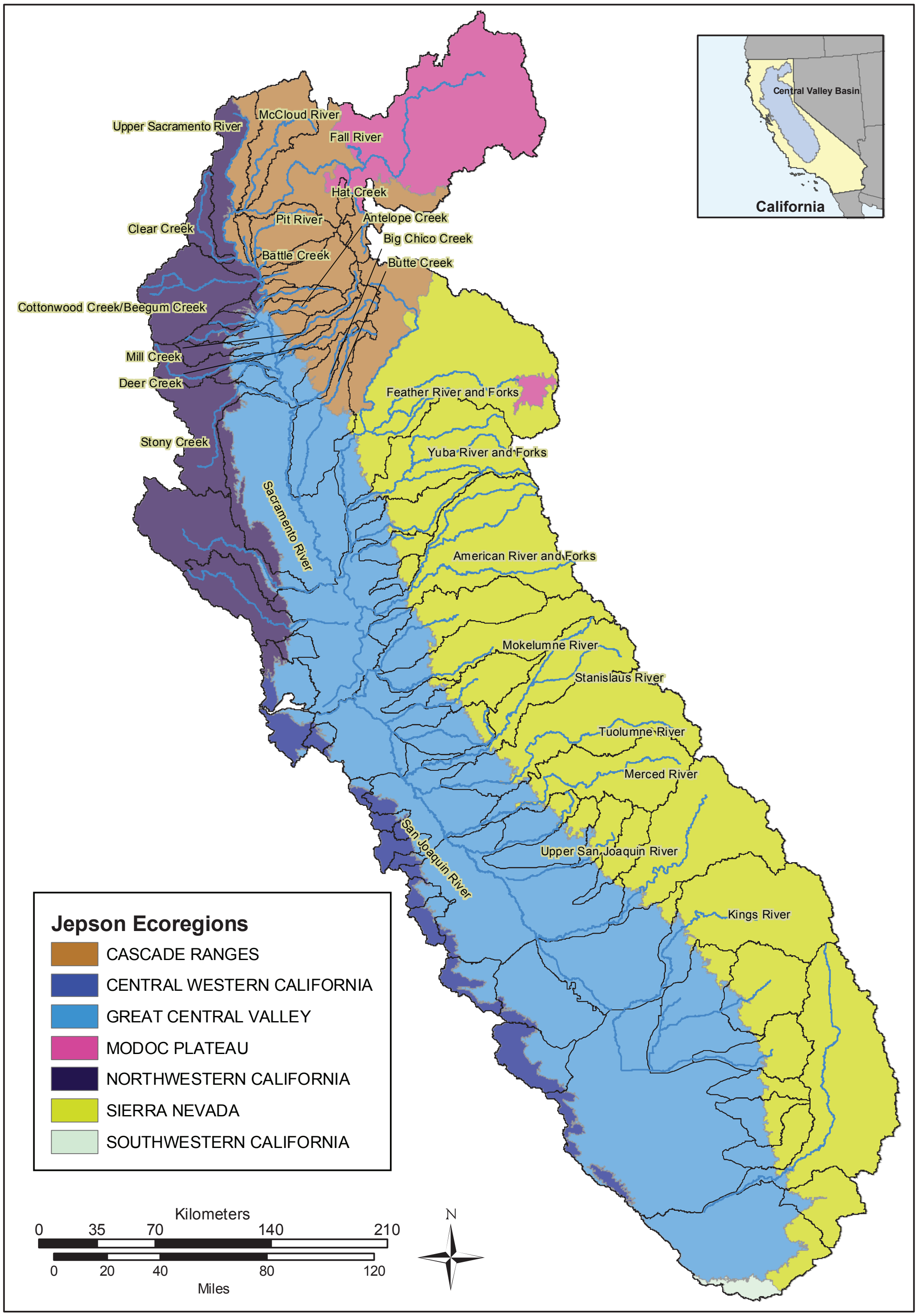

Plate 5. Floristic regions of the Central Valley basin.

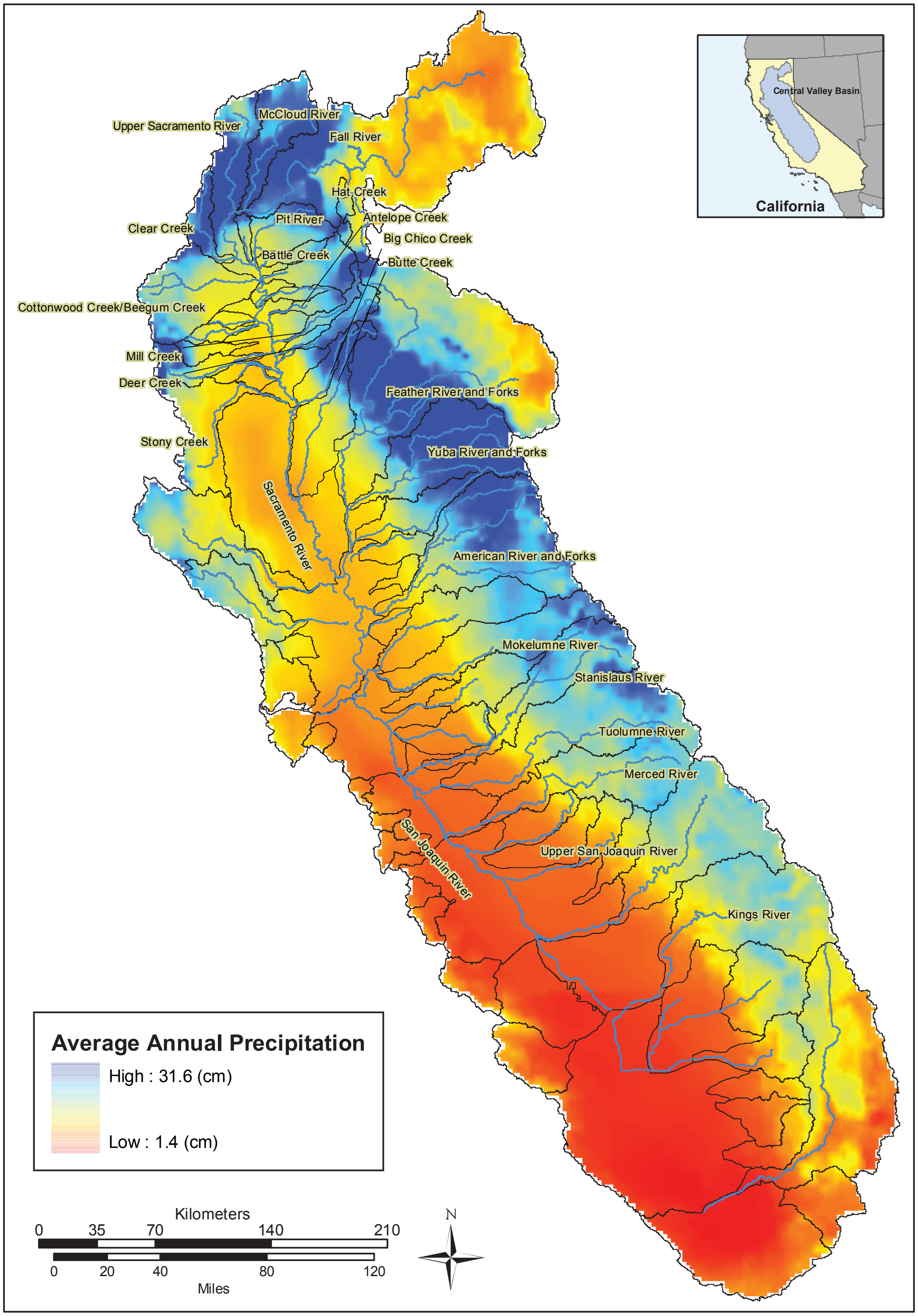

Plate 6. Average annual precipitation.

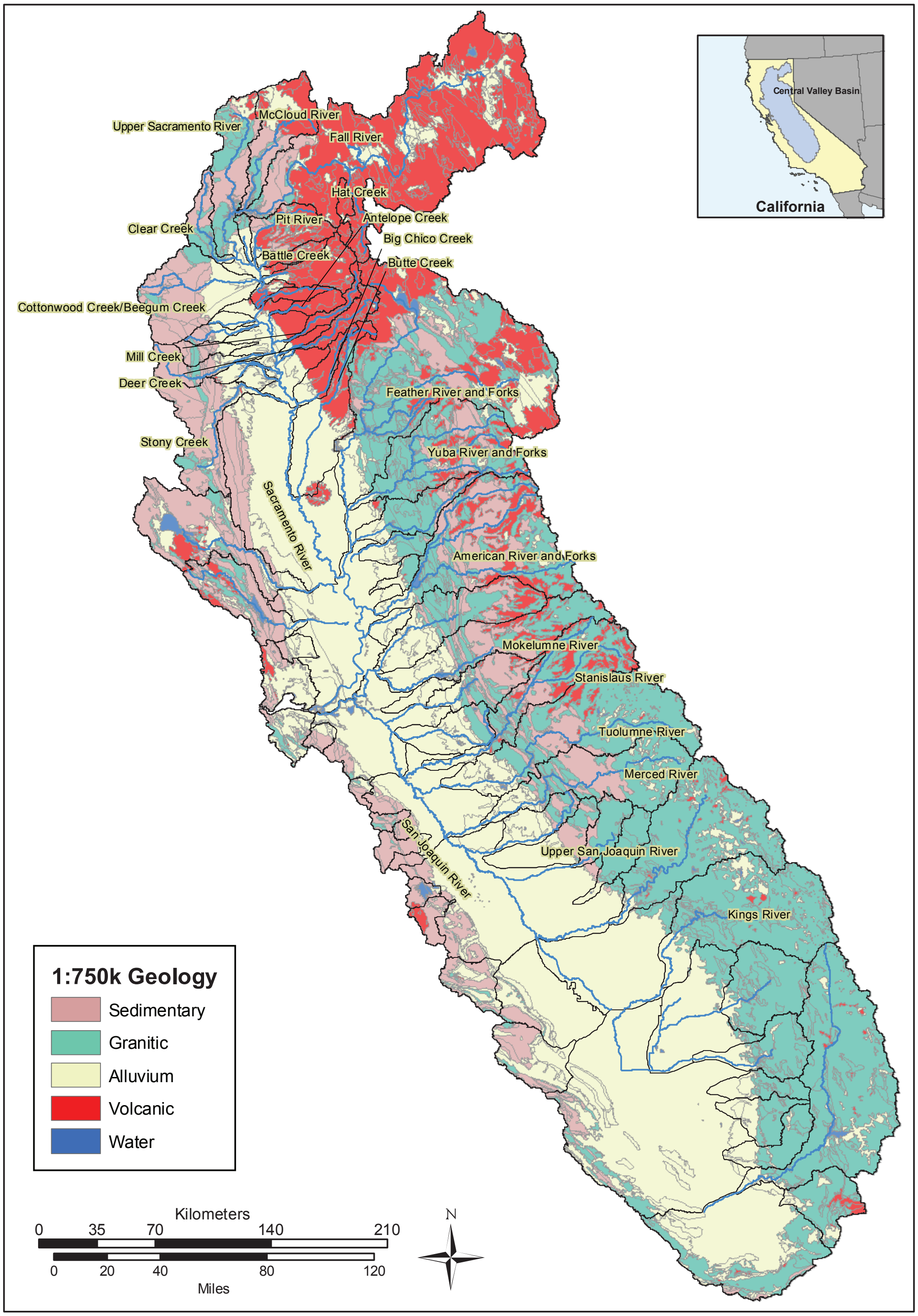

Plate 7. Geology of the Sacramento-San Joaquin basin.

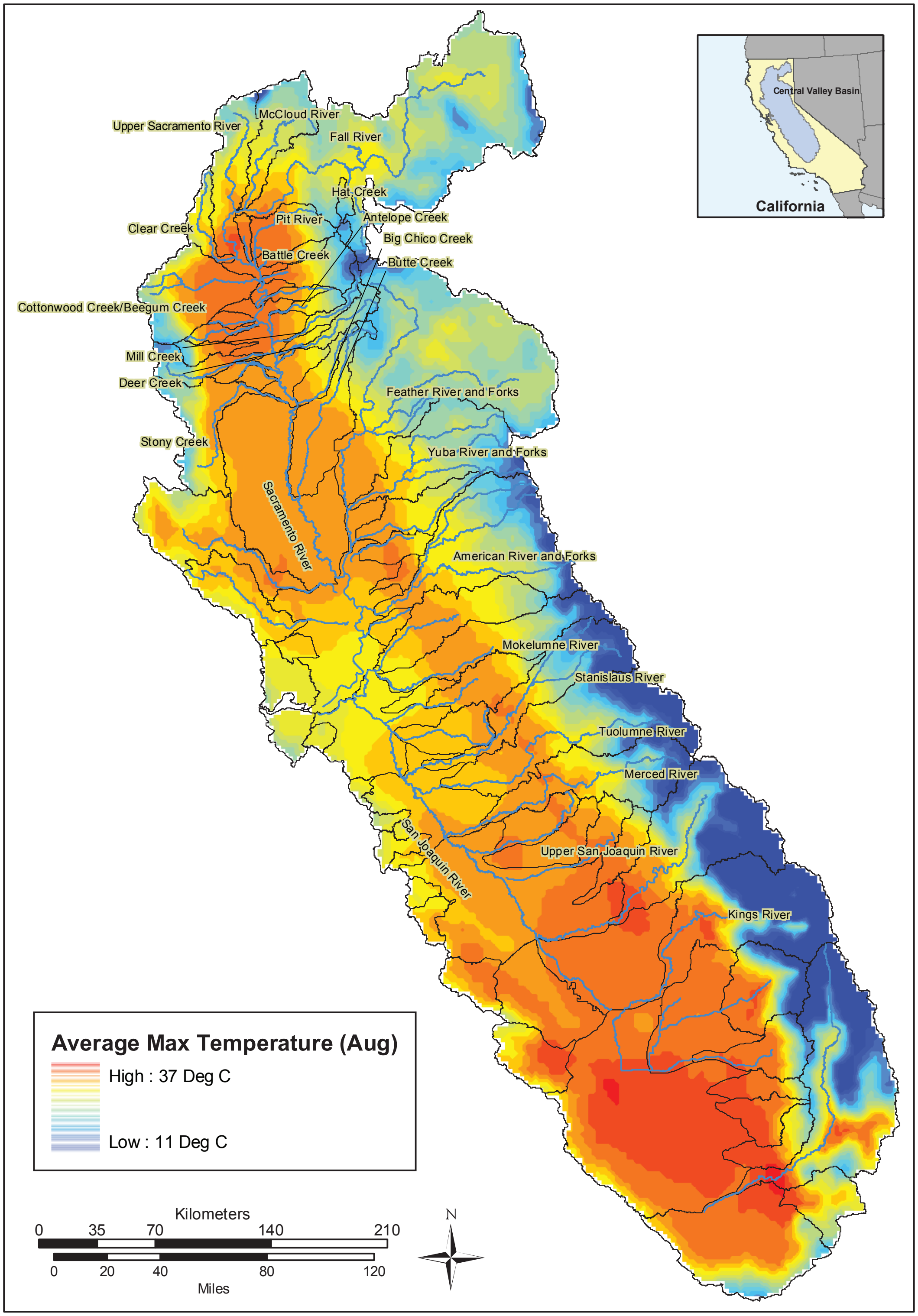

Plate 8. Average maximum August temperature.

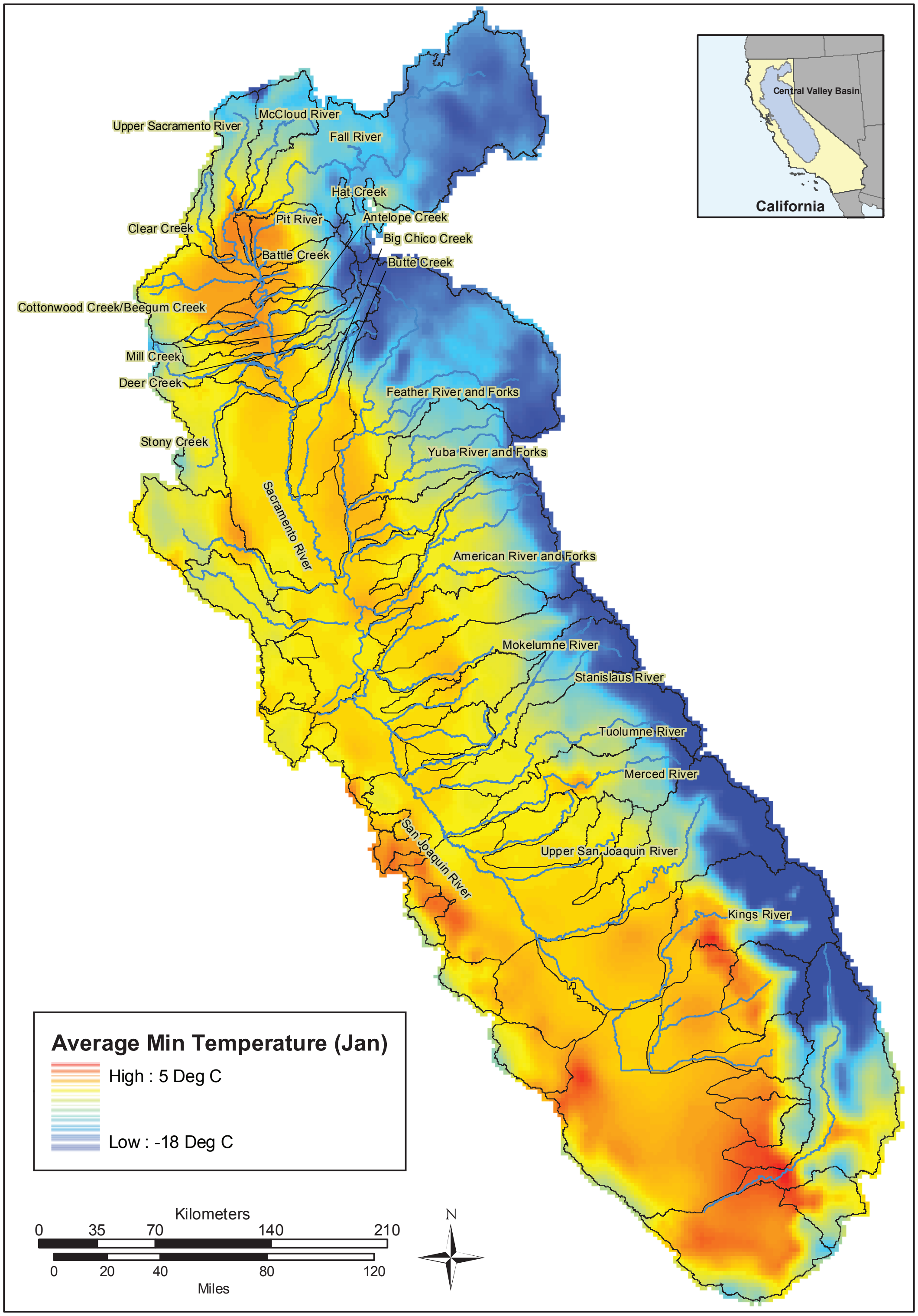

Plate 9. Average minimum January temperature.

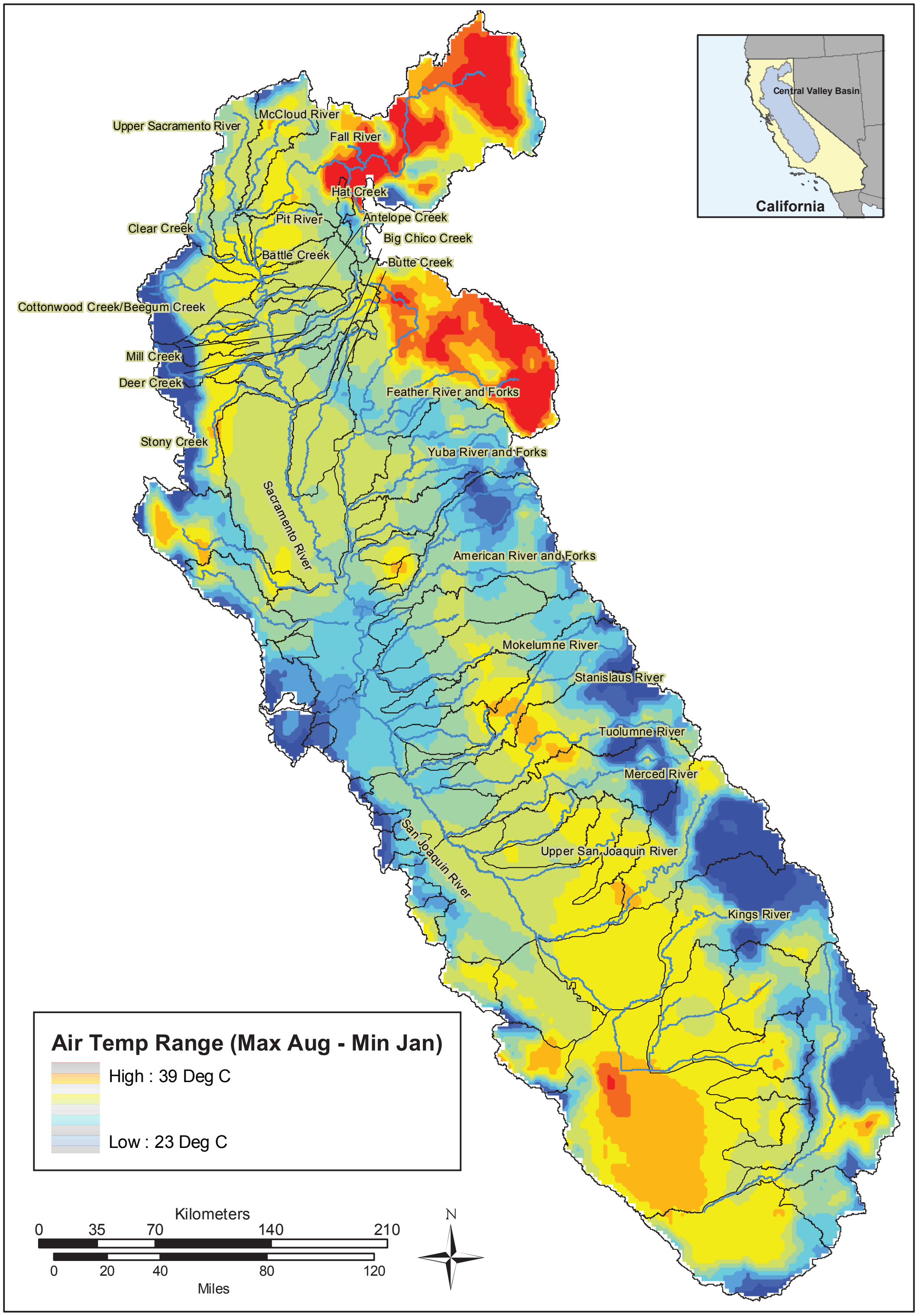

Plate 10. Temperature range (average maximum August temperature - average minimum temperature in January.

SAN FRANCISCO Estuary & Watershed SCIENCE

Historical Population Structure of Central Valley Steelhead and its Alteration by Dams

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ABSTRACT

Effective conservation and recovery planning for Central Valley steelhead requires an understanding of historical population structure. We describe the historical structure of the Central Valley steelhead evolutionarily significant unit using a multi-phase modeling approach. In the first phase, we identify stream reaches possibly suitable for steelhead spawning and rearing using a habitat model based on environmental envelopes (stream discharge, gradient, and temperature) that takes a digital elevation model and climate data as inputs. We identified 151 patches of potentially suitable habitat with more than 10 km of stream habitat, with a total of 25,500 km of suitable habitat. We then measured the distances among habitat patches, and clustered together patches within 35 km of each other into 81 distinct habitat patches. Groups of fish using these 81 patches are hypothesized to be (or to have been) independent populations for recovery planning purposes. Consideration of climate and elevation differences among the 81 habitat areas suggests that there are at least four major subdivisions within the Central Valley steelhead ESU that correspond to geographic regions defined by the Sacramento River basin, Suisun Bay area tributaries, San Joaquin tributaries draining the Sierra Nevada, and lower-elevation streams draining to the Buena Vista and Tulare basins, upstream of the San Joaquin River. Of these, it appears that the Sacramento River basin was the main source of steelhead production. Presently, impassable dams block access to 80% of historically available habitat, and block access to all historical spawning habitat for about 38% of the historical populations of steelhead.

KEYWORDS

Steelhead, *O. mykiss*, endangered species, population structure, dispersal, habitat model, dams, Central Valley.

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INTRODUCTION

Steelhead (*O. mykiss*) in California's Central Valley were identified as an evolutionarily significant unit (ESU) and listed in 1998 as a threatened species under the U.S. Endangered Species Act (1973). Myriad problems afflict steelhead in the Central Valley: impassable dams block access to much of the historically available spawning and rearing habitat (Yoshiyama and others 1996), and water diversions and withdrawals, conversion of riparian zones to agriculture, introduced species, water pollution, disruption of gravel supply, and other factors have degraded much of the habitat below the dams (McEwan 2001). Recovering Central Valley *O. mykiss* presumably will require some mix of improved access to historically available habitat and restoration of degraded habitat. A better understanding of the current and historical distribution and population structure of *O. mykiss* in the Central Valley will be critical for guiding such restoration actions, but currently available information deals with changes in distribution at a fairly coarse level and does not address population structure.

Detailed distribution data at the population level are fundamental to planning effective restoration and protection activities. In the short term, one must know where a species occurs in order to efficiently safeguard its existence. In the longer term, an understanding of historical distribution is important because it gives insight into how the species might have survived catastrophic disturbances. Prior to the era of intensive anthropogenic impacts, the Central Valley steelhead ESU apparently survived prolonged droughts (Ingram and others 1996), catastrophic volcanic eruptions (Kerr 1984), landslides triggered by fires, floods and earthquakes (Keefer 1994), and other devastating events, although individual populations of Central Valley steelhead probably were extirpated from time to time. Following recovery from disturbance, catastrophically disturbed areas likely were recolonized by neighboring populations whose members were adapted to similar environmental conditions. Understanding the historical distribution of populations within an ESU is therefore important to understanding how the ESU persisted in the past and how an altered ESU might or might not persist in the future.

To the extent that environmental conditions vary across the range of an ESU, population structure could influence the ability of the ESU to respond to climate or other sources of ecological change, as well as its resilience to catastrophic disturbances. McEwan (2001) concluded that steelhead were widely distributed in the Central Valley, ranging from the Pit River in the north to perhaps the Kings River in the south, a distribution spanning multiple ecoregions and climate zones. This wide distribution across diverse ecological conditions should have provided Central Valley *O. mykiss* with substantial opportunities for adaptation to local conditions, creating the genetic variation required for adaptation to changing conditions (Darwin 1859). While such variation would be important for ESU persistence, it also limits the ability of some populations to rescue others because the fitness of a locally adapted population would be expected to be lower in other environments (Taylor 1991). Knowing which populations might have members that are ecologically exchangeable would help guide reintroductions, should currently empty and degraded habitats be restored, and help to prioritize populations for conservation.

Habitat modeling is often used to extrapolate from and interpolate between observations of species occurrence to provide the comprehensive picture of the distribution of species that is needed to guide conservation and restoration. Ideally, habitat units are sampled randomly for the presence of the species and various qualities of the habitat are measured, allowing resource selection functions to be estimated (Manly and others 2002). These resource selection functions can then be used to characterize the suitability of habitat units that were not sampled for the occurrence of the species but for which the habitat information is available. A related but simpler approach is to characterize environmental attributes associated with specimen collections in terms of envelopes that characterize habitat as either suitable or unsuitable. The edges of these envelopes are defined by the most extreme conditions under which the organism has been commonly observed. Once defined, the envelopes can be used with appropriate environmental data to predict the distributional limits of the species. Within these distributional limits, the species may or may not be found, depending on the effects of other factors not characterized by the envelopes, but the species is not expected to be found outside of this distribution. Originally developed for predicting the distribution of agricultural pests (Cook 1929), such models are increasingly used in conservation planning for many species (e.g., Johnson and others 2004; Argáez and others 2005; Chefaoui and others 2005), including fish (Burnett and others 2003; Valavanis and others 2004; Wall and others 2004; Quist and others 2005).

In this paper, we use habitat models to describe the historical structure of the Central Valley *O. mykiss* ESU and assess how impassable dams have altered this structure. We start with a model of steelhead habitat to identify stream reaches within the Central Valley that were likely to have supported *O. mykiss* during summer months. We then analyze the spatial distribution of these stream reaches to identify clusters of reaches that are isolated from other clusters. These isolated clusters of stream reaches are presumed to have supported independent populations of *O. mykiss*. We assess the degree to which populations may be exchangeable by quantifying differences in climatic conditions experienced by the populations. Finally, we assess how man-made impassable barriers have reduced the amount of habitat available to steelhead, and how this reduction in habitat has altered the structure of the ESU.

METHODS

Modeling the Distribution of *O. mykiss*

O. mykiss habitat was predicted using two models. The first model predicts the spatial location of stream reaches, along with their mean annual discharge and gradient, using a digital elevation model (DEM) and precipitation (the PRISM data set (Daly and others 2002)) as inputs (Burnett and others 2003). Where available, we used the USGS 10-m DEM; where this was not available, we created a 10-m DEM by interpolating the USGS 30-m DEM to 10 m using a regularized spline procedure (SPLINE function, ArcGIS Ver. 9, ESRI, Redlands, CA). We recalibrated the precipitation-discharge equations in Burnett and others' (2003) model with data from the Central Valley (Appendix A).

The second model is a set of simple rules, or environmental envelopes, that define whether a given stream segment is suitable for steelhead. The envelopes include mean annual discharge (suitable if >0.028 m^3s^{-1}), gradient (suitable if <12%), and mean August air temperature (suitable if <24°C), and whether the area was considered by Knapp (1996) to be fishless prior to anthropogenic introductions. We are aware of no published data suitable for identifying a lower discharge limit for steelhead, but Harvey and others (2002) found that the density of age one-year-old-or-older steelhead was lower in streams with lower discharge in tributaries to the Eel River. A discharge of 0.028 $m^3 s^{-1}$ (or 1 cubic foot per second) was taken as a lower bound, although data of Harvey and others (2002) suggest that steelhead occasionally occur in streams with somewhat lower discharge. Steelhead are commonly found in stream reaches with gradients less than 6% (Burnett 2001; Harvey and others 2002; Hicks and Hall 2003), but in some systems they are not uncommon in reaches with gradients of up to 12% (and occasionally higher) (Engle 2002). Stream temperature is linearly related to air temperature between 0 and 24°C (Mohseni and others 1998). Steelhead in southern California are almost never found in areas where mean August air temperatures exceed 24°C (D. Boughton, NOAA Fisheries Santa Cruz Lab, in preparation). Schmidt and others (1979) reviewed available information on thermal tolerance of *O. mykiss*, and found that 24°C was the highest reported maximum temperature for *O. mykiss* rearing. More recently, Nielsen and others (1994) found that 24°C was the upper lethal temperature for juvenile steelhead in northern California. In the Eel River, steelhead were not found in streams with maximum weekly average summer temperatures greater than 22°C (Harvey and others 2002). Knapp (1996) developed a GIS coverage of historical fish distributions through a survey of published papers and unpublished reports. Most areas of the western Sierra Nevada above 1500-m elevation were historically fishless due to Pleistocene glaciation and numerous migration barriers (Moyle and Randall 1998). The final output of this stage of the analysis was a GIS dataset describing a collection of stream segments suitable for *O. mykiss*, connected by unsuitable stream segments.

Identification of Independent Populations

Following McElhany and others (2000), we define independent populations as "any collection of one or more local breeding units whose population dynamics or extinction risk over a 100-year time period is not substantially altered by exchanges of individuals with other populations." Within a basin such as the Central Valley, high summer temperatures at lower elevations fragment otherwise acceptable and continuous habitat into enclaves of interconnected habitats isolated from one another by downstream regions of thermally unsuitable habitat (Rahel and others 1996). If these enclaves are far enough apart, we expect that the enclaves will function as independent populations. We therefore intersected the 24°C mean August air temperature isotherm with the stream network to identify downstream boundaries of habitat patches. We assume implicitly that while discharge, gradient, and temperature all affect the suitability of a habitat, only temperature restricts movement between habitat patches. We computed the distance along the stream network among these downstream edges with the NODEDISTANCE function in the Network Module of ArcInfo, creating a matrix of distances among habitat patches. We used hierarchical clustering with a simple distance-based rule to group nearby patches into independent populations using the LINKAGE function (with the single linkage algorithm) in Matlab (Version 6.5.1, The Mathworks, Natick, MA). Following the Interior Columbia Basin Technical Recovery Team (2003), who reviewed available information on straying of Pacific salmonids, we chose 35 km as the critical dispersal distance: patches that link at 35 km were grouped together as independent populations. The sensitivity of the population delineation to the distance criterion was examined by calculating how the number of clusters declines with increasing linkage distance. If the total length of suitable stream habitat was less than 10 km, we ignored these small areas in subsequent analyses, on the assumption that isolated populations with less than 10 km of habitat would be unlikely to persist for long periods without immigration (Bjorkstedt and others 2005).

Quantification of Habitat Similarities

In most basins, spawning by salmonids can be successful only if it occurs at certain times, such that development and migration can occur before temperature or flow conditions become unsuitable (Montgomery and others 1996; Beer and Anderson 2001). Thus, climate, through its effects on stream temperature and flow regime, is thought to be an important selective force leading to local adaptation in salmonids (Burger and others 1985; Konecki and others 1995; Brannon and others 2004; Lytle and Poff 2004). As proxies for water temperature and flow, we characterized mean elevation (from the USGS DEM), mean annual precipitation and the temperature regime (annual mean, maximum monthly mean, minimum monthly mean and range of air temperature (all from PRISM)) over the watersheds containing the spawning and rearing habitats of each of the independent populations identified with the procedure above. Watershed boundaries were based on the CalWater 2.2 watershed map[1] of 1999, but in cases where CalWater boundaries follow political rather than geomorphic boundaries, we delineated boundaries by hand, following the DEM. We characterized the similarity of watersheds by calculating the Mahalanobis (1936) distance among the centroids of watersheds using the PDIST function in Matlab. The Mahalanobis distance reduces the effect of variables that are highly correlated with each other, and is equal to the normalized Euclidean distance between the centroids if variables are uncorrelated. We then used hierarchical clustering based on the average distance to join groups (using the LINKAGE function in Matlab), and plotted the results as a tree (with the DENDROGRAM function in Matlab).

Quantification of Habitat Loss to Dams

Goslin (2005) prepared a nearly comprehensive database of dams for California, using data from the Coastal Conservancy, McEwan (2001), USGS and the U.S. Army Corps of Engineers. We intersected these dams with our stream layer, and computed the amount of suitable habitat within each watershed that was above and below the lower-most dam that was impassable to anadromous fish, using the TRACE function in the network module of ArcInfo.

Results

Distribution of *O. mykiss* Habitat

Our model identifies 25,500 km of stream habitat suitable for *O. mykiss*, broken up into 151 discrete habitat patches, each having at least 10 km of stream habitat (Figure 1). Rivers and streams on the valley floor are largely rated as unsuitable for spawning and rearing because of high summer temperatures. The exception to this are tributaries around Suisun Bay, where summer temperatures are moderated by the marine influence of the nearby San Francisco Bay and Pacific Ocean. Large portions of the upper watersheds draining the central Sierra are ruled out because they were historically fishless according to Moyle and Randall (1998). At intermediate elevations, many small tributaries to the major San Joaquin River tributaries are of too high gradient or too low flow to support *O. mykiss*, and *O. mykiss* are restricted to the mainstems and larger tributaries. Streams in the southern Cascades, coast range and northern Sierra, in contrast, appear to have much more *O. mykiss* habitat due to their lower elevation and more moderate stream gradients.

1. The CalWater data can be obtained from the California Spatial Information Library, 900 N Street, Sacramento, CA 95814.

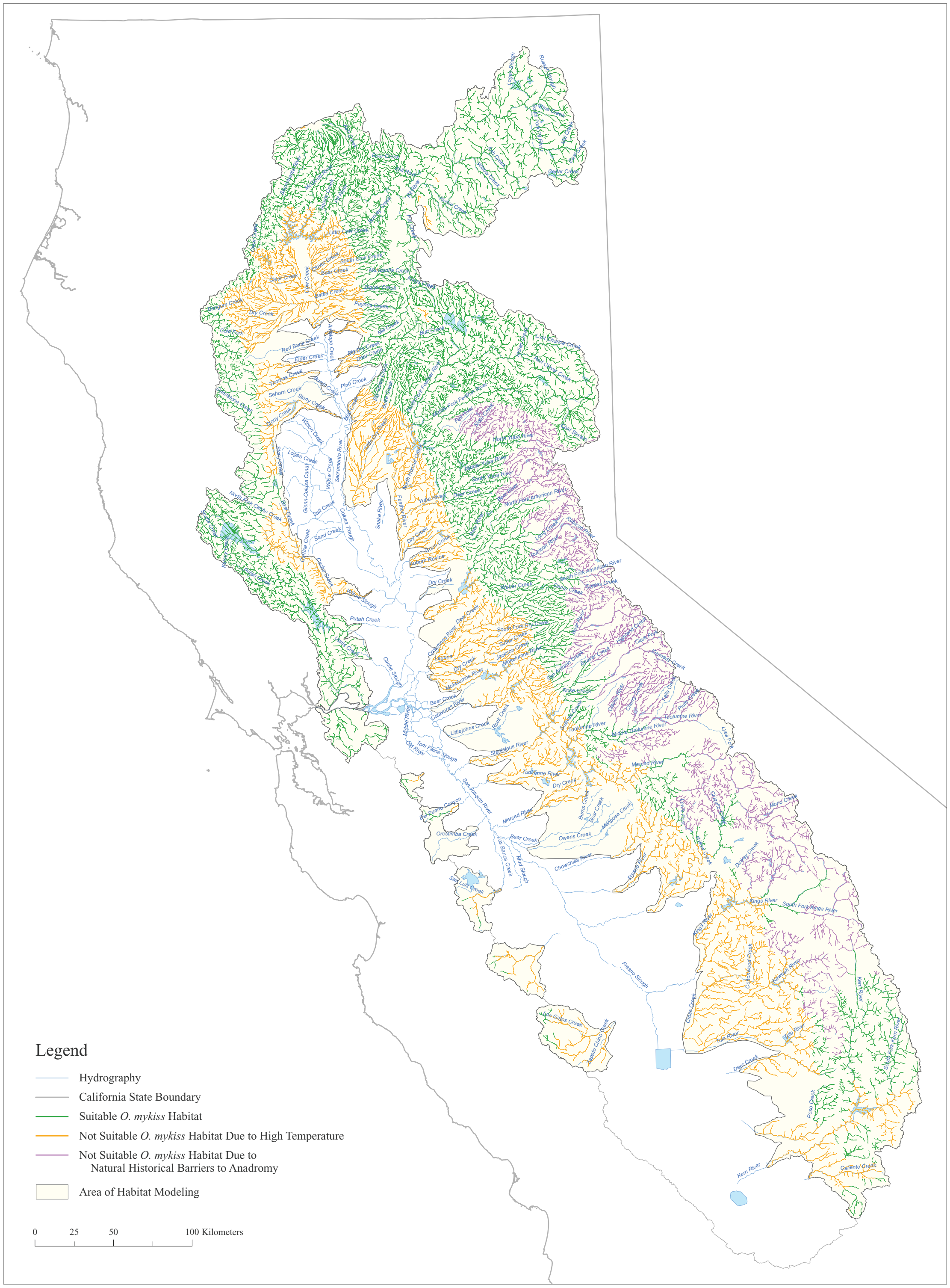

Figure 1. Predicted historical distribution of summer rearing habitat for anadromous *O. mykiss* (green). Stream reaches that would be suitable if not for high summer temperatures are shown in orange, and suitable stream reaches that were historically fishless due to natural migration barriers are shown in magenta. For legibility, streams with unsuitable gradient or discharge are not shown. Hydrography is USGS 1:1,000,000; other data are 1:24,000. (Click here for PDF file of larger image).

Independent Populations

Most subbasins of the Central Valley contain multiple discrete habitat patches, because high temperatures make the lower reaches of tributaries unsuitable in summer months. At a dispersal distance of 35 km, there are 81 clusters of habitat patches, suggesting 81 independent populations of steelhead in the Central Valley (Figure 2, Table 1). The geometry of a watershed and its relationship tothe 24°C August isotherm has a strong effect on the number of clusters within it: Cottonwood Creek, with its highly dendritic form and low elevation, has 6 isolated clusters, while the larger but more pinnate Tuolumne River contains a single cluster, as does the Pit River, which is entirely above the 24°C isotherm. The sizes of clusters are highly variable, with a few large clusters and many small ones (Table 1).

The choice of dispersal distance criterion has a strong effect on the number of independent populations identified by the clustering algorithm. There are only a few obvious breaks in the relationship between the number of clusters and the along-stream distance between them, occurring around 140, 225 and 280 km (Figure 3), corresponding roughly to the distance among the major subbasins of the Central Valley.

Similarity of Habitats

Figure 4 shows the similarity of the habitats occupied by the 81 independent populations of *O. mykiss* as a neighbor-joining tree based on Mahalanobis distance. As expected, nearby streams with similar mean elevations clustered together, although some San Joaquin tributaries clustered with Sacramento tributaries. Well-resolved clusters include the tributaries near Suisun Bay (including Sweany and Marsh creeks), the upper San Joaquin and its major tributaries draining the Sierra Nevada, the small west-side tributaries to the San Joaquin, tributaries to the now-dry Buena Vista and Tulare lakes, and a large group of Sacramento River tributaries. Within the large group of Sacramento tributaries are a few small tributaries that ultimately drain to the San Joaquin, including most notably the Calaveras River, but also smaller tributaries to the Merced, Kings and Mokelumne rivers. Some of the groupings shown in Figure 4 may be artifacts of representing the multidimensional environmental data as a neighbor-joining tree: the cophenetic coefficient (Sokal and Rohlf 1962) relating the tree to the underlying matrix of Mahalanobis distances is only 0.73 (an accurate representation would have a cophenetic coefficient close to 1.0).

Habitat Loss to Dams

About 80% of habitat identified by our model that was historically available to anadromous *O. mykiss* is now behind impassable dams, and 38% of the populations identified by the model have lost all of their habitat (Figure 5). Anadromous *O. mykiss* populations may have been extirpated from their entire historical range in the San Joaquin Valley and most of the larger basins of the Sacramento River. The roughly 52% of watersheds with at least half of their historical area below impassable dams are all small, low elevation systems. Of the eight population clusters that form at a Mahalanobis distance of 2 (Figure 4), for example, only two clusters contain watersheds with habitat that remains accessible to anadromous *O. mykiss*, suggesting that there has been a significant reduction in the diversity of habitats available to Central Valley *O. mykiss*.

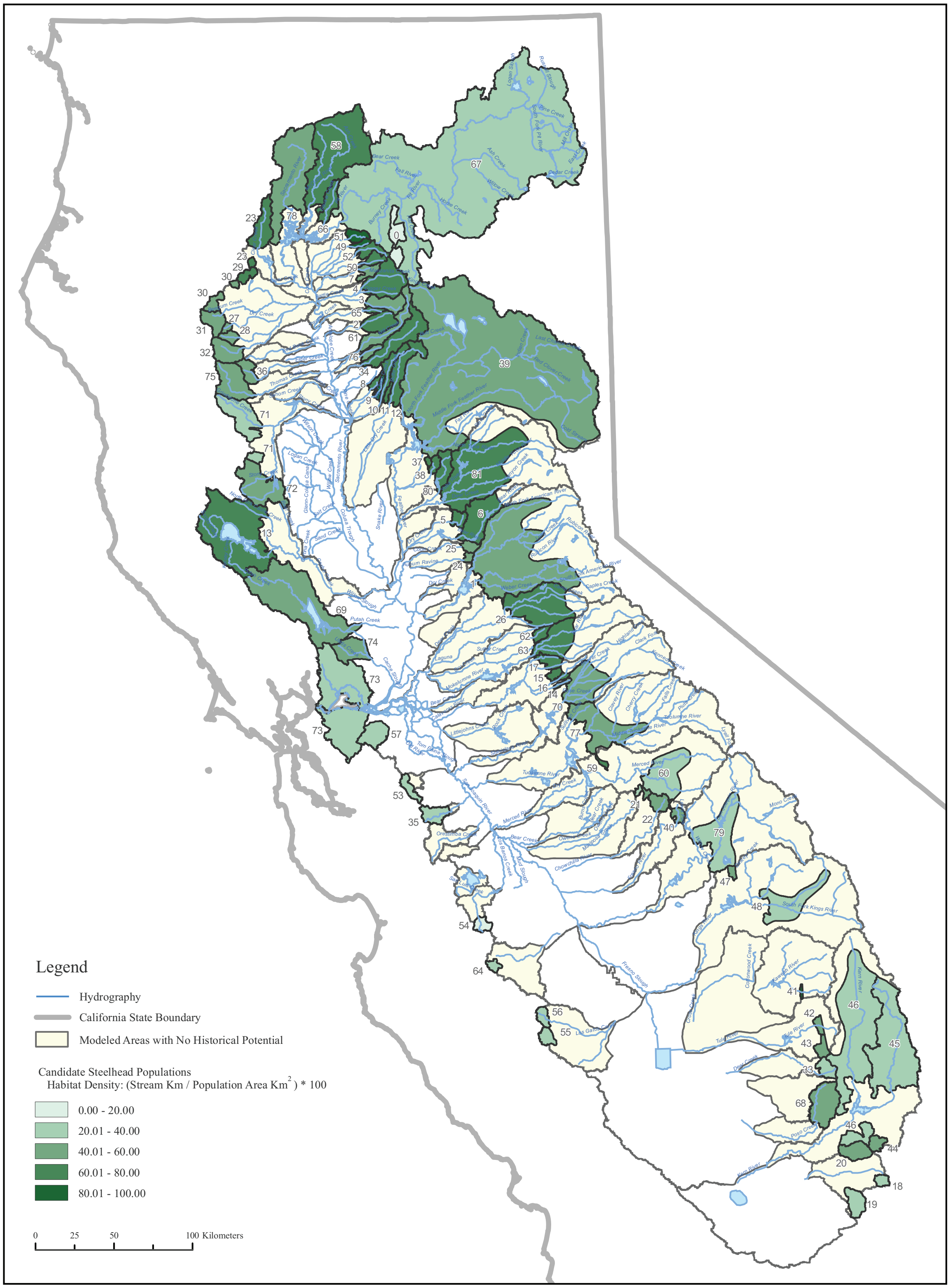

Figure 2. Spawning and rearing habitat areas of independent *O. mykiss* populations. Green polygons indicate habitat boundaries; color intensity indicates the density of habitat (km stream habitat km^{-2} x 100). (Click here for PDF file of larger image).

