

**State of California
The Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE**

**Butte Creek Spring-run Chinook Salmon
Adult Monitoring Annual Report 2021**



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Executive Summary

Butte Creek is a tributary to the Sacramento River located primarily in Butte County with smaller portions in Tehama, Glenn, Colusa, and Sutter Counties, California. Butte Creek supports one of three remaining Sacramento River tributaries that harbor self-sustaining (independent) populations of Central Valley spring-run Chinook salmon (SRCS; *Oncorhynchus tshawytscha*). SRCS are listed as threatened under the California Endangered Species Act (CESA; see Cal. Code Reg., tit. 14 § 675.5, subd. (b)(2)(c)) and the federal Endangered Species Act (see 64 FR 50394 and 70 FR 37160). Adult SRCS begin their upstream spawning migration into Butte Creek from the Sacramento River as early as January and continue through June (depending on the water year). Following migration, adults hold over summer within approximately 11 miles of cool deep canyon pools near Chico and Paradise until September when they shift to riffle complexes with substrate conducive to redd development and spawning.

This report provides a summary of the 2021 SRCS adult monitoring activities conducted by the California Department of Fish and Wildlife (CDFW) on Butte Creek. Adult SRCS passage into Butte Creek was not fully documented as a result of equipment failure in April 2021. Vaki Riverwatcher footage detected a partial count of 7,813 salmon traveling through the fish ladder at Durham Mutual Diversion Dam in Chico during their migration to summer holding habitat upstream. The annual Butte Creek SRCS snorkel survey was conducted July 12-16, 2021 and estimated 12,252 adult SRCS within the holding habitat (Nichols 2021). The 2021 estimate was low as a result of a pre-spawn mortality event. In response to observed high pre-spawn mortality in July, a mark-recapture survey was conducted through the summer. A total of 13,899 SRCS mortalities were either marked for recapture or chopped during the pre-spawn mortality survey. Using a modified Cormack Jolly-Seber (CJS) model (Bergman et al. 2012), the total SRCS population that did not survive to spawn in 2021 was estimated at 19,773. The carcass survey was conducted over 5 weeks from September 21 to October 21. A modified CJS model estimated the 2021 SRCS spawning population to be 1,807.

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Acronyms and Abbreviations

BCK	Butte Creek near Chico gauge
BSOG	Butte Slough Outfall Gates
CDFW	California Department of Fish and Wildlife
CDEC	California Data Exchange Center
CESA	California Endangered Species Act
CHD	Centerville Head Dam
CJS	Cormack Jolly-Seber
CWT	coded wire tag
PPDD	Parrot-Phelan Diversion Dam
SRCS	spring-run Chinook salmon
Vaki	Vaki Riverwatcher

1. Introduction

Butte Creek is a tributary to the Sacramento River located primarily in Butte County with smaller portions in Tehama, Glenn, Colusa, and Sutter Counties, California (Figure 1). With headwaters originating in Lassen National Forest, Butte Creek supports one of three remaining tributaries that harbor self-sustaining populations of Central Valley SRCS. The 90-mile anadromous portion of Butte Creek extends from the base of the Centerville Head Dam (CHD) downstream to the confluence of the Sacramento River at two locations: the Butte Slough Outfall Gates (BSOG) near Wards Boat Landing and the Sutter Bypass at Sacramento Slough near the confluence of the Feather and Sacramento Rivers (Figure 1).

SRCS are listed as threatened under the California Endangered Species Act (CESA; see Cal. Code Reg., tit. 14 § 675.5, subd. (b)(2)(c)) and the federal Endangered Species Act (see 64 FR 50394 and 70 FR 37160). Adult SRCS begin their upstream spawning migration to Butte Creek as early as January and continue through June (depending on the water year). After migration, adults hold within approximately 11 miles of cool deep canyon pools near Chico and Paradise until September when they move to riffle complexes with substrate conducive to redd development and spawning. Spawning habitat is found within an approximate 14.5-mile stretch of Butte Creek from the upstream most barrier at Quartz Bowl Pool downstream to Parrott-Phelan Diversion Dam (PPDD).

Since 1991, CDFW has monitored and estimated adult SRCS populations in Butte Creek (Ward et al. 2004). This report provides a summary of the 2021 SRCS adult monitoring activities conducted by CDFW. Monitoring efforts include:

- Adult SRCS passage estimates into upper Butte Creek using a Vaki Riverwatcher.
- A swimming snorkel survey to estimate the adult SRCS holding population.
- A mark-recapture pre-spawn mortality survey to estimate the number of SRCS adults that did not survive the summer holding period to spawn.
- A mark-recapture carcass survey to estimate the number of SRCS adults that survived through the summer to spawn.

CDFW has used mark-recapture surveys to monitor adult SRCS on Butte Creek since 2001 (Garman 2018). Resulting estimates are evaluated along with other adult survey efforts such as the swimming snorkel surveys and electronic passage estimates. Each survey provides valuable information on adult SRCS including migrating timing, level of prespawn mortality in the holding population, and number of adult spawners surviving the summer holding season. It is important to note that each surveying effort provides a unique dataset with potential sources of error but collectively provide unique insight into the

performance of adult SRCS within a given year. This monitoring collectively provides for valuable assessments of long-term trends and patterns for one of the few remaining naturally produced SRCS populations within the Central Valley.



Figure 1: Map of Butte Creek watershed showing the locations of Centerville Head Dam, the Butte Slough Outfall Gates, Sutter Bypass, and the confluence of the Sacramento and Feather Rivers.

2. Methods

2.1 *Vaki Riverwatcher*

A Vaki RiverWatcher Fish Counter (Vaki) has been installed in Butte Creek at Durham Mutual Diversion Dam Fish Ladder since 2014 to monitor passage of adult SRCS returning to Butte Creek. The Vaki combines both infrared scanning and video technology to passively monitor adult SRCS passage during the migration season (generally February through June), creating a minimum estimate of adult salmon moving into upstream holding and spawning habitats. This technology also provides images in turbid conditions. Video and silhouette data is uploaded weekly from the site and downloaded into the Winari software (VAKI Aquaculture Systems Ltd.) where images and videos are reviewed by staff to identify recorded fish to species, including details such as adipose fin presence and possible injuries or deformities. Additional metrics evaluated include fish length, speed of passage, and water temperature. Water temperature and flow are obtained from the Department of Water Resources California Data Exchange Center (CDEC) at gauge station BCK (Butte Creek near Chico) to compare SRCS passage with flow and temperature.

The goals of the Vaki monitoring include:

- 1) Estimation of abundance of adult SRCS migrating into upper Butte Creek holding habitats.
- 2) Evaluation of temporal distribution of adult SRCS passage.
- 3) Comparison of adult SRCS passage data with water temperature and flow conditions within Butte Creek.
- 4) Comparison of annual trends and timing of migration patterns of adult SRCS.

2.2 *Snorkel Survey*

SRCS adult holding surveys are conducted annually to estimate the number of SRCS adults that returned to Butte Creek to hold over summer prior to spawning in the fall. Additionally, this survey provides information regarding the holding distribution of adults and assesses pre-spawn mortality events. Holding surveys are conducted using standard snorkel methodology within Butte Creek from Quartz Bowl Pool downstream to PPDD for four consecutive days in July.

Data collection and analysis methodologies for this survey were standardized in 2001¹ to provide a total annual escapement estimate by summing the average observed fish count for each pool. However, snorkel survey methodology likely underestimates adult escapement when there are large populations (Garman

¹ Prior to 2001, each crew member developed an independent estimate for each holding pool, and before proceeding, a single estimate was made by group consensus and recorded in the field.

2016). The survey protocol requires each pool to be surveyed once by each crew member (either swimming the pool or observed from above the pool), and each crew member records a count separately for each pool. To increase accuracy of the count, snorkel surveys are conducted in an upstream to downstream direction, and the number of snorkelers entering a pool at a time is dictated by the width of the pool. This approach utilizes the swimming direction of the adult salmon to minimize double counting within a pool and prevents groups of fish from swimming around individual crew members and avoiding detection. Upon analysis of individual pool specific counts, uncertain or obvious outliers are excluded, and the estimated number of fish observed for an individual pool is calculated by averaging individual crew member counts. The total estimate of holding salmon is calculated by summing the averages for each pool.

2.3 Pre-spawn Mortality Survey

To assess the number of SRCS that did not survive to spawn over the summer holding period, pre-spawn mortality surveys are conducted annually between June and September. Prespawn mortality surveys are conducted weekly using standard snorkel survey methodology within Butte Creek from Quartz Bowl Pool downstream to PDD (Table 1). The prespawn mortality survey section is divided into six reaches. The first five reaches are subdivided into approximately 0.25-mile segments. The reach described in Table 1 as “Centerville Covered Bridge to Parrott-Phelan Diversion Dam” is subdivided into three segments. All reaches are surveyed once per week. Surveyors spread out and walk or swim downstream, covering both sides of the creek and any side channels.

Table 1: Butte Creek adult SRCS survey locations and distance

Reach	Location	Miles
A (sub reaches 1-5)	Quartz Bowl Pool to Whiskey Flat	1.89
B (sub reaches 1-8)	Whiskey Flat to Helltown Bridge	2.17
C (sub reaches 1-12)	Helltown Bridge to Quail Run Bridge	3.46
D (sub reaches 1-8)	Quail Run Bridge to Cable Bridge	1.93
E (sub reaches 1-7)	Cable Bridge to Centerville Covered Bridge	1.71
Covered Bridge to Parrott-Phelan Diversion Dam	Centerville Covered Bridge to Parrott-Phelan Diversion Dam	3.41
TOTAL		14.57

All Chinook salmon carcasses encountered during the survey are collected and evaluated for their status of decomposition and the presence of a coded-wire tag (CWT). Levels of decomposition are determined by the coloration of the fish’s eyes and gills. Carcasses containing either one clear eye or pink coloration

of the gills are denoted as “fresh” fish. Carcasses failing to contain one of the above-mentioned requirements are denoted as “non-fresh.”

All fresh fish are identified to sex and measured to the nearest millimeter (mm) fork length. Carcasses with a fork length ≥ 600 mm are classified as adult fish, while fork lengths ≤ 600 mm are classified as grilse, or young adult fish. Fresh carcasses possessing an adipose fin are processed and tagged with a unique numbered metal disc attached to the maxilla. Following the attachment of a metal disc tag, carcasses are returned to flowing water to simulate natural downstream dispersal. Decomposing non-fresh carcasses are chopped in half to prevent recounting. Non-fresh previously marked carcasses are either chopped in half or left in place and were recorded as a recovery.