Table 1. Proposed historical independent populations of steelhead in the Central Valley

Independent Population	*Basin*	*Total Stream (km)*	*Streams*
1	American R.	1357.1	Auburn Ravine, NF
2	Antelope Cr	176.5	Cold Fork
3	Battle Cr	122.8	MF, SF
4	Battle Cr	349.1	Knob Gulch, NF, Rock Cr
5	Bear R (Feather trib)	58.5	NF
6	Bear R (Feather trib)	356.1	Long Valley Cr
7	Bear R (Sac trib)	51.5	Digger Cr, SF Bear Cr
8	Big Chico Cr	30.9	SF
9	Big Chico Cr	46.8	Rock Cr, mainstem
10	Big Chico Cr	114.9	East Branch Mud Cr
11	Butte Cr	29.2	MF
12	Butte Cr	269.4	mainstem
13	Cache Cr	1100.0	Deer Cr, Dry Cr, Wolf Cr, mainstem
14	Calaveras R	14.5	Woods Cr
15	Calaveras R	22.8	mainstem
16	Calaveras R	34.6	San Antonio Cr, San Domingo Cr
17	Calaveras R	71.9	McKinney Cr, O’Neil Cr
18	Caliente Cr	12.4	Indian Cr
19	Caliente Cr	60.5	Tehachapi Cr
20	Caliente Cr	75.8	Walker Basin
21	Chowchilla R	12.9	mainstem
22	Chowchilla R	61.3	Willow Cr, mainstem
23	Clear Cr	255.7	Crystal Cr, mainstem
24	Coon Cr	15.6	mainstem
25	Coon Cr	38.9	mainstem
	Cosumnes R	587.8	Cedar Cr, MF, NF, SF
27	Cottonwood Cr	16.8	mainstem
28	Cottonwood Cr	44.2	SF
29	Cottonwood Cr	55.2	Jerusalem Cr, Moon Fork, NF Bear Cr
30	Cottonwood Cr	62.4	Duncan Cr, Soap Cr, mainstem
31	Cottonwood Cr	96.8	Wells Cr
32	Cottonwood Cr	121.2	mainstem
33	Deer Cr (Kaweah trib)	46.2	Bull Run Cr, Chimney Cr, SF
34	Deer Cr (Sac trib)	299.4	Little Dry Cr
35	Del Puerto Cr	33.8	Whisky Cr
36	Elder Cr	59.3	NF, mainstem
37	Feather R	14.4	Briscoe Cr
38	Feather R	41.7	Rocky Honcut Cr
39	Feather R	5193.5	Canyon Cr, Concow Cr, Little Butte Cr, MF, NF Elk Cr, WB
40	Fresno R	38.6	Big Cr, NF
41	Kaweah R	11.6	SF Tule R

Table 1. Proposed historical independent populations of steelhead in the Central Valley (Continued)

Independent Population	*Basin*	*Total Stream (km)*	*Streams*
42	Kaweah R	20.9	Tyler Cr
43	Kaweah R	42.9	mainstem
44	Kern R	35.1	NF
45	Kern R	532.2	French Gulch, Little Poso Cr, Tillie Cr
46	Kern R	693.0	Fay Cr, Kelso Cr, Marsh Cr,
47	Kings R	20.6	SF
48	Kings R	123.3	Bitterwater Cyn, SF, mainstem
49	Little Cow Cr	33.3	Clover Cr
50	Little Cow Cr	59.4	South Cow Cr
51	Little Cow Cr	83.5	Cedar Cr, mainstem
52	Little Cow Cr	88.5	Gelndenning Cr, Old Cow Cr
53	Lone Tree Cr	28.5	EF
54	Los Banos Cr	10.2	MF Tule R
55	Los Gatos Cr	19.5	mainstem
56	Los Gatos Cr	20.1	Rube Cr
57	Marsh Cr	82.9	SF
58	McCloud R	1201.2	Nosoni Cr, mainstem
59	Merced R	18.1	Snow Cr
60	Merced R	227.9	MF, Miami Cr, mainstem
61	Mill Cr	158.7	NF Willow Cr
62	Mokelumne R	53.3	Sutter Cr, mainstem
63	Mokelumne R	276.8	NF
64	Panoche Cr	11.4	Warthan Cr
65	Paynes Cr	29.9	Beegum Cr
66	Pit R	146.5	Squaw Cr
67	Pit R	3948.0	Potem Cr, mainstem
68	Poso Cr	168.5	Alamo Cr, Indian Cr
69	Putah Cr	982.2	Scott Cr
70	Stanislaus R	218.3	Curtis Cr
71	Stony Cr	184.6	Grindstone Cr, NF, SF, Salt Cr
72	Stony Cr	237.2	Little Stony Cr, Salt Cr, South Honcut Cr
73	Suisun Bay tribs, northern Kelso Cr	573.1	Sullivan Cr, mainstem
74	Sweany Cr	127.6	Jesus Maria Cr
75	Thomes Cr	179.1	Maple Branch Mud Cr
76	Toomes Cr	34.4	Big Dry Cr, mainstem
77	Tuolumne R	323.8	Bear Cr, Corral Hollow Cr, Maxwell Cr, Moccasin Cr, mainstem
78	Upper Sacramento R	766.6	Backbone Cr, Middle Salt Cr, Salt Cr, Squaw Cr, Sugarloaf Cr, mainstem
79	Upper San Joaquin R	205.8	Clear Cr, Erskine Cr, Mill Flat Cr, mainstem
80	Yuba R	138.4	mainstem
81	Yuba R	1077.1	Dry Cr, mainstem

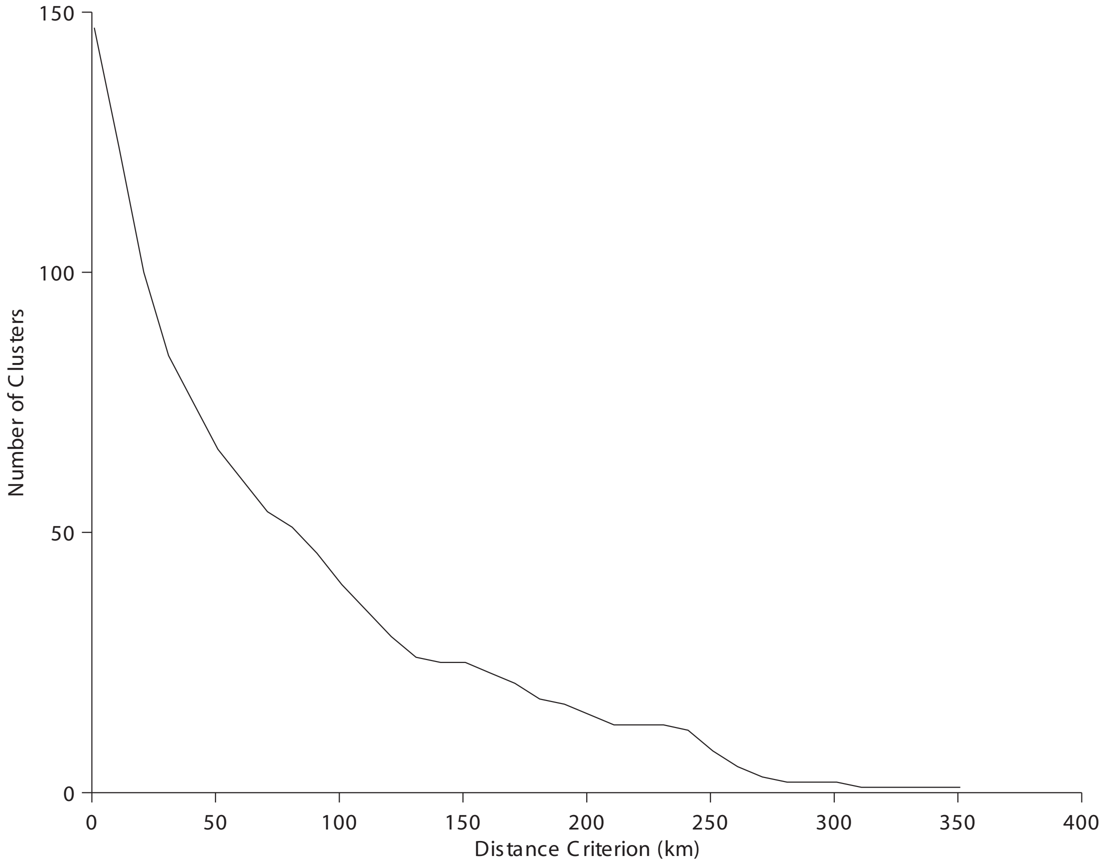

Figure 3. Linkage of habitat patches as a function of distance along the stream network. At a distance of 35 km, there are 81 discrete patches.

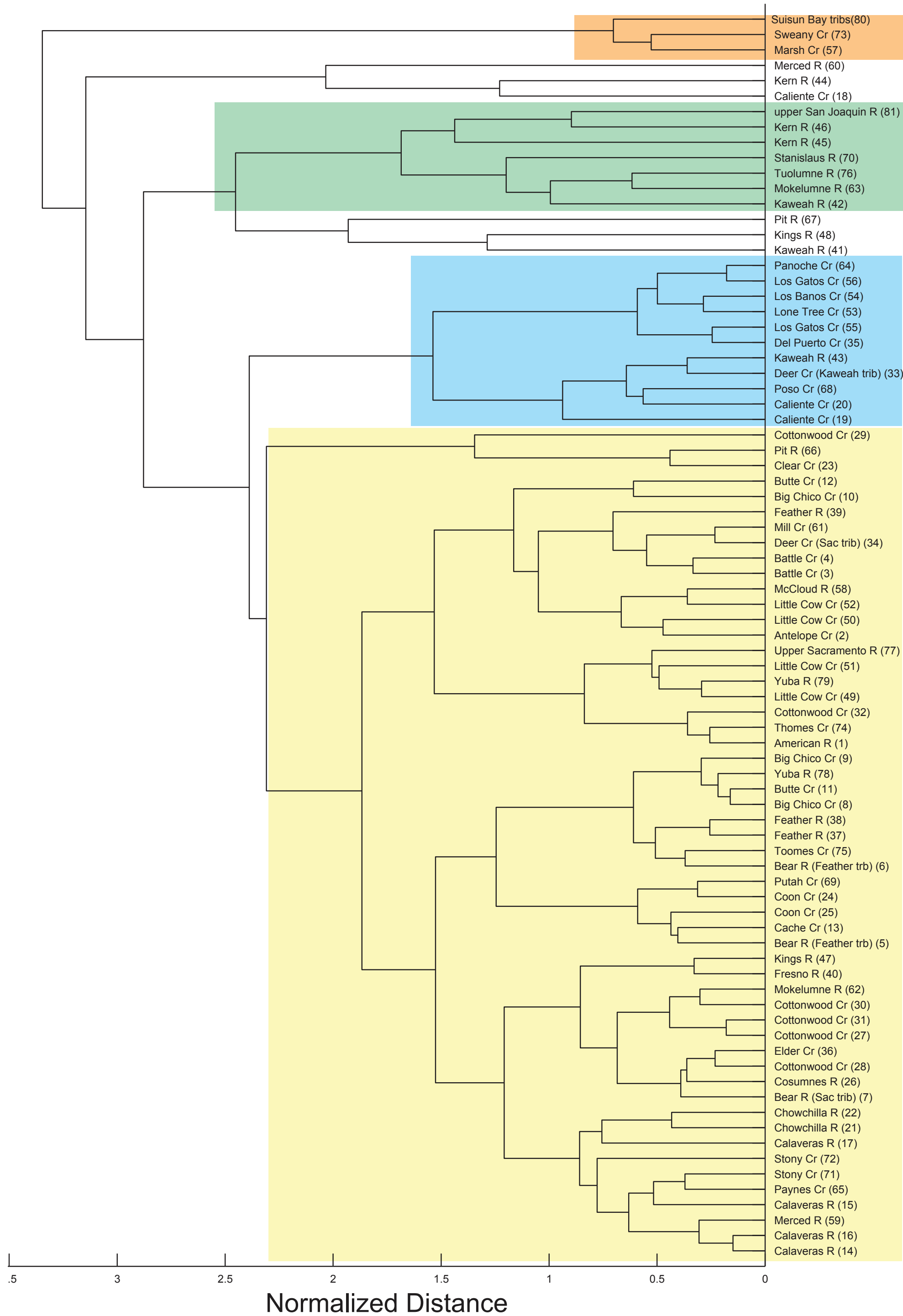

Figure 4. Neighbor-joining tree based on average Mahalanobis distances, calculated from normalized climatic variables and mean elevation. Colored backgrounds envelope clusters of basins that are largely from the same geographic region: orange—tributaries to the Sacramento below the delta; green—the upper San Joaquin and tributaries draining the southern Sierra Nevada; blue—other tributaries to the San Joaquin draining lower elevation areas; yellow—mostly tributaries to the Sacramento River. The numbers in parentheses after the basin name correspond to the population numbers in Table 1. (Click here for PDF file of larger image).

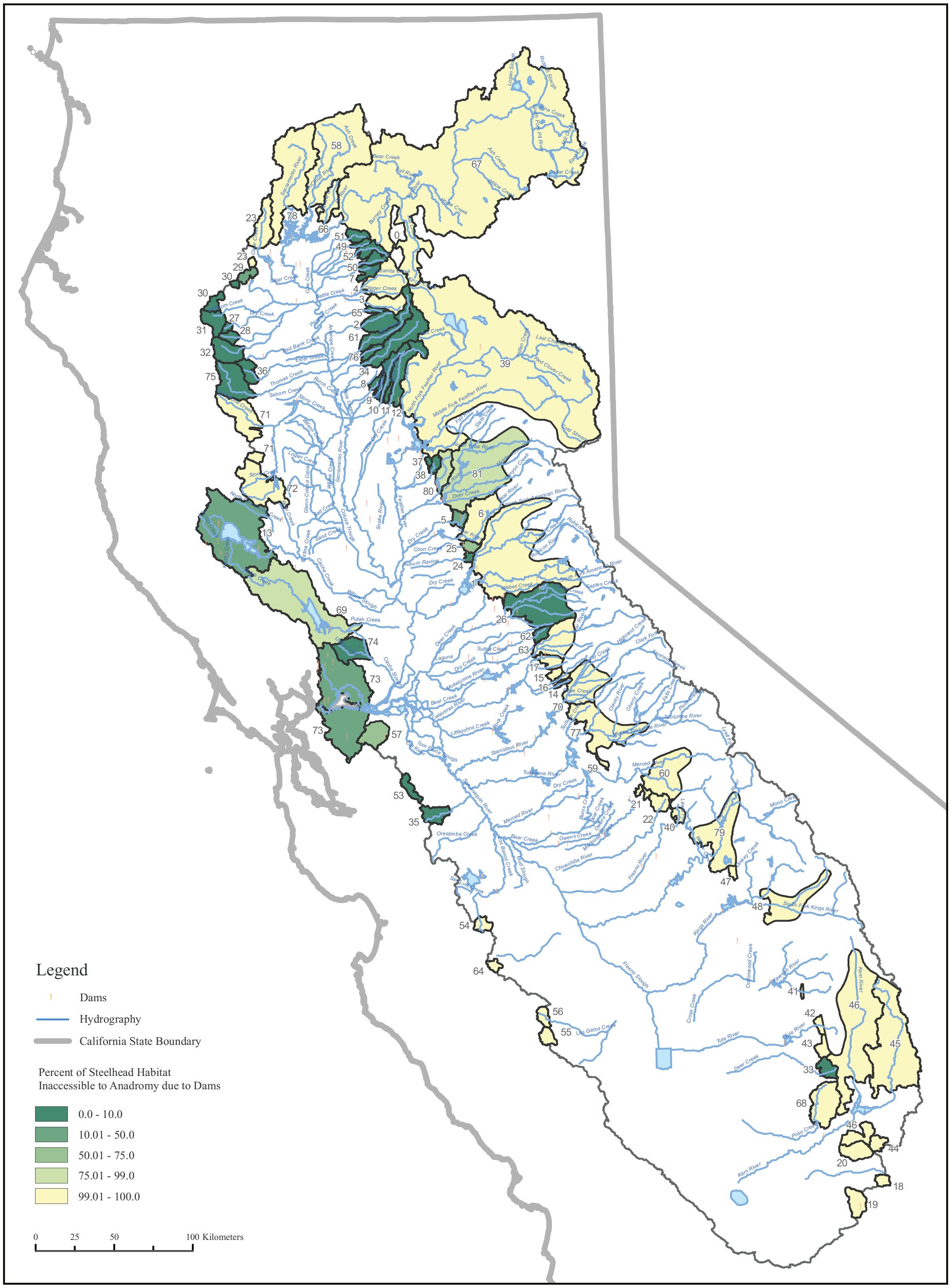

Figure 5. Percentage of historically accessible habitat behind impassable dams. Numbers indicate populations (see Table 1). (Click here for PDF file of larger image).

Discussion

We used a simple habitat model and readily available environmental information to predict the historical distribution of *O. mykiss* spawning and rearing habitat in the Central Valley. In agreement with the suggestions of McEwan (2001) and Yoshiyama and others (1996), our results suggest that *O. mykiss* was widespread throughout the Central Valley, but indicate that *O. mykiss* was relatively less abundant in San Joaquin tributaries than Sacramento River tributaries due to natural migration barriers. Due largely to high summer temperatures on the valley floor, *O. mykiss* habitat is patchily distributed, with 81 discrete patches isolated by >35 km of unsuitable stream habitat. The posited existence of 81 independent populations is likely to be an underestimate because large watersheds that span a variety of hydrological and environmental conditions, such as the Pit River, probably contained multiple populations.

High summer temperature on the valley floor is one important driver of habitat fragmentation, and thus population structure, in our model. At cooler times of the year, *O. mykiss* could potentially move freely among habitat patches. If fish commonly moved from where they were born to distant habitat patches for spawning, then the real population structure could be much simpler than that predicted by our model. It is well known that adult anadromous salmonids are capable of dispersing long distances, but this occurs at a low rate under natural conditions (Quinn 2005). Resident *O. mykiss* in the Kern River basin (Matthews 1996) and other systems (Bartrand and others 1994; Young and others 1997; Meka and others 2003) have small home ranges, on order of a few kilometers or less, suggesting that few juveniles regularly move more than a few kilometers except during their migration to sea. The other main driver of population structure in our model is our choice of 35 km as a threshold for delineating populations. While we believe that 35 km is a reasonable value, 25 or 50 km might also be reasonable, and the number of independent populations identified by our model changes significantly if these alternatives are used (Figure 3). Users of our model results should bear in mind that specific population boundaries are uncertain, and consider how different but still plausible delineations might influence their results.

The distribution of many discrete populations across a wide variety of environmental conditions implies that the Central Valley steelhead ESU contained biologically significant amounts of spatially structured genetic diversity. This hypothesis is bolstered by the presence of distinct subspecies of non-anadromous *O. mykiss* in several regions of the basin (Behnke 2002). According to Behnke's map (his p. 78), coastal rainbow trout (which include Central Valley steelhead) are distributed throughout the Central Valley, with the exception of the Pit and upper Kern rivers. Golden trout were historically found in the mainstem Kern River (*O. mykiss gilberti*), the South Fork Kern and Golden Trout Creek (*O. mykiss aquabonita*), and the Little Kern River (*O. mykiss whitei*). Similarly, redband trout (*O. mykiss stonei*) inhabit the upper Sacramento, including the McCloud, Pit, North and Middle Fork Feather rivers, and Butte Creek. Another implication of these observations is that not all of the *O. mykiss* habitat identified by our model may have been used by Central Valley steelhead, because coastal *O. mykiss* can interbreed with golden and redband trout, yet introgression appears to be a recent phenomenon.

It appears that much of the historical diversity within Central Valley *O. mykiss* has been lost or is threatened by dams. Figure 5 shows that dams have heavily altered the distribution and population structure of steelhead in the Central Valley. Our estimate of steelhead habitat loss is somewhat larger than the 70% habitat loss of Chinook salmon reported by Yoshiyama and others (2001), but quite similar to the 80% loss reported by Clark (1929). The loss is not spread evenly among populations, however. About 38% of the discrete habitat patches are no longer accessible to anadromous *O. mykiss*. For most anadromous fish, such an impact would generally mean extirpation of the affected population, but the life-history flexibility of *O. mykiss* means that formerly anadromous *O. mykiss* populations may persist as resident trout above the dams. Rainbow trout are indeed common in streams above reservoirs in the Central Valley (Knapp 1996; Moyle and others 1996). It is not at all clear, however, whether these populations are the residualized descendants of native anadromous populations, or are the descendants of rainbow trout that have been widely planted throughout California to enhance recreational trout fisheries. Nielsen and others (2005) found that fish from areas above barriers were more similar to other above-barrier populations than to fish from the same river downstream of the barrier. This could indicate a separate phylogenetic origin for these above-barrier populations (in particular, derivation from a common hatchery strain), or may be a case of long-branch attraction (Felsenstein 1978), an artifact of tree construction where widely divergent populations cluster together, away from the more closely-related populations.

The extensive loss of habitat historically available to anadromous *O. mykiss* supports the status of *O. mykiss* as a species threatened with extinction. An important next step is to identify and secure the sources of current natural production of steelhead, limited as they may be. Our model identifies those few streams where historical habitat may still be accessible (e.g., Mill, Deer, Butte and Cottonwood creeks) as likely candidates. Tailwater areas below dams with hypolimnetic releases, while not identified by our model, may also produce steelhead. Natural areas that continue to produce steelhead should be a top priority for conservation. Tailwater and above-barrier populations in the San Joaquin basin could also be important targets for conservation, because any such populations could be the only representatives of a presumably ecologically distinct segment of the ESU, assuming that they are descended from native anadromous populations. The value of these populations for recovering anadromous runs may be reduced due to the selective effects of the dams. Obviously, for populations above dams, reproductive effort devoted to producing anadromous offspring is completely lost to that population. More subtly, water releases from dams like Shasta change the thermal regime and food web structure of the river below (Lieberman and others 2001) in ways that may provide fitness advantages to resident forms. Clearly, the current state of the Central Valley landscape presents a very different selective regime than any faced by *O. mykiss* before, posing thorny issues for conservation of Central Valley steelhead.

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Monitoring and research needed to manage the recovery of threatened and endangered Chinook and steelhead in the Sacramento-San Joaquin basin

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In this report, we assess whether existing monitoring activities in the Central Valley are sufficient to determine if biological recovery goals are being met, and make recommendations for monitoring and research that could provide critically-needed information for effective management of Chinook salmon and steelhead beyond simple viability assessments. Assessing population status requires, at a minimum, estimates of abundance on the spawning grounds and the fraction of naturally-spawning fish that are of hatchery origin. We find that such data are generally available for independent populations of Chinook salmon, but are almost entirely unavailable for steelhead populations. Effective monitoring of steelhead run sizes at the population scale is needed urgently.

Effective management of listed salmonids requires more information than simply whether populations and ESUs are achieving viability targets. We anticipate that managers will need information on the response of salmonid populations to regional climate change, the use of freshwater habitat, mechanisms and magnitude of mortality in freshwater and the ocean, age- and stock-specific harvest rates, trends in effective population size and genetic diversity within and among populations, the effects of hatchery operations on naturally-spawning populations, how to go about reintroducing fish to reconnected or restored habitats, and the factors controlling and the implications of variable life history tactics of steelhead. We discuss why these information gaps need to be filled, and offer some suggestions on promising approaches to filling them. Finally, we recommend that new and existing data should be made accessible to researchers and managers through a central data portal that can aggregate information from the many existing databases.

1 Background

A key contribution of science to recovery planning is to ensure that recovery plans specify adequate monitoring of species status (Clark et al., 2002). Lindley et al. (in press.) laid out viability criteria for populations and evolutionarily significant units (ESUs) in the Central Valley recovery domain. Populations are assumed to be viable if they satisfy criteria relating to population size, trends in abundance, incidence of catastrophic disturbance, and hatchery impacts. ESUs are assumed to be viable if enough viable are distributed throughout the ESU. Monitoring ESU viability depends on monitoring the viability of populations. The first part of this report discusses the monitoring needed to determine if populations are satisfying viability criteria. Successful recovery of salmonid ESUs, however, will require more detailed information than that needed to merely assess their viability. In the second part of this report, we discuss the kinds of monitoring and research that are needed to guide recovery and management of Central Valley salmonids listed under the Endangered Species Act.

2 Monitoring for viability

Criteria for assessing the viability of threatened and endangered Chinook and steelhead in the Sacramento-San Joaquin basin are presented and discussed in Lindley et al. (in press.), and the populations, population groups, and ESUs to which they are to be applied are described by Lindley et al. (2004) and Lindley et al. (2006). The criteria and associated data requirement are summarized in Tables 1 and 2 (reproduced from Lindley et al. (in press.)). The criteria in Table 1 were modeled after IUCN (1994) as modified for Pacific salmon by Allendorf et al. (1997), and are designed for use with the data that are practical to collect, rather than the data that one might like to have for the purpose. Accordingly, use of the criteria imposes only modest requirements for monitoring: the abundance of returning adults, and the percentage of hatchery fish among the returning adults. High accuracy in these estimates may not be required, if the population clearly is not near the threshold values that separate risk categories. It is also important to note that abundance estimates need to correspond to specific populations. For example, if a simple weir count is to be used, the weir must be below the spawning grounds of a single population.

2.1 Existing monitoring programs

Existing monitoring programs for listed *Oncorhynchus* in the Central Valley are comprehensively described by Pipal (2005), and monitoring programs for all Central Valley *Oncorhynchus* are described by Low (2005); the programs are described only briefly here.

2.1.1 Spring-run Chinook salmon

Estimates of adult returns are routinely made on all Central Valley streams with extant independent populations of listed Chinook salmon, as well as on some streams with historically dependent populations. These data are available from CDFG's Grand Tab database[1], which is produced annually as part of the ocean salmon fishery assessment.

Various methods are used to estimate adult returns, including counts at ladders and weirs, snorkel surveys, and carcass surveys (Pipal, 2005; Low, 2005). Generally, estimates of adult returns in the Central Valley are given without confidence intervals or standard errors, so the accuracy of the estimates is uncertain and the statistical power of trend detection tests is unknown. A joint CDFG-NMFS review (CDFG and NMFS, 2001) noted that "The accuracy and variance of most Central Valley escapement estimates are currently unknown and may not be sufficient to meet management

[1]Grand Tab can be obtained from Robert Kano, Wildlife and Habitat Data Analysis Branch, CDFG, Sacramento, CA. or from http://www.delta.dfg.ca.gov/AFRP/

Table 1: Criteria for assessing the level of risk of extinction for populations of Pacific salmonids. Overall risk is determined by the highest risk score for any category. Reproduced from Lindley et al. (in press.) based on Allendorf et al. (1997).

	Risk of Extinction		
Criterion	High	Moderate	Low
Extinction risk from PVA	$>$ 20% within 20 years	$>$ 5% within 100 years	$<$ 5% within 100 years
	– or any ONE of –	– or any ONE of –	– or ALL of –
Population size[a]	$N_e \leq 50$	$50 < N_e \leq 500$	$N_e > 500$
	–or–	–or–	–or–
	$N \leq 250$	$250 < N \leq 2500$	$N > 2500$
Population decline	Precipitous decline[b]	Chronic decline or depression[c]	No decline apparent or probable
Catastrophe, rate and effect[d]	Order of magnitude decline within one generation	Smaller but significant decline[e]	not apparent
Hatchery influence[f]	High	Moderate	Low

[a] Census size N can be used if direct estimates of effective size N_e are not available, assuming $N_e/N = 0.2$.
[b] Decline within last two generations to annual run size $\leq$ 500 spawners, or run size $>$ 500 but declining at $\geq$ 10% per year. Historically small but stable population not included.
[c] Run size has declined to $\leq$ 500, but now stable.
[d] Catastrophes occuring within the last 10 years.
[e] Decline $<$ 90% but biologically significant.
[f] See Figure 1 of Lindley et al. (in press) for assessing hatchery impacts.

Table 2: Estimation methods and data requirements for population metrics. S_t denotes the number of spawners in year t; g is mean generation time, which we take as 3 years for California salmon.

Metric	Estimator	Data	Criterion
$\hat{S}_t$	$\sum_{i=t-g+1}^{t} S_i/g$	$\geq$ 3 years spawning run estimates	Population decline
N_e	$N \times 0.2$ or other	varies	Population size
N	$\hat{S}_t \times g$	$\geq$ 3 years spawning run estimates	Population size
Population growth rate (% per year)	slope of $\log(S_t)$ v. time $\times 100$	10 years S_t	Population decline
c	$100 \times (1 - \min(N_{t+g}/N_t))$	time series of N	Catastrophe
h	average fraction of natural spawners of hatchery origin	mean of 1-4 generations	Hatchery influence

needs, ...” However, as noted above, use of Table 1 does not necessarily require that abundance estimates be highly accurate (although standard errors for abundance estimates would be extremely useful).

In response to the need to review and improve escapement monitoring programs in the Central Valley, the CALFED Ecosystem Restoration Program approved funding in 2005 to develop a comprehensive Central Valley Chinook Salmon Escapement Monitoring Plan[2]. From January 2007 through June 2008, a project team consisting of a biostatistician, biologist, and database expert, will evaluate existing monitoring programs and make recommendations for new or revised programs, in coordination with the Central Valley Salmonid Escapement Project Work Team. The Plan is intended to improve monitoring programs for winter-run Chinook salmon and spring-run Chinook salmon, and make the data more relevant to recovery planning for these stocks. The Plan will include the design of a consistent, integrated database and data reporting and communication system for Central Valley salmon escapement monitoring data.

Currently, all spring-run Chinook salmon produced at Feather River Hatchery are marked with adipose fin clips and coded-wire tags, so that tracking the percentage of hatchery fish among spawning adults is relatively straightforward in principal. Available information indicates that the spring-run Chinook salmon population in the Feather River is clearly dominated by hatchery-origin fish. One serious complication arises from the fact that early run timing (a defining characteristic of spring Chinook salmon) appears in the progeny of FRH fall-run Chinook salmon. This raises the possibility that unmarked, early-running Chinook salmon from the FRH could stray to natural populations, where they would be difficult to detect. Ideally, all hatchery fish, or at least a constant fraction of every release group, would be marked in some way so that statistically defensible estimates of their straying rates into natural populations could be made.

Although the rugged terrain typically surrounding spring-run Chinook salmon holding and spawning habitat makes estimating the number or returning adults difficult, existing programs seem generally satisfactory for the narrow purpose of assessing population viability using Table 1. Further valuable information comes from monitoring programs for emigrating juveniles. Except for Clear Creek and the Feather River, current spring-run Chinook salmon populations fall either well below or well above the risk criteria for hatchery influence, so for the narrow purpose of applying Table 1 the accuracy of the estimates of hatchery influence for these populations is sufficient.

2.1.2 Winter-run Chinook salmon

Abundance estimates are generated from carcass surveys conducted in the area most heavily used for spawning by winter-run Chinook salmon, and by expanding counts of winter-run Chinook salmon made at Red Bluff Diversion Dam as the last portion of the run ascends seasonally-operated fish ladders. Resource managers use the carcass-based estimates for management purposes. The accuracy and precision of the mark-recapture estimates is uncertain, largely due to uncertainties surrounding how well the survey method meets the assumptions of the Jolly-Seber model used to estimate abundance. However, recent population estimates are much greater than the criterion for low risk in Table 1, and there is no apparent or probable population decline. At current abundance levels, estimates have sufficient accuracy and precision for assessing extinction risk using Table 1. For assessing the effectiveness of restoration actions, however, more accurate estimates may be needed.

In terms of Table 1, the hatchery influence criterion is more critical for winter-run Chinook salmon than the population criteria, since the rising proportion of hatchery fish among returning adults threatens to shift the population from low to moderate risk of extinction (Lindley et al., in press.). If the status of the winter-run Chinook salmon population is downgraded due to hatchery influence, the accuracy of the estimates of hatchery influence may become contentious. Bias may arise if hatchery fish differ from naturally-spawned fish in their distribution within the river, size or sex ratio. This possibility, and its effect on the estimate of hatchery contribution to natural spawning, should be examined.

2.1.3 Steelhead

In contrast to the existing monitoring programs for Central Valley Chinook salmon salmon, steelhead monitoring is insufficient to evaluate populations with respect to the criteria in Table 1, except for streams where hatchery operations likely satisfy the high risk criterion for hatchery effects (Lindley et al., in press.). Unfortunately, such information as does exist indicates sharp declines in abundance over the least half-century (McEwan, 2001). There are reasons for the dearth of data on anadromous steelhead. Steelhead spawn in the winter, when conditions for monitoring are difficult, and although many steelhead die after spawning, their carcasses are not concentrated near the spawning areas. There is also the difficulty of distinguishing resident and anadromous forms, because resident fish in the tail waters of dams that release cool water though the summer can attain the size of typical anadromous fish, and juveniles migrating downstream may not continue to the ocean. Moreover, the effectiveness of screw traps declines for larger fish, and many juvenile steelhead are large enough that they may be able to avoid the traps.

Given that the anadromous component of the ESU is critical for its long-term persistence, as made clear by the discussion of anadromous and resident *O. mykiss* in Travis et al. (2004), monitoring of the anadromous form should be substantially increased. Populations of *O. mykiss* in Central Valley streams with hatcheries are at high risk of extinction because of the high proportion of hatchery fish among naturally spawning fish (Lindley et al., in press.). More accurate estimates of adult returns will not change this assessment. Accordingly, priority should go to monitoring steelhead populations in streams without hatcheries that have the potential to support significant populations. These are likely often the same streams that support spring-run Chinook salmon, which suggests that efficiency could be maximized by employing methods capable of counting both Chinook salmon and steelhead. However, basic distributional data are needed to guide future monitoring efforts.

Traps at dams on some of these streams apparently have been effective for monitoring steelhead in the past (e.g., Figure 1). An automatic counting system such as the Vaki RiverWatcher or DIDSON sonar could be used in place of a trap, to avoid stress associated with trapping, and resistance board weirs might be used

[2]The proposal to CALFED is available online at `http://www.delta.dfg.ca.gov/erp/docs/2005grants/Central_Valley_Salmon_Esc_CMP_DA_Proposal.pdf`

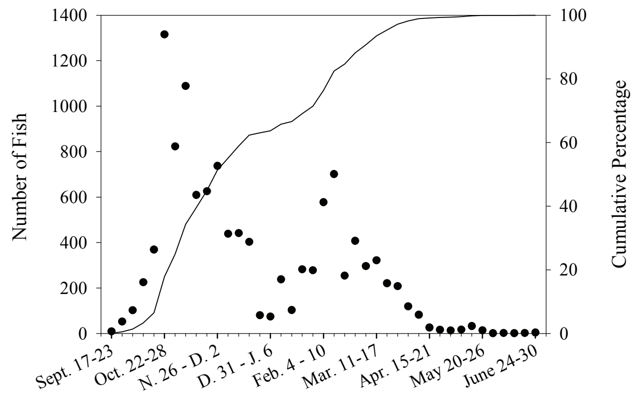

Figure 1: Total number of steelhead observed passing Clough Dam on Mill Creek, 1953-63. Data from Van Woert (1964). On average, 1,160 fish passed the dam each year. Harvey (1995), cited in Pipal (2005), reported that 34 steelhead were observed passing the dam in 1993-94, along with 76 spring Chinook.

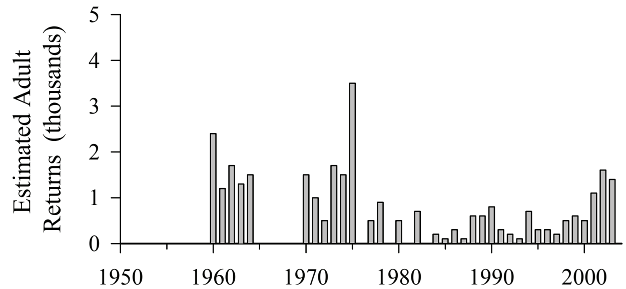

Figure 2: Estimated numbers of adult spring-run Chinook salmon returning to Mill Creek. Data from Van Woert (1964) and the CDFG GrandTab data base. For purposes of the tables, the population is the sum of the returns over a generation, i.e., 3 to 4 years.

instead of dams. Such monitoring will produce partial counts, because some fish will likely bypass the traps during high flows. These partial counts would need to exceed criteria for low extinction risk before the population could be determined to be at low risk. The same facilities could be used to obtain more accurate estimates of returning spring-run Chinook salmon.

In response to the need to develop monitoring programs for Central Valley steelhead, the CALFED Ecosystem Restoration Program approved funding in 2005 to develop a comprehensive Central Valley Steelhead Monitoring Plan[3]. From January 2007 through June 2008, a project team consisting of a biostatistician, biologist, and database expert, will design the comprehensive long-term monitoring program, in coordination with the Central Valley Steelhead Project Work Team. The plan will include the design of a consistent, integrated database and data reporting and communication system. We recommend that serious consideration be given to monitoring returning steelhead adults at weirs or traps on streams that do not have steelhead hatcheries.

3 Research and monitoring to assist management

In this section we provide recommendations regarding research that seems particularly important for improving the scientific basis for management and recovery. At the outset, however, we emphasize the close connection between monitoring and research in the context of adaptive management. The essence of adaptive management is treating management as experimental, so that monitoring provides the experimental results, and is part of science as well as part of management (Peterman et al., 1977; Halbert, 1993; Williams, 1999). Roni (2005) provides a recent review of monitoring and evaluation principles, including adaptive management, as applied to restoration of salmonid-bearing watersheds.

We emphasize that the data required for risk assessment (Table 1) are only a subset of the data required for effective management of the populations and recovery planning. Data on spring-run Chinook salmon in Mill Creek (Figure 2) illustrate this point.

Spring-run Chinook salmon in Mill Creek are monitored by redd counts, a not particularly precise method for estimating run sizes. From the data, however, it seems clear that the population has been over 2,500 in recent years, and over the last decade is not decreasing (note that for the genetic considerations underlying the population-size criterion, the population includes the adult returns for each year of a generation, which lasts 3 to 4 years; see the legend for Table 2). Because there is no reason to expect a significant hatchery influence, the population can be assigned to the low risk category, despite the considerable uncertainty in the abundance estimates.

For management, however, better data seem needed, as shown by the following example. Spring-run Chinook salmon in Mill Creek were monitored at a dam below the spawning grounds from 1954-63 (Van Woert, 1964), and the resulting information on the temporal distribution of the migration indicates that diversions for irrigation probably hinder late-arriving fish, especially in dry years (Figure 3). Better monitoring than now occurs would be required to confirm this, and to allow an assessment of the benefit to the population that might result from, say, pumping water from the Sacramento River to replace the water currently diverted from the creek a few miles upstream from the confluence. Put differently, abundance data by themselves say little about what might be done to improve conditions for the population. Similarly, although uncertain abundance estimates may be all that is needed to assess the viability of a population using Table 1, more accurate estimates may be needed to test hypotheses regarding the importance of various factors in regulating populations.

In the following subsections, we outline what we believe to be the major questions that need to be addressed in order to effectively manage salmon and steelhead in the Central Valley.

3.1 Climate change and temperature tolerance

Regional climate change (driven by global warming) is a critical issue for Chinook salmon and steelhead in the Central Valley (Lindley et al., in press.), and better information on future water temperatures and on the temperature tolerance of Chinook salmon and steelhead will be important for developing realistic recovery plans. This will require improved understanding at several levels: how temperature and precipitation will change at regional scales; how

[3]The proposal is available online at `http://www.delta.dfg.ca.gov/erp/docs/2005grants/Central_Valley_Steelhead_CMP_DA_Proposal.pdf`

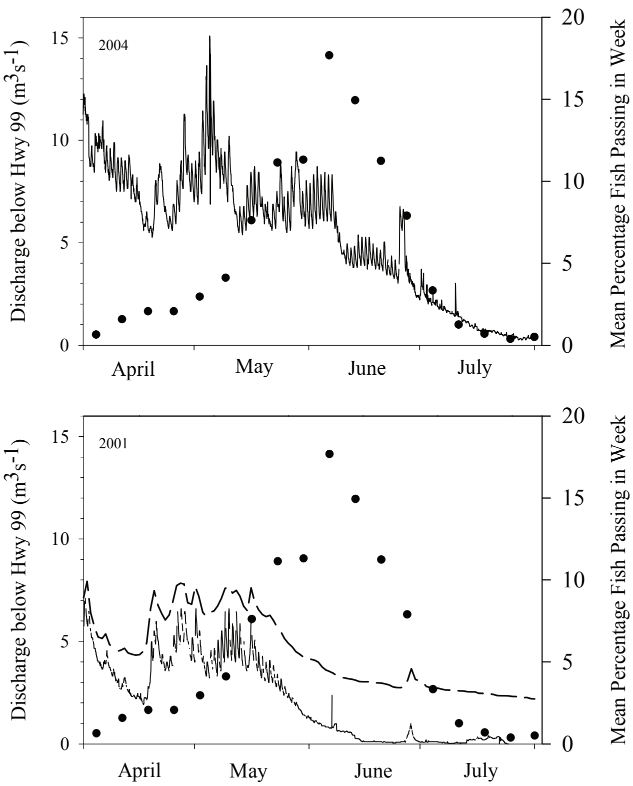

Figure 3: Temporal distribution of adult spring-run Chinook salmon migration for 1954-64 (circles), and discharge in Mill Creek at the DWR gage, downstream from diversions (solid line), and at the USGS gage, upstream from the diversions, 2001 and 2004. Migration data from Van Woert (1964). Copied from Williams (2006).

these regional-scale changes will alter conditions at the scales relevant to individuals and populations; and how individuals and populations will respond to these changes. Recent work has shown that the hierarchical structure linking large-scale climate variation to individual organisms must be understood in order to predict how organisms will respond to climate change (Gilman et al., 2006).

Several climatological studies dealing with warming and subsequent alterations to the hydrologic regime in the Central Valley have been published recently (Wilson, 2003; Dettinger et al., 2004; Hayhoe et al., 2004; Peterson et al., 2005), and we expect that more will be forthcoming. However, more focused efforts will be needed to translate the results of such studies to estimates of actual stream temperatures, which while strongly related to air temperature (Mohseni et al., 1998), are moderated by evapotranspiration, hill shading, groundwater inputs, and hyporheic exchange.

Temperature is a critical determinant of the shifting habitat mosaic (Hauer et al., 2003) that moves in time and space as river temperature isopleths migrate upstream to higher elevations in the spring/summer and downstream to the valley floor in the autumn/winter. For spring-run Chinook salmon the seasonal pattern of temperature is particularly critical. The adults enter in the spring and move to high elevations to avoid the lethal summer temperatures at lower elevations. In the autumn, temperature isopleths move downstream and the adults spread throughout the habitat to spawn. The eggs emerge and the fry move out of the system or seek temperature refugia prior to the next temperature cycle (Lindley et al., 2004).

To understand how climate change and restoration activities will affect this shifting habitat mosaic, salmon ecologist stress a landscape perspective that emphasizes the connectivity of riparian systems to associated terrestrial and aquatic ecosystems (Wissmar and Bisson, 2003). In particular, the hydrological and geological mechanisms controlling stream habitats and the fish responses to the conditions are important. In the Central Valley the seasonal patterns of precipitation and temperature determine snow accumulation and rainfall patterns which are then filtered through the surface and subsurface water exchanges to produce flow and temperature patterns in the salmon habitats. How fish respond to changes in flow and temperature over their critical life stages will determine their ability to respond and adapt to climate change.

While much information is available on the life-stage-specific temperature ranges of Chinook salmon and steelhead (McCullough, 1999) little is known about the specific responses of Central Valley species to temperature. Anecdotal evidence suggests that some species of Central Valley salmonids are heat tolerant: "The high temperature tolerance of San Joaquin River fall run salmon, which survived temperatures of 80° F, inspired interest in introducing those salmon into the warm rivers of the eastern and southern United States" (Ron Yoshiyama, public communication). The full suite of life-stage and species need not be investigated, but rather it may be sufficient to examine those life stages most vulnerable to warming. For winter-run Chinook salmon, which spawn in summer, the embryonic life stage is at greatest risk from warming. Slater (1963) found in laboratory studies that winter-run Chinook salmon eggs and alevins had almost complete mortality by the time water temperatures reached 17.4°C. For spring-run Chinook salmon, the most vulnerable stages are adults holding over the summer in streams, and the gametes that they contain, although spawners, eggs and fry may also be vulnerable into early fall. For steelhead, and for yearling spring-run Chinook salmon, older juveniles are also subject to high summer temperatures. Some juvenile spring-run Chinook salmon and steelhead may encounter stressfully warm water as they migrate through the the lower rivers and Delta in late spring. It may be possible to learn more about the effects of high temperatures under natural conditions by monitoring expression of heat shock proteins (e.g., Viant et al., 2003), viability of gametes, and mortality.

3.2 Use of freshwater habitat

Large numbers of winter-run Chinook salmon fry migrate past the Red Bluff Diversion Dam in late summer and fall (Gaines and Martin, 2002), but little is known about their survival or use of the habitat downstream from the dam. Studying small fish in large rivers is difficult, and it is not obvious how best to proceed, but some combination of exploratory and hypothesis-based research seems in order. A salient question is whether restoring more natural conditions in the Sacramento River upstream from Colusa (the meanderbelt concept) would benefit juvenile winter-run Chinook salmon.

Juvenile spring-run Chinook salmon in Butte Creek have access to a remnant of overbank habitat in the Butte Sinks and the Sutter Bypass, which may help explain the relatively high productivity of this population (Williams, 2006). This hypothesis should be explored, building on earlier Department of Fish and Game studies, because if confirmed it would provide support for the idea of increasing access to the Yolo Bypass for fish moving down the Sacramento River. Microstructural and microchemical analyses of otoliths from returning adults may be a reasonable approach.

The spatial and temporal distribution of fish from various listed ESUs in the Delta is not well known, particularly since the size criteria used to assign juvenile fish to runs are not highly accurate (Hedgecock et al., 2001). How juvenile salmon and steelhead use Delta habitats is also poorly understood, in spite of the long history of sampling in the Delta. This limits the effectiveness of habitat restoration in the Delta. Several management issues of immediate concern involve the effects of water operations on listed runs and whether operations need to be modified to avoid harm to the runs. Better understanding of the spatial and temporal patterns of habitat use by the various runs should allow more effective strategies to balance disruption of water operations and harm to the runs. Such information could be obtained by genetic analysis of tissue samples collected during regular monitoring of juveniles, as well as by more focused studies. To the extent that fish from listed ESUs are sacrificed, it seems appropriate to obtain as much information as is practicable from them; physiologically-based measures of condition, discussed by Williams (2006), should be considered for this purpose.

3.3 Juvenile migration and survival

Low survival of juvenile Chinook salmon during freshwater migration is widely believed to be a serious problem. This belief is based on the propensity of hatchery releases made in San Francisco Bay to yield much higher contribution rates to ocean fisheries than are observed for releases made near the hatchery, at least for the Feather River Hatchery, and on the recognition that river habitats have been highly altered. To date, there has never been a serious attempt to measure the survival of fish migrating down the Sacramento River or to identify locations of unusually high mortality, as has been done for many years on the Columbia River (e.g., Williams et al., 2001; Skalski et al., 2002).

CALFED has funded a collaboration between UC Davis and NOAA to estimate migration and survival patterns of late fall-run Chinook salmon and steelhead smolts as they move from Battle Creek to the ocean in 2007-09. These stocks were selected for logistical reasons, including being large enough to carry the ultrasonic transmitters used by the study, and availability of large numbers of fish. Other agencies will be tagging fish and releasing them in the Delta (USFWS) or Bay (USACOE) in coordinated studies. This study should provide new insights into the magnitude, location and perhaps mechanisms of mortality of salmonids as they migrate through the Sacramento River, Delta and Bay. As tag technology advances and tags become ever smaller, this study design should become feasible for spring-run Chinook salmon and winter-run Chinook salmon.

3.4 Population genetics

Genetic analyses have provided substantial new information about Central Valley Chinook (Banks et al., 2000; Hedgecock et al., 2001; Williamson and May, 2003), and more information will be forthcoming as improved methods for genetic analysis develop. Routine monitoring with population genetics tools can allow detection of population bottlenecks (Garcia and Williamson, 2001), estimation of effective population size (Waples, 2004), and introgression (Aurelle et al., 2002; Cordes et al., 2006). However, the utility of these methods will depend in large part of the availability of tissue samples from which DNA can be extracted. We suggest that fin samples be routinely taken when fish are handled, and sent to the CDFG Salmonid Tissue Archive. Examples of fish that should be routinely sampled would include: fish used for gamete production in hatcheries, migrating juveniles, resident *O. mykiss*, especially where both resident and anadromous forms occur, and fish used in attempts to initiate new runs.

3.5 Harvest

The harvest of listed Central Valley Chinook has generated little controversy in recent years, because populations have been stable or increasing. It seems likely that good ocean conditions have contributed substantially to this state of affairs, however, and harvest may come under greater scrutiny when ocean conditions change (see the current situation regarding Klamath River fall Chinook for a preview of what may happen when fishery management goals in the Central Valley cannot be easily achieved[4]). Harvest affects not only the number of returning adults but also their age structure, and the effects on age structure may be long-lasting (Williams, 2006). It can be anticipated that models will be used to assess the effects of harvest on populations and their viability (Newman and Lindley, 2006), in terms of effects on age structure as well as abundance. To support these assessments, appropriate sampling needs to occur both in the fisheries and on the spawning grounds.

Existing monitoring of ocean harvest provides estimates of total chinook landings and fishing effort stratified by month and catch area. Direct estimates of stock- and age-specific harvest are routinely available only for hatchery coded-wire tagged release groups, and the harvest rates on these CWT groups are used as a proxy measure of the harvest rates on their natural stock counterparts. These hatchery and natural stock counterparts may or may not be different in ways that would effect ocean harvest rates, but in any event the approach is limited to instances in which there is a suitable hatchery/natural counterpart (e.g. Livingston Stone Hatchery/natural born Sacramento River winter Chinook), and is not applicable otherwise (e.g. Central Valley spring Chinook).

Genetic stock identification (GSI) techniques have advanced significantly in recent years. When coupled with the coast-wide microsatellite database for Chinook salmon recently developed by the Pacific Salmon Commission, GSI analysis of fishery harvests should provide a substantial increase in the information available for stock-specific impact assessment and management, particularly for those stocks that do not have a CWT counterpart (although not all listed Central Valley populations are identifiable to river of origin). GSI assessments in themselves, however, do not provide the corresponding age information for the harvests, which is essential for fishery management and population dynamics modeling purposes. Therefore, existing monitoring of the harvest should be expanded to include not only the collection and processing of tissue for the purpose of stock identification, but also the collection and processing of scales or otoliths for the purpose of aging. This data together with stock- and age-specific freshwater harvest and escapement data will enable the estimation of stock-age-specific ocean harvest rates (stratified by month and catch area), maturation rates, and freshwater harvest rates. These estimates in turn provide the foundation for fishery and population viability modeling. We

[4] A Google search on "Klamath fishery controversy" on 23 January 2007 yielded 51,300 pages that will give the interested reader a sense of what to expect.

note that CDFG has recently begun routine aging of many Chinook salmon runs in the Central Valley[5]

The temporal distributions of adult freshwater migrations makes it easier to avoid harvest of listed ESUs in the freshwater fishery than in the ocean fishery, but analysis of tissue samples collected at appropriate times would serve as a check, and also provide information on the tails of the temporal distributions of the adult migrations of listed ESUs. Better monitoring of freshwater harvest is needed for effective management of fall-run Chinook salmon, and tissue samples could be collected as an adjunct to such monitoring.

3.6 Ocean climate influence

It is now generally recognized that ocean conditions can have strong effects on salmon populations, and better understanding of these effects is important for assessing the effectiveness of recovery efforts. Ocean conditions for salmon are the subject of a growing literature, but Central Valley salmon enter a unique ocean environment, the Gulf of the Farallones, and seem to respond differently to ocean conditions than do salmon farther north (MacFarlane et al., 2005; Williams, 2006). Moreover, ocean conditions probably affect winter-run Chinook salmon and spring-run differently, since most spring-run Chinook salmon enter the ocean as subyearlings in late spring, but winter-run Chinook salmon enter the ocean at larger size, in the winter or early spring. Accordingly, although studies elsewhere may provide useful information, direct assessment of the effects of ocean conditions on Central Valley ESUs seems necessary.

Studies of juvenile fall-run Chinook salmon in the Gulf of the Farallones, such as (MacFarlane et al., 2005), probably are applicable to spring-run Chinook salmon, and should be continued. Capturing juvenile winter-run Chinook salmon in the ocean does not seem feasible, even if it were desirable, and studying the otolith microstructure and microchemistry of winter-run Chinook salmon sampled during carcass counts or taken at the hatchery may offer the best opportunity for assessing year to year differences in growth during early ocean residency. Less intensive microstructural analyses of spring-run Chinook salmon may be in order, to confirm that most juveniles follow a life history pattern similar to that of fall-run Chinook salmon.

3.7 Hatchery influence

There is a broad range of concern regarding the effects of hatchery culture on salmonids (Utter, 1998; Waples, 1999), and issues at either end of the range are most relevant for Chinook salmon in the Central Valley. Regarding winter-run Chinook salmon, the concern is whether negative effects of culture in conservation hatcheries such as the Livingston Stone Hatchery outweigh the demographic benefits. More generally, work is needed on the dynamics of hatchery impacts and recovery from these impacts: the theoretical studies done to date (Goodman, 2005) examine steady-state solutions. Also, more empirical information is needed on the strength of domestication selection in the hatchery, the fitness consequences of this selection, and the strength of natural selection in counteracting domestication selection, in order to better identify the safe limits of hatchery impacts.

3.8 Estimating spawning run sizes

Despite their widespread use in the Central Valley, models to estimate in-river spawning escapement based on mark-recapture carcass survey data require a number of assumptions which may not be met in the surveys. A principal assumption of mark-recapture surveys is that the marked animals will distribute randomly among the population during the interval before the recapture sampling. This assumption is often violated for carcasses, with differing consequences on the final escapement estimate depending on the size of the run, the area sampled, and the degree to which random resampling designs are used. Another assumption in carcass mark-recapture sampling is that all fish are either available for marking or are available for recapture sampling. This assumption is likely not met in large streams with deep pools. In these areas, some carcasses may be unavailable to sampling by field crews. This may result in under or over-estimation of the actual run size as it represents an unsampled portion of the run. Research is needed to better understand the degree to which these problems may occur in carcass surveys, the effect that these violations of assumptions have on estimates, and analytical and field strategies to reduce bias.

Data should be gathered on the age and size distributions of returning adults, as well as their numbers. Data on size distributions are important for estimating fecundity, which should be taken into account in estimating the reproductive potential of a given year-class of adults, and data on age are important for assessing the effects of harvest, and more generally are needed for the age-structured population models that could be used in improved harvest and viability models. These data could be obtained during carcass surveys by measuring lengths and collecting otoliths from subsamples of fish. Otoliths could also be used for microstructure analysis to elucidate juvenile life histories, as described above. Scales might also be used to collect age information on adults, but would provide much less information on juvenile life histories.

3.9 Estimating juvenile production

Juvenile production estimates, in combination with adult return data, allow for the effects of ocean and freshwater conditions to be teased apart. Such information is extremely valuable for understanding whether habitat restoration is effective and whether ocean climate anomalies are driving abundance trends. Estimating juvenile abundance is challenging, due to problems of operating sampling gear in highly variable flows, estimating the efficiency, or capture probability, of the gear, identifying juveniles to ESU or population, and accounting for the importance of juvenile age. Advances in all of these areas are needed.

3.10 Life history of *O. mykiss*

As a species, *O. mykiss* exhibit great variation in their tendency to migrate, ranging from non-migratory (resident trout) to strongly migratory (anadromous steelhead moving from rivers to the subarctic Pacific). It is now well understood that these two forms represent two distinct life history strategies of the same taxonomic species. In some river systems, it appears that the two forms maintain separate populations; in others there is evidence that they comprise a single interbreeding population where one form can give

[5]The proposal for this project can be found online at `http://www.delta.dfg.ca.gov/erp/docs/2005grants/Cohort_Reconstruction_DA_Proposal.pdf`.

rise to the other (Zimmerman and Reeves, 2000). This type of population is said to be “polymorphic” in its life history.

In California, steelhead and resident rainbow trout are often sympatric within stream reaches accessible from the ocean. Resident and anadromous fish could either be two components of a polymorphic and panmictic population, or they might be largely separate breeding populations. In the Central Valley, there is limited evidence that at least some populations are polymorphic (Titus (2000), as cited in McEwan (2001)). How we should think about and manage *O. mykiss* populations depends on the prevalence migratory polymorphism. If it is common, then it is nonsensical to manage one of the morphs without reference to the other, because polymorphic populations should have ecological, demographic and evolutionary properties quite distinct from strictly anadromous or resident populations.

To answer the question of whether steelhead and resident rainbow trout comprise a single interbreeding population, one must determine if the two forms are reproductively isolated from one another. Reproductive isolation may occur through differences in spawning times, differences in spawning habitat, or assortative mating. A particularly attractive approach to this question is based on the ratio of strontium (Sr) to calcium (Ca) within the otolith to identify the migration history of individuals and whether that individual had a resident trout or anadromous steelhead mother. Rainbow trout that have migrated to the ocean retain a Sr/Ca signature in their otoliths. Similarly, a rainbow trout that has a steelhead mother, regardless of its own migratory history, also retains an ocean Sr/Ca signature in the primordia of its otoliths due to the fact that the egg from which it arose was formed while its mother was in the ocean. If anadromous and resident *O. mykiss* interbreed rarely, then this should be detectable as differences in the frequency of neutral genetic markers between the two populations (but such differences will not arise with even limited reproductive exchange).

We suspect that there has been a significant shift in the frequency of resident and anadromous life histories in *O. mykiss* in the Central Valley (Lindley et al., in press.), and this likely has important conservation consequences. A CalFed-funded project[6] at UCSC, NOAA and CDFG is examining the role that river regulation may have in driving these shifts, but further work is needed in documenting the distribution of life history types throughout the range, identifying the factors driving this shift, assessing the degree to which it is reversible, and evaluating the consequences for population and evolutionary dynamics.

3.11 Reintroductions

When previously blocked or degraded habitat is restored and made accessible to anadromous fish, how exactly should salmonids be reintroduced to habitats? A number of critical decisions will need to be made when new habitats are made accessible, including method of reintroduction (natural colonization, transplanting of natural fish, outplanting of hatchery fish), source population of founding stock, and methods to limit access by undesired populations, species or stocks. These decisions in turn hinge upon complex genetic, demographic and ecological processes and principles. The Southwest Fisheries Science Center is undertaking a literature review to develop a decision analysis tool to guide future reintroductions.

Figure 4: Number of spring Chinook returning to the Sacramento River above the Red Bluff Diversion Dam, as reported in the Grand Tab data base. The decrease after 1990 reflects changes in criteria for assigning fish to runs, not an actual population change.

A related effort is needed to evaluate the prospects for various fish passage technologies that might be employed to allow anadromous fish to move past currently impassable barriers. In concert with this effort, habitat and potential passage opportunities above rim dams in major tributaries of the Central Valley should be assessed.

3.12 Data Management

A good deal of data exist on Central Valley Chinook, steelhead, and their environments, from monitoring programs described by Pipal (2005) and Low (2005), and from other sources. Data are useful to the extent that they are used, however, and by and large the existing data are under used because they are not easily obtained. Worse, some of the data are misleading. Data management is difficult and expensive, but the cost of neglecting data is likely to be greater. Here are some recommendations:

1. Document the the strengths and weaknesses of existing datasets. The quality of existing datasets is highly variable, and sometimes not well documented, although Pipal (2005) provides good preliminary descriptions of many of them. For example, DFG maintains an Excel file, Grand Tab, with historical information on returns of Chinook to Central Valley streams. An apparent decline in returns of spring-run to the upper Sacramento River (above the Red Bluff Diversion Dam) after 1990 reflects a change in the criteria used to allocate fish to runs at the RBDD ladder, rather than an actual change in the population (Williams, 2006). Such problems with existing datasets need to be described before the people who know about them retire, and the descriptions need to be easily available to users of the data. This data about data is called metadata, and using metadata standards is an important step towards making comparisons among datasets feasible.

2. Develop a common portal for basic data on Central Valley salmon and steelhead and related environmental variables, using a common format and data retrieval protocols. A significant number of databases directly connected with ongoing monitoring programs exists for Central Valley fish and habitats. However, the coordination of these databases is weak, in part because the databases

[6]Proposal is available online at `https://solicitation.calwater.ca.gov/solicitations/2004.01/reports/public_proposal_compilation?proposal_id=0140`

were developed independently by programs and agencies for specific unrelated purposes. For example, CALFISH (`http://www.calfish.org/DesktopDefault.aspx`) provides information on fish migrations and trends, the IEP Data Vault points to the Bay Delta and Tributaries (BDAT) Project data on `http://bdat.ca.gov/` and the California Data Exchange (CDE; `http://cdec.water.ca.gov`) provides information on flows, storage and snow pack. The CALFISH and BDAT databases share some common variables but neither contains water data available at the CDE database and none of these sites has temperature information. Further, they use different data formats, data retrieval protocols, and have different temporal and spatial coverage.

Coordination of essentially independent databases with unique purposes is a major technical and organizational undertaking. However, the Pacific Northwest faces similar challenges and has developed the Northwest Environmental Data Network (NED) (`http://www.nwcouncil.org/ned/Default.asp`), a cooperative effort to improve collection, management and sharing of environmental data and information. The objective of the NED Portal is to direct scientific and resource management users of data to a consistent source of environmental geospatial and tabular data and metadata. In like fashion, Central Valley and related databases should be coordinated through a common data portal so that data and its metadata can be obtained in a common format using a common retrieval protocol.

3. Develop a portal for graphical data presentation. Analysis and synthesis are necessary to convert data into information. Although researchers and some others need data in numerical form, graphical presentations of data are more useful for most purposes. For example, as part of the Environmental Water Account program, DWR prepares graphics synthesizing data on fish and flow for the weekly conference calls of the Data Assessment Team. Other such graphics, designed to present up-to-date information on particular topics or to meet the needs of particular audiences, should be made available. As an example that might be emulated in the Central Valley, the DART data site (`http://www.cbr.washington.edu`) synthesizes data on fish, climate, and river conditions from various monitoring programs and provides graphical and textual information on historical, current, and forecasted fish migrations and trends. In general, if monitoring data are not worth presenting in graphical formats on a regular basis, probably they are not worth collecting. With modern graphical programs, creating such graphics and keeping them up to date would not be difficult.

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Framework for Assessing Viability of Threatened and Endangered Chinook Salmon and Steelhead in the Sacramento-San Joaquin Basin

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ABSTRACT

Protected evolutionarily significant units (ESUs) of salmonids require objective and measurable criteria for guiding their recovery. In this report, we develop a method for assessing population viability and two ways to integrate these population-level assessments into an assessment of ESU viability. Population viability is assessed with quantitative extinction models or criteria relating to population size, population growth rate, the occurrence of catastrophic declines, and the degree of hatchery influence. ESU viability is assessed by examining the number and distribution of viable populations across the landscape and their proximity to sources of catastrophic disturbance.

Central Valley spring-run and winter-run Chinook salmon ESUs are not currently viable, according to the criteria-based assessment. In both ESUs, extant populations may be at low risk of extinction, but these populations represent a small portion of the historical ESUs, and are vulnerable to catastrophic disturbance. The winter-run Chinook salmon ESU, in the extreme case, is represented by a single population that spawns outside of its historical spawning range. We are unable to assess the status of the Central Valley

steelhead ESU with our framework because almost all of its roughly 80 populations are classified as data deficient. The few exceptions are those populations with a closely associated hatchery, and the naturally-spawning fish in these streams are at high risk of extinction. Population monitoring in this ESU is urgently needed.

Global and regional climate change poses an additional risk to the survival of salmonids in the Central Valley. A literature review suggests that by 2100, mean summer temperatures in the Central Valley region may increase by 2-8°C, precipitation will likely shift to more rain and less snow, with significant declines in total precipitation possible, and hydrographs will likely change, especially in the southern Sierra Nevada mountains. Warming at the lower end of the predicted range may allow spring-run Chinook salmon to persist in some streams, while making some currently utilized habitat inhospitable. At the upper end of the range of predicted warming, very little spring-run Chinook salmon habitat is expected to remain suitable.

In spite of the precarious position of Central Valley salmonid ESUs, there are prospects for greatly improving their viability. Recovering Central Valley ESUs may require re-establishing populations where historical populations have been extirpated (e.g., upstream of major dams). Such major efforts should be focused on those watersheds that offer the best possibility of providing suitable habitat in a warmer future.

KEYWORDS

Central Valley, Chinook salmon, steelhead, *Oncorhynchus tshawytscha, Oncorhynchus mykiss,* population viability, conservation, recovery planning, catastrophes, climate change, endangered species, biocomplexity

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INTRODUCTION

Numerous evolutionarily significant units (ESUs) of Pacific salmon and steelhead are listed as threatened or endangered species under the US Endangered Species Act (ESA) of 1973. The ESA, as amended in 1988, requires that recovery plans have quantitative, objective criteria that define when a species can be removed from the list, but does not offer detailed guidance on how to define recovery criteria. Logically, some of the recovery criteria should be biological indicators of low extinction risk. Recovery plans prepared since the 1988 amendment typically have about six recovery criteria, but only about half of these are quantitative or clearly related to biological information (Gerber and Hatch 2002). Gerber and Hatch (2002) found a positive relationship between the number of well-defined biological recovery criteria and the trend in abundance for the species. This empirical finding supports our intuition that well-defined recovery goals are important for recovering species.

Recovery planning seeks to ensure the viability of protected species. Viability of populations and ESUs depends on the demographic properties of the population or ESU, such as population size, growth rate, the variation in growth rate, and carrying capacity (e.g., Tuljapurkar and Orzack 1980). In the short term, the demographic properties of a population depend largely on the quality and quantity of habitat. In the longer term, genetic diversity, and the diversity of habitats that support genetic diversity, become increasingly important (McElhany et al. 2000; Kendall and Fox 2002; Williams and Reeves 2003). Consequently, McElhany et al. (2000) suggested that the viability of Pacific salmon populations should be assessed in terms of abundance, productivity, spatial structure, and genetic and life-history diversity. ESUs can be assessed in these same terms. While providing a useful conceptual framework for thinking about viability of Pacific salmon, McElhany et al. (2000) did not provide quantitative criteria that would allow one to assess whether particular populations or ESUs are viable.

Developing objective, quantitative, and biologically meaningful recovery criteria for Pacific salmonid ESUs is difficult. Ideally, these criteria would be population- and ESU-specific, taking into account the constraints in some factors that influence viability. For example, quantity of suitable habitat will usually set some limit on the size of a population, and populations with less habitat will need to have higher intrinsic growth rates (or less variable growth) than populations with more habitat, if they are to have similar viability. Unfortunately, population-specific information is frequently unavailable. One way out of this problem is to forego population-specific goals and develop biologically relevant criteria that are generic to *Oncorhynchus* species. Conservation biologists have developed a number of such criteria for the related task of identifying and prioritizing species in need of conservation (Mace and Lande 1991; IUCN 1994; Gärdenfors et al. 2001), and these taxonomically general criteria have been modified for application to Pacific salmonids (Allendorf et al. 1997).

If extinction risks of populations were independent, assessing the extinction risk of the ESU would be straightforward—the extinction risk of the ESU would be the product of the extinction risks of all its populations. We expect the extinction risks of populations to be correlated, however, because normal environmental influences affecting the population dynamics of salmonids are spatially correlated. Perhaps even more importantly, the effects of catastrophes (defined as rare environmental perturbations with very strong negative effects on afflicted populations) can be quite widespread. Finally, in cases like the Central Valley, all populations must use certain small areas (e.g., San Pablo Bay) where a single event such as a toxic spill could affect all populations even though they are widely dispersed for most of their life cycle. In some cases, it may be possible to explicitly examine the vulnerability of ESUs to catastrophic risks. We are unlikely to be able to identify all possible sources of risk, however, so we should also think of managing risk by maximizing diversity within ESUs.

In this report, we develop an approach for assessing the viability of Pacific salmonid populations and ESUs, and apply it to listed ESUs in California's Central Valley domain. In the "Assessment Framework" section below, we extend the criteria-based approach of Allendorf et al. (1997) to account for the effects of hatchery fish on the extinction risk of naturally-spawning populations, and explicitly define a "low" extinction risk category. This low-risk definition can serve as a default goal for recovering populations for which too little data exist for more detailed goals to be developed. ESU viability is addressed in two ways. In the first, risk-spreading is assessed by examining how viable populations are spread among geographically-defined regions within the ESU. In the second, we attempt to account explicitly for the spatial structure of the ESU and the spatial structure of various catastrophic risks, including volcanos, wildfires, and droughts. In the "Application to Central Valley Salmonids" section, we apply the analyses to Central Valley spring-run Chinook salmon (*Oncorhynchus tshawytscha)*, Sacramento River winter-run Chinook salmon (*O. tshawytscha)*, and Central Valley steelhead (*Oncorhynchus mykiss)*. As these methods implicitly assume that the future will be like the recent past, we review the likely effects of climate variation and climate change in "Climate Variability and Change." The "Summary and Recommendations" section summarizes our findings and makes some recommendations for recovery planners.

ASSESSMENT FRAMEWORK

Population Viability

Risk Categories

The goal of our population-level viability assessment is to classify populations into one of six categories, including "extinct," "extinct in the wild," "high," "moderate," and "low" extinction risk, or "data deficient," following the general approach of the IUCN (1994) as modified for Pacific salmonids by Allendorf et al. (1997). The goal of recovery activities should be to achieve at least a low risk of extinction for focal populations. We assume that a 5% risk of extinction in 100 years is an acceptably low extinction risk for populations (Thompson, 1991). Many salmonid populations are capable of achieving much lower risk levels and can provide additional benefits to ecosystems (Schindler et al. 2003) and people (e.g., by providing fishing opportunities) at these higher levels of abundance and productivity.

For Chinook salmon, we infer that populations are extinct if all of their historically utilized spawning habitat is blocked by impassable dams. *O. mykiss* pop-

Table 1. Criteria for assessing the level of risk of extinction for populations of Pacific salmonids. Overall risk is determined by the highest risk score for any category. (Modified from Allendorf et al. 1977)

Criterion	Risk of Extinction: High	Moderate	Low
Extinction risk from PVA	$>20\%$ within 20 years	$>5\%$ within 100 years	$<5\%$ within 100 years
	– or any ONE of –	– or any ONE of –	– or ALL of –
Population size[a]	$N_e \leq 50$ –or– $N \leq 250$	$50 < N_e \leq 500$ –or– $250 < N \leq 2500$	$N_e > 500$ –or– $N > 2500$
Population decline	Precipitous decline[b]	Chronic decline or depression[c]	No decline apparent or probable
Catastrophe, rate and effect[d]	Order of magnitude decline within one generation	Smaller but significant decline[e]	not apparent
Hatchery influence[f]	High	Moderate	Low

[a] Census size N can be used if direct estimates of effective size N_e are not available, assuming $N_e/N = 0.2$.
[b] Decline within last two generations to annual run size ≤ 500 spawners, or run size > 500 but declining at $\geq 10\%$ per year. Historically small but stable population not included.
[c] Run size has declined to ≤ 500, but now stable.
[d] Catastrophes occuring within the last 10 years.
[e] Decline $< 90\%$ but biologically significant.
[f] See Figure 1 for assessing hatchery impacts.

ulations may persist above migration barriers even if spawning habitat is inaccessible to anadromous fish, so migration barriers can not be taken as evidence of extinction for *O. mykiss*. In some cases, dams create suitable habitat in downstream reaches (typically through regulated discharges of cold water), and may support a population. We assess the status of such populations with the criteria described below, but note that the identity of tailwater populations may differ from populations historically found above the barrier.

Populations entirely dependent on artificial production (i.e., found only in a captive broodstock program or hatchery) would be considered extinct in the wild.

Risk categories from "high" to "low" are defined by various quantitative criteria, and correspond to specific risks of extinction within specific time horizons (Table 1). We extend Allendorf et al.'s (1997) criteria categories and risk levels in two ways (Table 1). First, we define criteria for the "low" risk category, which are implicit in Allendorf et al. (1997) Table 1. To simplify analysis, we collapse Allendorf et al. (1997) "very high" and "high" risk categories into a single "high" risk category. We add a set of criteria to deal with fish produced by hatcheries that spawn in the wild. Allendorf et al. (1997) deal with hatchery fish in their assessment of conservation value, but for our purposes of defining recovery criteria, the influence of hatchery fish must be included in the viability criteria.

Populations are classified as "data deficient" when there are not enough data to classify them otherwise. It is possible to classify a population as "high" risk with incomplete data (e.g., if it is known that $N_e < 50$, but trend data and hatchery straying are lacking), but a low risk classification must be met with all criteria.

Risk Criteria

Following Allendorf et al. (1997), the first set of criteria deal with direct estimates of extinction risk from population viability models. If such analyses exist and are deemed reasonable, such assessments may be sufficient for assessing risk; indeed, Allendorf et al. (1997) intended that their other criteria be used when such analyses were not available. The simplest useful population viability assessments are based on the random-walk-with-drift model (Dennis et al. 1991), and can be extended to account for observation error (Lindley 2003); we use this model where possible in this paper. We note that trying to predict absolute extinction risk is subject to many pitfalls and is viewed with skepticism by many conservation biologists and ecologists (Beissinger and Westphal (1998) provides a review of the various issues). We therefore recommend that population viability analysis (PVA) results be compared to the results of applying the simpler criteria, described below.

The effective population size criteria in the second row of Table 1 relate to loss of genetic diversity. The effective population size, N_e, is smaller than the population census size N due to variation in reproductive success among individuals. For Chinook salmon, N_e/N ranges from 0.06 to 0.29 (Waples et al. 2004). N_e can be estimated from detailed demographic or genetic data (e.g., see Ardren and Kapuscinski 2003). Very small populations, for example with $N_e < 50$, suffer severe inbreeding depression (Franklin 1980; Soulé 1980), and normally outbred populations with such low Ne have a high risk of extinction from this inbreeding.

Somewhat larger, but still small, populations can be expected to lose variation in quantitative traits through genetic drift faster than it can be replaced by mutation. Franklin (1980) and Soulé (1980) used population genetics models to show that such drift is significant when $N_e < 500$. The assumptions behind the $N_e > 500$ rule are problematical in two ways. On one hand, the original models used to derive the 500 rule (Franklin 1980; Soulé 1980) assumed that all mutations were mildly deleterious, but later research showed that only 10% of mutations are mildly deleterious (Lande 1995). This means that mutation effectively introduces new genetic variation at only 10% of the rate previously assumed, so N_e should therefore be > 5000 to attenuate the loss of genetic diversity due to drift. On the other hand, the models of Franklin and Sóule also assume that populations are closed to immigration. Very low levels of immigration, on the order of one individual per generation, can prevent the loss of alleles through drift (Wright 1931). We note that salmonid populations within ESUs are expected to have immigration at such low rates. Given the countervailing effects of the violations of the assumptions underlying the $N_e > 500$ rule, we apply the Allendorf et al. (1997) criteria as they stand, but note that with future research, it may be possible to define population size targets that conserve genetic variation and account for migration and genetic structuring within ESUs (e.g., Whitlock and Barton 1997).

The population decline criteria are intended to capture demographic risks. The rationale behind the population decline criteria are fairly straightforward– severe and prolonged declines to small run sizes are strong evidence that a population is at risk of extinction. The criteria have two components– a downward trend in abundance and a critical run size (< 500 spawners). Note that spawning run size is distinct from N_e. Although it is not clear how Allendorf et al. (1997) chose 500 as the threshold spawning run size, we adopt this threshold to maximize consistency with their criteria. We also note that typical salmonid populations near a carrying capacity of 500 spawners require only modest intrinsic growth rates to have low probability of extinction, given typical levels of variation in population growth (D. Boughton, NOAA Fisheries, Santa Cruz, CA; in preparation).

The catastrophe criteria trace back to Mace and Lande (1991), and the underlying theory is further developed by Lande (1993). The overall goal of the catastrophe criteria is to capture a sudden shift from a low risk state to a higher one. Catastrophes are defined as instantaneous declines in population size due to events that occur randomly in time, in contrast to regular environmental variation, which occurs constantly and can have both positive and negative effects on the population. Catastrophes have a qualitatively different effect on the distribution of mean time to extinction than does environmental variation. Because of this, it is sensible to treat catastrophes separately from population declines. We view catastrophes as singular events with an identifiable cause and only negative immediate consequences, as opposed to normal environmental variation which can produce very good as well as very bad conditions. Some examples of catastrophes include disease outbreaks, toxic spills, or vol-

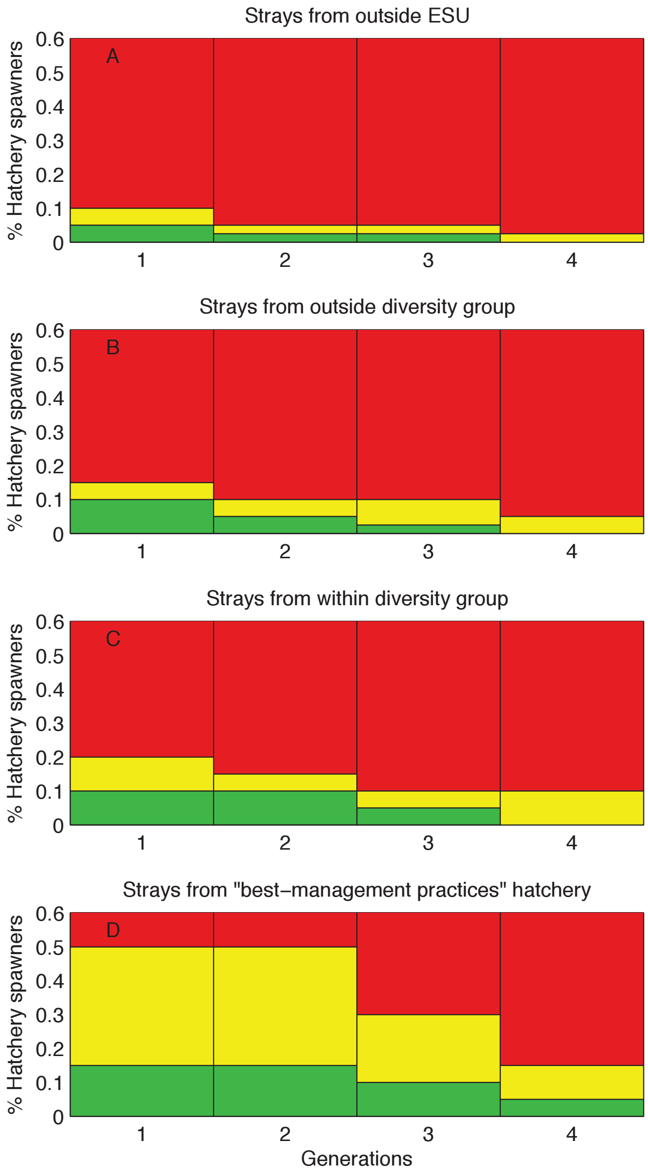

Figure 1. Extinction risk levels corresponding to different amount, duration and source of hatchery strays. Green bars indicate the range of low risk, yellow bars moderate risk, and red areas indicate high risk. Which chart to use depends on the relationship between the source and recipient populations. A: hatchery strays are from a different ESU than the wild population. B: Hatchery strays are from the same ESU but from a different diversity group within the ESU. C: Hatchery strays are from the same ESU and diversity group, but the hatchery does not employ "best management practices." D: Hatchery strays are from the same ESU and diversity group, and the hatchery employs "best management practices." Redrawn from Interior Columbia Basin Technical Recovery Team (2005).

canic eruptions. A high risk situation is created by a 90% decline in population size over one generation. A moderate risk event is one that is smaller but biologically significant, such as a year-class failure.

We view the spawning of hatchery fish in the wild as a potentially serious threat to the viability of natural populations. Population genetics theory predicts that fish hatcheries can negatively impact wild populations when hatchery fish spawn in the wild (e.g., Emlen 1991; Lynch and O'Hely 2001; Ford 2002; Goodman 2005). These predictions are supported by mounting empirical evidence (e.g., Reisenbichler and McIntyre 1977; Chilcote et al. 1986; Reisenbichler and Rubin 1999; McLean et al. 2003; Kostow 2004). In assessing the genetic impact of immigration on a population, one must consider the source of the immigrants, how long the impact goes on, the number of immigrants relative to the size of the recipient population, and how divergent the immigrants are from the recipient population. We adopt the approach of the Interior Columbia Basin Technical Recovery Team (TRT) (2005) to define how different scenarios relate to extinction risk for natural populations, summarized in Figure 1. We made one significant change to the Interior Columbia Basin Technical Recovery Team (2005) hatchery introgression criteria, allowing up to 5% of naturally spawning fish to be of hatchery origin while maintaining a low risk, if the hatchery fish are from a hatchery using "best management practices" (see Flagg et al. 2004; Olson et al. 2004; Mobrand et al. 2005, for a description of these practices) using broodstock derived from the wild population. This is consistent with the ICBTRT scheme, which can result in a low-risk classification even with moderate amounts of straying from best-practices hatcheries, so long as other risk measures are acceptable. We note that the risk levels depicted in Figure 1 are based on expert opinion, and that the empirical basis for relating hatchery impacts to extinction risk is currently limited (Bilby et al. 2003).

Allendorf et al. (1997) did not specify how to calculate estimates for the various viability criteria. Table 2 provides estimators that we have used in this paper. The average run size is computed as the mean of up to the three most recent generations, if that much data are available. Mean population size is estimated as the

Table 2. Estimation methods and data requirements for population metrics. St denotes the number of spawners in year t; g is mean generation time, which we take as three years for California salmon.

Metric	Estimator	Data	Criterion
$\hat{S}_t$	$\sum_{i=t-g+1}^{t} S_i/g$	$\geq$ 3 years spawning run estimates	Population decline
N_e	$N \times 0.2$ or other	varies	Population size
N	$\hat{S}_t \times g$	$\geq$ 3 years spawning run estimates	Population size
Population growth rate (% per year)	slope of $\log(S_t)$ v. time $\times 100$	10 years S_t	Population decline
c	$100 \times (1 - \min(N_{t+g}/N_t))$	time series of N	Catastrophe
h	average fraction of natural spawners of hatchery origin	mean of 1-4 generations	Hatchery influence

product of the mean run size and the average generation time. Population growth (or decline) rate is estimated from the slope of the natural logarithm of spawners versus time for the most recent 10 years of spawner count data. The fraction of naturally spawning fish of hatchery origin is the mean fraction over one to four generations.

ESU Viability

ESU viability depends on the number of populations within the ESU, their individual status, their spatial arrangement with respect to each other and sources of catastrophic disturbance, and diversity of the populations and their habitats. In the most general terms, ESU viability increases with the number of populations, the viability of these populations, the diversity of the populations, and the diversity of habitats that they occupy. Under natural conditions, most salmonid ESUs have persisted for at least many centuries, and perhaps much longer, given the observed level of genetic differentiation within and among them. How much can an ESU be altered before it is considered at risk of extinction? While we will not assess ESU viability in absolute terms, we assume that recovery planners will want ESUs to be likely to persist in the face of environmental variation of the sort we know has occurred over the last 500-1000 years. Such variation has included natural catastrophes such as prolonged drought, volcanic eruptions, large wildfires, and anthropogenic impacts such as the 1991 Cantara metam sodium spill. Such catastrophes could occur at any time in the foreseeable future. Therefore, for ESUs to be considered viable, they should at a minimum be able to persist if challenged by any one of these types of catastrophes.

Viability by Representation

We assess ESU viability with two different approaches. The goal of both approaches is to spread risk and maximize future potential for adaptation. The Puget Sound, Willamette/Lower Columbia and Interior Columbia TRTs have used variations on the idea of dividing ESUs into subunits (Myers et al. 2003; Ruckelshaus et al. 2002; Interior Columbia Basin Technical Recovery Team 2003), and requiring representation of all subunits and redundancy within the subunits (which we call the “representation and redundancy” rule). The ESU subunits are intended to capture important components of habitat, life history or genetic diversity that contribute to the viability of salmonid ESUs (Hilborn et al. 2003; Bottom et al. 2005). If extinction risks are not strongly correlated between populations, two populations, each with low risk of extinction, would be extremely unlikely to go extinct simultaneously (McElhany et al. 2003). Should one go extinct, the other could serve as a source of colonists to re-establish the extirpated population. Therefore, at

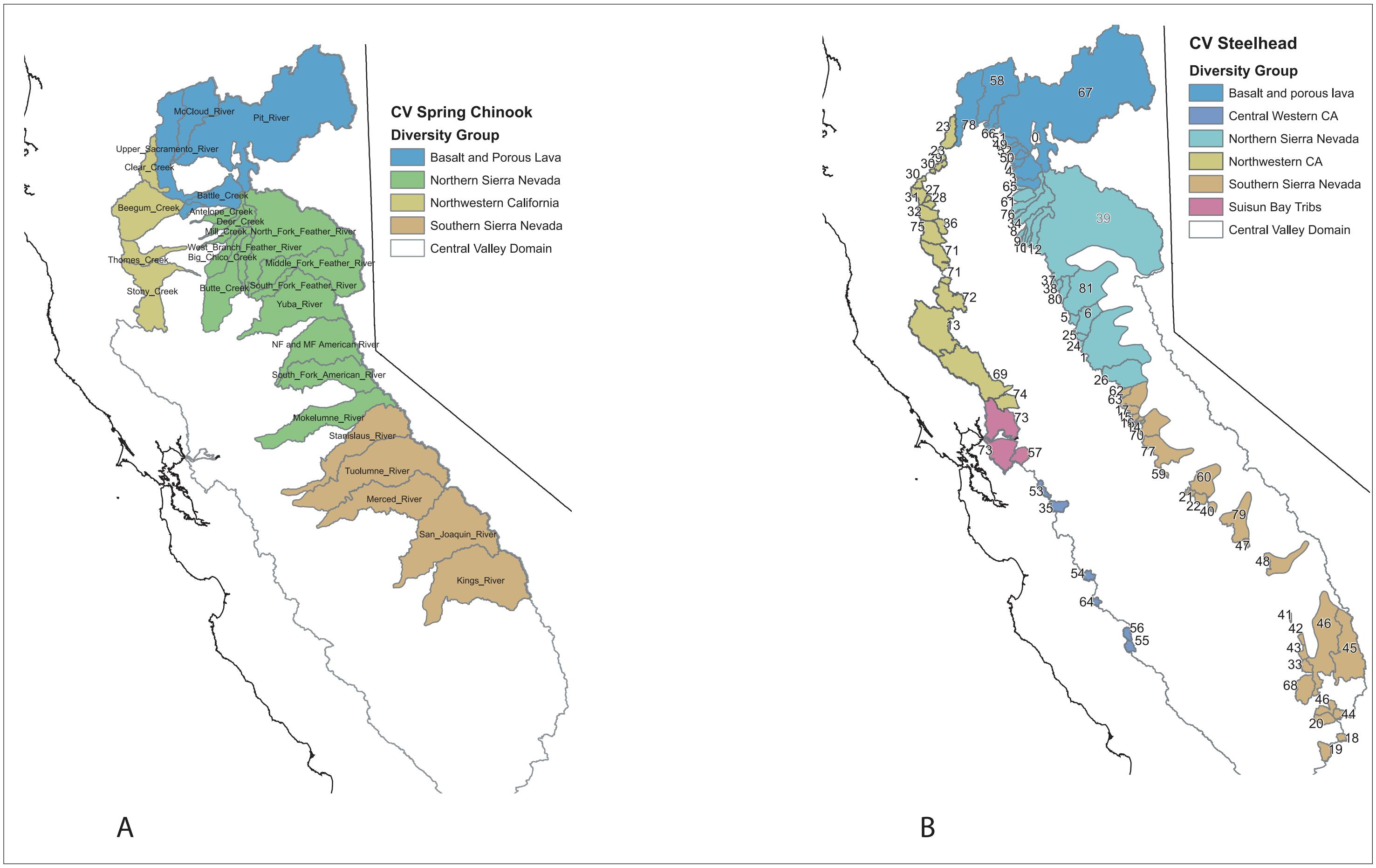

Figure 2. Salmonid ecoregions within the Central Valley. Map A: Central Valley spring-run Chinook salmon. Map B: Central Valley steelhead. Sacramento River Winter-run Chinook salmon not shown because this ESU has only one region (Basalt and porous lava). The numbers identifying steelhead populations correspond to Table 1 in Lindley et al. (2006).

least two viable populations within each ESU subunit are required to ensure viability of the subunit, and hence the ESU. In the cases of large subunits, more than two viable populations may be required to maintain connectivity among populations.

As discussed in Lindley et al. (2004), drainages in the Central Valley basin are characterized by a wide variety of climatological, hydrological, and geological conditions. To a first approximation, floristic ecoregions, such as the Jepson ecoregions defined by Hickman (1993), provide an integrative view of these differences. We use the Jepson ecoregions as a starting point for salmonid ecoregions, but modify them to account for the effect of springs, which are very influential on salmonids, but less influential to upland plants (Figure 2). Instead of the Cascade Ranges region, we define a “basalt and porous lava” region that comprises the streams that historically supported winter-run Chinook salmon. All of these streams receive large inflows of cold water from springs through the summer, upon which winter-run Chinook salmon depended. This region excludes streams south of Battle Creek, but would include the part of the Upper Sacramento drainage used by winter-run, and part of the Modoc Plateau region. The southern part of the Cascades region (i.e., the drainages of Mill, Deer, and Butte creeks) is added to the Sierra Nevada region, but the Sierra Nevada region is divided into northern and southern parts (split somewhat arbitrarily south of the Mokelumne River). This split reflects the greater importance of snowmelt runoff in the southern part, and distinguishes tributaries to the Sacramento and

San Joaquin rivers. The Central Valley steelhead ESU has two additional salmonid ecoregions: the Suisun Bay region which consists of tributaries to or near Suisun Bay, where summer temperatures are moderated by the marine influence of nearby San Francisco Bay and the Pacific Ocean, and the Central Western California ecoregion, which contains west-side San Joaquin Valley tributaries.

Viability by Assessment of Specific Threats

An alternative to the representation and redundancy rule is to assess the relationship between ESU structure and specific sources of catastrophic risk. For example, one can assess whether a spill of toxic material at a certain point could extirpate all populations of an ESU. The advantage of this approach is that it is explicit: benefits or shortcomings of a particular ESU structure can be seen. The disadvantage is that we are unlikely to foresee all possible catastrophes, and more generally, this approach does not fully consider the value that biocomplexity has for ESUs. With this caution in mind, we assess the present structure of ESUs in relation to volcanic eruptions, wildfire, and drought[1].

Volcanos may seem like an unlikely threat, but the Mt. St. Helens eruptions of 1980 extirpated salmon in the Toutle River (Jones and Salo, 1986). The Cascades Range, of which Mt. St. Helens is a member, forms the northeastern boundary of the Sacramento River basin and is volcanically active. To assess the risk from volcanic eruptions, we obtained data on impact for lava flow, volcanic blast, pyroclastic flows, and debris-lahar flows from Hoblitt et al. (1987). For each volcano and impact type, we computed the percentage of habitat that would be impacted for each population.

While probably less devastating than a major volcanic eruption, fires can cause large injections of fine particles into streams, and fires have been implicated in the extinction of trout populations (e.g., Rinne 1996; Brown et al. 2001). In addition, fire-fighting chemicals are toxic to juvenile salmon (Buhl and Hamilton 1998). Assessing whether two populations might be vulnerable to a single large fire is in part a question of how frequently fires of such size arise. Moritz (1997) provides a way of estimating the relationship between fire size and return frequency from fire size data. We acquired data on fire sizes within the Central Valley domain from the California Department of Forestry, and created a time series of the largest fire in each year for the period 1908–2003. We then found the maximum diameter of the polygon describing each fire. The probability of the largest fire in a year having a maximum diameter less than than some specific size x, P(Xmax ≤ x), was estimated empirically following Moritz (1997).

Prolonged droughts have been implicated in the extinction of riverine fish species in the southwestern US (Douglas et al. 2003; Matthews and Marsh-Matthews, 2003), and a short drought had severe impacts on Sacramento River winter-run Chinook salmon broods in 1976 and 1977 (National Marine Fisheries Service, 1997). We estimated the correlation scale for drought by computing the correlation among the Palmer drought severity index scores among the grid points within CA presented by Cook et al. (2004) using a spline correlogram, which estimates a non-parametric covariance function (Bjornstad et al. 1999). Of particular interest is whether this characteristic scale is larger or smaller than the scale of ESUs—if it is larger, then drought risk can not be mitigated by maintaining widely-separated populations (although it would reduce the risk of simultaneous drought).