Tissue, otolith, and scale samples are taken from the first 10 fresh carcasses encountered in each reach. Clean scissors are used to cut a small piece (10 sq mm) of tissue from the caudal fin. If all fins are eroded or decayed, a small piece of skin is taken. All samples are placed into a labeled container and scissors are rinsed in fresh water after each collection to prevent cross contamination.

An estimate of the number of SRCS that did not survive to spawn is calculated using the CJS mark-recapture model for open populations (Bergman et al. 2012) using RStudio statistical software (Version 1.3.1093).

2.4 Post-spawn Carcass Survey

To assess the number of SRCS that survived to spawn during the fall, post-spawn carcass surveys are conducted weekly beginning the third week of September and extending through October (approximately seven weeks) by walking and snorkeling six stream reaches between Quartz Bowl Pool and PPDD (Table 1).

All Chinook salmon carcasses encountered while conducting the survey are collected and evaluated for their status of decomposition and the presence of a CWT. Levels of decomposition are determined by the coloration of the fish’s eyes and gills. Carcasses containing either one clear eye or pink coloration of the gills are denoted to be “fresh” fish. Carcasses failing to contain one of the above-mentioned requirements are denoted to be “non-fresh.”

All fresh fish are identified to sex and measured to the nearest mm fork length. Carcasses with a fork length ≥ 600 mm are classified as adult fish, while fork lengths ≤ 600 mm are classified as grilse, or young adult fish. Fresh carcasses possessing an adipose fin are processed and tagged with a unique numbered metal disc attached to the maxilla. Following the attachment of a metal disc tag, carcasses are returned to flowing water to simulate natural downstream dispersal. Decomposing non-fresh carcasses

are chopped in half to prevent recounting. Non-fresh previously marked carcasses are either chopped in half or left in place and are recorded as a recovery.

Tissue, otolith, and scale samples are taken from the first 10 fresh carcasses encountered in each reach. Clean scissors are used to cut a small piece (10 sq mm) of tissue from the caudal fin. If all fins are eroded or decayed, a small piece of skin was taken. All samples are placed into a labeled container and scissors are rinsed in fresh water after each collection to prevent cross contamination.

An estimate of the number of SRCS that survived to spawn is calculated using the CJS mark-recapture model for open populations (Bergman et al. 2012) using RStudio statistical software (Version 1.3.1093).

2.5 Environmental Conditions

Flow data is obtained during both the pre-spawn mortality and carcass survey periods from the CDEC BCK gauge station. Additionally, water temperature data is collected from 3 different holding pools within Butte Creek using Onset Hobo Data loggers.

3. Results

3.1 Vaki Passage

The first adult SRCS documented to pass through the Vaki for the 2021 migration season occurred on February 20 (Figure 2). The Vaki was not operational for half of the SRCS migration season due to a component failure at the end of April, which resulted in an incomplete passage estimate. Prior to equipment failure, the Vaki counted 7,813 salmon traveling upstream through the ladder and migrating into the summer holding habitat. Salmon were observed bypassing the fish ladder and ascending over Durham Mutual Dam on several occasions throughout the migratory season. As a result, passage counts underestimated the actual adult holding population in 2021. Peak number of salmon passing through the Vaki occurred on March 13th and 16th with a total of 779 and 854 salmon respectively. Historical Vaki data on Butte Creek demonstrates SRCS passage into upper Butte Creek can continue through June depending on the water year and flow; however, as a result of equipment failure no passage was recorded after April 14. Figure 2 demonstrates SRCS passage estimates during the period of Vaki operation along with mean daily water temperature (°C) and flow (cfs) from the CDEC BCK gauge.