APPLICATION TO CENTRAL VALLEY SALMONIDS

Central Valley Spring-run Chinook Salmon

Perhaps 15 of the 18 or 19 historical populations of Central Valley spring-run Chinook salmon are extinct, with their entire historical spawning habitats behind various impassable dams (Figure 3 and Table 3). Butte Creek and Deer Creek spring-run Chinook salmon are at low risk of extinction, satisfying both the PVA (Figure 4) and other viability criteria (Table 3). Mill Creek is at moderate extinction risk according to the PVA, but appear to satisfy the other viability criteria for low-risk status. Lindley et al. (2004) were uncertain whether Mill and Deer creek populations were each independent or two parts of a single larger population. If viewed as a single population, Mill and Deer Creek spring-run Chinook salmon are at low extinction risk. Early-returning Chinook salmon persist within the

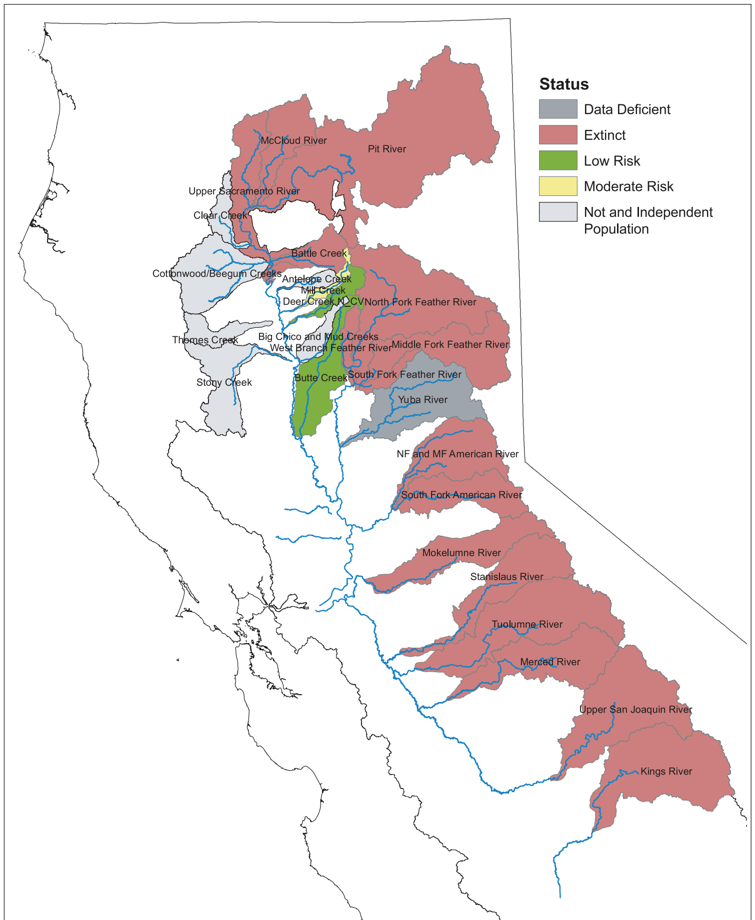

Figure 3. Status of historical Central Valley spring-run Chinook salmon populations.

Feather River Hatchery population and spawn in the Feather River below Oroville Dam and the Yuba River below Englebright Dam. The current status of these fish is impossible to assess due to insufficient data.

With demonstrably viable populations in only one of at least three diversity groups that historically con-

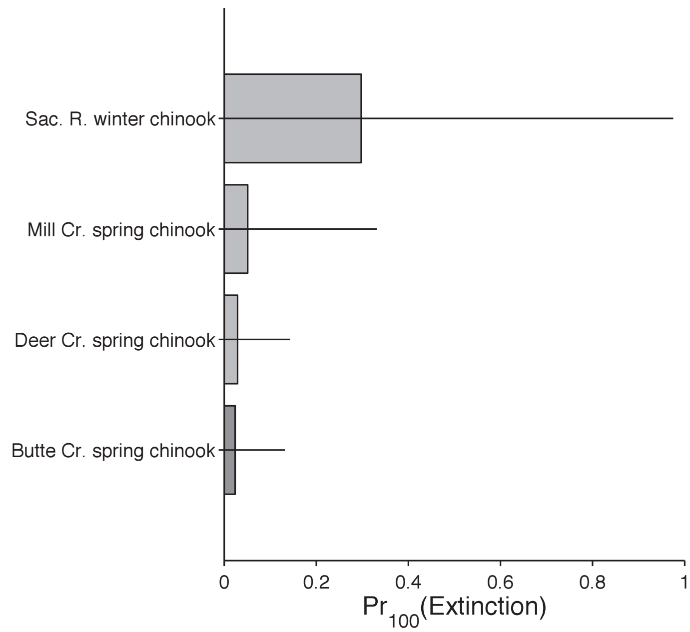

Figure 4. Probability of population extinction as estimated by the random-walk-with-drift model. Bars indicate the expected probability of extinction; lines indicate the 90% central interval for the estimate of the mean.

Table 3. Viability of populations. Steelhead populations that are not listed are data deficient. Chinook populations that are not listed are presumed extinct, due to impassable dams blocking access to spawning habitat. WRC = winter-run Chinook salmon; SRC = spring-run Chinook salmon. Catastrophes not included in this table because none were observed in the last decade. See Table 2 for definition of metrics. Spawning escapement data was obtained from California Department of Fish and Game's 2005 GrandTab database, available from the Native Anadromous Fish & Watershed Branch, 830 S Street, Sacramento, CA 95814. Steelhead data for American River from McCracken et al. (2005).

ESU	Population Name	PVA result	N	std	Pop. growth (% per year)	std	$\hat{S}$	std	h	Risk Category
Sac. R. WRC	mainstem	Moderate	26,870	2280	27.7	6.3	8140	691	Low	Low
C. V. SRC	Butte Cr	Low	22,630	7400	11.4	12.6	6860	2240	Very Low	Low
C. V. SRC	Mill Cr	Moderate	3360	1300	17.9	5.95	1020	394	Very Low	Low
C. V. SRC	Deer Cr	Low	6320	1920	7.63	7.58	1920	1010	Very Low	Low
C. V. SRC	Yuba									Data Deficient
C. V. SRC	Feather									Data Deficient
C. V. Steelhead	Feather								High	High
C. V. Steelhead	Battle Cr								High	High
C. V. Steelhead	American						< 500		High	High
C. V. Steelhead	Mokelumne								High	High

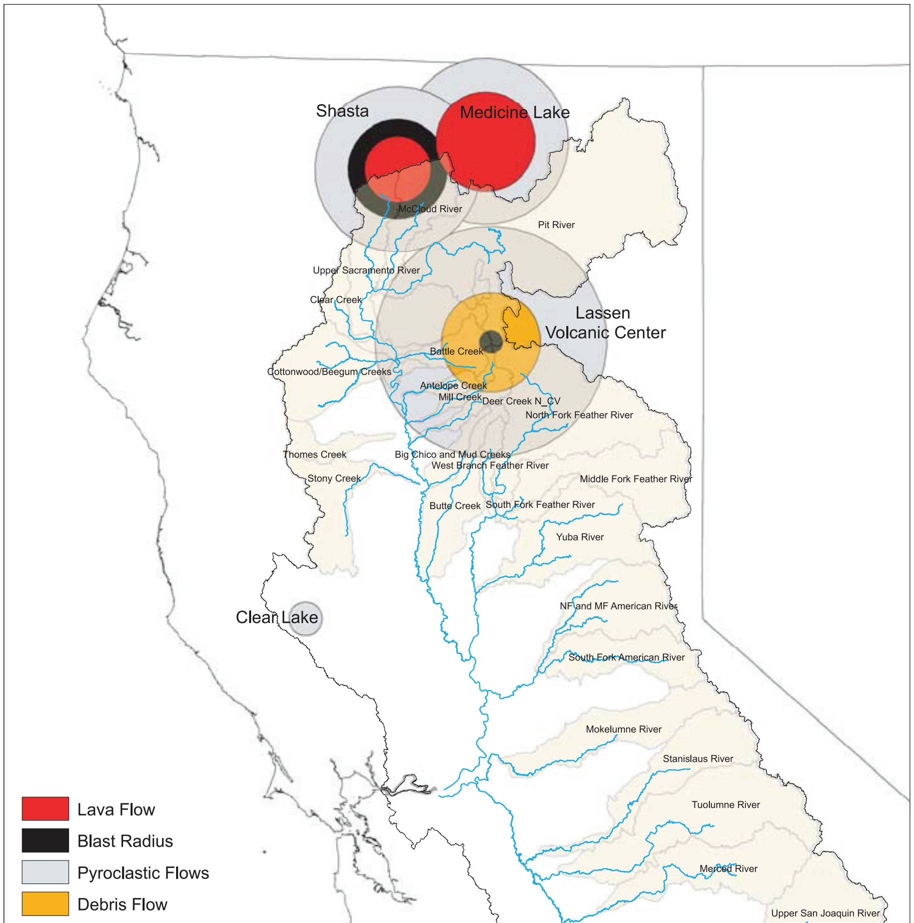

Figure 5. Volcanic hazards affecting the Central Valley recovery domain. Circles indicate the possible spatial extent of various kinds of volcanic effects that could devastate salmonid stream habitat, including lava flow, blast, pyroclastic flow, and debris. Data from Hobblitt et al. (1987)

tained them, Central Valley spring-run Chinook salmon fail the representation and redundancy rule for ESU viability. Historically, the Central Valley spring-run Chinook salmon ESU spanned four ecoregions: the region used by winter-run Chinook salmon plus the northern and southern Sierra Nevada and the northwestern California region. There are two or three viable populations in the northern Sierra Nevada (Mill, Deer and Butte creeks), although these populations were once probably relatively small compared to populations such as the Feather River. A few ephemeral or dependent populations are found in the Northwestern California region (e.g., Beegum and perhaps Clear creeks). Spring-run Chinook salmon have been entirely extirpated from both the basalt and porous lava region and the southern Sierra Nevada region.

The current distribution of viable populations makes the Central Valley spring-run Chinook salmon ESU vulnerable to catastrophic disturbance. All three extant independent populations are in basins whose headwaters lie within the debris and pyroclastic flow radii of Mt. Lassen (Figure 5), an active volcano that the USGS views as highly dangerous[2] (Hoblitt et al. 1987). The historical ESU was of such a large scale that neither Mt. Lassen, Mt. Shasta, or Medicine Lake could have extirpated even an entire diversity group, let alone the entire ESU. The current ESU structure is, not surprisingly, vulnerable to drought, which has a correlation scale of approximately 640 km (Figure 6), on order of the length of the historical ESU. Even wildfires, which are of much smaller scale than droughts or large volcanic eruptions, pose a significant threat to the ESU in its current configuration. A fire with a maximum diameter of 30 km, big enough to burn the headwaters of Mill, Deer and Butte creeks simultaneously, has roughly a 10% chance of occurring somewhere in the Central Valley each year (Figure 7).

We note that the historical Central Valley spring-run Chinook salmon ESU was widespread enough to be invulnerable to all of these catastrophes, except perhaps prolonged drought. The correlation scale of drought is roughly 640 km, and the Central Valley spring-run Chinook salmon ESU is about 500 km from the Pit River to the Kings River. It is possible that Central Valley spring-run Chinook salmon were less vulnerable to drought than might be expected because they once occupied diverse types of watersheds, including those with very high influence from springs. In fact, annual mean stream flow in Southern Cascade streams is less well correlated with annual mean precipitation than in other regions (see Appendix A in Lindley et al. (2006)).

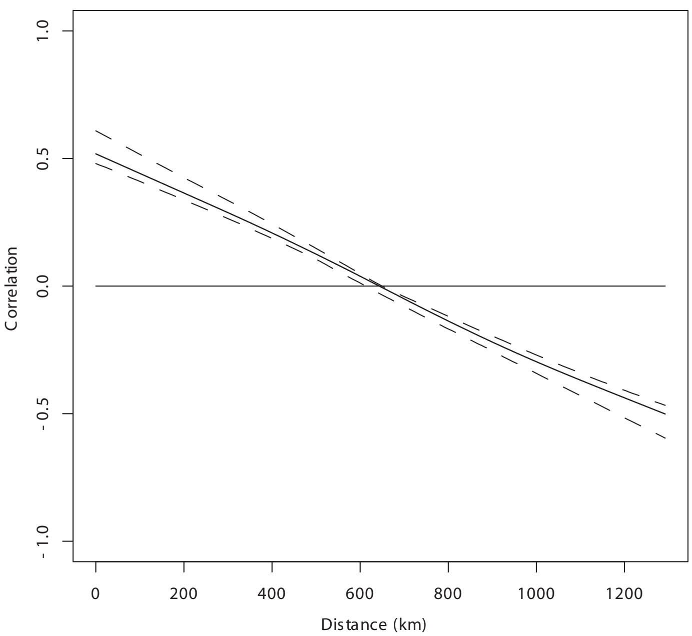

Figure 6. Spline correlogram fit to the gridded Palmer drought severity index data for California of Cook et al. (2004). Solid line indicates the estimated correlation function; dashed lines are the 95% confidence interval. Note that the correlation of drought indices declines with distance between locations, with no correlation evident at a distance 640 km.

Sacramento River Winter-run Chinook Salmon

All four historical populations of Sacramento River winter-run Chinook salmon are extinct in their historical spawning range (Table 3). The upper Sacramento, McCloud and Pit River populations had spawning and rearing habitat far upstream of impassable Keswick and Shasta dams, although these populations were apparently in poor condition even before the construction of Shasta dam in the 1940s (Moffett 1949). Winter-run Chinook salmon no longer inhabit Battle Creek as a self-sustaining population, probably because hydropower operations make conditions for eggs and fry unsuitable (National Marine Fisheries Service 1997). Also, until recently access to much of the basin was blocked by the Coleman National Fish Hatchery barrier weir.

The population of Sacramento River winter-run Chinook salmon that now spawns below Keswick dam is at moderate extinction risk according to the PVA (Figure 4), and at low risk according to the other criteria. Since roughly the mid-1990s, this population has been growing, although its previous precipitous decline to a few hundred spawners per year would have qualified it as high risk at that time, and prior to that, the 1976-77 drought would have qualified as a high-risk catastrophe. At present, the population easily satisfies the low-risk criteria for population size, population decline, and catastrophe, but hatchery influence is a looming concern. Since 2001, hatchery-origin winter-run Chinook salmon from Livingston Stone National Fish Hatchery (LSNFH, perhaps one of the best examples of a "best-management practices" Chinook salmon hatchery) have made up more than 5% of the natural spawning run, and in 2005 it exceeded >18% (K. Niemela, USFWS, Red Bluff CA, unpublished data). If the contribution of LSNFH to natural spawning exceeds 15% in 2006-07, the winter-run Chinook salmon population would be reclassified as moderate risk, and even the lower observed rates will become problematic if they continue for the next decade.

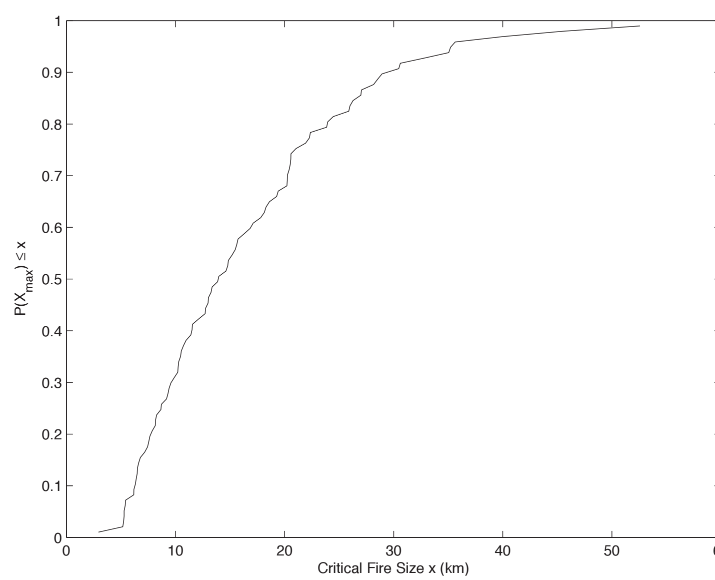

Figure 7. The probability that the largest fire in a year (Xmax) will be smaller than the critical size x. Based on observed fire sizes for the Central Valley recovery domain during the 1908–2003 period.

The Sacramento River winter-run Chinook salmon ESU does not currently satisfy the representation and redundancy rule because it has only one population, and that population spawns outside of the ecoregion where it evolved. For the Sacramento River winter-run Chinook salmon ESU to satisfy the representation and redundancy rule, at least two populations would need to be re-established in the basalt-and-porous-lava region. This may require passage past Shasta and Keswick dams.

Obviously, an ESU represented by a single population at moderate risk of extinction is at high risk of extinction over the long run. A single catastrophe could extirpate the entire Sacramento River winter-run Chinook salmon ESU, if its effects persisted for four or more years. The entire stretch of the Sacramento River used by winter-run Chinook salmon is within the zone of influence of Mt. Lassen. Some other possible catastrophes include a prolonged drought that depletes the cold water storage of Lake Shasta or some related failure to manage cold water storage, a spill of toxic materials with effects that persist for four years, or a disease outbreak.

Central Valley Steelhead

There are almost no data with which to assess the status of any of the 81 Central Valley steelhead populations described by Lindley et al. (2006). With few exceptions, therefore, Central Valley steelhead populations are classified as data deficient. The exceptions are restricted to streams with long-running hatchery programs: Battle Creek and the Feather, American and Mokelumne rivers. In all cases, hatchery-origin fish likely comprise the majority of the natural spawning run, placing the natural populations at high risk of extinction. In the American River, the natural spawning run appears to be comprised mostly of hatchery-origin spawners (McCracken et al. 2005). The broodstock used by Feather River Hatchery is derived from native fish from the Feather River, but hatchery-origin fish probably play a large role in maintaining the Feather River population (Kindopp et al. 2003). The Coleman National Fish Hatchery steelhead program uses many "best management practices," but hatchery fish make up substantially more than 15% of the natural spawners in Battle Creek (Campton et al. 2004).

There is no evidence to suggest that the Central Valley steelhead ESU is at low risk of extinction, or that there are viable populations of steelhead anywhere in the ESU. Conversely, there is evidence to suggest that the Central Valley steelhead ESU is at moderate or high risk of extinction (McEwan 2001; Good et al. 2005). Clearly, most of the historical habitat once available to steelhead has been lost (Yoshiyama et al. 1996; McEwan 2001; Lindley et al. 2006). Furthermore, the observation that anadromous *O. mykiss* are becoming rare in areas where they were probably once abundant (California Department of Fish and Game, unpublished data; McEwan (2001)) indicates that an important component of life history diversity is being suppressed or lost. It should be noted, however, that habitat fragmentation, degradation, and loss are likely having a strong negative impact on many resident as well as anadromous *O. mykiss* populations (Hopelain 2003).

Discussion

Population Viability

In this section, we applied viability criteria, and PVA where possible, to assess the status of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead populations identified by Lindley et al. (2004) and Lindley et al. (2006). For Central Valley steelhead, we were only able to assess the status of populations with a strong hatchery influence, even though the criteria-based approach that we employed has low data requirements compared to some PVA approaches. For extant, independent Chinook salmon populations, we were able to apply a PVA model as well as the simpler criteria (because relatively long time series of spawning run size are available for these populations). In two cases, the PVA gave the same result (Butte Creek and Deer Creek both classified as low risk), and in the other two cases, risk assignments differed by one category (winter-run Chinook salmon and Mill Creek spring-run Chinook salmon classified by the PVA as moderate risk, while the criteria indicate low risk). That populations can satisfy the criteria for low risk while just failing a PVA suggests that the criteria for low risk really are criteria for minimal viability. Recovery planners may want to aim somewhat higher for at least some populations as a precautionary measure.

There have been three population-level risk assessments for winter-run Chinook salmon, by Botsford and Brittnacher (1998), Lindley and Mohr (2003), and Good et al. (2005). The analysis of Botsford and Brittnacher (1998) was conducted at a time when it was much less clear that winter-run Chinook salmon were on an upward trend, and not surprisingly, Botsford and Brittnacher (1998) found that winter-run Chinook salmon were certain to go extinct if the trends seen up to the time of their analysis were to continue. Lindley and Mohr (2003) used a model that allowed for a change in population growth rate following initiation of conservation measures in 1989 and density-dependent reproduction. Allowing for the possibility that winter-run Chinook salmon population growth rate increased after 1989 led to a much more optimistic prediction for extinction risk of 24% in 100 years. The analysis in Good et al. (2005), like Lindley and Mohr (2003), allowed for a change in population growth in 1989, but included more recent data and ignored density dependence. Good et al. (2005) found that if the 1989-present growth rate holds into the future, the winter-run Chinook salmon population has essentially no risk of extinction. The varying conclusions of these studies illustrates the sensitivity of PVA results to both data and model assumptions, especially those about future conditions and the effect of density on population growth rate.

ESU Viability

Our assessment of the viability of Central Valley Chinook salmon ESUs is broadly consistent with other recent assessments. Good et al. (2005), based on the combined opinion of an expert panel, considered the Sacramento River winter-run Chinook salmon ESU to be in danger of extinction, and the Central Valley spring-run Chinook salmon ESU to be likely to become endangered in the foreseeable future. These findings were essentially unchanged from the earlier review of Myers et al. (1998). United States Fish and Wildlife Service (1994) suggested that Central Valley spring-run Chinook salmon could be considered "restored" when Mill and Deer creeks both have >500 spawners, and the average total number of spawners in Sacramento tributaries exceeds 8,000, with a minimum of 5,000 spawners, over a 15 year period that includes at least three critically dry years. Central Valley spring-run Chinook salmon have achieved these abundance levels since about 1998, but are not yet "restored" as defined by United States Fish and Wildlife Service (1994). The restoration goals of United States Fish and Wildlife Service (1994) are based on estimates of what could be attained in Sacramento River tributaries that are still accessible to spring-run Chinook salmon, and do not address issues of viability.

National Marine Fisheries Service (1997) proposed that for Sacramento River winter-run Chinook salmon to be recovered, there would need to be on average 10,000 females spawning naturally in the mainstem Sacramento River, and recommended creation of a second winter-run Chinook salmon population in Battle Creek. Should Sacramento River winter-run Chinook salmon achieve these draft goals, their status would be much improved, but they would still be excluded from much of the apparently unique areas in the upper Sacramento, McCloud, and Pit River tributaries that gave rise to their unique life-history strategy.

Good et al. (2005) found Central Valley steelhead to be in danger of extinction in the foreseeable future, in agreement with an earlier assessment (Busby et al. 1996). We were unable to assess the status of the Central Valley steelhead ESU with the more quantitative approach developed in this paper, because of data limitations. This should not be viewed as a contradictory finding—what little information is available for Central Valley steelhead is not positive (Busby et al. 1996; McEwan, 2001; Good et al. 2005).

Even if there were adequate data on the distribution and abundance of steelhead in the Central Valley, our approaches for assessing population and ESU viability might be problematical because the effect of resident *O. mykiss* on the viability of populations and ESUs is unknown. From one perspective, resident fish may reduce the extinction risk of the ESU through the production of anadromous individuals that can bolster or rescue weak steelhead populations. Such life history diversity also confers risk spreading, in that members of the ESU are spread among habitats that are subject to independent sources of disturbance. For instance, fish in the ocean are unaffected by flooding, while fish in rivers are immune to poor feeding conditions in the ocean. At the margins of a species' range, where conditions may be more frequently unfavorable, such life history diversity could be an adaptation to the unpredictable environment (Jonsson and Jonsson 1993.)

On the other hand, the apparent dominance of the resident form is a recent and unnatural phenomenon. It is likely that the apparent shift towards the resident life history strategy is partly a response to hypolimnetic releases from reservoirs, which alter trophic, temperature and flow conditions for some distance below the dam (McEwan, 2001). *O. mykiss* may take up residency in these altered areas due to their phenotypic plasticity, or the fitness of *O. mykiss* using these areas may exceed the fitness of anadromous fish, which would drive an evolutionary (i.e., genetic) change if life history strategy is heritable. Another component of the shift is likely the decline of steelhead due to loss of suitable steelhead habitat. Even if the shift in life history strategy is a plastic response, the fitness of steelhead may decline due to relaxed selection pressure. At longer time scales, this is likely to be a problem, because storage reservoirs have finite lifetimes, and when they are filled with sediments, the rivers downstream will be much less suitable for year-round residency.

Both the United States Fish and Wildlife Service (1994) goals for Central Valley spring-run Chinook salmon and the National Marine Fisheries Service (1997) goals for Sacramento River winter-run Chinook salmon are primarily focused on abundance and productivity, a traditional fisheries and natural resource perspective. In light of the mounting failures of that traditional perspective, ecologists are increasingly recognizing the importance of diversity in sustaining ecological processes (e.g., Daily 1999; Pauly et al. 2002; Elmqvist et al. 2003; Fischer et al. 2006). Recent thinking on salmonids (e.g., McElhany et al. 2000; Hilborn et al. 2003; Bottom et al. 2005) highlights the importance of habitat, life history, and genetic diversity as the foundation for productivity (and hence abundance). Our approach to assessing and specifying ESU viability broaden the focus from abundance and trends to include the numbers, diversity, and spatial distribution of populations across the landscape. Restoring and sustaining diverse populations of salmonids will require restoring and sustaining the habitats and ecological processes upon which they depend.

Summary

In this paper, we have developed a framework for evaluating the viability of salmonid populations and ESUs, based on simple criteria and rules that have modest data requirements. When applied to Chinook salmon ESUs, the framework makes clear that the risk facing these ESUs is not so much the low viability of extant populations, but rather that much of the diversity historically present in these ESUs has been lost. While the criteria and rules that comprise our framework are based in no small part on expert judgment and are subject to considerable uncertainty, our conclusions are not particularly sensitive to the exact values of the criteria.

The utility of our framework can be judged in several ways. It provides quantitative criteria that allow that status of salmonid ESUs to be assessed in an objective way, and it points out areas where things need to improve for ESUs to be removed from the endangered species list. The framework is, however, rather simplistic, and significant improvements, especially at the ESU level, could be made as our understanding of salmonid population biology improves. Perhaps the most significant shortcoming of our framework is the implicit assumption that future will be like the past. In the next section, we evaluate this critical assumption.

CLIMATE VARIABILITY AND CHANGE

Introduction

Viability assessments, including ours, typically attempt to answer the question of whether the population will persist into the future if it continues to experience conditions like it has in the recent past. Future conditions, however, are not likely to be like the recent past. In this section, we briefly review descriptions of natural climate variability, and regional-scale predictions of how climate might change over the next century in response to rising atmospheric greenhouse gas concentrations. Natural climate variation will make it difficult to properly assess whether ESUs are recovering in response to management actions. Anthropogenic climate change may preclude some otherwise attractive recovery strategies, depending on future greenhouse gas emissions and the response of regional climate.

Natural Climate Variability

Fisheries scientists have shown that ocean climate varies strongly at decadal scales (e.g., Beamish 1993; Beamish and Bouillon 1993; Graham, 1994; Miller et al. 1994; Hare and Francis 1995; Mantua et al. 1997; Mueter et al. 2002). In particular, the identification of the Pacific Decadal Oscillation (Mantua et al. 1997) seems to have led to the belief that decadal-scale variation may be cyclical, and thus predictable. As pointed out by Rudnick and Davis (2003) and Hsieh et al. (2005), apparent regime shifts need not be cyclical or predictable, but rather may be the expression of a stochastic process with red noise. If this interpretation is correct, then we should expect future ocean climate conditions to be different than those we have observed in the past few decades.

Terrestrial climate, like ocean climate, appears more variable the longer that it is observed. For example, Ingram et al. (1996) showed that freshwater inputs to San Francisco Bay varied with a period of 200 years, and several extreme and prolonged wet and dry periods occurred over the last 2,000 years. A 7,000-year river-flow reconstruction by Goman and Wells (2000) for the same area shows even longer-lasting periods of extreme conditions. Analysis of tree-ring data show that prolonged and intense droughts were more common during the period 750-1100 before present than in more recent centuries (Cook et al. 2004).

Natural climate variability poses several potential challenges for recovery planners. First, the population viability criteria that we have proposed may not offer sufficient protection in the case of a prolonged period of unfavorable climatic conditions. Second, a prolonged period of unusually favorable climatic conditions could cause populations to grow enough that they satisfy our biological viability criteria even though serious problems with habitat quality remain. In other words, the ESU may temporarily appear to be recovered, but its status would decline as soon as conditions become more typical. Conversely, the effects of substantial improvements to habitat quality could be masked by poor climatic conditions, possibly eroding society's enthusiasm for doing the hard work of salmon recovery. The key to overcoming these challenges is to consider climate variation in future assessments, hopefully with the benefit of improved understanding of the links between specific populations and regional climate conditions. Research is needed in this area.

Presumably, Central Valley salmonid ESUs are capable of surviving the kinds of climate extremes observed over the past few thousand years if they have functional habitats, because these lineages are on order of a thousand years old or older[3]. There is rising concern, however, that the future climate will be unlike that seen since perhaps the Pliocene, due to global warming in response to anthropogenic greenhouse gas emissions.

Climate Warming

The consensus of climate scientists is that the Earth's climate is warming, and that the warming is caused in part by the accumulation of greenhouse gases in the atmosphere (McCarthy et al. 2001; Oreskes, 2004). While there is a scientific consensus about global climate change, the effects of global warming at regional scales are generally less certain. Here, we briefly review available regional-scale forecasts relevant to the Central Valley domain, and then speculate on possible impacts on Central Valley salmonids.

Climate forecasts for the Central Valley

Making regional-scale climate forecasts involves choosing an "emissions pathway" and running one of a number of global climate models with an embedded regional-scale model that can capture features, such as mountain ranges, that can significantly modify the global pattern. As in any modeling exercise, there are a number of sources of uncertainty, but particularly important ones in this case are the assumption about future emissions and the choice of climate model. The uncertainties are addressed by examining a number of emissions pathways and by using several models.

The recent paper by Hayhoe et al. (2004) examines multiple emissions pathways using two global models to make regional forecasts for California. Their results are alarming. The more sensitive Hadley Center Climate Model (HadCM3) predicts that under the high emissions scenario (where CO_2 rises to 970 ppm by 2100, also known as the "business as usual" scenario), average summer temperature would rise 8.3°C and snowpack would be reduced by 89%. The HadCM3 also predicts that the climate will get drier, with possibly a 43% reduction of inflows to southern Sierra reservoirs. At the other extreme, the low-sensitivity Parallel Climate Model (PCM) predicts that average summer temperature would rise slightly more than 2°C if emissions were curtailed such that CO_2 rises to 550 ppm by 2100. The PCM predicts that total precipitation could rise slightly, but snowpack would still be reduced by 28% in this scenario.

Dettinger (2005) analyzed six different climate models under three emissions scenarios to produce distributions of future temperature and precipitation. This analysis showed that uncertainty due to the models was about equal to that due to emission scenario. There was general agreement among the models that temperatures will rise significantly (between 2 and 7 °C by 2100), while total precipitation is expected to decline slightly. Temperature and precipitation predictions were negatively correlated (i.e., warming is associated with drying).

Dettinger et al. (2004) and VanRheenen et al. (2004) used the PCM to investigate in detail how climate change may influence the hydrology of Central Valley rivers. These analyses find that average precipitation will decline over time, while the variation in precipitation is expected to increase substantially. Extreme discharge events are predicted to become more common, as are critically dry water years. Peak monthly mean flows will generally occur earlier in the season due to a decline in the proportion of precipitation falling as snow, and earlier melting of the (reduced) snowpack. By the end of the century, it may be difficult to achieve current operations targets for fish conservation even with substantial decreases in other demands for water. Knowles and Cayan (2002) show that in summer, saline water will intrude farther into the Bay and Delta than it does now. Within some limits, water storage reservoirs might be operated to mitigate changes to the hydrograph caused by climate change, although water project operations are likely to become even more contentious as temperature rises, snowmelt falls, and population rises.

Possible Effects on Salmon and Steelhead

Regional-scale climate models for California are in broad agreement that temperatures in the future will warm significantly, total precipitation may decline, and snowfall will decline significantly. What are the likely consequences for salmon and steelhead in the Central Valley? Melack et al. (1997) states that predicting the response of salmon to climate warming "requires examination of the responses of all life history stages to the cumulative effects of likely environmental changes in the lakes, rivers and oceans inhabited by the fish." Such an endeavor is beyond the scope of this paper, and the question of climate change effects on Pacific salmonids has received surprisingly little attention to date. In this subsection, we briefly review the literature and conduct a simple assessment of the effects of warmer summer temperature on the availability of freshwater habitat.

Focusing on freshwater life history phases, Neitzel (1991) reviewed the likely responses of salmonids in the Columbia River basin to climate warming, which he anticipated would affect salmonids through alterations to the timing of discharge and changes in sedimentation rate, temperature, and flow. Effects are predicted to depend on the river and on the species or run. As in the case of many salmonid populations in the Columbia River basin, spring-run Chinook salmon are likely to be negatively impacted by the shift in peak discharge (needed for smolt migration), and juvenile steelhead are likely to be negatively impacted by reduced summer flows. All Central Valley salmonids are likely to be negatively affected by warmer temperatures, especially those that are in freshwater during the summer.

Recent summer mortality of adult spring-run Chinook salmon in Butte Creek offers a case in point. Mean July water temperature in the middle of the spawning reach of Butte Creek is often around 18-20°C in July. In 2002 and 2003, mean water temperature in Butte Creek exceeded 21°C for 10 or more days in July, and 20-30% of adults in 2002 and 65% of adults in 2003 died (reviewed by Williams 2006), primarily from columnaris.

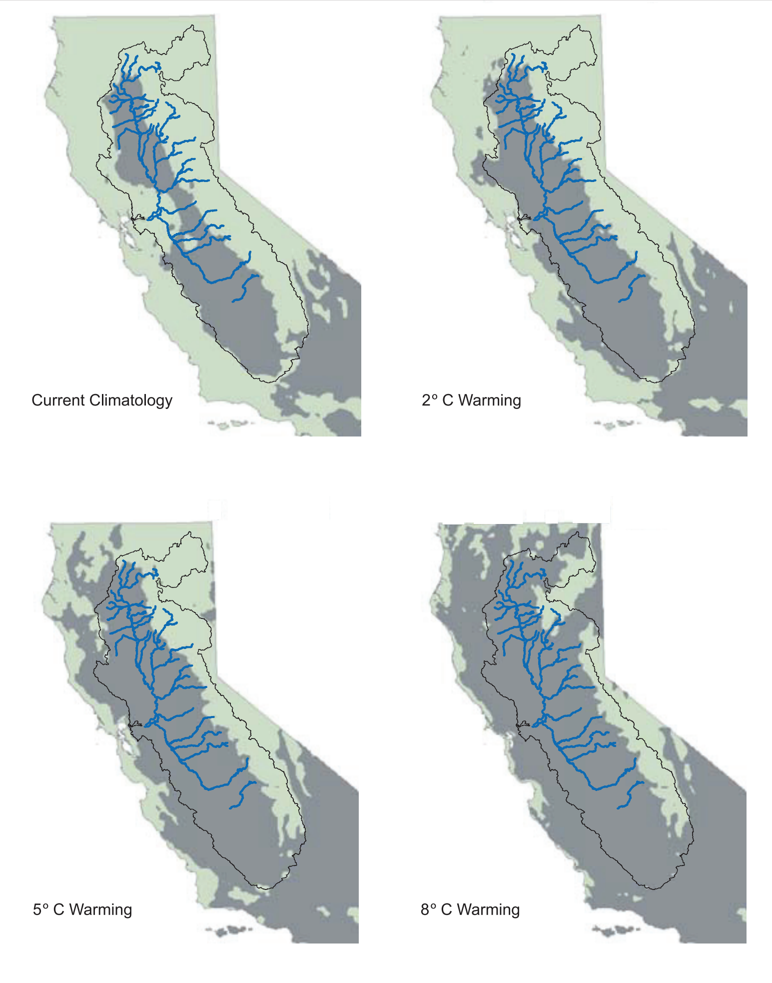

Figure 8. Effects of climate warming on availability of over-summer habitat. Mean August air temperatures exceeding 25°C are shown in gray; blue lines indicate the historical distribution of spring-run Chinook salmon.

Less obvious effects, such as reduced viability of gametes, may also have occurred. These data suggest that existing conditions in Butte Creek are close to the thermal tolerance limit for Chinook salmon.

Myrick and Cech (2004) state that juvenile Chinook salmon are unlikely to be capable of rearing for extended periods in temperatures exceeding 24°C, and juvenile steelhead may be able to withstand slightly higher temperatures. Maximum in-stream temperatures of many streams frequently exceed 24°C at lower elevations, which may determine the lower distributional limit of salmonids (Yoshiyama et al. 1996; Lindley et al. 2006). Distributions at higher elevations were once largely restricted by natural barriers to movement, but are now limited by dams in many streams (Lindley et al. 2006). If these artificial migration barriers are not removed, climate warming is expected to reduce the amount of habitat available to Central Valley salmonids that reside in freshwater during summer months, as the lower distributional limit rises, and the upper limit remains constrained by physical barriers.

A rough view of the consequences for Central Valley spring-run Chinook salmon and Central Valley steelhead can be obtained by adding the regional warming forecasts of Dettinger (2005) to PRISM temperature fields, and overlaying this with the distributional data presented in Lindley et al. (2004). Figure 8 shows how the area with high summer temperatures (mean August air temperature > 25°C) may expand under three warming scenarios. Under current conditions, streams that had major independent populations of spring-run Chinook salmon all have significant amounts of habitat above the 25°C isotherm, although dependent populations generally had little or no habitat above the 25°C isotherm (Figure 8, upper left). By 2100, mean summer air temperatures are expected to rise by at least 2°C. Under this scenario, the amount of habitat above the 25°C isotherm is reduced, but in general, most streams that historically contained habitat above this isotherm would not lose all such habitat. The exceptions are the Tuolumne, Merced, and upper San Joaquin rivers, and Butte Creek, where the 25°C isotherm might just rise to the upper limit of the historical distribution of spring-run Chinook salmon (Figure 8, upper right). Under the expected warming of around 5°C, substantial habitat would be lost, with significant amounts of habitat remaining primarily in the Feather and Yuba rivers, and remnants of habitat in the upper Sacramento, McCloud, and Pit rivers, Battle and Mill creeks, and the Stanislaus River (Figure 8, lower left). Under the less likely but still possible scenario of an 8°C warming, spring-run Chinook salmon habitat would be found only in the upper-most reaches of the north fork Feather River, Battle Creek, and Mill Creek. This simple analysis suggests that Central

Valley salmonids are vulnerable to warming, but more research is needed to evaluate the details of how warming would influence individual populations and subbasins.

The hydrologic effects of climate change are harder to evaluate. Increased frequency of scouring floods might be expected to reduce the productivity of populations, as egg scour becomes a more common occurrence. The timing of various life history events is presumably an adaption to past climate conditions (temperature and discharge timing), and populations may not be well-adapted to future hydrographs. One concern is that warmer summers will delay spawning, and earlier and more frequent floods will impact eggs and alevins before they emerge from the gravel, a phenomenon thought to limit the productivity of some Chinook salmon stocks (Beer and Anderson 2001), and one that might be impossible for salmonids to adapt to, given fundamental constraints on development.

The flip side of frequent flooding is the possibility of more frequent and severe droughts. Long-term climate records show that warm periods have been associated with droughts in California (Davis 1999; Cook et al. 2004), and the regional climate change models reviewed above hint at the possibility of increasing frequency of droughts. In the Central Valley, low flows during juvenile rearing and outmigration are associated with poor survival (Kjelson and Brandes 1989; Baker and Morhardt 2001; Newman and Rice 2002) and poor returns in subsequent years (Speed 1993).

Climate change may also impact Central Valley salmonids through community effects. For example, warming may increase the activity and metabolic demand of predators, reducing the survival of juvenile salmonids (Vigg and Burley, 1991). Peterson and Kitchell (2001) showed that on the Columbia River, pikeminnow predation on juvenile salmon during the warmest year was 96% higher than during the coldest.

To summarize, climate change may pose new threats to Central Valley salmonids by reducing the quantity and quality of freshwater habitat. Under the worst-case scenario, spring-run Chinook salmon may be driven extinct by warming in this century, while the best-case scenario may allow them to persist in some streams. Uncertainties abound at all levels, however. First, the composition of Earth's atmosphere is partly under human control, and we cannot predict how it might be managed in the future. Even if the emissions pathway was known, different climate models offer significantly different climate forecasts (although we note that the differences are quantitative, and the models are in qualitative agreement). Finally, we have only the crudest understanding of how salmonid habitats will change and how salmonid populations will respond to those changes, given a certain climate scenario. This is another area where research is needed.

SUMMARY AND RECOMMENDATIONS

For Central Valley steelhead, there are insufficient data to assess the risk of any but a few populations, and therefore, we cannot assess the viability of this ESU using the quantitative approach described in this paper. However, qualitative information does suggest that the Central Valley steelhead ESU is at a moderate or high risk of extinction. Most of the historical habitat once available to steelhead is largely inaccessible and the observation that the anadromous forms of *O. mykiss* are becoming less abundant or rare in areas where they were probably once abundant indicates that an important component of life history diversity is being suppressed or lost. Even in populations that exhibit life-history polymorphism, steelhead are important to viability and long-term persistence and are critical to the conservation of the population (Travis et al. 2004; Bilby et al. 2005).

For the Chinook salmon ESUs, we found that extant populations are now at low or moderate risk of extinction, but the extensive extirpation of historical populations has placed these ESUs in jeopardy of extinction. The proximate problem afflicting these ESUs and the Central Valley steelhead ESU is that their historical spawning and rearing areas are largely inaccessible, due to the direct or indirect effects of dams.

Recovering even a few populations may therefore be a challenging and slow process, although we stress that there appear to be some opportunities that, if successful, would greatly increase the viability of all three ESUs. Some possibilities that are being considered include restoring flows and habitat in the San Joaquin River below Friant Dam and in Battle Creek, and restoring access to the Yuba River above Englebright Dam. All of these actions, in our view, have the potential to significantly improve the status of affected ESUs, but achieving recovery may require access to additional historically-utilized spawning areas that are currently blocked by dams.

As we pursue the more ambitious and long-term habitat restoration solutions, there are some easier but very important things that should be done as soon as possible. These include the following, in no particular order:

1. Secure all extant populations. All three ESUs are far short of being viable, and extant populations, even if not presently viable, may be needed for recovery. An important lesson to draw from Hilborn et al. (2003) is that tomorrow's most important populations might come from populations that are relatively unimpressive today. We recommend that every extant population be viewed as necessary for the recovery of the ESU. Wherever possible, the status of extant populations should be improved.

2. Begin collecting distribution and abundance data for *O. mykiss* in habitats accessible to anadromous fish. This is fundamental to designing effective recovery actions and eventual delisting. Of equal importance is assessing the relationship of resident and anadromous forms of *O. mykiss*. Any quantitative assessment of population or ESU viability could be inadequate unless we know the role resident fish play in population maintenance and persistence. It has been well-documented that Chinook salmon has been the major focus of anadromous fish monitoring, assessment, and research in the Central Valley (McEwan 2001) and there needs to be a more equitable partitioning of research funds and effort.

3. Minimize straying from hatcheries to natural spawning areas. Even low levels of straying from hatchery populations to wild ones works against the goal of maximizing diversity within ESUs and populations. Current mark and recovery regimes do not generally allow reliable estimation of contributions of hatchery fish to natural spawning, so we recommend that all hatchery fish be marked in some way. A number of actions could reduce straying from hatcheries to natural areas, including replacing off-site releases with volitional releases from the hatchery, allowing all fish that attempt to return to the hatchery to do so, and reducing the amount of fish released (see CDFG and NMFS 2001, for a review of hatchery issues).

4. Begin conducting critical research on fish passage, reintroductions, and climate change[4]. To recover Central Valley salmon and steelhead ESUs, some populations will need to be established in areas now blocked by dams or insufficient flows. Assuming that most of these dams will remain in place for the foreseeable future, it will be necessary to move fish around the dams. We are unaware of such projects involving dams of the scale typical in the Central Valley. Assuming that a feasible solution to that problem is found, it is necessary to reintroduce fish to the newly available habitat. Should this be allowed to occur naturally, or should a more active approach be taken? If so, which fish should be used as the donors? Finally, in a warmer future, some basins might cease to be suitable for salmon or steelhead. It would be a costly mistake to invest heavily in restoring habitat that will become too warm to support salmonids.

5. Accept the notion that listed salmonid ESUs are likely to be conservation-reliant (Scott et al. 2005). It seems highly unlikely that enough habitat can be restored in the foreseeable future such that Central Valley salmonid ESUs could be expected to persist without continued conservation management. Rather, it may be possible to restore enough habitat such that ESUs can persist with appropriate management, which should focus on maintaining ecological processes at the landscape level. NOAA regulators should begin considering how to implement conservation agreements among agencies and stakeholders that will be acceptable to all parties and ensure the persistence of populations and ESUs.

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ENDNOTES

[1]We also examined the potential of toxic spills, earthquakes, and landslides to extirpate ESUs, but concluded that these risk sources were generally not a threat to ESUs with more than one population.

[2]We note that any particular debris flow would cover only a portion of the circle depicted in Figure 5, and that a single flow might not necessarily devastate all three spring-run Chinook salmon streams.

[3]Using data in Lindley et al. (2004) and relationships in Waples et al. (2004), the Fst observed between Sacramento River winter-run Chinook salmon and fall-run Chinook salmon (based on neutral markers) could have arisen in around 780 years if these ESUs were completely isolated from one another.

[4]The CVTRT is preparing a comprehensive list of research recommendations.

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Directed connectivity among fish populations in a riverine network

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Summary

1. The addition of large water storage dams to rivers in California's Central Valley blocked access to spawning habitat and has resulted in a dramatic decline in the distribution and abundance of spring-run chinook salmon *Oncorhynchus tshawytscha* (Walbaum 1792). Successful recovery efforts depend on an understanding of the historical spatial structure of these populations, which heretofore has been lacking.

2. Graph theory was used to examine the spatial structure and demographic connectivity of riverine populations of spring-run chinook salmon. Standard graph theoretic measures, including degree, edge weight and node strength, were used to uncover the role of individual populations in this network, i.e. which populations were sources and which were pseudo-sinks.

3. Larger spatially proximate populations, most notably the Pit River, served as sources in the historic graph. These source populations in the graph were marked by an increased number of stronger outbound connections (edges), and on average had few inbound connections. Of the edges in the current graph, seven of them were outbound from a population supported by a hatchery in the Feather River, which suggests a strong influence of the hatchery on the structure of the current extant populations.

4. We tested how the addition of water storage dams fragmented the graph over time by examining changing patterns in connectivity and demographic isolation of individual populations. Dams constructed in larger spatially proximate populations had a strong impact on the independence of remaining populations. Specifically, the addition of dams resulted in lost connections, weaker remaining connections and an increase in demographic isolation.

5. A simulation exercise that removed populations from the graph under different removal scenarios – random removal, removal by decreasing habitat size and removal by decreasing node strength – revealed a potential approach for restoration of these depleted populations.

6. *Synthesis and applications.* Spatial graphs are drawing the attention of ecologists and managers. Here we have used a directed graph to uncover the historical spatial structure of a threatened species, estimate the connectivity of the current populations, examine how the historical network of populations was fragmented over time and provide a plausible mechanism for ecologically successful restoration. The methods employed here can be applied broadly across taxa and systems, and afford scientists and managers a better understanding of the structure and function of impaired ecosystems.

Key-words: California, chinook salmon, connectivity, dispersal, evolutionarily significant unit (ESU), graph theory, *Oncorhynchus tshawytscha*, population spatial structure, restoration

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Introduction

Effective management of species requires knowledge of population structure, because this is key to understanding how local impacts may affect the larger entity at both ecological and evolutionary time scales (Kareiva & Wennergren 1995; Wennergren, Ruckelshaus & Kareiva 1995; Tilman & Lehman 1997). For example, a metapopulation may have quite different dynamics than a panmictic population of the same aggregate size, depending on factors such as the dispersal rates among populations and internal dynamics of the metapopulation components (Levins 1969; Kareiva 1990; Hanski & Gilpin 1991). Ignoring spatial structure, especially immigration from nearby populations, can impair the management of protected species, such as incorrectly diagnosing population status or the response to habitat restoration (Cooper & Mangel 1999). At longer time scales, the relationship between the structure and dynamics of populations and landscapes may determine the degree to which populations adapt to local conditions (Sultan & Spencer 2002) and how they respond to disturbance (Pickett & White 1985).

In many cases, species conservation problems can be framed in terms of problems with spatial structure, because impacts to species often take the form of lost habitat patches or dispersal corridors. Restoration is aided with a 'guiding image' (Palmer *et al*. 2005), and the virgin state of the system is often used as such. To be most effective, the guiding image should be in the form of a conceptual model that can show system function, system impairment and restoration strategies (Jansson *et al*. 2005). We propose that graph theory provides the tools needed to construct conceptual models for spatially explicit problems in conservation that allow quantitative comparisons of historical, contemporary and potentially restored population structures.

Graphs have been used across a variety of disciplines to study everything from the structure of the World Wide Web to subcellular protein networks. [See any of the following reviews, listed in approximate order of increasing specificity and mathematical complexity: Hayes (2000a, 2000b); Strogatz (2001); Watts (2004); Albert & Barabási (2002); and Newman (2003).] Graph theory is an appealing tool for analysis of population structure for several reasons. First, it allows us to characterize a complex system with a tractable, but explicitly spatial, mechanism (Urban & Keitt 2001; Brooks 2006; Gastner & Newman 2006). Secondly, using graphs we can assess the importance of individual elements in a graph both backwards in time as we examine how the graph, or network, breaks apart (Keitt, Urban & Milne 1997; Bunn, Urban & Keitt 2000; Urban & Keitt 2001) and forward in time to guide a conservation or restoration effort (Palmer *et al*. 2005). Thirdly, a graph is perhaps the simplest spatially explicit representation of a metapopulation (Urban & Keitt 2001; Brooks 2006). Lastly, there is a wealth of graph tools and algorithms that allow different graphs to be analysed and compared.

While graph theory carries with it its own terminology (Harary 1969), many of the terms have direct ecological interpretations. Nodes can represent a range of things, from individuals to populations to patches on a landscape. Edges are the connections between nodes. Construction of a landscape graph typically requires at least two data structures (Urban & Keitt 2001). The first structure includes information about the node's spatial location and some indicator of size. The second structure is a distance matrix between all of the nodes. The *degree* of a node is the number of edges incident to it. A regular graph is one where the edges are bi-directional, i.e. for nodes a,b the connection is $a \leftrightarrow b$ (Fig. 1a). In contrast, a digraph's edges (also called arcs) have direction, i.e. $a \rightarrow b$ (Fig. 1b). For a digraph, *degree* is slightly different: *outdegree* of a point v is the number of points adjacent from a node; and *indegree* is the number adjacent to a node. Logically, *outdegree* and *indegree* correspond to familiar source–sink dynamics with which most ecologists are familiar (Pulliam 1988). The connection between a pair of nodes in a given graph G is based on an adjacency matrix. The adjacency matrix is comprised simply of 0s and 1s, where 0 indicates no connection between a pair of nodes and 1 indicates that a connection, or edge, exists. [To help avoid confusion, we note that nodes can be adjacent (connected) in a graph theoretic sense even if they are not adjacent in a geographical sense.] Lastly, in most instances, populations and metapopulations can be represented realistically as weighted digraphs (Fig. 1c) with different population sizes and the asymmetric connections between them (Barrat *et al*. 2004; Bascompte, Jordano & Oleson 2006). These cartoon graphs serve as the conceptual basis for the connections in larger, more complicated, and in our case, spatially explicit graphs.

While the role of ecological connectivity in regulating and maintaining population distribution and population persistence has been documented in both the terrestrial (Fahrig & Merriam 1985; Taylor *et al*. 1993) and aquatic realms (Wiens 2002), the direction of the connectivity can have important impacts on a given system (Gustafson & Gardner 1996). Therefore, because regular graphs may not capture completely how connectivity influences population structure, we use weighted digraphs (Barrat *et al*. 2004; Bascompte *et al*. 2006) to examine how directed connectivity and asymmetrical dispersal elucidate population structure. Although directed connectivity has been mentioned previously (Gustafson & Gardner 1996; van Langevelde, van der Knaap & Claassen 1998; Urban & Keitt 2001; Schooley & Wiens 2003), its importance for fish populations has not been fully explored. Furthermore, the influence of the dendritic riverine structure on metapopulation persistence and population vulnerability for fish has only been noted relatively recently (Dunham & Rieman 1999; Gotelli & Taylor 1999; Fagan 2002) and no attempt has been made, to our knowledge, to use graphs to represent fish populations in a riverine

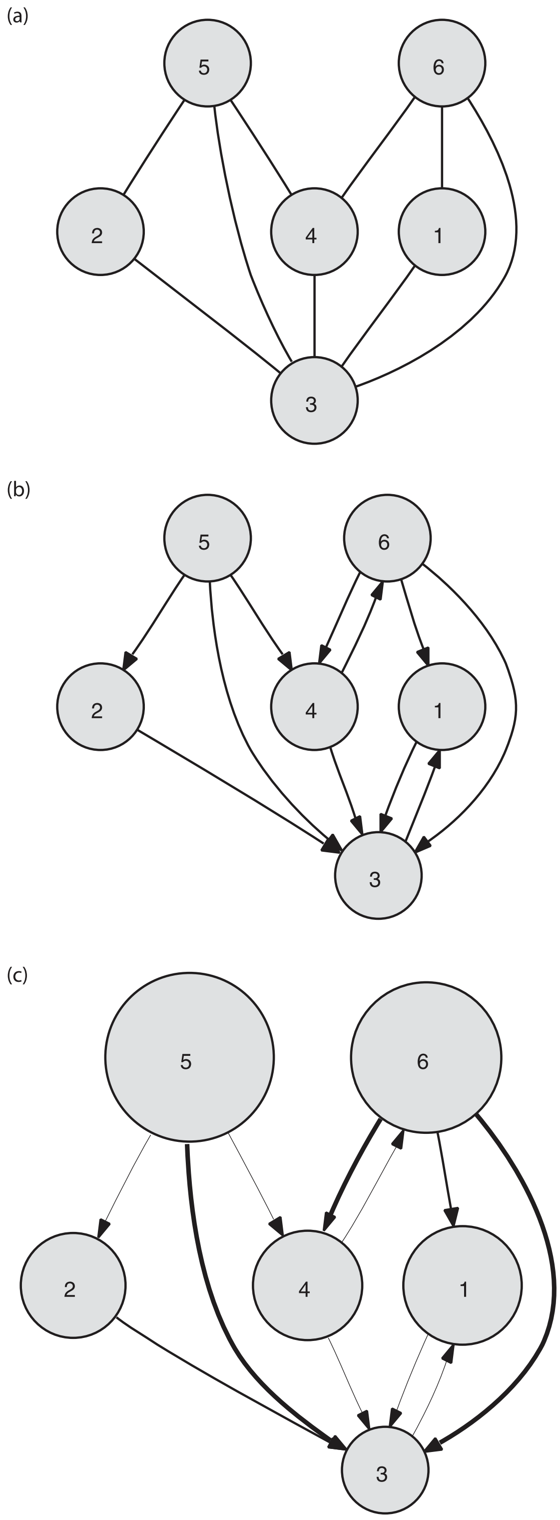

Fig. 1. Panels depict three different types of graphs: a regular unweighted graph (a), a directed unweighted graph or digraph (b), and a weighted digraph (c). Nodes in (a) and (b) are all equal size, while nodes in (c) have different size. Edges in (a) are regular and un-weighted. Edges in (b) are directed, while edges in (c) are both directed and weighted.

setting. The representation of river/stream fish populations as a graph is notably different from most terrestrial graphs, because the dispersal corridors (rivers and streams) are generally fixed and immutable at ecological time scales, i.e. the fish already live in a network.

Endangered salmonid populations are managed as evolutionarily significant units (ESU), which are defined as a salmon population or group of salmon populations that is substantially isolated reproductively from other populations and that contributes substantially to the evolutionary legacy of the species (Waples 1991, 1998). Typically, ESUs are structured internally (Gharrett, Gray & Brykov 2001; Olsen *et al*. 2003; Guthrie & Wilmot 2004) due to the fact that salmon mainly return to their natal rivers after spending several years at sea, but there is some low level of dispersal among the populations that is probably important for ESU persistence. As salmon return to their natal rivers they stray naturally at varying rates (Ricker 1972; Quinn 1993), which allows them to occupy new habitat (Milner & Bailey 1989; Wood 1995) and is the mechanism by which populations are connected. The rate at which salmon stray has proved difficult to quantify, although observed rates in the wild range from 0 to 67% (McElhany *et al*. 2000). Changing the spatial structure through population loss or increased straying must have effects on an ESU, but to date these have not been quantified.

We examine spring-run chinook salmon *Oncorhynchus tshawytscha* (Walbaum 1792) in California's Central Valley (Fig. 2), which are listed as threatened under the United States' Endangered Species Act. Spring-run chinook salmon are high-elevation mainstem spawners that migrate into the watersheds under high flow conditions in springtime (Yoshiyama *et al*. 2001; Lindley *et al*. 2004). They over-summer in cool temperature pools before migrating out of the pools in the fall to spawn (Lindley *et al*. 2004). After spawning the cool water temperatures delay maturation, and juveniles often remain in the system for a full year (Lindley *et al*. 2004). Spring-run chinook salmon occupied much of the Central Valley, although the installation and continued presence of major dams has blocked and restricted access to much of their historical habitat (Yoshiyama *et al*. 2001; Lindley *et al*. 2004) (Fig. 2). The first of 10 'keystone' dams in the Central Valley, i.e. the lowest-elevation dam that completely blocks upstream habitat, was installed in 1894. The addition of such keystone dams proceeded until 1968, removing a total of 19 populations from the ESU. Lindley *et al*. (2004) describe the putative historical structure of the ESU, which forms the basis for our analysis. We presume this was a viable ESU prior to 1894.

We build and test a dispersal model that accounts for directional connectivity between populations within the historic spring-run chinook salmon ESU, and use graph theoretic methods to test how connectivity influences the spatial structure of populations within the ESU. We focus on (a) the organisms' ability to disperse through fixed edges, (b) on the importance of individual fish populations (nodes) and (c) how the installation and continued presence of dams impacted the ESU. In addition, we examine the structure of the current spring-run chinook salmon ESU. Lastly, we use

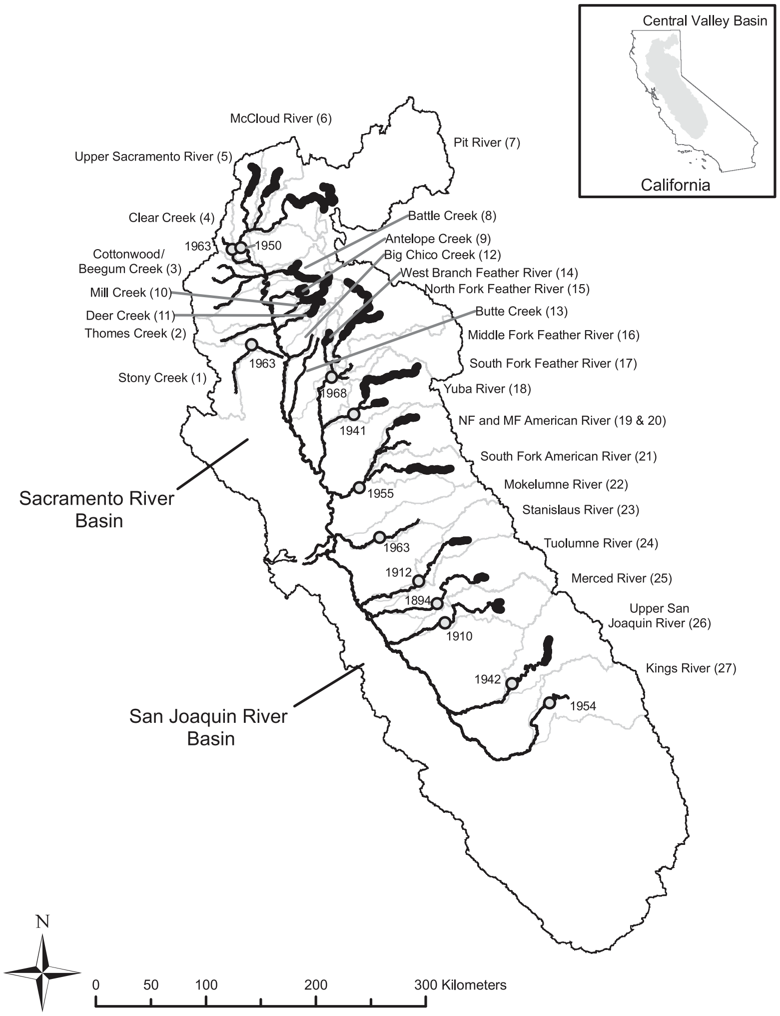

Fig. 2. Basemap of the study region. Depicted are the two river basins in the Central Valley, California (Sacramento River and San Joaquin River) and the major rivers within those basins that historically contained spring-run chinook salmon. The mainstems of the rivers are drawn up to the historical uppermost extent of spring-run chinook salmon as determined by Yoshiyama *et al.* (2001). Inferred spawning habitat above 500 m is shown in thick black lines. Populations are labelled with the river name and with a numerical ID that will be used in subsequent figures. Keystone dams are depicted as light grey nodes and are labelled with the year they were installed. For clarity, the Sacramento River Delta is omitted from the map.

these results – notably changes in graph metrics and in the role of populations – to discuss the persistence and survival of this threatened species. The graph theoretic methods presented herein have broad application across a variety of ecological systems, and can be used in data limited environments to predict population structure, persistence and synchrony.

Materials and methods

To populate the first graph data structure, we initially identified populations in the spring-run chinook salmon ESU that historically contained spawning groups (Lindley *et al.* 2004). The nodes in our graph represent populations; to identify these populations spatially, we located the intersection of the 500 m elevation contour and the mainstem of each river within the ESU. (Yoshiyama *et al.* 2001 identify 500 m as the approximate lower extent of the breeding range for spring-run chinook salmon.) This intersection is then the spatial representation of the node. To represent the size of the population (node) in the historical spring-run chinook salmon ESU, we used a habitat proxy: extent of the mainstem spawning range > 500 m elevation (Yoshiyama *et al.* 2001). For populations whose habitat was below 500 m, e.g. several small populations on the western side of the Central Valley, we used estimated ranges from Yoshiyama *et al.* (2001). Previous studies have shown that spawning habitat, as we have defined it here, correlates significantly with effective population size, N_e (Shrimpton & Heath 2003). To represent the size of the population (node) in the current spring-run chinook salmon ESU, we used the mean number of annual spawners since 1980 in lieu of the habitat proxy for the historical ESU (R. M. Kano, California Department of Fish and Game, Sacramento, CA., USA, unpublished data). [We note that these definitions of node size are different, and comparisons between the historic and current graph were made with an appropriate degree of caution. The correlation between habitat length and number of spawners was negative (–0·301); however, a plot of these revealed the relationship between the two was nonlinear and that this negative correlation was driven by an outlier (Butte Creek). Once Butte Creek was removed, the correlation between habitat length and number of spawners was positive (0·65).]

To create the second graph data structure, we used a network module of a commercially available geographical information system (GIS) package (ArcInfo® workstation version 9·0) to estimate 'as the fish swims' distance between all identified populations. By 'as the fish swims' we mean minimum straight-line distance along the river network, i.e. fish do not explore available tributaries. We used the ArcGIS Network module to estimate this distance between node locations along the river network of the Central Valley (1 : 100 k routed stream layer, version 2003·6, available from CalFish: http://www.calfish.org/DesktopDefault.aspx?tabId = 76, last accessed 18 August 2006). This yielded a full (upper and lower triangles) distance matrix, which served as the second input to our model.

Any two nodes in the graph were deemed connected by an edge if the proportion of incoming fish from one population exceeds a certain threshold level of the total recruitment (local + incoming) in the target population. The edges in the graph were developed from a migration matrix, N. To construct N we needed the following data structures: (1) a full distance matrix D of all the interpopulation 'as the fish swims' distances; (2) a dispersal kernel; (3) a matrix M of dispersal probabilities; and (4) a matrix X of population size.

We assumed in this analysis that a fraction of fish returning to spawn will stray from their natal stream and that the probability p_{ij} of a fish from node i migrating to node j is a function of the distance between the populations. While this inter-population distance may seem biologically counterintuitive, we repeated the same analysis using a model where salmon return to their natal watershed with some high fidelity, but make 'wrong' decisions with some small probability. Because the results were quite similar, we chose the more parsimonious model for interpopulation distance, because it rested on fewer unverifiable assumptions. (See supporting material for full characterization of this 'wrong-turn' model and results.)

To estimate p_{ij}, we fitted a dispersal kernel to the interpopulation distances. We used the kernel from Clark, Macklin & Wood (1998):

$$p_{ij} = \frac{c}{2\alpha\Gamma(1/c)} \exp\left(-\left|\frac{d_{ij}}{\alpha}\right|^c\right), \qquad \text{eqn 1}$$

where α is a dispersion parameter, c a shape parameter, and d_{jj}, an interpopulation distance measured along the stream network (from a full distance matrix D, described above). α is an estimate of a species dispersal capability, while c controls the shape of the tail in the kernel. To parameterize α we used two different studies on chinook dispersal from McClure *et al.* (2003, unpublished data, available at: http://www.nwfsc.noaa.gov/trt/col_docs/independent-popchinsteelsock.pdf, last accessed 23 August 2006). The first was a within-basin movement study of wild spring-run chinook salmon, which indicated an α = 31·6 km; the second was a cross-basin study of hatchery fish that indicated an α = 166 km. While the first data source is on wild fish, and probably represents a better source, it was limited to one river basin and does not account for basin-to-basin straying. The second estimate of α does account for basin-to-basin straying; however, it is probably biased upwards because of the reduced homing ability of hatchery fish. Therefore we chose the average of the two, or α = 98 km. The nature of the tail is controlled by c, whereby $c = 1$ and $c = 1/2$ correspond to a kernel with an exponential tail and a fat tail, respectively (Clark *et al.* 1998; Clark *et al.* 1999). We chose $c = 1$, where the shape of the kernel is exponential and dispersal probability is controlled by the value of α (personal communication, J. S. Clark, Duke University, Durham, NC 27708, USA).

Whether populations were deemed adjacent depended upon the magnitude of migration between them, the magnitude of total recruitment and a threshold for the ratio of the two. If the percentage of a population's total recruitment coming from immigrating fish from another donor population exceeded some value, these populations were deemed connected (Bjorkstedt *et al.* 2005). To find these connections we first created a dispersal probability matrix M comprised of a mixture model composed of two probabilities: (1) m, defined as straying probability and initialized at 5%; and (2) p_{ij}, as defined above. We then set the off-diagonal elements of M to mp_{ij} and the diagonal elements to 1 – m. Because p_{ij} represented a discrete interpopulation movement, we normalized the off-diagonal probabilities over all possible movements, i.e.

$$M_{i \neq j} = \frac{p_{ij}}{\sum_j p_{ij}} .$$

We then used the matrix of population sizes X (described in the previous section) in conjunction with M to define a migration matrix $N = XM$. The diagonal elements of N contained the number of fish resulting from self-recruitment, and the column sums of the off-diagonal elements contained the number of fish immigrating to the populations (*sensu* Bjorkstedt *et al.* 2005). The proportion of recruitment in population i that comes from population j was then calculated in order to examine pairwise directed dependence. If this ratio exceeded some threshold, then population i was dependent upon population j. The relationships among all populations were visualized as a directed graph. Independent populations in the graph were populations that are not dependent upon any others indicated either by populations with either no connections to other nodes, or only outbound connections. In our model, populations were adjacent (connected) if the donor population contributes more than 1% of total recruitment to the recipient. In addition, we preserved the strength of the connection to represent the weighted graph fully.

Lastly, we defined the population's independence (Bjorkstedt *et al.* 2005), or ζ, as:

$$\zeta_i = \frac{\delta_{ii} X_i}{\delta_{ii} X_i + \sum_{i \neq j} \delta_{ij} X_j}, \qquad \text{eqn 2}$$

where X represents population size, and δ_{jj} is local recruitment. We assessed how the trajectory of population independence changed over time by recalculating ζ for the remaining populations after each dam addition.

We examined the source–sink structure (Pulliam 1988) of the ESU by evaluating the importance of individual populations to the historical graph at the ESU scale (Bunn *et al.* 2000; Urban & Keitt 2001). Specifically, we examined node sensitivity for *outdegree* and *indegree* of a given node. *Outdegree* and *indegree* correspond logically to a qualitative representation of source and sink structure (Pulliam 1988), while *node strength* provides a quantitative representation of this structure (Barrat *et al.* 2004; Bascompte *et al.* 2006). We calculated *outdegree* and *indegree* of a given node by summing the rows and columns of the adjacency matrix $A(D)$, respectively. To calculate *node strength*, we summed the row and column sums of the off diagonal elements of N. Note that we assumed all populations have at least some local recruitment and may be more accurately termed pseudo-sinks (Watkinson & Sutherland 1995).

We combined methods from Bunn *et al.* (2000) and Urban & Keitt (2001) with our digraphs to examine the

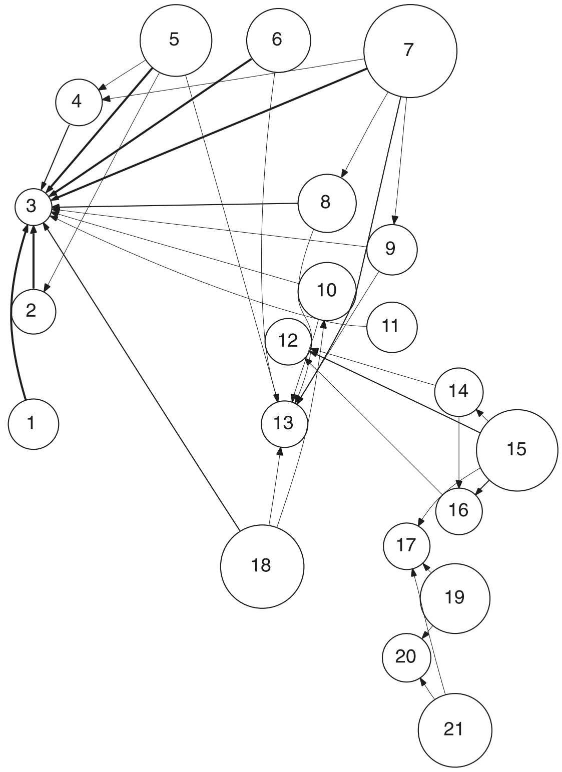

Fig. 3. Digraph for dispersal through the historical spring-run chinook salmon ESU. Because there were no connections into or out of any of the San Joaquin Basin populations (numbers 22–27), they are excluded from the figure. Populations are connected if donor population contributes more than 1% of local recruitment to the receiving population. Increased edge thickness corresponds to increased demographic dependence (1–4·9%, 5–9·9%, > 10%). The size of the nodes corresponds to the amount of habitat present in each watershed (log +1·5 transformed), and the location of the nodes in the figure is an approximation of their true location. Populations are numbered as in Fig. 2.

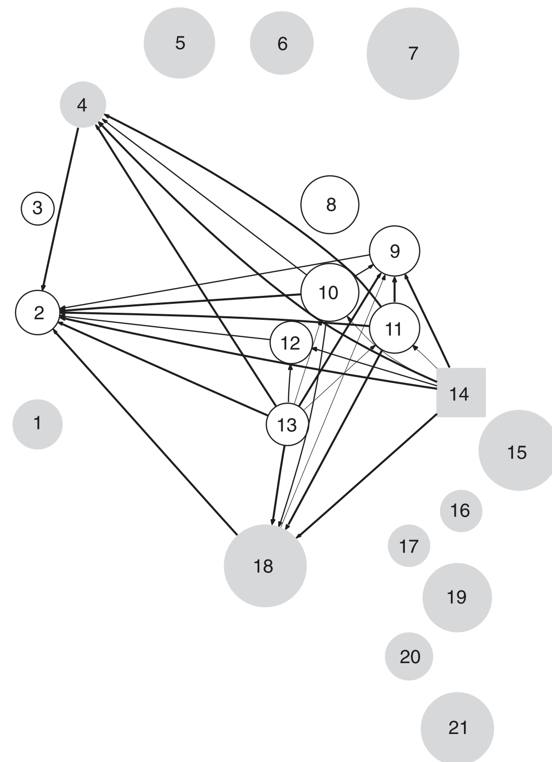

Fig. 4. Digraph for dispersal through the extant populations in the spring-run chinook salmon ESU. In addition the Feather River Hatchery is included in the graph, and is in the same place as the West Branch Feather River (14). Nodes for extinct populations are depicted in grey. Several populations whose historical habitat was blocked by hydropower dams now have some small populations spawning below dams, hence the presence of edges into grey nodes. These include Clear Creek (4) and the Yuba River (18).

effect dam addition had on the structure of the ESU. In addition to observing the actual fragmentation of the ESU, we used our model of connectivity and a series of alternate node removal scenarios (random, removal by largest available habitat and removal by largest node strength) to observe what happened to the graph as populations in the ESU went extinct.

We tested the sensitivity of the model to our assumptions by perturbing each of five model parameters by 10% and tallying the percentage change in the total number of edges in the graph. These parameters included: (1) the α parameter in the dispersal kernel; (2) the percentage of fish straying; (3) that migration is proportional to the interpopulation distance; (4) that population size is proportional to historical spawning extent; and (5) that all fish arriving at a new population recruit into that population (i.e. fitness of natives vs. strays).

Results

The historical digraph G_1 based on the dispersal adjacency matrix outlined above exhibited unbalanced *indegree* and *outdegree*, and contained six entirely disconnected (independent) populations (Fig. 3). All these populations are in the San Joaquin system, where the geography of the river basins is such that the populations are quite far apart (Fig. 2). In addition, the geographically closest of these populations (23–25) are all small enough to preclude outbound/inbound connections (Fig. 2). There are several populations in the Sacramento River Basin whose connections (> 1) were all outbound: Upper Sacramento (5), McCloud (6), Pit (7), Yuba (18), North Fork Feather (15) and the North and South Forks of the American River (19, 21) (Fig. 3). These large source populations, like those in the San Joaquin, are also demographically independent. Stronger demographic connections, on average, exist between nearby populations in which the source population is larger than the pseudo-sink population; as expected, the strength of the connection tends to decay with distance (Fig. 3).

The current graph is smaller than the historic graph, because most spawning habitat for historical populations is now behind dams (Fig. 4). At the ESU scale there are 15 demographic connections above the 10% threshold, four of which are outbound from the Feather River Hatchery (14). Butte Creek (13), a net

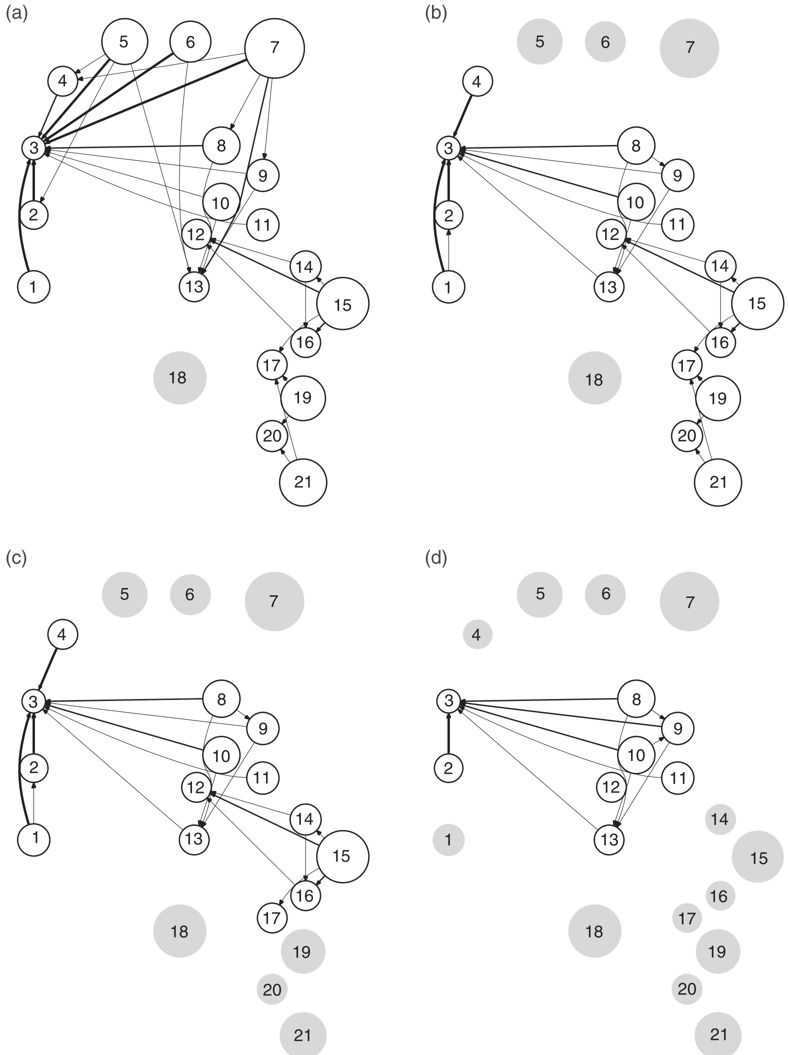

Fig. 5. Four panels depict the addition of dams to certain rivers, and the accompanying change in the graph. Shown are (a) Englebright Dam on the Yuba River (1941), (b) Shasta Dam on the Sacramento River (1945), (c) Nimbus Dam on the American River (1955) and (d) Oroville Dam on the Feather River (1968). Nodes and edges are depicted as in Fig. 3, except for extinct populations whose nodes are in grey.

importer before dam construction (*indegree* = 6, *outdegree* = 1 in Fig. 3), is a net exporter (*indegree* = 0, *outdegree* = 7 in Fig. 4). Both Stony (1) and Beegum Creek (3) had an average of zero reported spawners, hence the lack of connections in either direction (Fig. 4). Lastly, there is only one independent population, Battle Creek (8), in the current graph, while there were nine such populations in the historical graph.

In addition to blocking habitat, dam addition affects the remaining nodes both by increasing demographic independence on average and reducing the strength of the connections between nodes (Fig. 5a–d). As large spatially proximate nodes are removed from the graph, edges with an initial high weight are lost and the weight of certain remaining edges increases as migrants have fewer possible destinations (Fig. 5a–d). For example, when Shasta Dam was constructed in 1945 it blocked access to several major rivers including the Pit, McCloud and the Upper Sacramento (located just above the northernmost dam in Fig. 2), and the results illustrate what a vital source these three rivers were to the overall graph (Fig. 5b). Each of these nodes (especially the Pit River) had a high outdegree, and the removal of these three nodes results in a loss of 12 edges (Fig. 5b). However, the loss also affected the context of populations such as Battle Creek (8), which had an increase in the number of outbound edges, as well as their weight (Fig. 5b–d). The last two panels depict the loss of the American River and the Feather River populations through the addition of Nimbus Dam and Oroville Dam, respectively (Fig. 5c,d). Any dam that blocked access to anadromous habitat in the San Joaquin system had little effect on the remaining populations, because these populations were all quite isolated (nodes not shown).

Independence of smaller populations increases with the loss of large source populations (Fig. 6), suggesting that recolonization rates are lower under the current structure than they were historically. Some losses are worse than others; the addition of Shasta Dam (1942) not only removed many edges (Fig. 5b), but it also caused a dramatic increase in population independence for many of the populations present in the ESU (Fig. 6). Consider, for example, Butte Creek (13), which progresses from $\zeta = 0{\cdot}77$ in 1850 to $\zeta = 0{\cdot}87$ in 1968 (Fig. 6).

The median ζ across the ESU shows markedly different patterns when exposed to different node-removal scenarios (Fig. 7). Under the scenario aimed at removing the nodes with the highest node strength, population independence ζ of the remaining populations increased the fastest. The random removal scenario has the next strongest effect, followed by removal based on the largest habitat size of the remaining populations (Fig. 7). The difference between the node-strength and the random removal scenarios is particularly evident after approximately one-third of the habitat has been removed. Population independence ζ increased faster for all of these scenarios, as compared to actual removal (Fig. 7).

Our model was most sensitive to two parameters: (1) uncertainty about the percentage of fish that stray; and (2) to percentage of straying fish that recruit into the recipient population (Table 1). The model was less sensitive to uncertainty in dispersal capabilities of

Table 1. Results from sensitivity analysis. For each parameter listed, we implemented a 10% perturbation and tallied the absolute change in number of edges in the final historical graph. Noted are the number of edges and the absolute percent change. There were 35 edges in the base historic graph

Parameter	No. of edges	% Change
α	37	5·7
% of fish that stray	38	8·6
Habitat size	35	0
Inter-population distance	33	5·7
% Strays recruiting	38	8·6

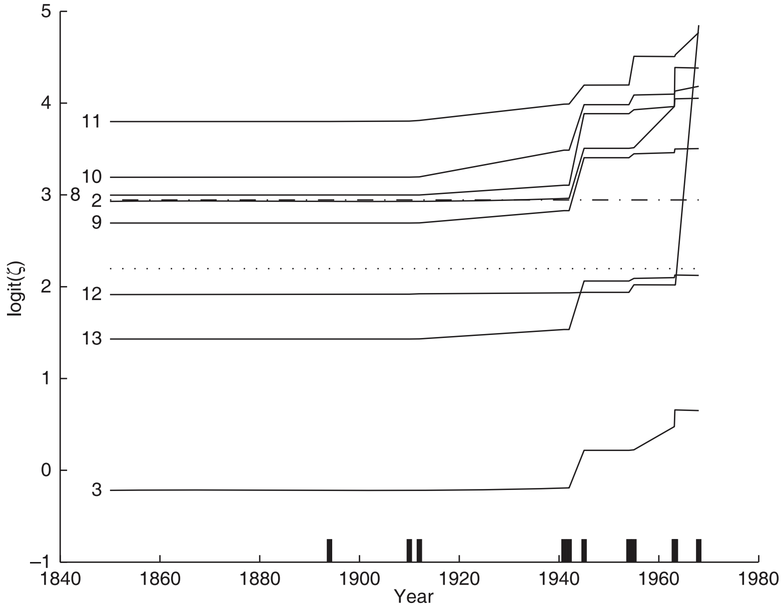

Fig. 6. Independence level (ζ) for each extant population in the ESU from 1850 up to the last dam addition in 1968. Population independence increases as populations are removed from the ESU (dam additions denoted by thick tick-marks on the *x*-axis). ζ-values are logit-transformed for visual clarity; for reference $\zeta = 0{\cdot}9$ and $\zeta = 0{\cdot}95$ are included as dashed and dash-dot lines, respectively. A dramatic change in population independence is seen after 1945, when the construction of Shasta Dam blocked access to the Pit, McCloud and Upper Sacramento Rivers. Populations are labelled as in Fig. 2.

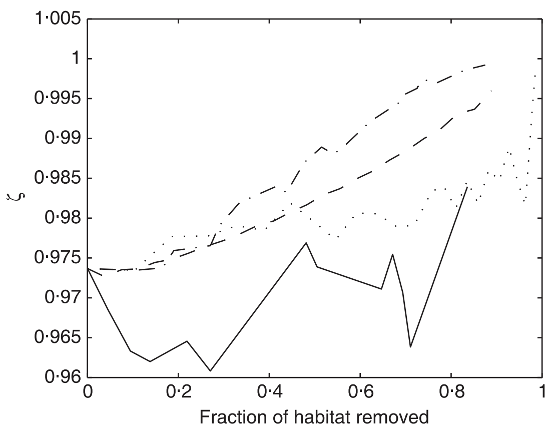

Fig. 7. Effect of node removal on median independence (ζ) of remaining populations in the ESU for four different removal scenarios: actual (solid line), random (dashed line), largest population first (dotted line), population with largest node strength first (dashed–dotted line). Random line represents the mean of 1000 iterations.

chinook and interpopulation distance. The model was not sensitive to our definition of population size. While we present only results for the historical graph (Table 1), these results hold as the graph fragments and the relative impacts of dams are the same as the unaltered empirical graph.

Discussion

Weighted digraphs have enabled us to understand more clearly the population context in the spring-run chinook salmon ESU, because they have shown whether populations are importers, exporters, or functionally independent. The historical digraph had both source and pseudo-sink populations, and a range of demographic connections between populations. The current graph has fewer source populations and fewer independent populations. Additionally, the current graph has populations that switch context from their position in the historical graph, and has more and stronger demographic connections between populations. While the impact of dams on fish populations has long been known, our examination of the sequential dam addition in the Central Valley showed clearly how a single dam can impact almost the entire ESU. This impact meant a loss of source populations to the ESU, resulting in fewer edges and increased isolation for the remaining nodes. This translates to decreased opportunity for recolonization after extinction or disturbance events.

Previous graph theoretic attempts to model how organisms perceive their landscape have relied mainly on regular graphs (Bunn *et al*. 2000; Urban & Keitt 2001; Brooks 2006) (although see Fortuna *et al*. 2006 for a recent example of the utility and strength of a digraph application). Here we have accounted for the strength and directionality of the connections in the graph, and while this is an obvious and intuitive extension of graph theoretic applications that has been mentioned several times in the literature (Gustafson & Gardner 1996; van Langevelde *et al*. 1998; Urban & Keitt 2001; Fagan 2002), we stress its importance in this and future applications. Imagine, for example, the different interpretation of Butte Creek (13) in a regular graph. There Butte Creek might jump out as a stepping-stone population (*sensu* Urban & Keitt 2001); however, it is clear from the digraph that this, in fact, is a pseudo-sink population whose demographic trajectory is influenced by several populations in the graph. Lastly, by accounting for recruitment as a measure of connectivity (*sensu* Bjorkstedt *et al*. 2005), we have extended the purely spatial application of graph theoretic measures and have uncovered not only how nodes are connected spatially, but what that spatial positioning means for the trajectories of populations within the ESU.

Defining what comprises a population remains an active research area in ecology and evolution. Indeed, relatively little work has been conducted on ascertaining what fraction of incoming recruitment affects population trajectories enough to consider them linked (Waples & Gaggiotti 2006). Hastings (1993), in a theoretical system, has shown that the 10% threshold is sufficient to consider population trajectories as linked. However, Lande, Engen & Sæther (1999) showed that under certain circumstances, i.e. weak density regulation, even very small migration rates can help to increase the spatial scale of synchrony. At two extremes, therefore, we can assume independence for populations with no edges or only outbound edges in

Fig. 3, and cannot assume independence for populations with inbound connections over 10% (Fig. 3). Even if absolute independence thresholds are not definitive, relative changes in population independence are clear from the pattern of dam addition that successively fragmented the ESU and isolated remaining populations (Fig. 6).

Graph theoretic applications are appealing from a conservation standpoint because they are relatively simple to implement and they offer critical insight at both the landscape and population level (Urban & Keitt 2001). The graphs herein show interpopulation connectivity across the ESU, population importance, and how the removal of populations over time fragmented the ESU. Because this is a riverine setting, edge removal between two populations means typically that there are no alternate edges between that pair of populations (Fagan 2002). This means that fragmentation events lower down in the trunks of a watershed (Fagan 2002) can have dramatic effects – witness the effect of two single such events (Shasta and Oroville Dams) in our ESU, which removed a total of seven populations from the ESU (Fig. 5b,d). Clearly, the Pit River (7) had a major impact on the ESU, and were it not for the considerable complexities involved with removing major dams like Shasta *and* Keswick (just downstream of Shasta and the one depicted in Fig. 2), this would be an obvious place to highlight conservation and restoration efforts. However, Shasta Dam holds much of Northern California's water and so its removal would have serious implications for both the amount of water and its flow regulation throughout Northern California.

Palmer *et al*. (2005) underscore the need for a guiding image when restoring river ecosystems, and our depiction of the historical graph (Fig. 3) provides such an image. Further, the simulation of node-removal under different scenarios provides information that could be key to managers, as it highlights which restoration methods would bring about a reduction in demographic isolation fastest. While one might assume naively that restoring large populations first would have the greatest affect, that is not the case here (Fig. 7). Clearly, a scenario centred around restoring populations with large node strength first would accomplish this by adding more connections back to the graph (Fig. 7). Somewhat counter-intuitively, ζ decreased initially under the actual removal scenario; however, this is due simply to the spatial arrangement and timing of dam removal in the Central Valley. Notably, the first populations to be removed were in the southern San Joaquin, which meant that while habitat was lost, the resulting graphs were initially more compact and less isolated. Lastly, and perhaps most importantly, our graph framework accomplished what Jansson *et al*. (2005) called for in terms of a conceptual model that shows system function, system impairment and restoration strategies that 'will move the system back to the guiding image'.

Connections are the mechanism by which recolonization can occur following disturbance, and they add stability and resilience to a system. It is intuitive that with more connections the removal of any one edge has less effect on the overall stability of the graph. Given the historical level of connections, then the graph as of 1968 (Fig. 5d) suffers from a lack of connections, and must be viewed as less resilient. This is echoed by the demographic isolation seen in Fig. 6, and adding connections back into the system would decrease demographic isolation and increase stability. There is a limit to this, however, in that a graph can have too many connections. While an increase in connectivity increases the likelihood of rescue (Brown & Kodric-Brown 1977), it also increases both the likelihood of pathogen spread (Hess 1996a) and spatial coupling. Hess (1996a,b) has shown that intermediate levels of connectivity provide a balance between extinction and persistence. With increased spatial coupling, Keeling, Bjørnstad & Grenfell (2004) have shown that synchronous populations are increasingly vulnerable to a similar extinction trajectory. Connections should therefore be viewed in light of a balance between these two opposing forces; simulation and/or analytical studies could help to uncover an optimum level of connectivity for population and ESU persistence.

The conceptual model presented herein has highlighted at least two other areas of future research. First, we might ask what other types of migration models make sense for salmon. We experimented with other models of straying, including implementing a 'wrong-turn' model where returning fish are faced with a series of choices as they migrate back to their natal stream. While this model is potentially more representative of the actual process undergone by a returning adult salmon, its results were qualitatively quite similar (see Appendix S1 in Supplementary Materials) to the more parsimonious distance-based model presented here, and it was less extensible to other systems. Secondly, we might ask how representative this model is for salmon dynamics. It was our intention that this model serve as an illustrative model of salmon connectivity, not necessarily a usable model of metapopulation dynamics. While the sensitivity results indicate that the model is fairly robust to uncertainty, they point to areas of further research. Namely, we need additional information about the percentage of fish that stray and the percentage of strays that recruit into populations.

Remarkable progress has been made in graph theory in just the last 8 years. Ecologists willing to wade into this realm will find that much awaits them in the way of different network structures, rapidly advancing algorithms and a wealth of interesting applications (Proulx, Promislow & Phillips 2005). Here graphs have enabled us to accomplish the following: (1) to enhance our understanding of the overall ESU structure; (2) to examine how ESU structure changed through time; and (3) to understand the historical importance of individual populations. In a data-limited environment, this exercise has shed light on this system from both an ecological and conservation standpoint. Our model of directed connectivity can be extended to many other systems, riverine or otherwise, and we recommend graph theory as an attractive analytical tool for rapid assessment of critical landscapes and endangered populations.

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Supplementary material

The following supplementary material is available for this article.

Appendix S1. Description and graphical results of the 'wrong-turn' model.

This material is available as part of the online article from: http://www.blackwell-synergy.com/doi/full/10.1111/j.1365-2664.2007.01383.x
(This link will take you to the article abstract).

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APPENDIX D

Habitat Restoration Cost References for Salmon Recovery Planning

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Introduction

The Endangered Species (ESA) requires that recovery plans for listed species include "estimates of the time required and the cost to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal" (ESA Section 4(f)(1)(B)(iiii)). The purpose of this report is to facilitate recovery planning for ESA-listed salmonid stocks in California by providing information on costs associated with habitat restoration activities relevant to their recovery.

Data from publicly available sources were used to obtain estimates of restoration cost. Ideally these estimates would be identifiable to a specific restoration activity (e.g., fish screen, culvert replacement), include life cycle project costs (e.g., planning, design, permitting, construction, monitoring, maintenance), and be relatable to the scale, scope and location of the project. However, sources vary in terms of the extent to which they provide such details. Most cost estimates originate from sources generally intended for purposes other than recovery planning (e.g., contract administration). Thus reported costs may be incomplete if, for instance, some aspects of restoration are not covered by the contract or if the work involves a match from another funding source. For projects involving multiple restoration activities, costs are more typically broken down by input (e.g., labor, materials) than by activity. Given the diverse factors that affect restoration costs (see Allen *et al.* 2004) and the lack of standardization in available project and cost data, a meta-analysis of project costs as they relate to project characteristics was not possible. However, some of the sources do provide insights into factors affecting costs; to the extent that such information is available, it is briefly summarized in the tables below.