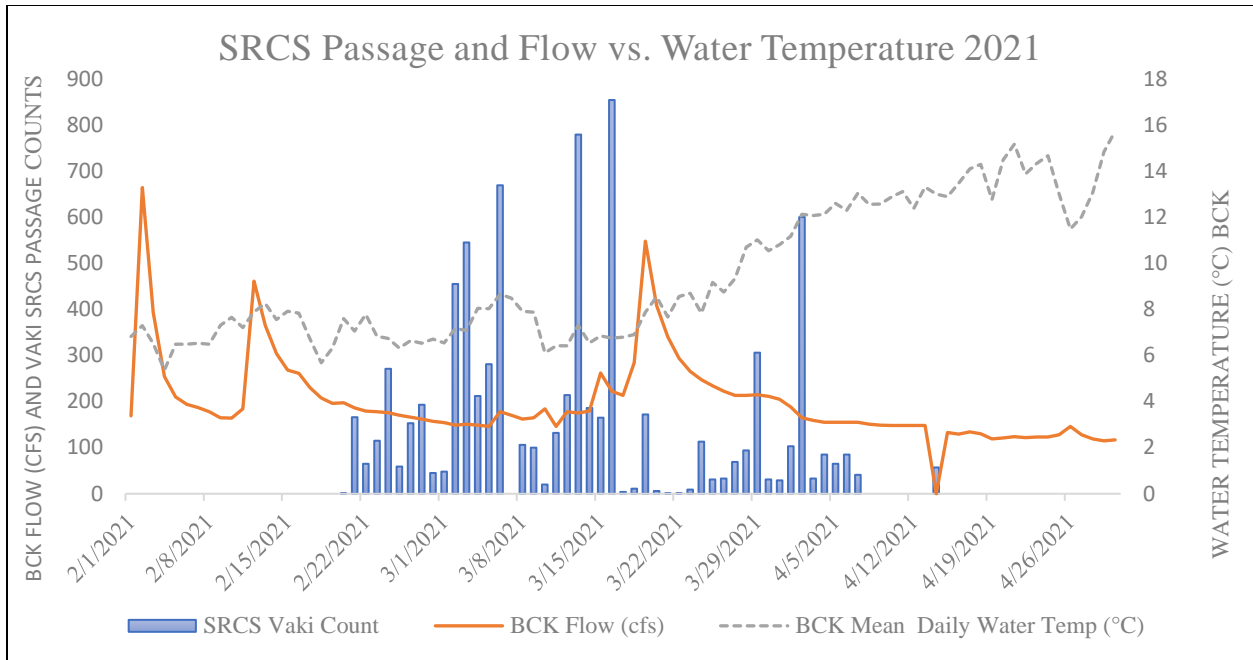


Figure 2: Adult SRCS daily passage estimates from Vaki Riverwatcher counts in 2021 along with water temperature and flow data taken from the BCK gauge (CDEC).

3.2 Snorkel Survey

The annual SRCS snorkel survey was conducted from July 12–16, 2021 from CHD downstream to PPDD (Figure 1). Four reaches between Quartz Bowl Pool and PPDD were surveyed on four consecutive days, July 12–15. A fifth reach from CHD to Quartz Bowl Pool was conducted on July 16.

The 2021 adult snorkel survey estimated 12,252 SRCS adults returned to Butte Creek to hold over summer prior to spawning in the fall (see Nichols 2021). Table 2 displays the range and average number of adult SRCS observed within each of the five reaches. It should be noted that pre-spawn mortalities that took place both before and after the snorkel survey were not included in the estimate. The snorkel survey provides a snapshot in time of the estimated number of live SRCS in Butte Creek and their holding patterns.

Table 2. Range and average number of SRCS observed in each reach during the 2021 Butte Creek Spring-run Chinook salmon snorkel survey.

Date	Reach	SRCS Observed (Range)	SRCS Observed (Average)	% Of Total
7/12	Quartz Bowl Pool to Helltown Bridge	9,742-14,021	11,889	97.03%
7/13	Helltown Bridge to Quail Run Bridge	343 - 379	361	2.95%
7/14	Quail Run Bridge to Centerville Covered Bridge	1-3	2	0.02%
7/15	Covered Bridge to Parrot-Phelan Diversion Dam	0	0	0%
7/16	Centerville Head Dam to Quartz Bowl Pool	0	0	0%
Totals		10,086 - 14,403	12,252	100%

3.3 Pre-Spawn Mortality Survey

Survey Periods

The pre-spawn mortality survey was conducted over 13 survey periods from June 8 to September 16, 2021 (Table 3). Two consecutive survey weeks (August 10–12 and August 17–19) were canceled due to hazardous air quality from the Dixie Fire and were excluded from the survey schedule (Table 3). During late June and early July, critically low flows, and warm water temperatures (70°–73°F) resulted in a large proportion of the returning adult cohort holding in the upper most four miles of Butte Creek’s holding habitat as documented during the holding snorkel survey (Table 2). Beginning July 6th, a notable rise in adult pre-spawn mortalities was documented. On July 13, veterinarians from the CDFW Fish Health Laboratory collected a subset of SRCS carcasses for necropsy. Pathological evaluation of sampled SRCS mortalities identified severe columnaris disease (*Flavobacterium columnare*) as well as moderate ich (*Ichthyophthirius multifiliis*) parasite infestation contributing to the mortality of fish (Richey 2021). Warmer water temperatures and reduced flows in Butte Creek favor development, acceleration, and facilitation of columnaris and ich pathogen transmission. Due to the high numbers of fish observed during the 2021 pre-spawn mortality event, an attempt was made to process and sample each fish that was encountered. However, due to time and staff constraints, it was determined that not all mortalities could be processed within each survey reach and a subsample rate was determined to complete each scheduled event.

Table 3: Summary of survey periods for the 2021 Butte Creek SRCS pre-spawn mortality mark-recapture survey.

Survey Period	Date Range
1	June 8–10
2	June 15–17
3	June 22–June 24
4	June 29–July 1
5	July 6–8
6	July 13–15
7	July 20–22
8	July 27–29
9	August 3–5
10	August 24–26
11	August 31–Sept. 2
12	September 7–9
13	September 14–16

A total of 13,899 SRCS mortalities were either marked for recapture or chopped during the pre-spawn mortality survey. The greatest number of processed mortalities occurred during survey period 6 (July 13–15) when a total of 296 fresh mortalities were tagged and 3,964 non-fresh mortalities were chopped to prevent from recounting. Consequently, this was the same week that the snorkel survey was performed and contributed to the lower estimate (Table 4, Figure 3). Mean water temperature (\pm standard deviation) was recorded in three different pools within the holding habitat for each survey week with the exception of week 13 due to logger malfunction (Table 5, Figure 4). Peak mean water temperatures occurred in all three pools during survey period 4 (June 29–July 1), approximately two weeks prior to peak pre-spawn mortality occurrence (Table 5, Figure 4).

Table 4. Summary of total SRCS mortalities processed by period during the 2021 pre-spawn survey.