Many of the projects discussed in this report were funded by the California Department of Fish and Game (CDFG) as part of the Fisheries Restoration Grants Program and (to a lesser extent) the Klamath River Restoration Grant Program. The report is thus approximately organized according to the restoration categories used by these two programs. Restoration activities covered by this report are as follows:

- Fish ladders (FL)
- Fish passage at stream crossings (FP) - culvert replacement/improvement
- Fish screening of diversions (SC)
- Instream barrier modification (HB) - modification of fish passage barriers in the stream channel and along the streambank (tidegates, sandbars, dams, other non-culvert barriers)
- Instream habitat restoration (HI) - enhancement of stream channel and streambank habitat (instream structures, spawning gravel supplementation, floodplain tributary reconnection, side channel reconnection, wetland/floodplain restoration, levee evaluation/repair/setback)
- Riparian restoration - restoration of area, including fencing, between the fence and middle of stream (e.g., livestock exclusion, revegetation)

- Streambank stabilization (HS) - stabilization of eroding, collapsing of otherwise de-stabilized banks
- Upland watershed restoration (HU) - largely pertains to upslope erosion control (e.g., road decommissioning/upgrade, landslide/gully stabilization, upslope planting)
- Tailwater management (TM)
- Water conservation (WC) - e.g., ditch lining, piping
- Water purchase/lease (WP)
- Habitat acquisition and conservation easement (HA)
- Monitoring status and trends (MD) - monitoring of baseline conditions and status/trends in habitat, watershed processes and/or populations.
- Monitoring watershed restoration (MO) - monitoring to determine if project treatments were constructed correctly and as planned, effectiveness monitoring to determine if restoration has produced desired habitat conditions and/or watershed processes, and validation monitoring to determine if hypothesized responses of habitat, watershed processes and/or populations to restoration were correct
- Watershed evaluation, assessment and planning (PL) - developing watershed plans with site-specific, prioritized recommendations for restoration of salmon/steelhead habitat. Includes partial assessments (e.g., road erosion surveys, stream surveys).
- Watershed organizational support and assistance (OR) - organizational support to local watershed groups and development/maintenance of databases that facilitate organizational aspects of restoration
- Cooperative fish rearing (RE)
- Water measuring devices (WD) - e.g., head gate
- Wildlife management (WM) - e.g., control of exotic species such as pike minnow
- Research (RES) - general research on productivity (e.g., life cycle monitoring/analysis), spatial structure (fish distribution surveys), genetic diversity (laboratory analysis of tissue samples), and estimation of abundance.

Restoration cost estimates were obtained by searching the published and gray literature, including the following:

- reports that provide actual or estimated costs associated with specific projects (e.g., grant proposals, contract reports),
- reports that provide average costs for multiple projects involving the same restoration activity,
- reports that describe "typical" costs associated with a particular restoration activity,
- cost guidelines associated with environmental improvement programs sponsored by entities such as the Natural Resources Conservation Service (NRCS),
- reports that use regression and other methods to relate project costs to selected project characteristics, and
- environmental impact statements that provide cost estimates for each of the restoration alternatives considered.

Only restoration cost estimates that met at least one of the following criteria are included in this report:

- Top priority for inclusion are cost estimates pertaining to restoration activities in California. However, examples from other states are also included (as available) for those activities where California examples are limited. A notable exception: Cost estimates developed by Evergreen Funding Consultants for restoration in Puget Sound (Evergreen 2003) are particularly instructive, as they cover a wide range of restoration activities, provide life cycle estimates of project costs, and demonstrate how costs vary with project characteristics. Thus all of Evergreen's cost estimates are included in this report - even when they pertain to activities where a fairly large number of California examples are also available.

- Cost estimates are generally more useful for recovery planning when related to the scale of restoration. Thus only cost estimates that are accompanied by a relevant measure of project scale (e.g., stream miles, acres of land) are included in this report.

- For most projects involving multiple types of restoration activities, data sources typically do not provide a cost breakdown by activity. Given the focus of this report on activity-specific costs, most of the cost estimates were by necessity obtained from single-activity projects. However, to ensure some representation of multi-activity projects, some projects involving several closely related activities (e.g., fencing + stockwater system, fish ladder + screen) conducted at the same site are included in this report. Also, cost summaries provided by the Pacific States Marine Fisheries Commission for projects sponsored by CalFED's Ecosystem Restoration Program (Holycross *et al.* 2007) include some estimates of cost per activity for multi-activity projects.

- To help ensure that cost estimates reflect fairly recent restoration technology, the report focuses largely on projects that have occurred since 1998. However, in cases where project data for a particular restoration activity are sparse, pre-1998 project data are also provided, as available.

All costs described in this report pertain to direct expenditures on restoration and do not include economic opportunity costs (e.g., foregone profits associated with restrictions on livestock grazing, timber harvest and other activities). It is important to note the following:

- Even the direct costs described in this report are not necessarily comparable across projects, as some cost estimates are more inclusive than others. Some data sources - e.g., Evergreen Funding Consultants (2003), Neal (2004), Steere (2004) - provide cost estimates that include pre- and post-construction requirements as well as construction itself. In other cases, cost estimates are largely limited to engineering and/or implementation aspects of the project (e.g., CDFG's Fisheries Restoration Grants

Program, NRCS Environmental Quality Improvement Program) and do not include agency involvement in planning, design, management, maintenance and monitoring. In still other cases, documentation is not adequate to determine exactly what is included and excluded from the cost estimates.

- For most projects involving capital construction (e.g., bridges, fish screens), costs are not amortized but rather provided as a lump sum. One notable exception is the Independent Economic Analysis Board's (2002) estimates of amortized capital construction costs for Columbia River hatcheries.

For each restoration activity, one or more tables are provided that include cost estimates for that activity - by location, year, project scale, cost per scale unit, and data source.

- Depending on available information, each project example is variously identified by stream/creek/river, watershed, county, recovery domain,[1] or state.

- Depending on the source of a cost estimate, year may pertain to the year of a funding proposal or contract. In cases where a document includes cost estimates for projects conducted in years prior to publication of the document, the project year is used when available; otherwise the publication year is used.

- The metric used for project scale varies, depending on the nature of the restoration activity. Thus for instance, design approach velocity (cubic feet per second, cfs) is used for fish screens; linear feet for levee work, fencing, bank stabilization; acres for revegetation, wetland restoration, land purchase/easement; and miles for road decommissioning/upgrade.

- As indicated above, this report focuses largely on 1998-2006 projects. Cost estimates for these projects are provided in current dollars (uncorrected for inflation). In situations where paucity of 1998-2006 data warranted inclusion of pre-1998 projects, costs of pre-1998 projects were corrected to 2006 dollars. In some cases, the data sources themselves provide inflation-corrected cost estimates. The base year for these estimates is documented in this report, along with the year(s) when the restoration actually occurred (e.g., Hildner/Thomson's (2007a) results are denoted "98-05" and "2003$" to reflect the fact that their cost estimates are based on 1998-2005 project data and have been corrected to 2003 dollars).

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[1] The recovery domains include: Southern Oregon/Northern California Coast (SONC), North/Central California Coast (NOCECA), Central Valley, and South Central California Coast (SCACO). There is an area of geographic overlap between the SONC and NOCECA, which is referenced in this report as NOCECA-SONC.

- The nature of the cost estimates vary somewhat, depending on the data source: (i) In cases where cost is reported for a specific project, total project cost, project scale, and average cost per scale unit are provided, as available. (ii) In cases where cost is reported as an average value across multiple projects, the sample size and range of project costs (as available) are reported along with average cost. (iii) In cases where a "typical" cost is reported, the "typical" cost and the range of "typical" costs (as available) are provided. (iv) In cases where cost is estimated from a regression equation, the equation itself is provided as well as a range of fitted values associated with the regression parameters.

- In cases where management/administrative costs are reported for a multi-activity project and the cost estimate in the table pertains to one activity, management/administrative costs (which are not solely attributable to that one activity) are provided separately and not included in the calculation of cost per scale unit.

- Data sources are identified in the tables by last name or initials of author(s) and table and/or page numbers as appropriate. In cases where the data sources were grant proposals submitted to CDFG's Fisheries Restoration Grants Program (FRGP) or Klamath River Restoration Grant Program (KRRGP), those sources are identified in the tables by the fiscal year in which the proposal was submitted (01-02 through 06-07) and the project ID number (CDFG-xxx for the FRGP, Kxxx for the KRRGP). In cases where the data sources are projects sponsored by CALFED's Ecosystem Restoration Program (ERP), the projects are identified by the year of the proposal and the project ID (ERP-xx-xxx). In cases where costs associated with an ERP project could be broken down by activity, that project ID appears multiple times in the tables. All data sources are fully documented in the "References" section at the end of this report.

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FL - FISH LADDER.

Table FL-1 provides estimates of fish ladder costs. CDFG's Coho Recovery Strategy (CDFG'04, p1.14) assumed $500K/ladder on tributaries and $900K/ladder on streams. This cost range pertains to central/northern CA coastal streams and is not necessarily applicable to projects outside that geographic range. However, most of the projects in Table FL-1 do fall within that range. Notable exceptions (exceeding $2M/ladder) include a project in the South Central California Coast (SCACO) recovery domain (HT07a-T61, p121) and several Central Valley projects (HT07a-T61, p121, ERP-99-B03) . Note: Some of the projects pertain to ladders only, others to ladder/screen combinations.

Table FL-1. Fish Ladder ($/project)

Location	Year	Units	Cost Per Unit	Source
CA	2004	typical	Small waterway (tributary): $500K/ladder Large waterway (stream): $900K/ladder	CDFG'04, p1.14
Young'sDam	03-04	1ladder	$494K - sloping plate, selfclean, excluding design	CDFG-057
SONC CentralVly SCACO	98-05 2003$	1site 1site 1site	$530.1K $2.1M $2.1M	HT07a-T61, p121
Gorrill Dam/Butte Creek	1997	2ladder	$660K ($330/ladder) +$12.8K project mgmt + $58.8K construction mgmt - construct ladder and screen	ERP-97-M03
Adams Dam/Butte Creek	1997	1ladder	$298.7K (+$6.3K project mgmt + $3K project coordination) - construct ladder and screen	ERP-97-M04
Battle/Soap/ Ripley Creeks	1999	3projs	$2.7M ($902.7K/project) - decommission several PG&E dams, provide ladders/ screens for remaining dams	ERP-99-B01
Sacramento River	1999	2 projs	$4.56M ($2.28M/project) + $130K project mgmt - Anderson-Cottonwood Irrig Dist	ERP-99-B03
Battle Creek	1999	1 proj	$731K +$105.3K project mgmt - improve CNFH fish ladder & barrier weir	ERP-99-B08

FP - FISH PASSAGE AT STREAM CROSSINGS.

Tables FP-1 and FP-2 pertain to culvert replacement, Table FP-3 to culvert replacement with a bridge, and Table FP-4 to culvert improvement.

Table FP-1 describes Evergreen's estimates of culvert replacement costs, while Table FP-2 provides similar estimates from other data sources. Evergreen's estimates include not only construction but also design, permitting, monitoring, maintenance and management, and are much more inclusive than the estimates in Table FP-2. Most of the latter examples are derived from grant proposals submitted to CDFG's Fisheries Restoration Grants Program - with costs largely limited to engineering/construction aspects of the project. The Table FP-2 estimates generally fall within the range of $100K-$400K/culvert, although there are some projects that cost in the $10,000s (e.g., Dupont-T10, p66; HT07a-T60, p118; HT07a-T61, p121) and one very costly project ($4.1M, CntySBPublicWrks) in Santa Barbara. Culvert type is reported here when available from the data source.

Evergreen's estimates show typical culvert replacement costs for Puget Sound by road type and size of waterway.Like Evergreen, Hildner/Thomson show cost per culvert being lower for rural roads than major highways (HT07b-T42, p61) and increasing with stream order (HT07b-T44, p62). Excluding 4+ lane highways (which are not covered by Hildner/Thomson), the estimates obtained by HT from restoration contractors fall within Evergreen's cost ranges. E.g., forest roads - Evergreen: $15K-$150K, HT: $23.4K; minor 2 lane road - Evergreen: $50K-$280K, HT: $227K; major 2 lane road - Evergreen: $100K-$450K, HT: $420K. Small waterway - Evergreen: $15K-$200K, HT: $70K; medium waterway - Evergreen: $50K-$350K, HT: $175K; large waterway - Evergreen: $80K-$450K, HT: $286K.

Table FP-1. Culvert Replacement - $/project (Source: Evergreen 2003, p. 21)
Cost estimates pertain to Puget Sound. Estimates include construction, design, permitting, basic monitoring & routine maintenance (2 yrs), reestablishing site to prior conditions, project management

Size of Waterway	Road Type			
	Forest Road	Minor 2 Lane	Major 2 Lane	Hwy 4+ Lane
Small 0-10'	$15K-40K	$50K-100K	$100K-200K	$200K-350K
Med 10-20'	$50K-100K	$140K-240K	$200K-350K	$300K-450K
Large 20-30'	$80K-150K	$180K-280K	$250K-450K	$600K-800K

Table FP-2. Culvert Replacement - $/project				
Location	Year	Units	Cost Per Unit	Source
AlbionR/Marsh Crk-MendcnoCnty	01-02	3culvrt	$180.5K ($60.2K/culvert)	CDFG-007
PeacockCrk-DelNorteCnty		1culvrt	$295.0K - open bottom	CDFG-009
JohnsonCrk-MendcnoCnty		1culvrt	$100.9K - bottomless pipe arch	CDFG-009
DeerCrk-MendcnoCnty		1culvrt	$97.5K - bottomless pipe arch	CDFG-010
JordanCrk-DelNorteCnty		1culvrt	$246.3K - box culvert	CDFG-059
RyanCrk-MendcnoCnty		1culvrt	$151.5K - bottomless pipe arch	CDFG-068
PorterCrk-RussianR	02-03	2 culvrt	$266,250 ($133.1K/culvert)	CDFG-028
StansberryCrk-MattoleR		1culvrt	$197.5K	CDFG-265
GibsonCrk-MattoleR		1culvrt	$213.1K	CDFG-266
StanleyCrk-MattoleR		1culvrt	$239.4K	CDFG-267
SaundersCrk-MattoleR		1culvrt	$269.5K	CDFG-268
IndianCrk-MattoleR		1culvrt	$55.0K	CDFG-270
DarkGulch-MndocnoCnty		1culvrt	$202.1K	CDFG-305

AlbionR/Marsh Crk-MendcnoCnty RyanCrk-MendocnoCnty JohnsonCrk-BigR-MendocnoCnty YonkersCrk-DelNorteCnty GrahamGulch-HumboldtCnty PainterCrk-MattoleR-HumboldtCnty SoldierCrk-TrinityR-TrinityCnty	03-04	2culvrt 1culvrt 1culvrt 1culvrt 1culvrt 1culvrt 2culvrt	$299,592 ($149.8K/culvert) - natural bottom pipe arch $278.8K - natural bottom pipe arch $128.1K - natural bottom pipe arch $242.6K - bottomless arch $245.8K - bottomless multiplate arch $246.2K - bottomless multiplate arch $305.3K ($152.7K/culvert)	CDFG-098 CDFG-099 CDFG-104 CDFG-149 CDFG-165 CDFG-166 CDFG-236
BatesCanyonCrk-MarinCnty WarrenCrk-MadR-HumboldtCnty	04-05	1culvrt 1culvrt	$208.4K $326.3K - bottomless multiplate arch	CDFG-026 CDFG-233
WardenCrk-EelR-HumboldtCnty RockyGulch-HumboldtCnty	05-06	1culvrt 2culvrt	$44.5K - bottomless arch $381.6K ($190.8K/culvert) - embedded structural plate metal box culvert	CDFG-062 CDFG-137
CA	98-05 2003 $	3culvrt	$13.3K ($1.9K-$24.2K)	HT07a-T60, p118
SONC SONC-NOCECA SCACO	98-05 2003 $	1culvrt 1culvrt 1culvrt	$1.9K $13.9K $24.2K	HT07a-T61, p121
 CA CA CA	02-04	 27clvrt 13clvrt 1culvrt	Road Type: ForestRoad: $23.4K ($379-$217.9K) Minor2Lane: $227.1K ($5.1K-$412.8K) Major2Lane: $420.4K	HT07b-T42, p61,contrctr
 CA CA CA	02-04	 30clvrt 8clvrt 1culvrt	Stream Order: 1st order: $70.4K ($970-$420.4K) 2nd order: $175.4K ($851-$412.8K 3rd order+: $285.5K	HT07b-T44, p62,contrctr

CA CA	02-04	7culvrt 11clvrt	Culvert Type: Open-btm arch:$262.8K ($124K-$401K) Pipe: $7.4K ($970-$17.2K)	HT07b-T49, p71,contrctr
Sta Ynez	07-12	2culvrt	$8.11M ($4.1M/culvert, reinforced concrete box culvert)	CntySB PublicWrks
Idaho		1culvrt	$15K-$25K - bottomless arch, 30-60 yrs $8K-$20K - buried culvert, 20-50 yrs $500-$5K - ford	Dupont-T10, p66

Costs of culvert replacement with bridge described in Table FP-3 generally range from $100K to $500K/bridge. A few projects cost <$50K (e.g., 02-03 CDFG-065; 03-04 CDFG-201 & CDFG-311; 05-06 CDFG-077; Dupont-T9, p65). Projects that cost >$650K all occurred in southern or south-central California (04-05 CDFG-031 & CDFG-241; 06-07 CDFG-090). Information on bridge type - which is reported here when available from the data source - suggests that prefabricated bridges fall toward the lower end of the cost spectrum. Dupont provides information on expected lifetime of various types of bridges, although his information pertains to Idaho rather than California.

Table FP-3. Culvert Replacement with Bridge ($/project)				
Location	Year	Units	Cost Per Unit	Source
JohnSmithCrk-MendcnoCnty HayworthCrk-MendocnoCnty	01-02	1bridge 2bridge	$189.5K - flat car bridge $89,711 ($44.9K/bridge)	CDFG-043 CDFG-060
ApanolioCyn-SanMateoCnty OldCreekRd-VenturaR SoFork CottanevaCrk-MendcnoCnty TrinityR KellyGulch-SiskiyouCnty	02-03	1bridge	$250K - 3sided bridge $111.5K $22.6K $500K $163.2K	CDFG-015 CDFG-038 CDFG-065 CDFG-119 CDFG-284

FrenchmansCrk-SanMateoCnty FrykmanGulch-BigR-MendcnoCnty IndianCrk-HumboldtCnty LindsayCrk-MadR QuarryBridge-GualalaR	03-04	1bridge	$130.2K - clear span bridge $77.6K $437.3K $26.0K - manufactured $46.0K - 45' modular	CDFG-028 CDFG-052 CDFG-168 CDFG-201 CDFG-311
ArroyoSecoR-MontereyCnty CampCrk-NavarroR-MendcnoCnty O'NeilCrk-KlamathR-SiskiyouCnty SolsticeCrk-LA	04-05	1bridge	$1.5M $234.6K - includes rock weirs $100K - concrete, single span $653.3K - precast open bottom	CDFG-031 CDFG-041 CDFG-064 CDFG-241
LindsayCrk-MadR-HumboldtCnty CedarCrk-SmithR-DelNorteCnty	05-06	1bridge	$54K $347.9K	CDFG-077 CDFG-269
StaRosaCrk-SanLuisObispo SoquelCrk-StaCruzCnty	06-07	1bridge	$746.3K $409.6K	CDFG-090 CDFG-195
HorseCrk-Klamath	06-07	1bridge	$230.5K	K002
Idaho	2000	typical	Bridge Type: Wood stringer, 25-50yr lifetime: $10-$20K Prefab concrete, 40-60yr lifetime: $15K-$25K Railroad, 40-60yr lifetime: $15K-$30K Steel/concrete, 50-75yr lifetime: $30K-$50K	Dupont-T9, p65
SONC	98-05 2003$	1site	$109.6K	HT07a-T61, p121

CA	02-04	6sites	$217.9K ($23K-$420.4K)	HT07b-T49, p71,contrctr
CA	98-05 2003$	2sites	$261.3K ($22.7K-$500K)	HT07b-T41, p59,CHRPD
CA	FY07	typical	Bridge Size: >40ft: $100K <40 ft, flatbed railroad: $50K	NRCS

Most of the culvert improvement costs described in Table FP-4 range from about $5K to $65K. The two notable exceptions are $463.1K (03-04 CDFG-320) and $485K (05-06 CDFG-162) - both of which seemed to also involve substantial habitat work around the culvert. The NRCS examples pertain to culvert removal rather than improvement, but are included here in case such actions are considered for farmland in recovery planning.

Table FP-4. Existing Culvert Improvement - $/project				
Location	Year	Units	Cost Per Unit	Source
JollyGiantCrk -Arcata	01-02	1culvrt	$10.2K	CDFG-124
SoForkBigR-MendcnoCnty	02-03	1culvrt	$23.3K	CDFG-286
ElCapitanCrk -StaBarbCnty	03-04	1culvrt	$463.1K - baffles, replace culvert floor, construct pools	CDFG-320
BrownsCrk-PajaroR-StaCruzCnty	04-05	1culvrt	$65.5K - replace floor, add weirs	CDFG-068
ChaddCrk-EelR-HmboldtCnty	05-06	1culvrt	$485K - 9.5 ft dia steel plate culvert, retrofit w/baffles & jump pools	CDFG-162
Idaho	2000	1culvrt	Culvert Type: Angle iron fish ladder: $1,185 Chimney block fish ladder - $375 Baffles - $2,530 Downstream drop structure - $1,180	 Dupont-T1, p59 Dupont-T2, p60 Dupont-T3, p60 Dupont-T4, p61
NOCECA	98-05 2003$	1site	$4.7K/baffle	HT07a-T61,p121

CA	02-04	1culvrt	Culvert Type: Boulder weir: $13.3K Baffles: $17.9K Other: $575	HT07b-T50, p74,contrctr
CA	98-05 2003$	2culvrt	$9.4K ($4.7K/culvert) - baffle	HT07b-T51, p74,CHRPD
Sonoma Crk	2000	1culvrt	$21.6K	ERP-00-E04

SC - FISH SCREENING OF DIVERSIONS

Table SC-1 provides cost estimates for fish screens relative to the design approach velocity of the screen (cubic feet per second, cfs). Cost of screens produced by the CDFG screen shop range from $2K to $10K/cfs (BM, p. J-3). Most of the other cost estimates in the table fall within this range. Some notable exceptions include projects on the Klamath River (e.g., 05-06 CDFG-200) and in the Central Valley (e.g., ERP-00-B02, ERP-95-M05, ERP-96-07, ERP-97-C01, ERP-97-M07).

Table SC-1. Fish Screen - $/cfs, $/screen

Location	Year	Units	Cost Per Unit	Source
CA	2005	typical	$2K-$10K/cfs (CDFG screen shop)	BM, pJ-3
KlamathR KlamathR KlamathR	05-06	15.3cfs 3.51cfs 1.2cfs	$99,173/screen ($6.5K/cfs) - self clean $39,758/screen ($11.3K/cfs) $29,961/screen ($25K/cfs) - design/install preexisting tube screen	CDFG-049 CDFG-173 CDFG-200
CA	2004	typical	Type of Waterway: Small tributary: $10K/screen Large stream: $40K/screen	CDFG'04, p1.15
CalFED	2000	4scrns 1scrn	Flow Range: 350-800cfs: $8.5K-$15K/cfs 15-20cfs: $100K ($3.3K-$5K/cfs)	Hayes-Fig2,p174 Hayes-p183

WA	2000	Sample of 1-15cfs screens	***Figure 2: C=6060.4 cfs ^1.2405*** 2cfs: $14,320/screen ($7.2K/cfs) 4cfs: $33,834/screen ($8.5K/cfs) 6cfs: $55,950/screen ($9.3K/cfs) 8cfs: $79,944/screen ($10K/cfs) 10cfs: $105,439/screen ($10.5K/cfs) 12cfs: $132,198/screen ($11K/cfs) 14cfs: $160,056/screen ($11.4K/cfs)	Hudson-p192
		Sample of 1-58cfs screens	***Figure 3: C=8221.2 cfs ^ 1.0108*** 10cfs: $84,282/screen ($8.4K/cfs) 20cfs: $169,831/screen ($8.5K/cfs) 30cfs: $255,864/screen ($9K/cfs) 40cfs: $342,214/screen ($8.6K/cfs) 50cfs: $428,799/screen ($8.6K/cfs) 60cfs: $515,573/screen ($8.6K/cfs)	Hudson-p192
		Sample of 1-210cfs screens	***Figure 4: C=11083 cfs ^ 0.9025*** 50cfs: $344,279/screen ($6.9K/cfs) 100cfs: $643,561/screen ($6.4K/cfs) 150cfs: $927,923/screen ($6.2K/cfs) 200cfs: $1,203.010/screen ($6K/cfs)	Hudson-p193
OR	2000	 12scrns 4scrns 3scrns 3scrns 2scrns 10scrns 10scrns	<u>Screen Type, Flow Range*:</u> Rotary drum, 0.4-25 cfs: $1.3K-$11.3K/cfs Rotary drum prefab, 0.8-2cfs: $3.9K-$9.4K/cfs Belt, 10cfs: $2.3K-$3.2K/cfs Panel, 12-30cfs: $2.8-$3.1K/cfs Pump, low veloc, 0.5-1.8cfs: $0.8K-$1.9K/cfs Pump, Clemons, 0.6-4.2cfs: $0.5K-$2.2K/cfs Pump, SureFlo, 0.5-6cfs: $0.5K-$2.5K/cfs	Kepshire-T1, p207
* Engineering costs incurred only for screens >25 cfs.				
CA farmland	FY07	typical	<u>Flow Range*:</u> <1cfs: $2K/screen ($2K/.5cfs=$4K/cfs) 1-5cfs: $6K/screen ($6K/2.5cfs=$2.4K/cfs) 5.1-10cfs: $14K/scrn ($14K/7.5cfs=$1.9K/cfs) >10cfs: $20K/screen (<$2K/cfs) * $/cfs estimated using midpoint of cfs range	NRCS CA

WA	1999$	 16scrns 19scrns 5scrns 7scrns 5scrns	Flow Range: 1-10cfs: $3.6K-$17.8K/cfs 10-50cfs: $4.5K-$16.6K/cfs 50-100cfs: $4.5K-$9.8K/cfs 100-1000cfs: $2.4K-$7.0K/cfs >1000cfs: $2.0K-$7.0K/cfs	WDFW
Sacrmnto River	2000	1 scrn	$435.4K (44.6 cfs screen, $10K/cfs) - Pump Station #1	ERP-00-B01
Sacrmnto River	2000	1 scrn	$303K +5K project mgmt + $2.5K project coordination + $59.6K engineering design (20 cfs screen, $15K/cfs) Tuttle Pump Relocation Project	ERP-00-B02
Amer/Sacramento R	2001	2 projcts	$40.4M + $750K project mgmt + $3.1M construction mgmt ($20.2M/screen) - replace intake SacR Water Treatment Plant, replace screen EA Fairbairn Water Treatment Plant.	ERP-01-N51
Sacrmnto River	2001	10scrns 8-39cfs	$1.1M + $521.7K program admin/mgmt/ coordination ($111.7K/screen)	ERP-01-N52
Sacrmnto River	1995	1 projct 150 cfs	$3.2M + $100K project mgmt + $173K construction mgmt ($21.3K/cfs) - decommission old diversion at M&T Ranches' Parrot-Phelan Pumping Station, relocate/construct/screen new diversion	ERP-95-M05
Suisun Marsh	1995	5 screens	$765.3K ($153.1K/screen) Phase 1 - diversion evaluation & selection	ERP-95-M07
Sacrmnto River	1996	1 projct 600 cfs	$9.4M + $698.3K project coordination ($15.7K/cfs) - consolidate 3 diversions into 1 new diversion, Princeton-Codora-Glenn Irrig Dist & Provident Irrig District	ERP-96-07
Yuba River	1996	1 projct 65 cfs	$202K ($3.1K/cfs) - Browns Valley Irrig District	ERP-96-M17
Sacrmnto River	1997	1 projct 700 cfs	$10.4M ($14.0K/cfs) - Reclamation District 108's diversion structure at Wilkins Slough	ERP-97-C01
Butte Creek	1997	1 projct 162 cfs	$660.3K + $12.8K project mgmt + $58.8K construction mgmt ($4.1K/cfs) - Gorrill Dam	ERP-97-M03

Butte Creek	1997	1 projct 135 cfs	$515.9K + $6.3K project mgmt + $3K project coordination ($3.8K/cfs) - Adams Dam	ERP-97-M04
San Joaquin R	1997	1 projct 250 cfs	$7.6M + $62K project mgmt + $411K construction mgmt + $154K post-construction services ($30.4K/cfs) - vertical V fish screen, Banta-Carbona Irrig District	ERP-97-M07
Sacrmnto River	1998	1 projct 22 cfs	$270.5K ($12.3K/cfs) - Boeger Family Farm Fish Screen Phase II: Construction	ERP-98-B26
Lindsay Slough/ Cache Slough	1998	1 projct 53 cfs	$416K ($7.8K/cfs) - Hastings Tract Fish Screen Phase II: Construction	ERP-98-B27
Battle/ Soap/ Ripley Creeks	1999	1 projct	$1.06M (3 screens - 55 cfs, 70 cfs, 220 cfs; $3.1K/cfs) - decommission several PG&E diversion dams, provide ladders/screens for those that remain	ERP-99-B01
Sacrmnto River	1999	1 projct 450 cfs	$4.56M + $130K project mgmt ($10.1K/cfs) - ACID Fish Screen Phase III: Construction	ERP-99-B03
Sacrmnto River	1999	1 projct 960 cfs	$6.222M ($6.5K/cfs) - Tisdale Positive Barrier Phase IV: Construction/Performance Eval	ERP-02D-P70

HB - INSTREAM BARRIER MODIFICATION FOR FISH PASSAGE

This section covers modification of non-culvert fish passage barriers in the stream channel and along the stream bank. Table HB-1 focuses on tide gates, Table HB-2 on sandbars, Table HB-3 on dam,, and Table HB-4 on other barriers.

Based on a limited number of examples, the replacement cost of a tide gate is ~$105K; retrofit cost is $26K.

Table HB-1. Tide Gates - $/unit

Location	Year	Units	Cost Per Unit	Source
HumboldtBay	03-04	3 tidegates	$317,148 ($105.7K/tidegate) - replace 2 tidegates & add 3rd	CDFG-143
HumboldtBay	2005	1 tidegate	Retrofit: $26K	MA, p2

Based on a single example, cost of sandbar breaching is $13K/breaching.

Table HB-2. Sandbar Breaching - $/unit

Location	Year	Units	Cost Per Unit	Source
Estero de San Antonio (MarinCnty)	1993	1breaching	$10K/breaching *(2006$: $13.1K)* - incl equip rental	WC, p19

Based on a single example, cost of dam decommission is $1.5M.

Table HB-3. Dam Decommission/Removal - $/unit

Location	Year	Units	Cost Per Unit	Source
BattleCrk/SoapCrk/ RipleyCrk	1999	5 dams	$7.53M ($1.5M/decommission)	ERP-99-B01

Barrier modification projects identified in Table HB-4 typically involve weirs, head gates, fish screens and/or measuring structures. Most of the modifications cost $30K-$170K, with the exception of two $1M+ barrier removal/fish screen projects on the Shasta River (06-07 K010 & K011). A single estimate of weir repair cost is provided: $10.8K/weir (06-07 K034).

Table HB-4. Other Non-Culvert Barrier Modification - $/unit

Location	Year	Units	Cost Per Unit	Source
EastForkScott/French Crk/ShacklefordCrk// ScottR-KlamathRiver	06-07	13 barriers	$962.9K ($74.1K/barrier) - remove seasonal barriers/install head gate to measure diversion volume	K025
ShastaR-Klamath	06-07	1 barrier	$1356.5K - remove barrier/install fish screen	K010
ShastaR-Klamath	06-07	1 barrier	$981.9K - remove barrier/install fish screen	K011
ColdCrk-KlamathR	06-07	1 barrier	$65.1K - replace diversion w/fish passable weir, update screen	K014
ShastaR-Klamath	06-07	4 barriers	$120.9K ($30.2K/barrier) - replace 2 barriers w/boulder weirs; install head gate/fish screen/measuring weir on 2 unscreened diversions	K023
Scott-KlamathR	06-07	1 barrier	$170K - replace barrier with boulder weirs/head gate/ measuring structure	K032
FrenchCrk/MinersCrk/ PattersonCrk/ ShackefordCrk-KlamathR	06-07	6 weirs	$65K (10.8K/weir) - repair storm-damaged secondary weirs in 6 locations	K034
Guadalupe River (So SanFran Bay)	1998	2 passage structures	$147.9K ($74K/structure)	ERP-98-B23
Carriger Creek (Sonoma Creek)	2001	1 barrier	$67.6K - boulder weir ladder	ERP-01-N27

HI - INSTREAM HABITAT RESTORATION

This section covers restoration of instream habitat. Tables HI-1 & HI-2 pertain to instream structures such as wood/boulder structures and large woody debris, Table HI-3 to spawning gravel supplementation, Table HI-4 to floodplain tributary reconnection, Tables HI-5 and HI-6 to channel restoration, and Table HI-7 to wetland/floodplain restoration.

Evergreen (Table HI-1) estimates restoration costs for small/medium streams with small/medium transportation & material requirements on a per-mile basis, and estimates costs for large streams with medium/high transportation & material requirements on a per-structure basis. The examples in Table HI-2 also represent a mixture of per-mile and per-structure estimates; however, the units of measure in Table HI-2 were not based on any systematic criterion (as per Evergreen) but rather reflect whatever units were available from each data source. Cost-per-mile tends to be lower using Evergreen's estimates ($10K-$50K/mile) than the Table HI-2 estimates, which ranged from ~$25K to $500K/mile (with the exception of a $1.4M/mile project (01-02 CDFG-156) where cost per mile was derived by expanding the cost of that 40' project to an entire mile). Conversely cost-per-structure tends to be higher using Evergreen's estimates ($10K-$80K/structure) than the Table HI-2 estimates (~$500-$11K/structure). These results are not surprising, given that Evergreen systematically applied cost-per-mile to lower-cost projects and cost-per-structure to higher-cost projects.

Table HI-1. Engineered Logjams and Large Woody Debris - $/structure, $/stream mile (Source: Evergreen 2003, p. 25)

Cost estimates pertain to Puget Sound. Estimates include construction, design, permitting, basic monitoring & routine maintenance (2 yrs), reestablishing site to prior conditions, project management costs. All estimates assume purchased materials.

Stream Size (cfs)	Transportation & Material Requirements		
	Low Cost	Medium Cost	High Cost
Small 1-100 cfs	$10K-30K*	$20K-50K*	$20K-40K
Med 100-2000 cfs	$20K-50K*	$15K-45K	$40K-70K
Lge 2000+ cfs	$10K-20K	$40K-60K	$60K-80K

* Cost per stream mile, assuming 100-400 pieces per stream mile. Estimates in all other cells measured as cost per structure.

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Table HI-2. Instream Structures - $/mile, $/structure				
Location	Year	Units	Cost Per Unit	Source
WindR-WA	2000	typical 1 project 1 project	Channel rehab: $86K ($41K-$137K)/mi Onsite material: $65K/mi Imported material: $140K-$160K/mi	Bair-pp107-108
UpperMattoleR-HumboldtCnty EelR LowerSodaCrk-EelR-MndcnoCnty	01-02	12 strctrs 40' 640'	$23,507 ($1959/structure) - log $10,979 ($1.4M/mi) $54,329 ($448.8K/mi)	CDFG-048 CDFG-156 CDFG-258
FelizCrk-RussianRiver MoonCrk-KlamathR-DelNorteCnty	02-03	1300' 15 strctrs	$20,580 ($83.7K/mi) $40,600 ($2707/structure)	CDFG-011 CDFG-127
HayworthCrk/NFNoyoR-MendcnoCnty UpperMattole-HumboldtCnty	03-04	55 strctrs 14 strctrs	$30,422 ($553/structure) $36,510($2608/structure) - wood/boulder	CDFG-216 CDFG-233
SultanCrk-SmithR-DelNorteCnty WilsonCrk-DelNorteCnty RedwoodCrk-RussianR-SonomaCnty	04-05	10 strctrs 10 strctrs 1.08 mi	$20,497 ($2050/structure) $25,998 ($2600/structure) $60,419 ($55.9K/mi)	CDFG-143 CDFG-145 CDFG-247
EelR DelNorteCnty	06-07	4.5 mi 10 strctrs	$112,437 ($25K/mi) $46,753 ($4675/struc) - +1000 native conifers to replenish wood instream	CDFG-056 CDFG-110

CA	2004	typical	Distance from Road: 0.25-0.5mi: $26K/mi 1-2mi: $27K/mi 2-3mi: $28K/mi >3mi: $29K/mi	CDFG'04 p1.24
TectahCrk- KlamathR	06–07	5 mi	$275.4K ($55.1K/mi) - LWD construction/placement with helicopter	K003
ScottR-Klamath	06-07	6-8 major structures	$65.8K ($8.2K-$11K/structure)	K037
CA		37projcts	20 struc/mi: $25.3K ($5.6K-$70.8K)/mi, $1762/structure)	Hampton-T1, pp122-123
CA		37projcts	***$/mile=24,482+427*#structures/mi*** 20 struc/mi: $33.0K/mi 50 struc/mi: $45.8K/mi 100 struc/mi: $67.2K/mi 200 struc/mi: $109.9K/mi 300 struc/mi: $152.6K/mi 400 struc/mi: $195.3K/mi	Hampton- p124
CA	98-05 2003$	24 sites 5 sites	$2.5K ($214-$11.3K)/structure $364.5K ($220.5K-$552.1K)/mi	HT07a-T60, p118
SONC SONC-NOCECA NOCECA NOCECA SCACO SCACO	98-05 2003$	3 sites 5 sites 1 site 15 sites 4 sites 1 site	$1.3K ($214-$2.1K)/structure $3K ($2.4K-$3.5K)/structure $534.1K/mi $2K ($680-$4.1K)/structure $322K ($220.5-$552.1K)/mi $11.3K/structure	HT07a-T61, p121
CA	02-04	58 sites	$12,375 ($250-$175K)/structure	HT07b-T53, p74,contrctr
CA	02-04	45 sites	$2.2M ($4K-$46.8M)/mi	HT07b-T54, p75,contrctr
OR-priv forest OR-state forest OR-USFS	2000	typical	Assume 120 trees/mile: $77.6K/mi - non-contract $82.4K/mi - contract $47.6K/mi - LWD-helicopter	Lacy-p139 Lacy-p139 Lacy-p140
King County, WA		600'	$113.5K ($99.8K/mi)	Neal-T4, p163

Table HI-3 pertains to spawning gravel supplementation. The WDFW example (WDFW-T3, p14), which is actually based on a British Columbia data source, estimates cost of spawning gravel supplementation at $20-$40/cubic yard. With the notable exception of the Stanislaus River project (ERP-97-N21) - where costs include evaluation as well as gravel treatment - the Central Valley examples indicate a range of costs ($11-$36/cubic yard) similar to WDFW's.

Table HI-3. Spawning Gravel Supplementation - $/cubic yard (cy)				
Location	Year	Units	Cost Per Unit	Source
WA	2004	typical	Gravel placement: $50-$70/m^3* Sorted gravel: $20-$40/cubic yard	WDFW-T3, p14
* Gravel placement - sorted gravel supplied, limited delivery distance, machine placed, does not include control structures.				
Tuolumne River	2002	10K cy	$3.59M + $50K project mgmt/admin ($36/cy)	ERP-02-P29
Sacramento River	1995	4964 cy	$52.5K ($11/cy)	ERP-95-M04
Tuolumne River	1997	6632 cy	$191.2K ($20/cy)	ERP-97-C11
Stanislaus River	1997	9220 cy	$667.9K ($72/cy) - Knights Ferry, incl evaluation of effects of diff size/sources of gravel on habitat utilization	ERP-97-N21

Tables HI-4 and HI-5 describe Evergreen's cost estimates for floodplain tributary reconnection (which vary with material and earthmoving requirements) and sidechannel reconnection (which vary with earthmoving requirements and energy of waterway).

Table HI-4. Floodplain Tributary Reconnection - $/acre (Source: Evergreen 2003, p. 39)

Cost estimates pertain to Puget Sound. Estimates include construction, design, permitting, basic monitoring & routine maintenance (2 yrs), reestablishing site to prior conditions, project management.

Materials	Extent of Earthmoving		
	Minimal	Moderate	Substantial
Minimal	$5K-10K	$10K-20K	$30K-40K
Moderate	$10K-20K	$20K-30K	$40K-60K
Substantial	$30K-40K	$40K-60K	$60K-80K

Table HI-5. Side Channel Reconnection - $/acre (Source: Evergreen 2003, p. 41)

Cost estimates pertain to Puget Sound. Estimates include construction, design, permitting, basic monitoring & routine maintenance (2 yrs), reestablishing site to prior conditions, project management.

Extent of Earthmoving	Energy of Waterway		
	Low	Medium	High
Minimal/Near	$20K-40K	$40K-70K	$60K-90K
Moderate/Avg Distance	$40K-60K	$70K-100K	$100K-200K
Substantial/Far	$60K-100K	$130K-200K	$200K-300K

Table HI-6 provides cost estimates for channel restoration projects. All estimates pertain to Central Valley rivers and range from $1.2M/mile (ERP-99-B01) to $8.7M/mile (ERP-97-M08).

Table HI-6. Channel Restoration - $/mile				
Location	Year	Unit	Cost per Unit	Source
Merced River	1999	2.19 mi	$2.635M ($1.2M/mi) - large-scale reach restoration-channel realignment/floodplain creation	ERP-99-B01
Tuolumne River	2002	1.2 mi	$8.29M + $74.1K construction mgmt ($6.9M/mile) - large-scale reach restoration-channel realignment/floodplain creation	ERP-02-P19-D
Tuolumne River	1997	0.23 mi	$2.011M + $174K construction/proj mgmt ($8.7M/mile) - restore natural channel morphology	ERP-97-M08
Tuolumne River	1997	2.6 mi	$5.054M + $284 construction mgmt ($1.9M/mile) - restore natural channel morphology	ERP-97-M09
Tuolumne River	1998	2.2 mi	$5.054M ($2.3M/mile) - restore natural channel processes & habitats	ERP-98-F06
Merced River	1998	2.2 mi	$3.635M ($1.7M/mile) - restore natural channel processes & habitats	ERP-98-F11

Most of the wetland restoration cost estimates in Table HI-7 pertain to San Francisco Bay/Estuary; several estimates of annual operations & maintenance (O&M) and monitoring costs are included. Steere's information is notable in that he provides estimates by wetland type. The NRCS estimates indicate much lower wetland restoration costs for farmland ($75-$375/acre); these projects are likely much more modest in scale than the types of projects that occur in San Francisco Bay.

Table HI-7. Wetland Restoration - $/acre				
Location	Year	Units	Cost per Unit	Source
Topanga Crk-LA	05-06	12acres	$249.8K ($20.8K/acre) - remove 26Ktons of lead contaminated fill matl	CDFG-029
SF Bay/ Estuary	1995	typical	$20K-$30K/acre, up to $80K/acre *(2006$: $25K-$38K/acre, up to $101K/acre)*	Anon '95

SF Bay/ Estuary	2000	typical	Wetland Type: Tidal wetland: \$5K-\$100K/acre Seasonal wetland: \$9K/acre (large-scale project) Wetland enhancement: \$1K/acre (reveg, exotic species removal, limited irrig, modest mgmt) Monitoring: \$500/acre for 5 yrs	Steere, pp231-233
SF Bay/ Estuary	1999	5 sites	(1) 500 acre wetland: \$14K/acre/yr for 5 yrs, \$35K/yr thereafter (land acquisition =\$5M, planning/permitting=\$250K, construction=\$1.3M,monitoring=\$25K/yr for 5 yrs, O&M=\$35K/yr) (2) \$1K/acre (restore tidal action to salt pond) (3) \$18K/acre (seasonal/tidal wetland) (4) \$27K/acre (levee construction/repair, extensive dredging) (5) \$56K/acre (highly engineered, large soil volume, channel excavation, low berms)	USEPA '99, p170 USEPA '99, p172 " " "
CA farmland	FY07	typical	Light: \$75/acre Moderate: \$187.50/acre Intensive: \$375/acre	NRCS

HR - RIPARIAN RESTORATION

This section covers restoration of erosion-prone banks adjacent to the stream and within the riparian corridor. Riparian area is defined as the area, including any necessary fencing, between the fence and the middle of the stream. Table HR-1 pertains to fencing/livestock exclusion, Table HR-2 to fence maintenance, Tables HR-3 and HR-4 to riparian planting, Table HR-5 to irrigation, and Table HR-6 to invasive/noxious weed control.

As indicated in Table HR-1, Evergreen (Evergrn p11) estimates fence construction costs at $1-$12/foot, with an "overall average" of $3-12/foot. CDFG's Coho Recovery Strategy (CDFG'04, p1.20) uses the midpoint of this latter range ($8/foot). Cost of all individual fencing projects (CDFG-xxx, HT07a, HT07b, NRCS CA) are expressed in $ per foot, even for projects that also include components other than fencing (e.g., revegetation, irrigation, stock water systems). For most of these projects (even those with added components), costs generally fall within the $1-$12/foot range indicated by Evergreen.

Table HR-1. Fencing/Livestock Exclusion - $/foot

Location	Year	Units	Cost Per Unit	Source
Puget Snd	2003	typical	<u>Fence Material:</u> Simple: $1-$4/ft Average: $5-$8/ft Complex: $9-$12/ft Overall Average: $3-$12/ft	Evergrn p11
CA	2004	typical	$8/ft	CDFG'04, p1.20
ShastaR	01-02	7800'	$56.6K ($7.26/ft, 7800' fence, 6 stockwater areas)	CDFG-065
EelR EelR EelR SLO Cnty TrinityCnty ShastaR ShastaR	02-03	1.1 mi 2 mi 3.5 mi 7600' 1 mi 1250' 850'	$40,800 ($7.02/ft) $19,993 ($1.89/ft) $28,664 ($1.55/ft) $56.4K ($7.42/ft; fencing, alternative water sources for cattle, riparian planting, temporary irrigation) $31,138 ($5.90/ft) $7,032 ($5.63/ft, +10yr maint & grazing exclusion) $4963 ($5.84/ft, +10yr maint & grazing exclusion)	CDFG-026 CDFG-116 CDFG-193 CDFG-243 CDFG-251 CDFG-324 CDFG-342
SmithR (dairy) RussianR	03-04	2K' 800'	$32,890 ($16.45/ft, incl riparian plant) $6.7K ($8.40/ft; fencing, water pump in stream to provide water for livestock)	CDFG-131 CDFG-195
ShastaR ShastaR ShastaR	04-05	13,500' 25,000' 3200'	$91,944 ($6.81/ft,native plants 1,685') $116,674 ($4.70/ft) $61,604 ($19.25/ft)	CDFG-194 CDFG-231 CDFG-243
SmithR KlamathR KlamathR	05-06	3000' 2600' 3600'	$21,259 ($7.09/ft, native trees) $17,494 ($6.73/ft, trees 3 acres) $25,850 ($7.18/ft)	CDFG-046 CDFG-188 CDFG-266

ShastaR	06-07	3500'	$28,213 ($8.06/ft, riparian veg)	CDFG-078
CA	98-05 2003$	10 sites	$7 ($2.43-$22.07)/ft - $37K/mi	HT07a-T60, p118
SONC SONC-NOCECA SCACO	98-05 2003$	6 sites 3 sites 1 site	$9 ($4.58-$22.07)/ft - $48.1K/mi $3.39 ($2.43-$4.89)/ft - $7.9K/mi $5.15/ft - $27.2K/mi	HT07a-T61, p121
CA	02-04	 2 sites 7 sites 2 sites	Fence Material: Simple: $1.89 ($0.79-$3.00)/ft Avg: $4.32 ($2.00-$7.00)/ft Complex: $4.72 ($3.44-$6.00)/ft	HT07b-T13, p34,contrctr
CA	98-05 2003$	9 sites	$7.24 ($2.43-$22.07)/ft	HT07b-T12, p33, CHRPD
CA	FY07	typical	Fence Material: Conventional: $3/ft Conventional extreme terrain: $8/ft Electric: $2/ft Woven: $6/ft	NRCS CA

OR	1993	typical	System Type: Access ramp: $600+fence ($100/yr maint) *(2006$: $788, $131/yr maint)* Nose/stream powered pump (surf/grndwtr): $350-$450/pump+fence ($50/yr maint) *(2006$: $460-$591, $66/yr maint)* Stream-powered pump w/flow&elev needs: $500-$1000/pump+fence ($50/yr maint) *(2006$: $657-$1314, $66/yr maint)* Plastic pipe (grndwtr): $1-$2/pipeline ft +troughs ($50/yr maint) *(2006$: $1.31-$2.63/ft, $66/yr maint)* Solar powered pump (grndwtr): $2K-$6K for solar equip, tank, fence, pad *(2006$: $2628-$7884)* Spring development (grndwtr): $700+fence+trough ($50/yr maint) *(2006$: $920, $66/yr maint)*	TSWCD, p6

Fence maintenance costs described in Table HR-2 range from $0.09 to $0.26/foot/year, depending on the fencing material. It should be noted that these estimates pertain to Iowa, not California.

Table HR-2. Fence Maintenance - $/foot

Location	Year	Units	Cost Per Unit	Source
Iowa	2005	1330'	Fence Material: Woven wire: $0.26/ft/yr Barbed wire: $0.21/ft/yr Hi-tensile, non-elec: $0.15/ft/yr Hi-tensile, elec: $0.09/ft/yr	MO-T6

Table HR-3 describes Evergreen's estimates of riparian planting cost, while Table HR-4 describes estimates from other data sources. Evergreen's estimates are $5K-135K/acre, and vary with the level of site preparation and material/site accessibility. The estimates used for CDFG's Coho Recovery Strategy (CDFG-04, p1.17) are $30K-60K/acre and were selected to fall within the range of Evergreen's estimates. Project costs reported in HT07a and HT07b are ~ $100K-$120K/acre (with the notable exception of a $434.8K/acre project). The NRCS estimates are at the low end of this range: ~$100-$1800/acre - depending on what is planted (trees or plants) and planting requirements (e.g., protected, shelters, wire cages, native species). An NRCS estimate of landing clearing costs is also included to address situations where clearing is a prerequisite for planting. The Bair example - $110/acre, pertaining to riparian reforestation - was also at the lower end of Evergreen's range .

For the examples from CDFG and Hampton, costs could be calculated on a per-mile but not a per-acre basis. Costs vary widely ($1K to > $200K/mile); some of this difference may be due to variations in the width of the buffer being planted (which is not clear from the data sources). Evergreen uses the following conversion from miles to acres (with acreage doubled when planting on both sides of the stream).
1 mile x 50 foot buffer = 6 acres (100% planted)
1 mile x 50 foot buffer = 1.8 acres (30% planted)
1 mile x 150 foot buffer = 18.2 acres (100% planted)
1 mile x 150 foot buffer = 5.5 acres (30% planted).

Table HR-3. Riparian Planting Projects - $/acre (Source: Evergreen 2003, p. 16)
Cost estimates pertain to Puget Sound. Estimates include construction, design, permitting, basic monitoring & routine maintenance (2 yrs), reestablishing site to prior conditions, project management.

Materials/Site Accessibility	Level of Site Preparation		
	Flat/Light Clearing	Avg Slope/Avg Clearing	Steep/Heavy Clearing
Low Cost	$5K-25K	$20K-50K	$60K-100K
Medium Cost	$10K-35K	$45K-65K	$70K-120K
High Cost	$30K-50K	$55K-80K	$100K-135K

Table HR-4. Planting - $/acre, $/stream length For entries involving multiple projects, cost reported as mean or mean (range) as avail.				
Location	Year	Units	Cost Per Unit	Source
CA	2004	typical	Distance from Road (assuming 50' buffer along streams): <0.25 mi: $30K/acre 0.25-0.5mi: $35K/acre 0.5-1mi: $45K/acre 1-2mi: $50K/acre 2-3mi: $55K/acre >3mi: $60K/acre	CDFG-04 p1.17
SONC SONC NOCECA NOCECA CentralVly SCACO	98-05 2003$	1 site(10ac) 2 sites(4mi) 4sites(128ac) 7 sites(3mi) 4sites(610ac) 1 site(28ac)	$1.8K/acre $30.8K ($8.8K-$52.9K)/mi $8K ($1.8K-$13.5K)/acre $95K ($3.7K-$436.6K)/mi $4.8K ($2K-$7.8K)/acre $23.6K ($495-$63.1K)/acre	HT07a-T61, pp121-125
CA	02-04	 18 sites 14 sites 10 sites	Site Accessibility: Easy:$55.8K ($600-$434.8K)/acre (median=$8.9K/acre) Average: $9.1K ($40-$87.5K)/acre (median=$1.3K/acre) Difficult: $4K ($910-$15.1K)/acre (median=$2.3K/acre)	HT07b-T21, p 43.contrctr
CA	02-04	 19 sites 11 sites	Prevailing Wages Required: No: $1.8K ($40-$8.5K)/acre Yes: $77.1K ($1.8K-$434.8K)/acre	HT07b-T30, p50,contrctr

CA	02-04	 2 sites 8 sites 8 sites 22 sites	<u>Irrigation Type</u> Dri-water: $46.1K ($8.5K-$83.7K)/acre Drip irrig: $33.0K ($163-$120.5K)/acre Hand irrig: $26.2K ($414-$100K)/acre None: $27.1K ($40-$434.8K)/acre	HT07b-T34, p54,contrctr
CA farmland	FY07	typical	170-259 trees/acre: $109/acre 260-300 trees/acre: $154/acre 301-435 trees/acre: $182/acre 436-681 trees/acre: $240/acre 110 trees/acre (protected): $770/acre 300 trees/acre (protected: $2000/acre 170-260 trees/acre (shelters): $130/acre 261-325 trees/acre (shelters): $175/acre 326-434 trees/acre (shelters): $200/acre >435 trees/acre (shelters): $260/acre 95-150 plants/acre (wire cages):$225/acre 151-200 plnts/acre (wire cages):$320/acre 201-325 plnts/acre (wire cages):$470/acre 95-150 plants/acre (native spp): $735/acre 150-200 plnts/acre(native spp):$1050/acre 200-260 plnts/acre(native spp):$1380/acre 261-325 plnts/acre(native spp):$1755/acre Land clearing: $400/acre	NRCS CA
WindR-WA	2000	mile	$5K ($4K-$8K)/mi; $110/acre - riparian reforestation	Bair-p107
MaacamaCrk-SonomaCty	01-02	300'	$12,790 ($225K/mi) - willow walls	CDFG-186

KlamathR WilsonCrk ShastaR	02-03	2600' 1 mi 2 mi	$27.6K ($52.8K/mi) $18.1K/mi $109,934 ($55K/mi)	CDFG-170 CDFG-208 CDFG-296
GarciaR-MendcnoCnty LowerTerwer Crk-KlamathR-DelNorteCnty	03-04	1600' 1600'	$67,695 ($223K/mi) - bioengineer $39,671 ($131K/mi) - willows, native	CDFG-117 CDFG-223
Klamath ShastaR	04-05	1600' 7000'	$55,868 ($184K/mi) - willow/native trees/bioengineer/removal of exotics $79,573 ($60K/mi)	CDFG-122 CDFG-172
CA	2000	11 projects	$13.7K ($1.0K-$47.5K)/mi	Hampton-T3, p125
CA		12 projects	$8 ($0.17-$23)/ft or $42.2K ($898-$121K)/mi	Hampton-T4, p125

Some of the projects in Table HR-4 above included irrigation in combination with revegetation. Table HR-5 provides estimates of irrigation costs only (NRCS CA) that range from $800 to $3K/acre and vary by irrigation method and habitat type. An example of capital cost (irrigation pumps, CDFG-279) is also provided.

Table HR-5. Irrigation - $/acre, $/project

Location	Year	Units	Cost Per Unit	Source
CA farmland	FY07	typical	Irrig system, surf & subsurface: $3K/acre Micro-irrig, hillside: $1.5K/acre Micro-irrig, wildlife-upland habitat: $800/acre Sprinkler irrig, hillside/sloping: $2.5K/acre	NRCS CA
Eel R	04-05		$17.3K - solar powered irrigation pumps to ensure seedling survival until natural roots grow	CDFG-279

Information on invasive weed control is limited: $5K-$12K/acre for projects on the Napa and Smith Rivers (04-05 CDFG-072 & CDFG-077). NRCS cost estimates for farmland are much lower ($10-$375/acre) and vary, depending on eradication method (e.g., mechanical/chemical, mechanical/chemical/handtool), land type (e.g., upland, wetland), and vegetation type (e.g., woody, herbaceous). A Russian River project (02-03 CDFG-325) can be costed on a per-mile basis but cost per acre is not known.

Table HR-6. Invasive/Noxious Weed Control - $/acre, $/mile				
Location	Year	Units	Cost Per Unit	Source
RussianR	02-03	2.5mi	$30.2K ($12.1K/mi,broom,native reveg)	CDFG-325
NapaR SmithR	04-05	22,865yd^2 (4.7acres) 10acres	$55.7K ($11.9K/acre, arundo erad) $49.5K($5K/acre,Eng ivy, plantseedlng)	CDFG-072 CDFG-077

CA farmland	FY07	typical	***Exotic Vegetation Management*** Woody veg, mech/chem/handtool Light: $18.75/acre Moderate: $37.50/acre Intensive: $75/acre Mechanical/chemical, upland Light: $10/acre Moderate: $20/acre Intensive: $50/acre Woody veg (early successional), mech/chem/handtool Intensive: $50/acre Herbaceous veg, early successional, mech/chem/handtool Moderate: $25/acre Mult applic/yr, wetland, mech/chem/ handtool Light: $75/acre Moderate: $187.5/acre Intensive: $375/acre ***Competing Vegetation Management*** Conservation cover General: $50/acre Riparian herbaceous: $50/acre Forest stand improvement Mastication: $920/acre Hand, 0-15%slope, 20-40%cover:$600/acre Hand, 15-30%slope, 40-60%cover:$900/acre Hand, 30-50%slope, 60-90%cover:$1200/acre Brush rake: $379/acre Chemical: $150/acre	NRCS CA

HS - BANK STABILIZATION

This section covers stabilization of eroding, collapsing or otherwise de-stabilized bank.s. Table HS-1 provides Evergreen's cost estimates for streambank stabilization, Table HS-2 provides similar estimates from other data sources, and Table HS-3 focuses on levee restoration.

Evergreen's estimates ($30-$1000/foot) vary by extent of excavation and waterway size. Cost estimates used in CDFG's Coho Recovery Strategy (CDFG'04, p1.19) were $250-$350/foot and fall within the range of Evergreen's estimates for small/medium waterways. Generally speaking, other project costs in Table HR-2 also fall within Evergreen's range of estimates.

The higher cost projects appear to involve stabilization work other than just revegetation and/or work on steep terrain (e.g.,03-04 CDFG-285, 04-05 CDFG-263). For those projects that are identifiable to location, costs also appear to be higher in urban areas - e.g., southern California (05-06 CDFG-065, 069, 097) and King County, WA (Neal-T2, p159 & Neal-T3, p161). By contrast, cost in the rural Wind River watershed ($9-$42/ft, Bair-p107) falls toward the low end of Evergreen's range.

Table HS-1. Streambank Improvements - $/lineal foot (Source: Evergreen 2003, p. 30)
Cost estimates pertain to Puget Sound. Estimates include construction, design, permitting, basic monitoring & routine maintenance (2 yrs), reestablishing site to prior conditions, project management.

Extent of Excavation	Size of Waterway		
	Small	Medium	Large
Minimal	$30-60	$60-150	$150-400
Moderate	$60-100	$150-250	$400-700
Substantial	$100-200	$250-500	$700-1000

Table HS-2. Bank Stabilization - $/foot

Location	Year	Units	Cost Per Unit	Source
CA	2004	typical	<u>Distance from Road:</u> 0.25-0.5mi: $250/ft 0.5-1mi: $275/ft 1-2mi: $300/ft 2-3mi: $325/ft >3mi: $350/ft	CDFG'04, p1.19
GualalaR	01-02	3200'	$91,850 ($29/ft)	CDFG-196
NF MattoleR EelR BearR-HmbldtCnty	02-03	1500' 4915' 260'	$46,806 ($31/ft) $157.3K ($32/ft) $37,962 ($146/ft)	CDFG-096 CDFG-134 CDFG-181
StaRosaCrk-SonomaCnty	03-04	350' long x 30' high creekbank	$124,201 ($355/ft) - stabilize/ construct/revegetate)	CDFG-285

SalmonCrk RussianR VanDuzenR StaYnezR	04-05	150' 150' 1500' 520'	$15,187 ($101/ft) - bioengineer $18,774 ($125/ft) - bioengineer $75,065 ($50/ft) - boulder, bioengineer $296,692 ($571/ft) - stabilize/ construct/revegetate	CDFG-030 CDFG-069 CDFG-158 CDFG-263
VenturaR StaYnezR StaMonicaBy KlamathR EelR	05-06	300' 1600' 300' 950' 3080'	$62,571 ($209/ft) $264,605 (165/ft) $110,894 ($370/ft) $86,609 ($91/ft) $92,241 ($30/ft) - incl riparian tree planting	CDFG-065 CDFG-069 CDFG-097 CDFG-118 CDFG-279
SONC NOSECA/ SONC SCACO	98-05	1 site(0.2mi) 1 site(0.03mi) 1 site(2.0mi)	$163.9K/mi ($31/ft) $181.9K/mi ($34/ft) $510K/mi ($97/ft)	HT07a-T61, pp121-124
CA	98-05 2003$	3 projects	$54 ($31-$97)/ft	HT07b-T63, p 90,CHRPD
CA	02-04	 10 projects 25 projects 18 projects	<u>Material Complexity:</u> Minimal:$30 ($5-$59)/ft Moderate:$120 ($4-$750)/ft Substantial:$181 ($6-$895)/ft	HT07b-T69, p 96,contrctr
Sacrmnto/San JoaquinDelta	2002	3.72 mi	$1.5M ($76/ft) - bioengineering, planting/baffling	ERP-02-P12
WindR-WA	2000	typical	$9-$42/ft	Bair-p107
King County, WA	1995 1997	1400' 100'	$444K ($317/ft) - instream/ floodplain)* *(2006$: $560K/project, $400/ft)* $93K ($930/ft) - LWD/bank stabilization* *(2006$: $113K/project, $1133/ft)*	Neal-T2, p159 Neal-T3, p161
* Includes design, land/easements, permits, SEPA and construction. For 1995 project, replanting, irrigation and 5 year plant maintenance also included.				

Table HS-3 provides levee-related cost estimates for several Central Valley rivers, the Pajaro and San Lorenzo Rivers (in Santa Cruz/Monterey counties), and Green River (in Washington). Comparison of estimates from different time periods suggests that levee repair costs have increased significantly (beyond the rate of inflation) - perhaps reflecting major change in levee demand and/or input supply conditions in recent years.
Central Valley:** **A single example of levee evaluation costs was found ($11/foot; Harder 06, p21). Levee repair costs from the 1980s and early 1990s were ~$500-$1000/foot (after correcting for inflation). More recent cost estimates are ~$5K-$6K/foot. Although per-foot cost estimates were not available for the Yuba/Feather River project (EPS '06, Tables B1&B2), levee improvement: environmental mitigation cost ratios from that project (25:1 for the Yuba, 8:1 for the Feather) are provided here, as they may also be useful for recovery planning.
Pajaro/San Lorenzo River:** **The 1989 cost estimates were ~$200-$500/foot (after correcting for inflation). The more recent estimates (developed by USACOE to evaluate various alternatives for Pajaro River flood protection) are ~$1.5K to $5K/foot.
Green River:** **Suggests the wide range of costs possible for levee repair.

Table HS-3. Levee Evaluation/Repair/Setback/Habitat Enhancement ($/foot)

Location	Year	Units	Cost per Unit	Source
CentralValley	2006	typical	$60K/mi (11/ft) - structural re-evaluation	Harder 06, p.21
SacrR	2006	29 sites, 30K ft	$172.5M ($5750/ft) - emergency erosion repair	DWR 06
SacrR	1980s 2005	typical typical	$300/ft - repair *(2006$: $500/ft)* Up to $5K/ft - repair	DWR 05, p.5
Bear River	2007	10K ft	$51M ($5.1K/ft) - setback	GEI 07
Twitchell Island, SanJoaqR	early 90s	3K ft	$2.5M/mi ($473/ft) - setback *(2006$: $636/ft)* $3.5-$4M/mi ($663-$758/ft) - setback+planting *(2006$: $891-$1019/ft)*	Nuedeck 00
 Yuba R Plain FeatherRPlain	2006		Levee improve$:envir mitigatn$ $40.5M:$1.6M=25:1 $191.6M/$23.4M=8:1	EPS 06, Tables B-1 & B-2
SanLorenzoR PajaroR	1989	5.2K ft 12K ft	$1.75M ($337/ft)-rebuild levee *(2006$: $499/ft)* $1.84M ($153/ft)-repair *(2006$: $226/ft)*	McDonnell '92

Pajaro River mainstem	2002	11.4mi* 60,192'	Alt 1-$145.8M ($2422/ft), floodwall/levee raise Alt 2-$175.4M (2914/ft), 100'setback Alt 3-$177.3M ($2946/ft), 100'-225' setback Alt 4-$322.2M ($5353/ft), floodwall	USACOE ‘02
Pajaro River tributaries (Salsipuedes &Corralitos Creeks)	2002	4.4mi* 23,232'	Alt T1-$35.1M ($1511/ft), levee raise Alt T2-$38.8M (1670/ft), setback Alt T3-$34.7M ($1494/ft), hybrid raise/setback	USACOE ‘02
Pajaro River mainstem (MS) & tributaries (T)	2003	15.8mi* 83,424'	Alts 2A&T4-$217.7M ($2610/ft), 100' setback Alts 3&T3-$218.3M ($2617/ft), 225' setback Alts 2A&T3-$215.3M ($2581/ft), 100' MS, 225' T Alts 3&T4-$220.7M ($2646/ft); 225' MS, 100' T	USACOE ‘03
* Info on project size obtained from MIG Inc (2001), p. 14. Mainstem includes river reaches 1-4; tributaries include river reaches 5-6.				
Green River, Seattle	2007	typical	$1K-$15K/ft, repair	Johnson 07

HU - WATERSHED RESTORATION (UPSLOPE)

This section covers upslope restoration to reduce stream sedimentation. Table HU-1 pertains to road decommissioning, Table HU-2 to road upgrade, Table HU-3 to landslide/gully stabilization and Table HU-4 to planting in upland areas (as distinct from riparian planting described in Table HR-4).

According to Weaver/Hagans (WH-T7, p100), road decommissioning costs generally range from $2K-$35K/mile but may go as high as $51K/mile for moderately difficult roads. Most of the other examples fall within Weaver/Hagans' range. CDFG's Coho Recovery Strategy (CDFG '04, p1.28) assumes $9K/mile, which is toward the lower end of the Weaver/Hagans' range.

Table HU-1. Road Decommissioning - $/mile				
Location	Year	Units	Cost Per Unit	Source
CA	2000	typical	Moderately difficult roads: $51K/mi Range of roads: $2K-$35K/mi	WH-T7, p100
CA	2004	typical	$9K/mi	CDFG'04 p1.28
KlamathR Mendcno Klamath	02-03	9 mi 3.5 mi 34.3 mi	$32,029 ($3.6K/mi) - timber road $105,025 ($30K/mi) $348,407 ($10.2K/mi) - forest road	CDFG-214 CDFG-233 CDFG-331
TrinityR NoyoR	03-04	3.6 mi 8.5 mi	$43,690 ($12.1K/mi) $137,495 ($16.2K/mi)	CDFG-197 CDFG-267
SalmonR KlamathR TrinityR	04-05	5.9 mi 4.5 mi 1.4 mi	$259,087 ($43.9K/mi) $257,787 ($57.3K/mi) $130,567 ($93.3K/mi)	CDFG-004 CDFG-006 CDFG-251
TrinityR VanDuzenR HumboldtBy HumboldtBy	05-06	5 mi 2.25 mi 3 mi 9.7 mi	$320,866 ($64.2K/mi) $188,560 ($83.8K/mi) $333,736 ($111.2K/mi) $411,567 ($42.4K/mi)	CDFG-015 CDFG-119 CDFG-120 CDFG-121
Klamath-FS TrinityR	06-07	13.3 mi 2.33 mi	$392,797 ($29.5K/mi) $25,000 ($10.7K/mi)	CDFG-169 CDFG-104
SONC	98-05 2003$	2 sites	$121.6K ($8.2K-$235K)/mi	HT07a-T61, p121
CA	02-04	39 sites	$34,090 ($4K-$200K)/mi	HT07b-T76, p101.contrctr
CA	98-05 2003$	3 sites	$285.2K ($164K-$510K)/mi	HT07b-T77, p102,CHRPD
WA-ForestSvc	2000	6 sites	$6,522 ($1,8K-$15K)/km, or $4.1K ($1.1K-$9.3K)/mi	Coffin-T1, p53

According to Weaver/Hagans (WH-T7, p100), road upgrade costs are generally $10K-$35K/mile but may go higher than $45K/mile for difficult or high-density sites. CDFG's Coho Recovery Strategy (CDFG '04, p1.27) assumes $15.9K/mile, which is toward the lower end of the Weaver/Hagans' range (~$23K/mile). Most of the other examples fall within Weaver/Hagans' range.

Table HU-2. Road Upgrade - $/mile				
Location	Year	Units	Cost Per Unit	Source
CA	2000	typical	Upgrade Type: Difficult, 100 yr design: $42.5K/mi Mod-diff, hi-site density: $45.5K/mi Watershed-wide, low/high priority, 100 yr design: $25K-$35K/mi Watershed-wide avg, 100 yr design: $10K-$35K/mi	WH-T7, p100
CA	2004	typical	$15.9K/mi	CDFG'04 p1.27
MendcnoCnty SiskiyouCnty	01-02	1.1 mi 17.6 mi	$32,963 ($30K/mi) $741,656 ($42.1K/mi)	CDFG-159 CDFG-165
KlamathR SalmonR SalmonR	02-03	22.2 mi 16.7 mi 16.7 mi	$558,016 ($25.1K/mi) $698,384 ($41.8K/mi) $492,376 ($29.5K/mi)	CDFG-017 CDFG-018 CDFG-019
SmithR MndocinoCnty	03-04	10.9 mi 6 mi	$509,363 ($46.7K/mi) $173.3 ($28.9K/mi)	CDFG-007 CDFG-037
EelR RussianR GarciaR EelR RussianR MattoleR	04-05	12.1 mi 11.7 mi 5.25 mi 23.1 mi 11 mi 2 mi	$176,718 ($14.6K/mi) $560,476 ($47.9K/mi) $155,382 ($29.6K/mi) $299,076 ($12.9K/mi) $427,212 ($38.8K/mi) $59,706 ($29.9K/mi)	CDFG-027 CDFG-111 CDFG-195 CDFG-225 CDFG-268 CDFG-285
EelR	06-07	8 mi	$389,486 ($48.7K/mi)	CDFG-009
CA	98-05 2003$	12 sites	$18K ($1.9K-$52K)/mi	HT07a-T60, p118

SONC NOCECA-SONC NOCECA	98-05 2003$	3 sites 2 sites 7 sites	$12.3K ($2.1K-$32.1K)/mi $12.7K ($3.3K-$22.1K)/mi $22K ($1.9K-$52K)/mi	HT07a-T61, p121
CA	02-04	43 sites	$169K ($1K-$3.5M)/mi	HT07b-T86, p123,contrctr

Limited information contained in Table HU-3 (mostly from the Eel River) shows landslide repair costs ~ $1K-$3.5K/site.

Table HU-3. Landslide and Gully Stabilization - $/acre				
Location	Year	Units	Cost Per Unit	Source
EelR EelR MarinCnty EelR	04-05	34 sites 54 sites 80 sites 30 sites	$115.9K ($3410/site) $86.5K ($1601/site) $279.8K ($3497/site) $29.7K ($990/site)	CDFG-156 CDFG-160 CDFG-174 CDFG-213

The estimate of <u>upland</u> planting cost in Table HU-4 falls toward the lower end of <u>riparian</u> planting costs previously described in Table HR-4; however, it is difficult to generalize from a single example.

Table HU-4. Planting - $/acre				
Location	Year	Units	Cost Per Unit	Source
TrinityCnty	02-03	100 acres	$194,468 ($1945/acre)	CDFG-254

TW - TAILWATER MANAGEMENT

Cost of tailwater management is represented in Table TW-1 in terms of acres of farmland irrigated by tailwater. Costs are ~$20-$400/acre. The NRCS example suggests that cost per acre declines as total acreage increases.

Table TW-1. Tailwater Management System - $/acre				
Location	Year	Units	Cost Per Unit	Source
SiskiyouCnty	01-02	540 ac	$220.2K ($408/acre, collect, hold and return water to high end of unit for re-use)	CDFG-049
CA	1987	typical	$125/acre *(2006$: $198/acre)*	USEPA p13
CA-rice	1990	typical	System Type: Static irrig system*:$95/acre (6-10 acre basin) *(2006$: $135/acre)* Recirculating system: $20/acre (1000 acre system) to $150/acre (80 acre system) *(2006$: $28-$214/acre)*	Hill 4/7 Hill 3/7
* Static irrigation consists of a ditch and flashgated pipe system that limit inflow into basin to amount required to replenish water lost to evapotranspiration and percolation. This recent innovation in rice irrigation eliminates possibility of tailwater spillage into public drains.				
CA	FY07	typical	***Size of Area Covered by System:*** 1-50 acres: $10K, $400/acre(=$10K/25ac) 51-100 acres: $20K, $267/acre 101-200 acres: $30K, $200/acre 201-300 acres: $40K, $160/acre 301-400 acres: $60K, $171/acre 401-500 acres: $80K, $178/acre	NRCS CA
CA-cotton	2000	typical	Furrow irrig+tailwater system: $60-$80/acre	Sanden
Colorado	1998	typical	$150-$225/acre (earthwork, pipeline install, pump assembly)	Broner

WC - WATER CONSERVATION MEASURES

This sections cpertains to methods of providing more efficient use of water extracted from stream systems. Table WC-1 pertains to ditch lining and Table WC-2 to piping.

Canal lining costs described in Table WC–1 are ~ $15-$96/foot. Such projects often involve installation of related equipment such as control structures. For large projects, the cost of planning/environmental/administrative aspects can comprise a substantial portion of total project costs (e.g., 62% of total costs for the ACID project). Project life ranges from 20-50 years. In cases where proponents provided estimates of project benefits (in terms of value of conserved water), benefits were estimated using water prices of $25-$75/acre foot.

Table WC-1. Ditch Lining - $/ditch length, $/acre farmland treated				
Location	Year	Units	Cost Per Unit	Source
Anderson	01-03	2 mi	<u>Cost Breakdown:</u> Planning/environ/admin: ~$4M Control struc, measurement flumes, SCADA systems@13 sites: $1.494M ($114.9K/site) Concrete anal lining: $1M ($96/ft) Project life=30yrs Value conserved water=$50/af	ACID
MercedCnty	01-03	25K' 600 ac	$2M ($79/ft, $3.4K/acre) Includes 50 control structures Project life=50yrs Value conserved water=$25/af	MCWD
CA	FY07	typical	<u>Liner Type:</u> Plain concrete: $20/ft Flexible membrane: $15/ft Galvanized steel: $20/ft	NRCS CA
CA	01-03	13.5K’	$251K ($19/ft) - concrete Project life=20yrs Value conserved water=$75/af	OWID
CA	2001	8K’	$242K ($30/ft) - concrete Project life=20yrs	OWID ‘01

PlacerCnty	01-02	3 mi	Cost Breakdown: Planning/environ/admin: $81K 12 remote flow monitoring stns:$450K ($37.5K/stn) Canal lining: $794K ($50/ft) - concrete Project life=25 yrs Value conserved water=$40/af	PCWA

As indicated in Table WC-2, the only piping example found was $16/foot.

Table WC-2. Piping - $/pipe length				
Location	Year	Units	Cost Per Unit	Source
CA farmland	FY07	typical	$16/ft - irrig water conveyance, aluminum pipeline	NRCS CA

WD - WATER MEASURING DEVICES

This section pertains to instream and water diversion measuring devices to track mainstem/tributary flows. Table HB-4 above provides cost estimates for instream projects that involve use of head gates with other devices. Table WD-1 pertains to head gates alone. The limited examples provided indicate head gate costs of $2.8K-$10K.

Table WD-1. Head Gate - $/project				
Location	Year	Units	Cost Per Unit	Source
SiskiyouCnty	01-02	123 diversions	$350K ($2.8K/diversion) - lockable head gate & flow measuring device	CDFG-056
ScottR-Klamath	06-07	14 diversions	$142K ($10.1K/diversion) - head gate & flow measuring device	K033
CA farmland	FY07	typical	Headgate <3cfs: $5K Headgate >3cfs: $10K	NRCS CA

WP - WATER PURCHASE/LEASE

Table WP-1 pertains to purchase/lease/acquisition of short- or long-term water rights to improve water quality and/or quantity. The DWR sources indicate Central Valley water transfer prices of $43 - $246/acre foot/year. CDFG's Coho Recovery Strategy (CDFG'04, p1.43) assumes $100/af/yr - a value within the range of the DWR data. The water prices in Table WC-2 (previously presented in section "WC-Water Conservation Measures") are considerably higher than the prices imputed to water conserved in estimating value of water conserved by ditch lining in Table WC-2. A major distinction between the two is that Table WC-2 pertains to conserved water valued at the existing price being paid by the water user, while the Table WP-1 prices are transfer prices.

Table WP-1. Purchase/Lease of Water Right - $/acre foot (af)

Location	Year	Units	Cost Per Unit	Source
CA	2004	typical	$100/af/yr	CDFG'04 p1.43
Central Valley	01-02	 135K af 7.1K af 36.8K af 60.6K af	***Upstream of Delta*** State-YubaCntyWater Agency: $10.1M ($75/af/yr) Fed-SacmntoGrndwtrAgency: $535.7K ($75/af/yr) ***South of Delta*** State-KernCntyWtrAgency: $6.7M ($181/af/yr) Fed-KernCntyWaterAgency: $11M ($181/af/yr)	DWR
Central Valley	02-03	 4.9K af 65K af 125K af 20K af	***Upstream of Delta*** State-OrovilleWyandotteIrrigDist: $386.6K ($75/af/yr) State-YubaCntyWaterAgency: $5.5M ($85/af/yr) ***South of Delta*** State-KernCntyWaterAgency: $21.3M ($170/af/yr) Fed-StaClaraVlyWaterDist: $3.2M ($162/af/yr)	DWR
Central Valley	03-04	 100K af 20K af 35K af	***Upstream of Delta*** State-YubaCntyWaterAgency: $8.8M ($88/af/yr) State-PlacerCntyWaterAgency: $1.7M ($83/af/yr) ***South of Delta*** State-KernCntyWaterAgency: $8.6M ($246/af/yr)	DWR

Central Valley	04-05	 4.6K af 89.7K af 8.8K af	***Upstream of Delta*** State-YubaCntyWaterAgency: $200K ($43/af/yr) ***South of Delta*** State-KernCntyWaterAgency: $15.8M ($177/af/yr) State-StaClaraVlyWaterDist: $1.6M ($184/af/yr)	DWR

HA - HABITAT ACQUISITIONS/LEASES/CONSERVATION EASEMENTS ($/ACRE)

Tables HA-1 and HA-2 respectively describe Evergreen's cost estimates for undevelopable land and parcels with medium-high development potential. Table HA-3 describes costs of easements and land purchases administered by California's Wildlife Conservation Board (WCB). Tables HA-4 and HA-5 respectively describe land acquisition and easement costs from a variety of other sources. Evergreen's estimates are inclusive of transaction and management costs as well as land acquisition price, while WCB's estimates include only acquisition price. The other data sources likely also include only acquisition price.

Evergreen's prices are $700-$4800/acre for undevelopable land (Table HA-1. For parcels with medium/high development potential and low to high amenity value, prices are $5K-$300K/acre for rural residential land, $60K-$600K/acre for suburban residential land, and $300K-$1.2M/acre for urban land; prices of parcels with very high amenity value are unpredictable (Table HA-2).

Table HA-1. Cost of Undevelopable Land - $/acre (Source: Evergreen 2003, p. 7)
Cost estimates pertain to Puget Sound. Estimates include appraisal, closing, commission, surveying, legal, project management costs.

Proximity to Urban Area	Zoning	
	Forest	Agricultural
Far 41+ mi	$700-1800	$1800-2400
Medium 21-40 mi	$1800-2400	$2400-3600
Near 0-20 mi	$2400-4800	$3600-4800

Table HA-2. Cost of Parcels with Medium-High Development Potential - $/acre (Source: Evergreen 2003, p. 6) Cost estimates pertain to Puget Sound. Estimates include appraisal, closing, commission, surveying, legal, project management costs.				
Zoning	Amenity Value			
	Low	Medium	High	Very High
Rural Residential	$5K-35K	$24K-60K	$60K-300K	$300K-1.2M
Suburban Residtl	$60K-120K	$120K-240K	$300K-600K	Unpredictable
Urban	$300K-600K	$600K-1.2M	Unpredictable	Unpredictable

The prices in Table HA-3 were derived by dividing WCB's expenditures for purchase/easement in each county by the number of acres subject to purchase/easement. These derived prices are $42 -$104.7K/acre for easements, and $267-$45.5K/acre for acquisitions. The acquisition prices are on the low side relative to Evergreen's estimates of $5K-$300K/acre for rural land and $300K-$1.2M/acre for urban land, (Table HA-2) and likely underestimate actual costs, as WCB's wildlife habitat acquisitions are often done on a cost-share basis.

Table HA-3. WCB Actions in 2000-2004: Total Acreage and $/Acre, by County (Source: Wildlife Conservation Board, 2005)				
	Conservation Easement		Fee Title	
County	Acres	$/Acre	Acres	$/Acre
Alameda			16,500	$4,485
Alpine				
Butte	10,369	$866	4,557	$726
Calaveras	3,669	$395		
Colusa	13,131	$128		
Contra Costa			3,808	$843
Del Norte			25,675	$812
El Dorado	1,178	$501	1,295	$4,239
Fresno			1,310	$7,291

Glenn			24,158	$568
Humboldt	3,640	$253	5,905	$5,184
Imperial				
Inyo			218	$4,394
Kern			4,743	$1,093
Lake			269	$968
Lassen			278	$1,079
Los Angeles			4,178	$43,083
Madera	443.5	$1636	1,140	$15,380
Marin			737	$7,017
Mariposa	6,801	$487		
Mendocino	560	$6607	39,704	$267
Merced	15,620.9	$893	4,359	$818
Modoc			2,080	$640
Mono	6,350	$506		
Monterey	27,715	$241	14,598	$1,408
Napa	17	$104,706	12,817	$546
Nevada			494	$1,387
Orange			6,508	$12,782
Placer			155	$1,131
Plumas	21,137	$140	279	$1,935
Riverside	1,324	$591	60,926	$1,871
Sacramento	5,526	$577	4,819	$1,159
San Bernardino			572	$6,324
San Diego			54,871	$2,135
San Francisco				
San Joaquin	3,515	$545		

San Luis Obispo	82,106	$420	32,551	$1,045
San Mateo	1,000	0	6,020	$2,495
Santa Barbara	1,406	$2,156	948	$15,651
Santa Clara			5,205	$1,822
Santa Cruz	18	$167	464	$12,349
Shasta	3,784	$158	1,524	$2,949
Sierra	500	$620	2,147	$12,809
Siskiyou	2,479	$42	118	$1,102
Solano	535	$1,903	5,536	$701
Sonoma	165	$10,333	5,484	$2,279
Stanislaus				
Sutter				
Tehama	21,557	$116	8	$44,063
Tulare	722	$176	2,667	$413
Tuolumne			333	$302
Ventura			3,018	$45,518
Yolo	6,983	$351	21,106	$865
Yuba	2,115	$56	2,153	$2,152
Total				

Tables HA-4 and HA-5 include information on habitat type, when available. Several projects involved expenditures on both acquisition and easement where it was not possible to determine how much was spent on each. Such projects were placed in Table HA-4 if most of the acreage involved acquisition and in Table HA-5 if most of the acreage involved easement; cost per acre was estimated by dividing total cost by total acreage (acquisition + easement).

Land acquisition values used by NMFS for the Columbia River Estuary Recovery Plan were $5K/acre for rural land and $100K/acre for urban land (Table HA-4, NOAA p5-46). These values are as low or lower than Evergreen's lowest prices for rural and urban land ($5K/acre and $300K/acre respectively, Table HA-2). For most other acquisitions described in Table HA-4, prices are ~ $200-$20K/acre, with the notable exception of several multi-million-dollar-per-

acre purchases in north/central California and southern California - both highly urbanized areas (Table HA-4: HT07a-T61, p121, NOCECA and SCACO). Prices of conservation easements (Table HA-5) are ~$300-$5.7K/acre - with the notable exception of a $65K/acre easement in Santa Barbara (CntySBPublicWrks).

Table HA-4. Land Acquisition - $/acre

Location	Year	Units	Cost Per Unit	Source
ColR	2006	typical	Rural: $5K/acre Urban: $100K/acre	NOAA, p5-46
Mill/RockCrks-SmithR-DelNorteCnty	01-02	24,580 ac	$5M ($203/acre)	CDFG-034
SLOCreek	02-03	80 acres	$100K ($1250/acre)	CDFG-218
SONC SONC-NOCECA NOCECA CentralValley SCACO	98-05 2003$	16 sites 16 sites 51 sites 67 sites 87 sites	$12.1K ($157-$37.3K)/acre $10K ($316-$53.7K)/acre $295.6K ($138-$1.8M)/acre $5.9K ($195-$32.6K)/acre $87.3K ($387-$1.7M)/acre	HT07a-T61, p121
SanFranBay	1999	typical	$6K-$15K/acre (South Bay) $2K-3K/acre (North Bay)	USEPA '99, p171
Badger Creek (Cosumnes River)	1996	4300 acres	$12.0M ($2.8K/acre) - wetland/ forest/vernal pool, Valensin Ranch	ERP-96-M06
Cache Slough (SacrmntoR/ SanJoaquinDelta)	1997	4760 acres	$8.747M ($1.8K/acre) - tidal wetland/ riparian corridor/upland, Liberty Island	ERP-97-B03
San Joaquin River	1997	6288 acres	$20.5M ($3.3K/acre) -floodplain, USFWS SanJoaq Natl Wildlife Refuge 4324 acr fee, 1964 acr easement	ERP-97-B04
Sacramento River	1997	1880 acres	$8.705M ($4.6K/acre) - seasonal wetland/riparian/riverine/aquatic	ERP-97-N02
Sacramento River	1997	95 acres	$838.7K ($8.9K/acre)	ERP-97-N04
Butte Creek	1997	93 acres	$151K ($1.6K/acre) - partial funding only	ERP-97-N06

Cosumnes River	1997	1655 acres	$5.210M ($3.1K/acre) - agricultural/dairy/woodland/ grassland/seasonal wetlands, incl cleanup/repair	ERP–97-N14
Napa River	1998	68 acres	$910K ($13.4K/acre) - marsh wetland, incl restoration	ERP-98-B13
Merced River, Tuolumne River	1998	360 acres	$830.5K ($2.3K/acre) -riparian/ wetland/riverine, Basso Bridge Ecological Reserve & Merced River ranch land	ERP-98-CO4/CO5
Butte Creek	1998	93 acres	$160.4K ($1.7K/acre) - riparian/ wet meadow/grassland/woodland	ERP-98-F03
Sacramento River	1998	537 acres	$2.123M ($4.0/acre) - aquatic/ wetland/riparian, Stones Lake NWR	ERP-98-F12
Petaluma River	1998	181 acres	$255K ($1.4K/acre) - Petaluma Marsh	ERP-98-F13
San Joaquin River	1998	224 acres	$1.1M ($4.9K/acre) - riparian wetland, San Joaquin NWR	ERP-98-F21
Napa River Marsh	1998	453 acres	$1.976M ($4.4K/acre) - South Napa R Tidal Slough	ERP-98-F23
Cosumnes River	1999	1512 acres	$5.2M ($3.4K/acre) - farmland/ riparian, McCormack-Williamson Tract	ERP-99-F04
Tuolumne River	2000	303 acres	$1.386M ($4.6K/acre) - Bobcat Flat Floodplain Acquis	ERP-00-F01
Cosumnes/ Mokelumne Rivers	2001	771 acres	$2.843M + $12.1K project mgmt ($3.7K/acre) - agricultural/ seasonalwetlands/upland/vineyard	ERP-01-N10
Stanislaus River	2001	371 acres	$2.613M ($7K/acre) - riparian/ agricultural land	ERP-01-N11
Sacrmnto/San Joaquin Delta	2001	9269 acres	$12.659M + $87.5K program mgmt ($1.4K/acre) -agricultural/ marsh/riparian/riverine land, Staten Island	ERP-01-N23

Sacrmnto/San Joaquin Delta	2002	1166 acres	$23M ($19.7K/acre) - wetland/ upland, Dutch Slough	ERP-02-C07-D
Tuolumne River	2002	198 acres	$706.6K($3.6K/acre) - floodplain/ riparian habitat, Big Bend 66 acres fee, 132 acres easement	ERP-02-D01
Stanislaus River	2002	184 acres	$2.4M + $357K project mgmt & admin ($13.2K/acre)	ERP-02D-C11
PetalumaRivDelta, SanPabloBay	2002	631 acres	$2.0M ($3.2K/acre) - tidal wetland/adjacent upland, Bahia site	ERP-02-P14
BigChicoCreek/ MudCreek/ SacrmntoRiver	2002	146 acres	$2.278M + $59.5K project mgmt & admin ($15.6K/acre) - irrigated cropland	ERP-02-P16-D
Crevis Creek (Deer Creek, Cosumnes River)	2002	294 acres	$823.2K ($2.8K/acre)	ERP-02-P49

Table HA-5. Conservation Easement - $/acre

Location	Year	Units	Cost Per Unit	Source
CA	03-04	typical	$209-$730/acre - rangeland	Anon'06,p4
Wolverton Gulch-Van DuzenR-HmboldtCnty ArroyoSeco R-MntereyCnty	04-05	48 acres 100 acres	$30K ($625/acre) $300K ($3K/acre)	CDFG-128 CDFG-259
SouthCoast StaBarbCnty	07-12	5 acres	$3.525M ($65K/acre)	CntySB PublicWrks
San Joaquin River	2001	362 acres	$2.075M ($5.7K/acre) - riparian/seasonal wetland	ERP-01-N08
Battle Creek	2001	2499 acres	$851.6K ($341/acre)	ERP-01-N24

NorthFork Cosumnes R	2002	2162 acres	$2.0M ($925/acre) - riparian/upslope 1814 acres easement, 348 acres fee	ERP-02-P02
Mill Creek/ Deer Creek	2002	23,846 acres	$4.470K ($187/acre - agricultural land	ERP-02-P26
Tuolumne River	1998	140 acres	$687.0K ($4.9K/acre) - permanent easement, Grayson Riv Ranch	ERP-98-F07
San Joaquin River Delta	1998	168 acres	$425K ($2.5K/acre) - permanent easement, Fern Headreach Island complex	ERP-98-F16
Deer Crk/Mill Crk - Sacr R	1998	166 acres	$688K ($4.2K/acre) - orchards/row crop agriculture/lowlands	ERP-98-F20
Sacrmnto River	1999	1512 acres	$2.0M ($1.3K/acre) - riparian/riverine	ERP-99-B12
LwrTuolumne /San Joaquin	1999	1073 acres	$1.4M ($1.3K/acre) - floodplain	ERP-99-R01
Battle Creek	1999	6851 acres	$2.048M ($299/acre) - 3 ranches, woodland/riparian/grassland/chaparral	IMM-02-I01

MD - MONITORING STATUS AND TRENDS (includes monitoring of baseline, status and trends in habitat, watershed processes and/or populations)

Table MD-1 includes monitoring projects funded by CDFG's Fisheries Restoration Grants Program over the past three fiscal years. Information on the nature of monitoring is provided, as available. Most of the projects focus on life history, migration, distribution, and abundance of particular species on particular streams. Costs are ~$12K-$300K/project. Most of the >$200K projects (e.g., 04-05 CDFG-054, CDFG-208, CDFG-260, CDFG-261; 05-06 CDFG-158 and CDFG-159) appear to have a strong analytical as well as monitoring component.