Survey Period	Date Range	Disc Tagged	Chopped	Total Mortalities Processed	Percent Total (%)
1	June 8–10	5	4	9	0.06
2	June 15–17	28	17	45	0.32
3	June 22–24	17	22	39	0.28
4	June 29–July 1	28	26	54	0.39
5	July 6–8	70	446	516	3.71
6	July 13–15	296	3964	4260	30.65
7	July 20–22	205	2630	2835	20.40
8	July 27–29	160	3376	3536	25.44
9	August 3–5	126	2349	2475	17.81
10	August 24–26	17	24	41	0.29
11	August 31–Sept. 2	22	17	39	0.28
12	September 7–9	13	9	22	0.16
13	September 14–16	14	14	28	0.20
Total		1001	12898	13899	100%

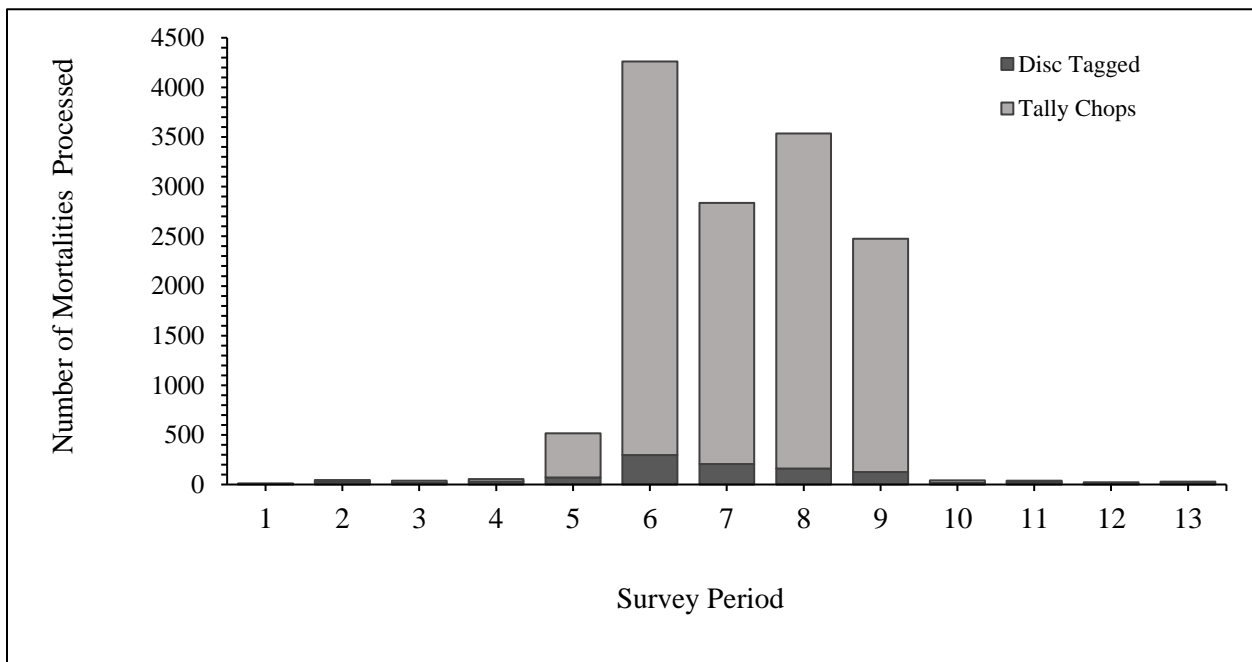


Figure 3: Temporal distribution of marked and chopped mortalities processed during the 2021 pre-spawn mortality survey on Butte Creek.

Table 5. Mean water temperature (°C) (\pm standard deviation) by survey period located in 3 different pools within the summer holding reaches of Butte Creek. Water temperatures for week 13 were lost and not recorded.

Survey Period	Quartz Bowl	Pool 4	Centerville
1	15.81 \pm 1.78	16.81 \pm 1.69	17.74 \pm 1.63
2	17.23 \pm 0.76	18.36 \pm 0.86	18.97 \pm 0.80
3	19.21 \pm 0.27	20.17 \pm 0.42	20.77 \pm 0.53
4	20.41 \pm 0.43	21.71 \pm 0.51	22.76 \pm 0.80
5	19.88 \pm 0.36	20.93 \pm 0.43	22.05 \pm 0.27
6	19.54 \pm 0.86	20.5 \pm 0.83	21.5 \pm 0.77
7	18.33 \pm 0.54	19.3 \pm 0.60	20.43 \pm 0.81
8	18.5 \pm 0.49	19.38 \pm 0.49	20.23 \pm 0.52
9	18.39 \pm 0.81	19.29 \pm 0.90	20.15 \pm 0.97
10	16.51 \pm 0.23	17.33 \pm 0.37	18.32 \pm 0.22
11	16.25 \pm 0.69	17.18 \pm 0.64	18.08 \pm 0.73
12	15.65 \pm 0.09	16.58 \pm 0.24	18.12 \pm 0.63
13	NA	NA	NA