Table MD-1. Physical/Project-Scale Monitoring - $/project			
Location	Year	Cost Per Unit	Source
TopangaCrk	04-05	$98.3K-relate rainfall to recruitment/survival	CDFG-009
StaMonicaBay		$152.9K-steelhead abund/distribution	CDFG-010
MillCrk		$156.9K-life history, pop size	CDFG-012
SproulCrk(EelR)		$45.9K-production, run timing & size	CDFG-040
HumboldtBay		$216.2K-estuary use/residence time	CDFG-048
UpprRedwdCrk		$65.1K-juvenile migration, biometric data	CDFG-051
LowrRedwdCrk		$62.3K-juvenile migration, biometric data	CDFG-052
MendocnoCnty		$281.2K-life history in 6 streams, eval potential biases in spawning surveys	CDFG-054
ScottCrk		$192K-life history, support artificial propag programs to maintain ESA-listed pops	CDFG-153
SoCenCA		$82.4K-baseline data on spawning/rearing habitat conditions in 8 watersheds	CDFG-196
ScottR		$67K-data on watershed condition/stock status	CDFG-200
ScottR		$77.8K-outmigrant trapping	CDFG-202
ScottR		$45.9K-streamflow/precip gauging for Water Balance Model	CDFG-205
PrairieCrk-Hmbldt		$211.2K-validate monitoring protocols for watershed restoration	CDFG-208
Scott/ShastaR		$169.4K-juvenile migration	CDFG-224
DelNorte/Hmbldt		$307.1K-juvenile sal abundance for 2 regional watersheds, validate effectiveness of juvenile abundance trends as indic of adult pop conds	CDFG-260
SLO		$238.3K-distribution/habitat use; quantify linkages among stream physical habitat, water quality, macroinverts, land use & fish	CDFG-261
CanoeCrk-Hmbldt		$65.8K-effect of wildfire on habitat & aquatic ecosystem processes	CDFG-071

Mattole Eel/Salinas,SLrnzo McGarveyCrk(Kla mathRiver) MendocnoCnty FreshwaterCrk UpperRdwoodCrk LowerRdwoodCrk TomalesBay Scott/ShastaR MatilijaCrk	05-06	$11.5K-life stage monitoring, smolt prod est $78.2K-historical baseline for genetic monitoring $141.9K-life history, pop status $183.8K-life history 3 streams, evaluate potential biases in spawning surveys $264.8K-life history, eval potential biases in spawning surveys $48K-estimate smolt pop using mark-recapture $53.9K-estimate smolt pop using mark-recapture $149.5K-life history $170.4K-juvenile migration $140K-steelhead assessment	CDFG-082 CDFG-089 CDFG-116 CDFG-158 CDFG-159 CDFG-164 CDFG-166 CDFG-245 CDFG-252 CDFG-277
MattoleR MattoleR UpprRedwoodCrk LowrRedwoodCrk Scott/ShastaR MattoleR HumboldtBay TopangaCyn VenturaR	06-07	$15.6K-downstream migrant monitoring, abundance estimate for chinoook/coho $17K-smolt production monitoring $48.4K-smolt abundance estimation $54.4K-smolt abundance estimation $170K-juvenile emigration monitoring $30K-escapement monitoring $168K-estuary use/residence time by juv sal $55.3K-steelhead distribution/abundance $76.6K-juvenile stlhead distribution/abundance	CDFG-207 CDFG-208 CDFG-064 CDFG-066 CDFG-127 CDFG-204 CDFG-062 CDFG-027 CDFG-034

MO - MONITORING WATERSHED RESTORATION

Table MO-1 pertains to implementation monitoring to determine if project treatments were constructed correctly and as planned, effectiveness monitoring to determine if restoration has produced desired habitat conditions and/or watershed processes, validation monitoring to determine if hypothesized responses of habitat, watershed processes and/or populations to restoration were correct.

The descriptions in Table MO-1 pertain to the type of restoration activity being monitored, with the cost estimates pertaining only to the monitoring component. The highest cost ($221.7K, ERP-97-N13) was for a bank stabilization project involving large-scale monitoring of many variables. Costs associated with monitoring of other individual projects ranged from $7K (for revegetation project ERP-97-N08) to $90K (for fish screen evaluation project ERP-97-C02). Several other estimates ($87.4K for 04-05 CDFG-036, $142K for 05-06 CDFG-171) involved monitoring of multiple projects funded by CDFG's Fisheries Restoration Grants Program.

Table MO-1. Implementation, Efectiveness and Validation Monitoring - $/project			
Location	Year	Cost Per Unit	Source
CA CanoeCrk-Hmbldt ShastaR Mattole	04-05	$87.4K - monitor pending/completed Fisheries Restoration Grants projects $65.8K - effect of wildfire on habitat&aquatic ecosystem processes $61.4K - monitor restoration sites for project effectiveness (habitat and fish) $65.1K - evaluate effectiveness of watershed rehab project	CDFG-036 CDFG-071 CDFG-273 CDFG-284
CA	05-06	$142K-monitor pending/completed Fisheries Restoration Grants projects	CDFG-171
Sacramento River	1997	$90K-screen evaluation project at Princeton Pumping Plant Fish Screen Facility	ERP-97-C02
Tuolumne River	1997	$47.6K - spawning gravel introduction (11K tons)	ERP-97-C11
Sacramento River	1997	$34K - restoration of 200 acres agricultural land to native riparian forest	ERP-97-N03a
Sacramento River	1997	$102.5K - restoration of 93 acres agricultural land to native riparian forest	ERP-97-N03b
Mill Creek/ Sacramento River	1997	$7.0K - restoration of native riparian vegetation for anadromous fish	ERP-97-N08
Barker/Lindsay/ Cache Sloughs-Sacr/SanJoaqDelta	1997	$29.8K - vegetative restoration	ERP-97-N10
Barker/Lindsay/ Cache Sloughs-Sacr/SanJoaqDelta	1997	$48.7K - exotic species removal	ERP-97-N10
Georgiana Slough/ NoMokelumne R-Sacr/SanJoaqDelta	1997	$221.7K - evaluation of alternative vegetative/ biotechnical techniques for stabilizing bank erosion/restoring levees	ERP-97-N13
Tolay Creek-San Pablo Bay	1997	$60K - 435 acre wetland restoration	ERP-97-N19

Prospect Island/ Cache Slough- SacramentoRiver	1998	$2.353M - levee repair and pump out; large scale monitoring of fish/wildlife/water quality/ phytoplankton/zooplankton/vegetation/benthic/ bathymetry/organic carbon	ERP-98-A01
SacramentoRiver	1998	$49K - fish screen construction	ERP-98-B26
Sacramento River	2000	$10.8K - fish screen installation on intake structure at Pump Station #1	ERP-00-B01
SanJoaquinRiver	2001	$233.4K - riparian/wetland restoration	ERP-01-N08
Sacramento River	2001	$86.3 ($8.6K/screen) 10 vertical screens <40 cfs	ERP-01-N52
Tuolumne River	2002	$203K - riparian floodplain/riverine habitat	ERP-02-P19-D
Mokelumne River	2002	$224.9K - songbird response to riparian restoration	ERP-02-P20

PL - WATERSHED EVALUATION, ASSESSMENT AND PLANNING

Table PL-1 provides examples of watershed evaluations/assessments, including partial assessments such as road erosion surveys and stream surveys. Almost all of the examples in the table come from CDFG's Fisheries Restoration GrantsProgram. Information on the nature of the assessment is provided, as available. Included are road inventory/sediment assessments (costed at $/mile), stream crossing assessments (costed at $/crossing), and watershed/estuary plans (costed at $/acre). According to Weaver/Hagans (WH-p91), the Grants Program allows up to $1.2K/mile for road assessments; just about all the road assessment examples in Table PL-1 meet this criterion. Stream crossing assessments cost $650-$1365/crossing. Most of the watershed plans cost $8-$13/acre and appeared to pertain mostly to erosion control. Several exceptions include a project on the Klamath River to address riparian/channel problems ($76/acre, 05-06 CDFG-115) and two projects involving Humboldt Bay ($853 and $3157/acre, 02-03 CDFG-169 & 227). CDFG's Coho Recovery Strategy (CDFG'04, p1.34) uses a planning cost estimate that is not scaled to the size of the plan ($200K/ planning exercise).

Table PL-1. Watershed Evaluation, Assessment and Planning - $/acre, $/mile, $/crossing				
Location	Year	Units	Cost Per Unit	Source
CA	2000	mile	$1.2K (max allowed by CDFG FRGP for full inventory/assessment/erosion control plan for roads)	WH-p91
HumboldtCnty	01-02	6063 ac	$48,080 ($8/acre) - erosion/hab rest	CDFG-106
DelNorteCnty		8718 ac	$83,959 ($10/acre) - erosion/hab rest	CDFG-107
EelR		45 mi	$20,338 ($452/mi) - road inventory	CDFG-136
HumboldtCnty		7 mi	$2011 ($287/mi) - road inventory	CDFG-140
HumboldtCnty		10.3 mi	$11,387 ($1106/mi) - road inventory	CDFG-141
RussianR	02-03	20 mi	$16.1K ($805/mi) - road inventory	CDFG-046
EelR		100 mi	$60K ($600/mi) - sediment assess	CDFG-077
EelR		8 mi	$2.7K ($333/mi)	CDFG-106
EelR		9 mi	$3.0K ($329/mi)	CDFG-125
HumboldtBay		35 acres	$29.9K ($853/acre) - estuary rehab plan	CDFG-169
HumboldtCnty		76.9 acres	$242,785 ($3157/acre) - erosion/hab rest	CDFG-227
SanFranCnty		66 mi	$70,786 ($1072/mi)	CDFG-279
StaCruz		153 mi	$142,812 ($933/mi) - erosion	CDFG-332
Dnorte/Humb/ MendoCnties		65 stream crossings	$42,246 ($650/crossing)	CDFG-327
EelR	03-04	50 mi	$38.1K ($763/mi) - sediment assess	CDFG-266
SalmonCrk	04-05	50 mi	$48,621 ($972/mi) - road inventory	CDFG-047
MattoleR		40 mi	$23,128 ($578/mi) - road inventory	CDFG-062
GualalaR		22 mi	$16,756 ($762/mi) - road inventory	CDFG-112
MendocinoCty		140 mi	$145,175 ($1037/mi) - sediment assess	CDFG-197
SLO Cty		130 mi	$124,269 $956/mi) - sediment assess	CDFG-210
EelR		110 mi	$131,023 ($1191/mi) - sediment assess	CDFG-238
MadR		49.1 sqmi	$329,810 ($11/acre)	CDFG-255
		(31424		
SmithR		ac)	$55,828 ($13/acre)	CDFG-256
		6.7 sqmi		
NavarroR		(4288 ac)	$22,771 ($1035/mi, sediment assess	CDFG-271
		22 mi		

CottonevaCrk MendcnoCnty MendcnoCnty MontereyCnty KlamathR MendcnoCnty HumboldtBay	05-06	110 mi 165 mi 80 crossng 14 mi 383 acres 50 mi 1.75 mi	\$107,637 (\$979/mi) - sediment assess \$163,001 (\$988/mi) - sediment assess \$64.4K (\$805/crossing) -inventory/assess \$23,549 (\$1682/mi) - sediment assess \$29,240 (\$76/acre) - ripar/chnnel dysfunc \$55,514 (\$1110/mi) \$47,338 (\$27.1K/mi) - estuary rehab	CDFG-040 CDFG-078 CDFG-101 CDFG-109 CDFG-115 CDFG-130 CDFG-276
RussianR Eel-SmithR	06-07	10 mi 50 crossng	\$15,606 (\$1560/mi) - sediment assess \$68.2K (\$1364/crossing)	CDFG-051 CDFG-084
CA	2004	typical	\$200K/planning exercise	CDFG'04 p1.34

WATERSHED ORGANIZATION SUPPORT AND ASSISTANCE (OR)

Table OR-1 includes organizational support projects funded by CDFG's Fisheries Restoration Grant Program during the three most recent fiscal years. These can be roughly divided into two categories:
(1) database maintenance, costed at $135K-$152K/project/year. Data requiring maintenance include the California Habitat Restoration Project Database (CHRPD)(04-05 CDFG-033 & 05-06 CDFG-023), passage assessment data (04-05 CDFG-039 & 05-06 CDFG -031), and stream inventory reports (05-06 CDFG-033);
(2) watershed coordination/outreach, costed at $24K-$259K/project . The low end of this range range ($24K, 04-05 CDFG-219) pertains to support of a part-time watershed coordinator, while the high end ($259.1K, 05-06 CDFG-076) pertains to organizational work by a southern California non-profit. CDFG's Coho Recovery Strategy assumes $60K per educational/ technical assistance program (CDFG'04, p.1.35).

Table OR-1. Organizational Support and Assistance - \$/project				
Location	Year	Units	Cost Per Unit	Source
CA CA SmithR HumboldtCnty LindsayCrk ShastaValley	04-05	1 project 1 project 1 project 1 project 1 project 1 project	\$134.3K - maintenance of CHRPD \$196.7K - passage assessment database \$52.0K - watershed coordinator \$95.9K - RCD org support to landowners \$24.1K - parttime watershed coordinator \$137.3K - RCD outreach coordinator	CDFG-033 CDFG-039 CDFG-120 CDFG-211 CDFG-219 CDFG-230

CA	05-06	1 project	$151K - maintain CHRPD	CDFG-023
CA		1 project	$116.9K - passage assessment database	CDFG-031
CA		1 project	$151.5K - consolidate stream inventory reports into CalFish	CDFG-033
StaBarb/ Ventura		1 project 1 project	$259.1K - organizational support by Community Environmental Council	CDFG-076
SmithR		1 project	$103.8K - WatershedCoordinator	CDFG-098
SalmonR		1 project	$54.2K - org support by Restoration Council	CDFG-256
AptosCrk to ORborder		1 project	$141.3K - develop sampling frame for salmon monitoring	CDFG-268
CA	2004	typical	$60K per education/tech assist program	CDFG'04 p1.35

PM - PROJECT MAINTENANCE FOLLOWING PROJECT IMPLEMENTATION

Weaver/Hagans suggest $275/mile/year for culvert maintenance. Dupont estimates culvert life of 10-30 years, although his estimates pertain to Idaho (not California).

Table PM-1. Culvert maintenance - $/culvert/year

Location	Year	Units	Cost Per Unit	Source
CA	2004	typical	Routine culvert replacement/cleaning/fill slope excavation: $275/mile/year	WH, p101
Idaho	2004	typical	Culvert Type: Iron fish ladder - $10/yr (30 yrs) Block fish ladder - $10/yr (10 yrs) Baffled culvert - $20/yr (30 yrs) Drop structure - $40/yr (30 yrs)	Dupont-T5 (p62), T6 (p63)

Maintenance of 50 screens on Scott River cost $1.4K/screen/year. These are probably fairly small screens. Maintenance costs may be higher for larger screens.

Table PM-2. Fish Screen Maintenance - $/screen/year

Location	Year	Units	Cost Per Unit	Source
ScottR	01-02	50 screens	$68,896 ($1378/screen/year)	CDFG-034

Weaver/Hagans suggest $25/mile/year for maintenance of forest roads. Estimates for other types of roads could not be found.

Table PM-3. Road Maintenance - $/mile/year				
Location	Year	Units	Cost Per Unit	Source
CA	2000	typical	Maintenance inspection forest roads: $25/mi/yr	WH, p101

The only plant thinning example found was specific to farmland. Costs were contingent on the method of thinning (mechanical, hand, chemical).

Table PM-4. Upslope/Riparian Plant Thinnings - $/project				
Location	Year	Units	Cost Per Unit	Source
CA farmland	FY07	typical	Forest Stand Improvement-Thinning Mechanical: $850/acre Hand,15-30%slope,40-60%cover: $900/acre Hand,30-50%slope,60-90%cover: $1200/acre Chemical: $150/acre	NRCS CA

RE - COOPERATIVE FISH REARING

Flagg and Nash (1999) make a number of recommendations regarding operation of conservation hatcheries - e.g., select broodstock using appropriate genetic protocols, maintain broodstock on natural photoperiod and water temperatures, provide incubation and rearing environments that mimic conditions in the wild (e.g., overhead cover, instream structures/substrates), reduce rearing densities, vary water-flow velocities, provide "natural" diet composition and feeding rates, provide bottom feed delivery systems, rear fish in water from the intended return location, release hatchery smolts at sizes similar to wild smolts, provide for volitional releases that do not exceed carrying capacity, have multiple broodstock facilities to protect against local disasters (e.g., equipment failure), establish appropriate monitoring and evaluation strategies. They conclude that "Implementation of such [conservation hatchery] programs would require significant capital expenditure, with increased hatchery operating costs and reduced fish production. Some increased costs would be offset by conservation hatcheries releasing smaller numbers of highly adaptable fish."

Construction and operational costs of a conservation hatchery depend on a variety of factors - e.g., whether the hatchery is newly constructed or a modification of an existing hatchery, which of the Flagg/Nash recommendations are implemented at the hatchery and the particular facilities and protocols needed for such implementation, scale of hatchery production, the particular species at the hatchery (since rearing time varies among species).

The Kingfisher Flat Hatchery on Big Creek operates an artificial propagation program to supplement depressed wild coho runs. The hatchery receives about $95K/year from the CDFG Fisheries Restoration Grants Program (Table RE-1). The extent to which the $95K reflects the cost of the hatchery's coho conservation program is difficult to determine, given that (1) the hatchery engages in other activities as well (e.g., chinook rearing), (2) the hatchery relies heavily on volunteer labor and also receives funding from other sources, (3) the SWFSC Santa Cruz's captive broodstock program provides gametes to the Kingfisher facility to increase coho genetic diversity (at no cost to the hatchery).

Table RE-2 describes capital and operating costs for a number of Columbia River hatcheries that are larger than Kingfisher Flat. While some of these hatcheries engage in some conservation activities, they are largely production hatcheries. Information provided in Table RE-2 is intended to give a very rough idea of hatchery costs.

Table RE-1. Hatchery Operation

Location	Year	Cost	Production	Source
Kingfisher Flat Hatchery	04-05	$94.3K/year	~240K chinook smolts, 45K steelhead smolts,100s coho smolts	CDFG-281
Kingfisher Flat Hatchery	05-06	$99K/year	~240K chinook smolts, 45K steelhead smolts,100s coho smolts	CDFG-276

Table RE-2. Columbia River Hatcheries (Source: IEAB 2002)			
Name/ Operator	Cost		
	Annual Cost: Annualized Capital (Cap)*, O&M, M&E	$/Released Fish	Production Goal
Spring Creek/ USFWS	$2.07M=$1.17M (Cap) +$900K (O&M)	$0.14	15M sub-yearling tule fall chinook
Clatsop Econ Development Council/ ClatsopCnty	AcclimationCosts: FallChin - $41.8K SprChin - $242K Coho - $98.4K FullCycleCosts: Coho - $124.2K	 $0.23 $0.28 $0.04 $0.18	 180K fall chinook smolts 850K spring chinook smolts 3.4M coho smolts
NezPerce/ tribe	$5.3M=$1.2M (Cap)+$2M (O&M)+$2.1M(M&E)	$2.60	1.4M fall chinook smolts 625K spring chinook smolts
Yakima/tribe	$4.7M=$1.5M (Cap) +$3.2M (O&M)	research facility	810K spring chinook smolts 700K coho smolts
Leavenworth/ USFWS	O&M by Facility: Leavenworth-$863K Entiat-$329K Winthrop-$430K (Built 1939-40, no capital cost, fully depreciated)	By Facility: $0.33 $0.46 $0.47	3M spring chinook smolts 200K summer steelhead smolts
PriestRapids/ WDFW	$527K=$210K (Cap) +$317K (O&M)	$0.08	3.7M fall chinook smolts
Irrigon/ ODFW	$1.95M=$794K (Cap) +$1.156K (O&M)	$1.30	1.7M summer steelhead smolts
McCall/ Idaho DFW	$899K=$418K (Cap) +$481K (O&M)	$1.09	8K adult summer chinook
* Annual capital costs, calculated as the original construction cost amortized over 50 years at 3%.			

WILDLIFE MANAGEMENT

The average cost per pikeminnow harvested in the Columbia River bounty program is $6.05/fish. Whether this cost estimate would be similarly applicable to a California eradication program would depend on the nature and scale of the program and the extent of angler interest and success in harvesting pikeminnow.

Table WM-1. Invasive Aquatic Species (e.g., pike minnow eradication)			
Location	Year	Cost Per Unit	Source
ColR	2005	Annual program cost (rewards+tags): $1,546,232 Avg $6.05/fish (=$1,460,724 total rewards/241,357 total fish harvested)	Porter, p41

RES - RESEARCH - productivity research (life cycle monitoring/analysis), spatial structure (fish distribution surveys), genetic diversity (laboratory analysis of tissue samples), and abundance estimates

Columns 2-3 of Table RES-1 describe start-up and annual costs of monitoring activities identified by CDFG/NMFS in several recent workshops. Several caveats in interpreting the cost estimates: (1) The estimates pertain only to coastal salmonids (i.e., exclude Central Valley), (2) the estimates are incremental in that they represent what is needed over and above what is currently being spent for coastal salmonid monitoring, and (3) the estimates assume that all labor is paid (no volunteers).

Monitoring costs are provided here because monitoring data are essential to conducting research on VSP (viable salmon population) attributes. Columns 4-7 of Table RES-1 identify which types of data are relevant to evaluating which VSP attribute. Because some of the data requirements relate to multiple VSP attributes, it is impractical to devise separate costs for each attribute.

As reflected in Table RES-1, the monitoring program is intended to follow different strategies in northern and southern areas. The northern area is defined as the Oregon border to Aptos Creek (five ESUs); the southern area is defined as the Pajara River southward (two ESUs). The boundaries of the two monitoring areas do not coincide with the boundaries of the recovery domains. However, it may be possible to allocate monitoring costs among domains (e.g., on the basis of proportion of total salmonid stream miles within each domain).

The costs noted in Table RES-1 are incomplete with regard to overall coastal salmonid research needs. Other activities mentioned in Boydstun and McDonald (2005) include: (1) habitat condition monitoring, (2) augmented samples for genetic monitoring, (3) other biological monitoring (e.g., otoliths, adult gender, length-weight samples), and (4) laboratory and computer analysis of data.

Table RES-1. Monitoring Activities and Costs as They Relate to Specific VSP Attributes Source: Boydstun & McDonald 2005 - pp 54-55 & Table8/p 58.						
Monitoring Activity	Estimated Cost		VSP Attribute			
	Startup	Annual	Abundance	Distri-bution	Genetic Diversity	Producti-vity
Northern spawner survey (OR border-Aptos Creek)	$566K	$2,545K	X	X	W/additnal sampling	X
Southern steelhead monitoring (PajaroR southward)	$65K	$541K	X			X
Life cycle monitoring stations (2 stns per coastal recovery domain)	$1,036K	$1,370K				X
Juvenile salmonid surveys	$177K	$1,307K	Cutthroat only*	X	W/additnal sampling	Cutthroat only*
25% hatchery fish marking (additional marking needed @ Iron Gate & Rowdy Creek only)	$0	$69K				X
Angler creel survey SmithR-SLO Creek, except Klamath/Trinity chinook/coho (already monitored by CDFG)	$14K	$369K				X
Administrative/ special studies	$36K	$789K				
* Assume monitoring from Eel River to Smith River and 30 miles inland.						

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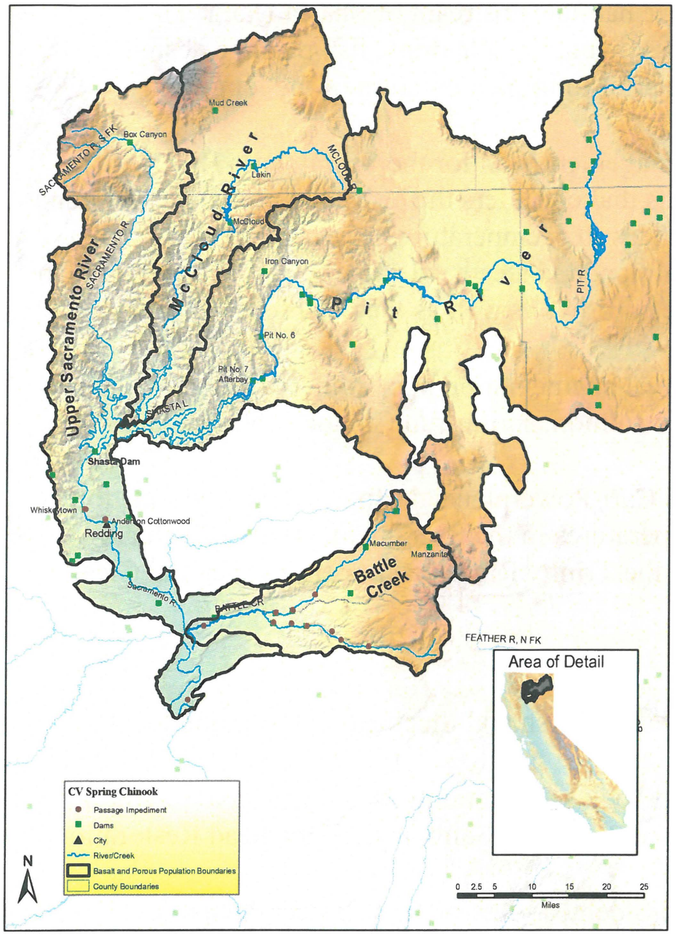
Basalt and Porous Lava Diversity Group



Core 1 Populations

- Sacramento River below Keswick Dam winter-run Chinook salmon
- Battle Creek spring-run Chinook salmon and steelhead

Primary Areas for Reintroduction

- McCloud River (winter-run Chinook salmon, spring-run Chinook salmon, steelhead)
- Battle Creek (winter-run Chinook salmon)

Core 2 Populations

- Sacramento River below Keswick Dam spring-run Chinook salmon and steelhead
- Cow Creek steelhead
- Redding-area tributary steelhead

Key Threats

- Keswick and Shasta Dams blocking access to historical habitat
- Flows and water temperatures below Keswick and Shasta Dams affecting all life stages
- Lack of spawning gravel
- Introgression of fall- and spring-run below Keswick and Shasta Dams
- Passage impediments in Battle Creek
- Lack of biological data for steelhead in the Diversity Group

Priority 1 Recovery Actions in the Basalt and Porous Lava Diversity Group[1]

Sacramento River

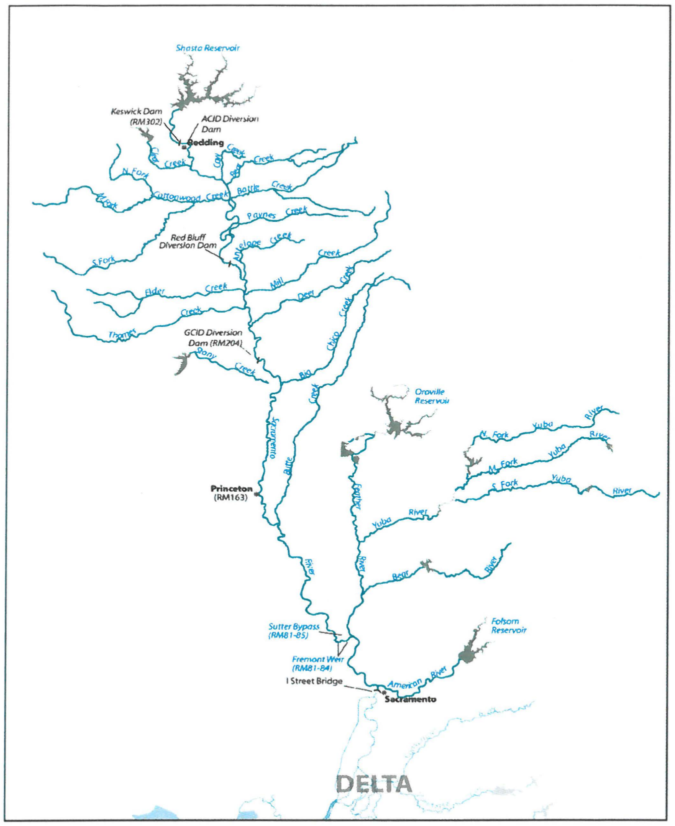
- Develop and implement a program to reintroduce winter-run Chinook salmon, spring-run Chinook salmon, and steelhead to historic habitats upstream of Shasta Dam. The program should include feasibility studies, habitat evaluations, fish passage design studies, and a pilot reintroduction phase prior to implementation of the long-term reintroduction program.
- Develop and implement a river flow management plan for the Sacramento River downstream of Shasta and Keswick dams that considers the effects of climate change and balances beneficial uses with the flow and water temperature needs of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead. The flow management plan should consider the importance of instream flows as well as the need for floodplain inundation.
- Develop and implement a long-term gravel augmentation plan to increase and maintain spawning habitat for winter-run Chinook salmon, spring-run Chinook salmon, and steelhead downstream of Keswick Dam.
- Avoid full power peaking at Trinity and Carr Powerplants during sensitive periods for water temperatures to reduce water temperatures in the Sacramento River. Evaluate impacts of power peaking operations in the Trinity River, Sacramento River and Clear Creek.

Battle Creek

- Fully fund and implement the Battle Creek Salmon and Steelhead Restoration Project through Phase 2.
- Develop and implement a winter-run Chinook salmon reintroduction plan to re-colonize historic habitats made accessible by the Battle Creek Salmon and Steelhead Restoration Project.
- Implement the Battle Creek Salmon and Steelhead Restoration Project Adaptive Management Plan.
- Develop an Adaptive Management Plan for Coleman National Fish Hatchery and continue to integrate hatchery operations with Battle Creek Salmon and Steelhead Restoration Project activities.
- Enhance watershed resiliency in Battle Creek by developing a strategy to identify and prioritize vegetation and fuels treatments that would reduce the potential extent and/or the magnitude of high severity wildfires.

[1] Not all priority 1 recovery actions for this diversity group are shown here.

Mainstem Sacramento River Migratory Corridor



- Populations of winter- and spring-run Chinook salmon and steelhead spawn in the upper reaches of the Sacramento River below Keswick Dam. The priority of these populations is described in the regional summary of the Basalt and Porous Lava Diversity Group.
- The threats and actions identified below relate to the Sacramento River as a migratory corridor for populations in the Northwestern California, Basalt and Porous Lava, and Northern Sierra Nevada diversity groups. Threats and actions relating to spawning and embryo incubation in the Sacramento River are identified in the Basalt and Porous Lava diversity group summary.

Key Threats

- Loss of riparian habitat and instream cover affecting juvenile rearing and outmigration
- Loss of floodplain habitat affecting juvenile rearing and outmigration
- Levee maintenance actions that reduce the conservation value of migration and rearing corridors
- Predation
- Juvenile fish injury and mortality at unscreened or poorly screened water diversions
- Degraded water quality from agricultural and urban runoff
- Lack of biological data for steelhead in the Diversity Group

Priority Recovery Actions

- Restore and maintain riparian and floodplain ecosystems along both banks of the Sacramento River to provide a diversity of habitat types including riparian forest, gravel bars and bare cut banks, shady vegetated banks, side channels, and sheltered wetlands, such as sloughs and oxbow lakes following the guidance of the Sacramento River Conservation Area Handbook.

- In an adaptive management context, implement short- and long-term solutions to minimize the loss of adult Chinook salmon and steelhead that enter the Yolo bypass, and Colusa and Sutter-Butte basins.

- Install NMFS-approved, state-of-the-art fish screens at the Tehama Colusa Canal diversion. Implement term and condition 4c from the biological opinion on the Red Bluff Pumping Plant Project, which calls for monitoring, evaluating, and adaptively managing the new fish screens at the Tehama Colusa Canal diversion to ensure the screens are working properly and impacts to listed species are minimized.

- Improve wastewater and stormwater treatment in residential, commercial, and industrial areas within the Sacramento River watershed.

- Increase monitoring and enforcement to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants entering the Sacramento River.

- Implement studies designed to quantify the amount of predation on winter-run Chinook salmon, spring-run Chinook salmon, and steelhead by non-native species in the Sacramento River. If the studies identify predator species and/or locations contributing to low salmonid survival, then evaluate whether predator control actions (e.g., fishery management or directed removal programs) can be effective at minimizing predation on juvenile salmon and steelhead in the Sacramento River.

- Implement projects to minimize predation at weirs, diversions, and related structures in the Sacramento River.

Northern Sierra Diversity Group

Core 1 Populations

- Mill Creek spring-run and steelhead
- Deer Creek spring-run and steelhead
- Butte Creek spring-run
- Antelope Creek steelhead

Primary Area for Reintroduction

- Upper Yuba River spring-run and steelhead

Core 2 Populations

- Antelope Creek spring-run
- Big Chico Creek steelhead
- Butte Creek steelhead
- Lower Feather River spring-run and steelhead
- Lower Yuba River spring-run and steelhead
- Auburn Ravine steelhead
- Lower American River steelhead
- Lower Mokelumne River steelhead

Key Threats

- Small passage impediments in Antelope, Mill, Deer, and Big Chico, and in the Feather and Yuba Rivers
- Large dams in the Feather, Yuba, and American rivers
- Low flows and warm water temperatures throughout the diversity group
- Hatchery impacts from the Feather River and Nimbus Fish hatcheries
- Loss of riparian and floodplain habitat
- Predation
- Lack of biological data for steelhead in the diversity group

Priority 1 Recovery Actions in the Northern Sierra Diversity Group[1]

Mill Creek

- Modify Ward, Upper, and Cemetery Ditch Siphon diversions and associated structures to provide unimpeded passage for adult and juvenile Chinook salmon and steelhead.
- Develop and implement instream flow agreements with Mill Creek diverters designed to provide flows that best support the life stages of spring-run Chinook salmon and steelhead that occur in the flow control reach (i.e., downstream of Upper Diversion to the confluence with the Sacramento River).

Deer Creek

- Modify the Cone-Kimball Diversion, Stanford-Vina Dam, and the Deer Creek Irrigation District Dam in order to provide unimpeded passage for adult and juvenile Chinook salmon and steelhead.
- Develop and implement instream flow agreements with the Deer Creek Irrigation District and the Stanford-Vina Ranch Irrigation Company designed to provide flows that best support all life stages of spring-run Chinook salmon and steelhead.

Butte Creek

- Identify and establish minimum instream flow requirements for Butte Creek that support all life stages of spring-run Chinook salmon and steelhead.
- Implement projects that improve water temperature management in Butte Creek, including facility modifications to the DeSabla-Centerville Hydroelectric Project

Antelope Creek

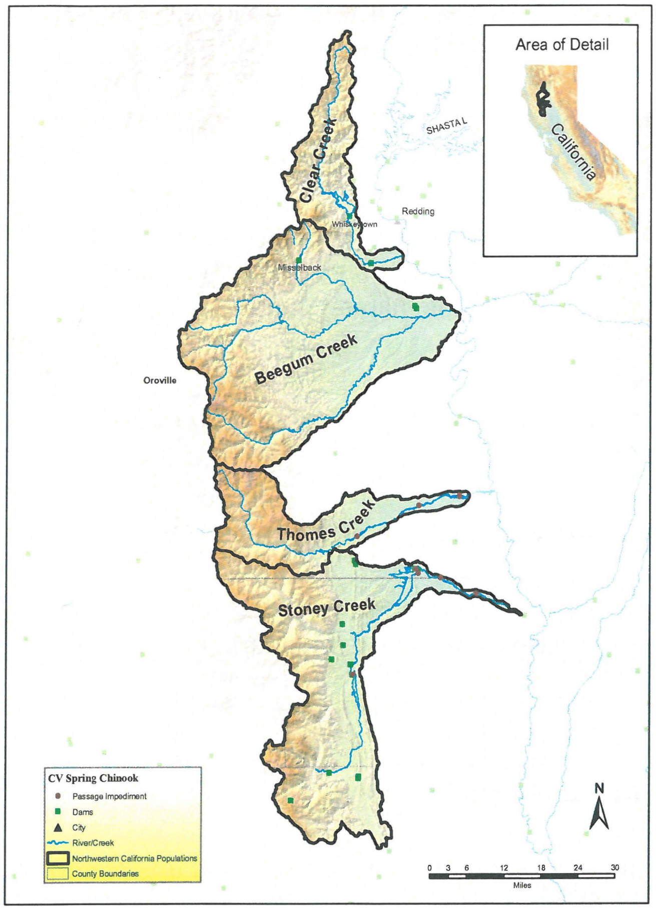
- Restore instream flows during upstream and downstream migration periods through water exchange agreements and provide alternative water supplies to Edwards Ranch and Los Molinos Mutual Water Company in exchange for instream fish flows.
- Implement fish passage improvement projects at Edwards Ranch and Penryn.

Yuba River

- Develop and implement a program to reintroduce spring-run and steelhead to historic habitats upstream of Englebright Dam. The program should include feasibility studies, habitat evaluations, fish passage design studies, and a pilot reintroduction phase prior to implementation of the long-term reintroduction program.
- Modify Daguerre Point Dam to provide unimpeded volitional upstream passage of adult steelhead and Chinook salmon (and sturgeon) and to minimize predation of juveniles moving downstream.

[1] Only a few of the priority 1 recovery actions for this diversity group are shown here.

Northwestern California Diversity Group



Core 1 Populations

- Clear Creek spring-run Chinook salmon and steelhead

Core 2 Populations

- Beegum Creek spring-run Chinook salmon and steelhead
- Thomes Creek steelhead
- Putah Creek steelhead

Priority Areas for Reintroduction

- None

Key Threats

- Hybridization between fall-run and spring-run Chinook salmon in Clear Creek
- Lack of spawning gravel
- Water temperatures and water quality affecting adult immigration and holding, spawning and embryo incubation
- Low flow conditions affecting all life stages
- Gravel mining and passage impediments on Thomes Creek
- Lack of biological data for steelhead in the diversity group

Priority 1 Recovery Actions in the Northwestern California Diversity Group[1]

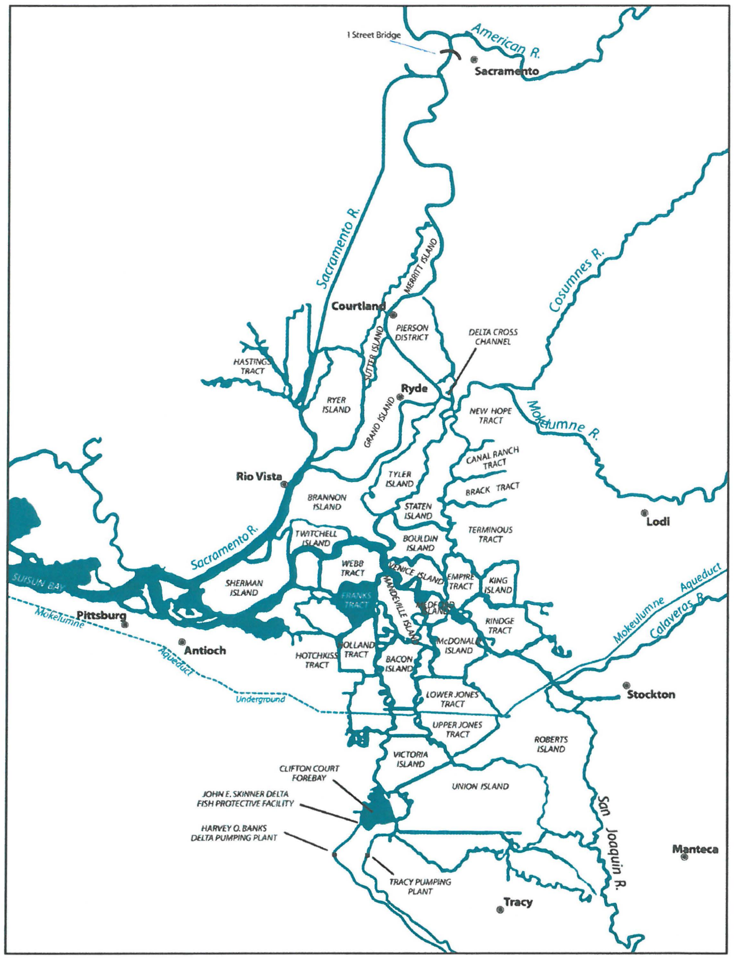
- Continue operation of the Clear Creek segregation weir to create reproductive isolation between fall-run Chinook salmon and spring-run Chinook salmon.
- Develop a new spawning gravel budget and implement a long-term gravel augmentation plan in Clear Creek, including acquisition of a long-term gravel supply.
- Manage releases from Whiskeytown Dam with instream flow schedules and criteria to provide suitable water temperatures for all life stages, reduce stranding and isolation, protect incubating eggs from being dewatered, and promote habitat quality and availability.
- Implement channel maintenance flows in Clear Creek as called for in the 2009 CVP/SWP biological opinion.
- Develop water temperature models to improve Clear Creek water temperature management.
- Adaptively manage Whiskeyotwn Reservoir releases and water temperatures to increase anadromy in *O. mykiss*.

Priority 2 Recovery Actions in the Northwestern California Diversity Group[1]

- Implement gravel mining best management practices to allow for unimpeded upstream and downstream passage conditions for all life stages of steelhead.
- Implement floodplain restoration projects in Clear Creek
- Conduct a feasibility study on potential channel modifications that would improve upstream migration conditions in Thomes Creek.
- Modify water releases from Black Butte Dam and water diversions in order to provide improved flows for all steelhead life stages in Stony Creek.

[1] Not all priority 1 or priority 2 recovery actions for this diversity group are shown here.

Sacramento-San Joaquin Delta



Key Threats

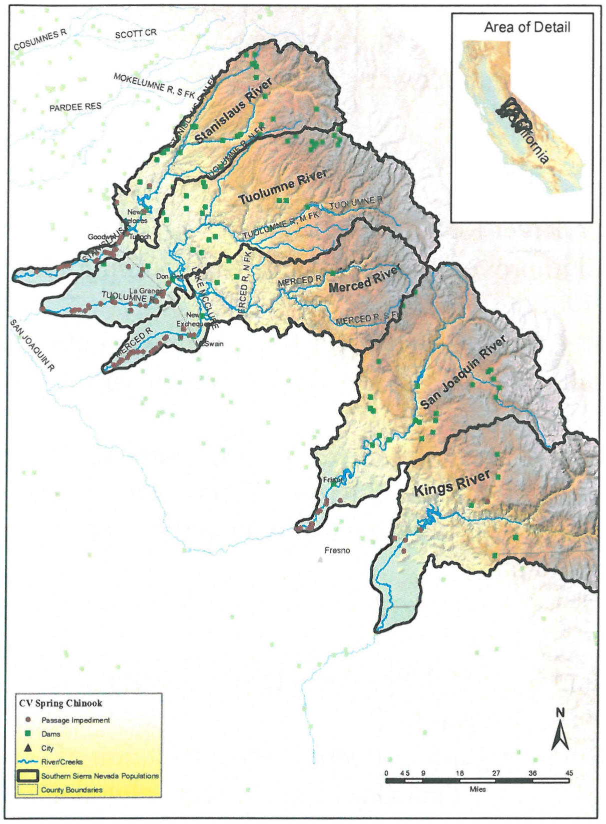
- Unnatural flow regimes through the Delta pulling juvenile salmonids towards the south Delta pumps.
- Loss of riparian habitat and instream cover affecting juvenile rearing and outmigration
- Loss of floodplain habitat affecting juvenile rearing and outmigration
- Levee maintenance actions that reduce the quality of migration and rearing habitat
- Predation by non-native fish species
- Entrainment at unscreened diversions
- Water quality impacts from agricultural and urban runoff
- Fish passage impediments/barriers for immigrating adults in the Sacramento Deepwater Ship Channel and in the Yolo bypass

Priority 1 Recovery Actions[1]

- Develop, implement, and enforce new Delta flow objectives that mimic historic natural flow characteristics, including increased freshwater flows (from both the Sacramento and San Joaquin rivers) into and through the Delta and more natural seasonal and inter-annual variability.
- Reduce hydrodynamic and biological impacts of exporting water through Jones and Banks pumping plants.
- Provide pulse flows of approximately 17,000 cfs or higher as measured at Freeport periodically during the winter-run emigration season (i.e., December-April) to facilitate outmigration past Chipps Island.
- Identify management targets for Yolo Bypass inundation timing, frequency, magnitude, and duration that will maximize the growth and survival of juvenile winter-run Chinook salmon and spring-run Chinook salmon; and then manage the Yolo Bypass to those targets.
- Conduct landscape-scale restoration of ecological functions throughout the Delta to support native species and increase long-term overall ecosystem health and resilience.
- Develop and implement a targeted research and monitoring program to better understand the behavior, movement, and survival of steelhead, spring-run Chinook salmon, and winter-run Chinook salmon emigrating through the Delta from the Sacramento and San Joaquin rivers.
- Provide access to new floodplain habitat in the South Delta for migrating salmonids from the San Joaquin system.
- Modify Delta Cross Channel gate operations and evaluate methods to control access to Georgiana Slough and other migration routes into the Interior Delta to reduce diversion of listed juvenile fish from the Sacramento River and the San Joaquin River into the southern or central Delta.
- Minimize the frequency, magnitude, and duration of reverse flows in Old and Middle River to reduce the likelihood that fish will be diverted from the San Joaquin or Sacramento River into the southern or central Delta.
- Curtail exports when protected fish are observed at the export facilities to reduce mortality from entrainment and salvage.
- Improve fish screening and salvage operations to reduce mortality from entrainment and salvage.
- Utilize a Delta operations technical group to assist in determining real-time operational measures, evaluating the effectiveness of the actions, and modifying them if necessary.

[1] Not all priority 1 actions for the Delta are shown here.

Southern Sierra Diversity Group and Mainstem San Joaquin River



Core 1 Population

- Calaveras River steelhead

Priority Areas for Reintroduction

- San Joaquin River from Friant Dam downstream to the Merced River (spring-run Chinook salmon)
- At least one other among the Stanislaus, Tuolumne, and Merced rivers (spring-run Chinook salmon and steelhead)

Core 2 Populations

- Lower Stanislaus River steelhead
- Lower Tuolumne River steelhead
- Lower Merced River steelhead

Key Threats

- Large passage impediments/barriers in the Stanislaus, Tuolumne, Merced, and San Joaquin rivers
- Small seasonal passage impediments/barriers and low flow conditions in the Mokelumne, Calaveras, and San Joaquin Rivers
- Low flows and warm water temperatures
- Loss of riparian and floodplain habitat affecting juvenile rearing and outmigration;
- Predation by non-native fish species
- Lack of biological data for steelhead in the Diversity Group

Priority 1 Recovery Actions for the Southern Sierra Nevada Diversity Group[1]

Calaveras River

- Develop and implement long-term year-round instream flow schedules and water temperature requirements that are protective of all steelhead life stages.
- Remove or modify all fish passage impediments in the lower Calaveras River to meet NMFS fish passage criteria

San Joaquin River

- Continue implementation of the San Joaquin River Restoration Program
- Develop and implement a suite of actions to improve salmon and steelhead outmigration survival through the lower San Joaquin
- Develop and implement an ecologically based San Joaquin River flow regime to help restore natural river processes and support all life stages of steelhead and spring-run Chinook salmon
- Implement projects that improve wastewater and stormwater treatment in residential, commercial, and industrial areas throughout the San Joaquin River watershed to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants.

Stanislaus River

- Manage releases from Tulloch, Goodwin, and New Melones dams to provide suitable water temperatures and flows for all steelhead life stages.
- Develop a Stanislaus River steelhead team to help guide collection and evaluation of baseline data to help address hypotheses for why resident *O.mykiss* are more abundant than anadromous *O.mykiss* in the Stanislaus River.

Tuolumne River

- Manage releases from La Grange and Don Pedro dams to provide suitable flows and water temperatures for all downstream life stages of steelhead.
- Develop a Tuolumne River steelhead team to help guide collection and evaluation of baseline data to help address hypotheses for why resident O.mykiss are more abundant than anadromous *O.mykiss* in the Tuolumne River.

Merced River

- Manage the water storage in Crocker-Huffman and New Exchequer reservoirs in order to provide suitable water temperatures and flows for all downstream life stages.
- Work with State and Federal water acquisition programs to dedicate instream water in the Merced River.

[1] Only a few priority 1 recovery actions for this diversity group are shown here.