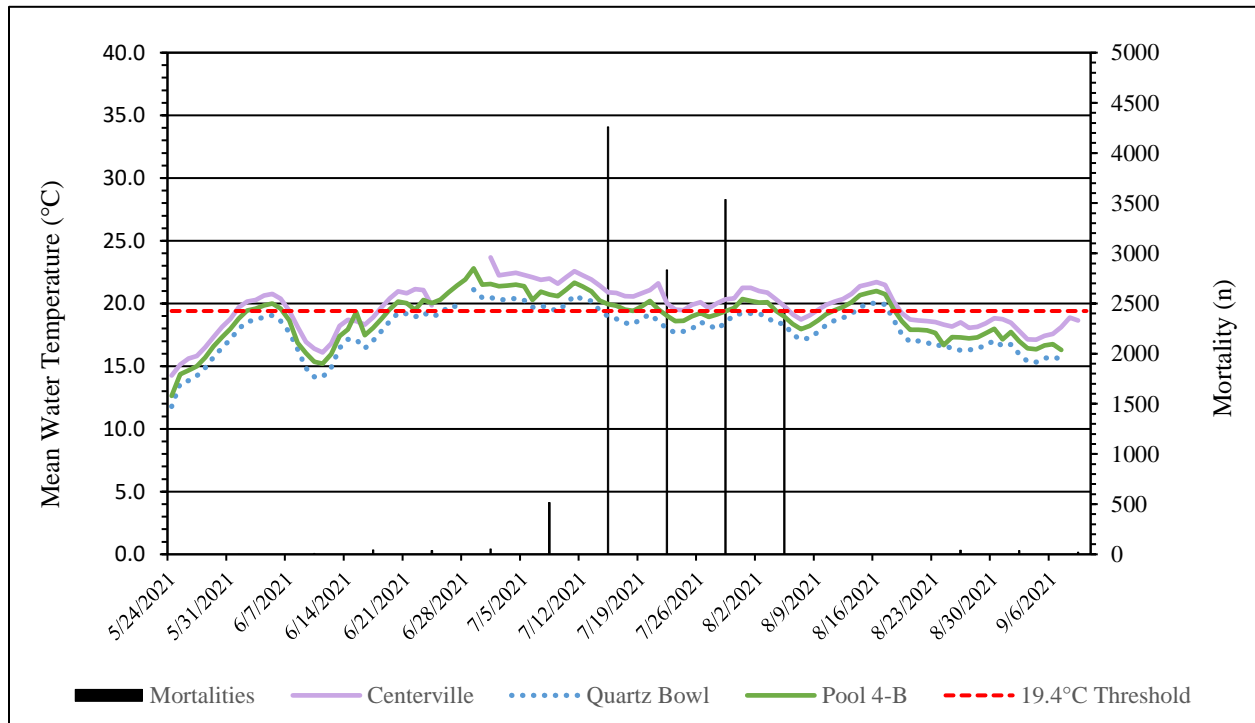


Figure 4: Recorded mean water temperature (°C) within the 3 holding pool locations along with numbers of pre-spawn mortalities recorded throughout the pre-spawn mortality survey.

Length Composition

A total of 1,001 pre-spawn mortalities were processed for fork length and sex determination (Table 6, Figure 5). Females accounted for 62% (n=616) of processed pre-spawn mortalities. Fork length ranged from 50 cm to 91 cm with a mean fork length of 71.0 cm (\pm 5.3). Male pre-spawn mortalities accounted for 38% (n= 385) of processed pre-spawn mortalities and fork lengths ranged from 56 cm to 99 cm with a mean fork length of 74.2 cm (\pm 10.6) (Table 6, Figure 5).

Table 6. Summary of total number of mortalities processed over duration of SRCS pre-spawn survey.

Survey Week	Female	Male	Not Recorded	Total
1	5	0	4	9
2	16	12	17	45
3	6	11	22	39
4	16	12	26	54
5	51	19	446	516
6	220	76	3964	4260
7	119	86	2630	2835
8	80	80	3376	3536
9	68	58	2349	2475
10	6	11	24	41
11	14	8	17	39
12	7	6	9	22
13	8	6	14	28
Totals	616	385	12898	13899
% Total	62%	38%		

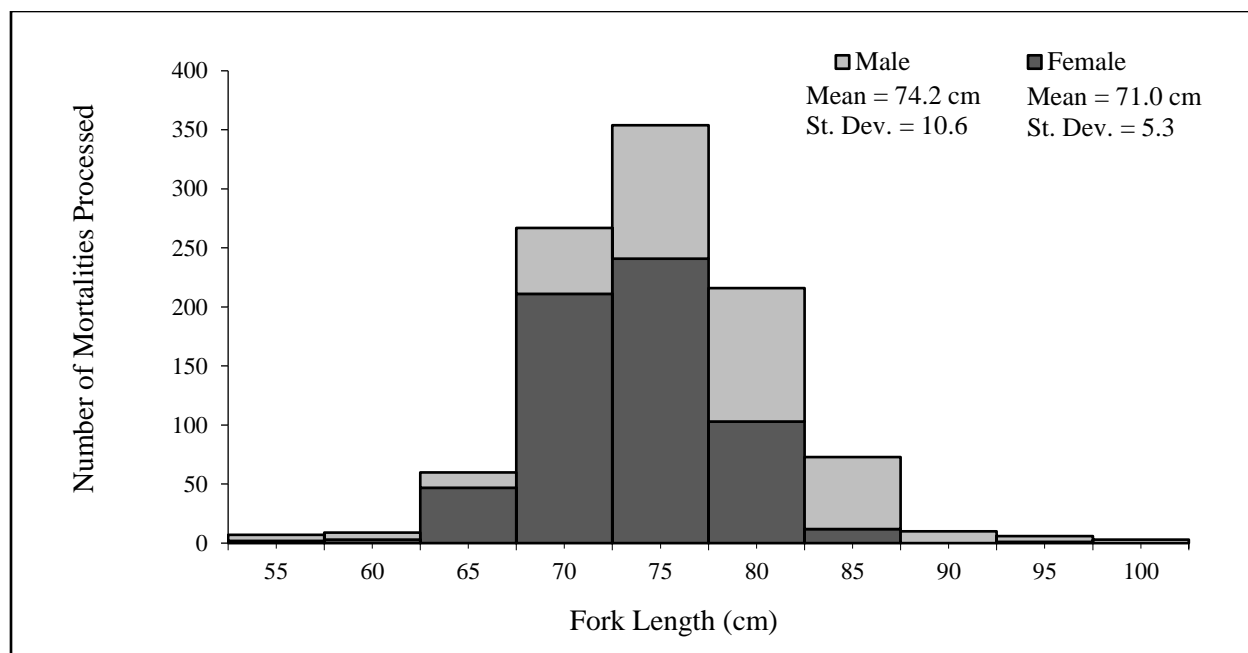


Figure 5: Fork length distribution of male and female mortalities processed during the pre-spawn mark-recapture survey.

Spatial Distribution

Reaches A and B accounted for 81% of observed pre-spawn mortalities (n= 11,303) during the survey (Table 7). These results coincide with the SRCS spatial distribution observed during the holding snorkel survey (Table 2). Additionally, 94.4% of observed pre-spawned mortalities were processed between survey periods 6 through 9 (Table 7). Figure 6 demonstrates the percent weekly mortality contribution by reach for the 2021 pre-spawn survey season.

Estimate of SRCS Prespawn Mortality

The CJS model was used to estimate the number of SRCS that did not survive to spawn (Cormack 1964, Bergman et al. 2012). Three matrix files were created to run the model: a capture history, a chops history, and covariate data. To account for the large discrepancy between tagged mortalities and chops, non-fresh totals were modeled at the same subsample rate as processed fresh mortalities. Additionally, to account for canceled survey weeks, a capture interval gap file was included in the analysis. The CJS model was run using the escape MR package in RStudio (Version 1.3.1093). Upon analysis, the model with the lowest QAICc was N=19,773. The bootstrap estimate of the standard error of the modeled population was 2818.847 (n=1,000 bootstrap iterations). With 95% confidence intervals, the total SRCS population that did not survive to spawn in 2021 is estimated at 19,773 (Figure 7).

Table 7. Summary of pre-spawn mortalities (and percent totals) recorded by survey reach and period.

Survey Period	A	B	C	D	E	Total	%Total
1	2	4	2	1	0	9	0.06
2	12	32	1	0	0	45	0.32
3	20	15	4	0	0	39	0.28
4	18	27	9	0	0	54	0.39
5	225	236	53	2	0	516	3.71
6	2422	1429	378	30	1	4260	30.65
7	NA	1780	933	86	36	2835	20.40
8	2533	NA	780	169	54	3536	25.44
9	1211	1220	NA	35	9	2475	17.81
10	28	7	6	0	0	41	0.29
11	27	10	2	0	0	39	0.28
12	14	8	0	0	0	22	0.16
13	15	8	5	0	0	28	0.20
Totals	6527	4776	2173	323	100	13899	100%
% Total	46.96	34.36	15.63	2.32	0.72	100%	

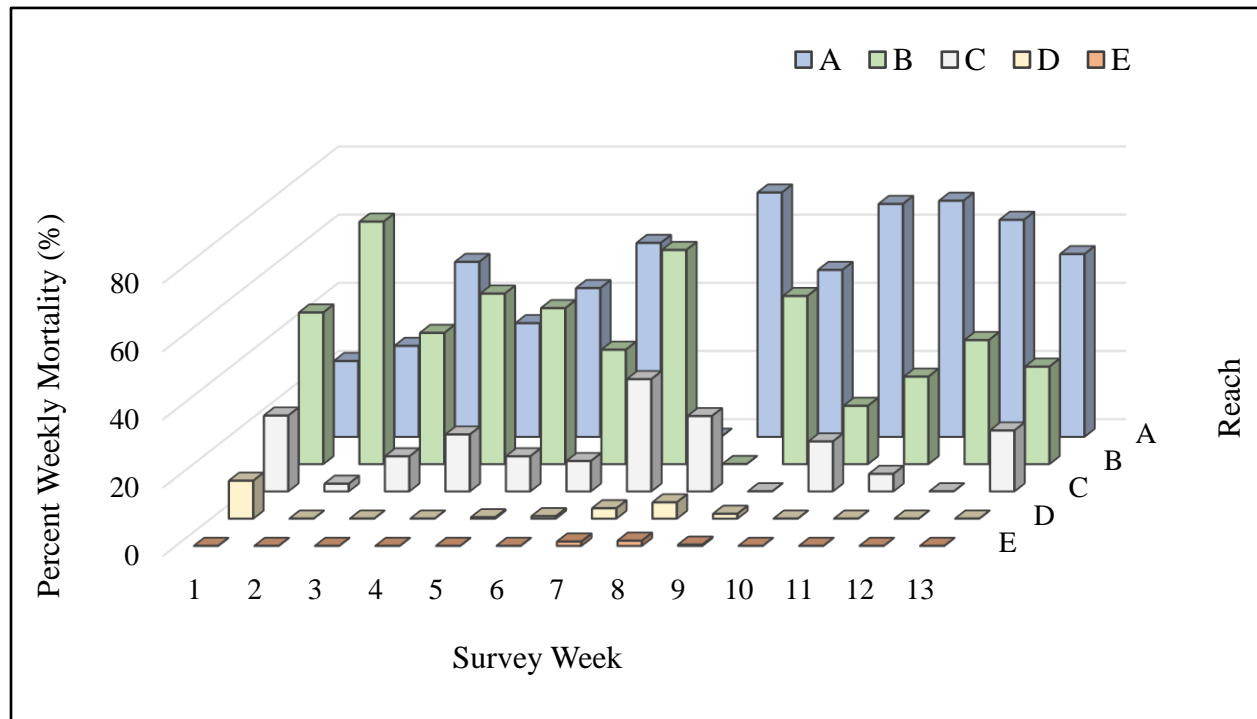


Figure 6: Percent total of SRCS pre-spawn mortalities recorded by reach during the 2021 pre-spawn mortality survey.

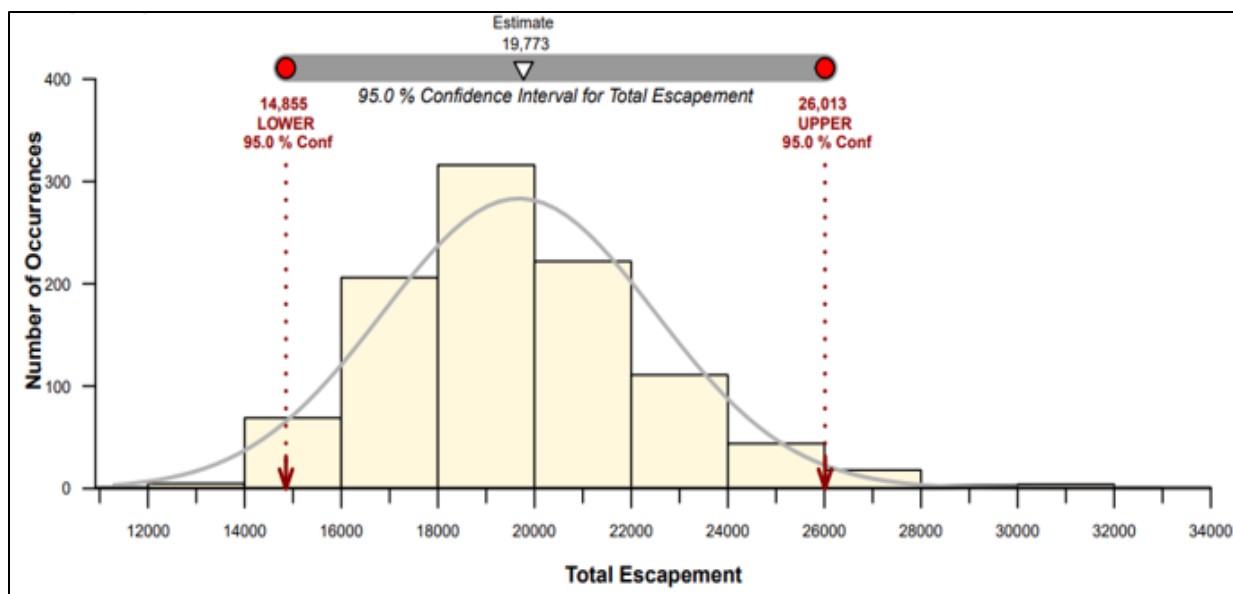


Figure 7: Modified Cormack Jolly-Seber (CJS) histogram of 1,000 bootstrap iterations and 95% confidence intervals.

3.4 Post-Spawn Carcass Survey

Survey Periods

The carcass survey was conducted over 5 weeks from September 21–October 21 (Table 8). The survey ended prematurely (1 week early) due to a storm event contributing to high flows that would jeopardize personnel safety. All carcasses encountered were processed. Fresh carcasses were marked for recapture and non-fresh carcasses were chopped to prevent from recounting.

Table 8. Summary of survey periods for the 2021 Butte Creek SRCS carcass mark-recapture survey.

<u>Survey Period</u>	<u>Dates</u>
1	Sep. 21 to Sep. 23
2	Sep. 28 to Sep. 30
3	Oct. 4 to Oct. 7
4	Oct. 12 to Oct. 14
5	Oct. 19 to Oct. 21

A total of 374 carcass were processed during the 5-week survey. Disc-tagged fresh carcasses accounted for 41% of carcasses (n=153), while the remaining 59% were categorized as non-fresh and chopped to prevent recounting (n=221). Survey period 3 observed the largest number of processed carcasses within a single survey week (October 4 – October 7) (Table 9, Figure 8).

Table 9. Summary of total SRCS mortalities processed by period during the 2021 carcass survey.

Survey Period	Dates	Disc Tagged	Tally Chops	Total Carcasses Processed
1	Sep. 21 to Sep. 23	24	10	34
2	Sep. 28 to Sep. 30	55	42	97
3	Oct. 4 to Oct. 7	51	95	146
4	Oct. 12 to Oct. 14	23	61	84
5	Oct. 19 to Oct. 21	0	13	13
Total		153	221	374
% Total		41%	59%	100%

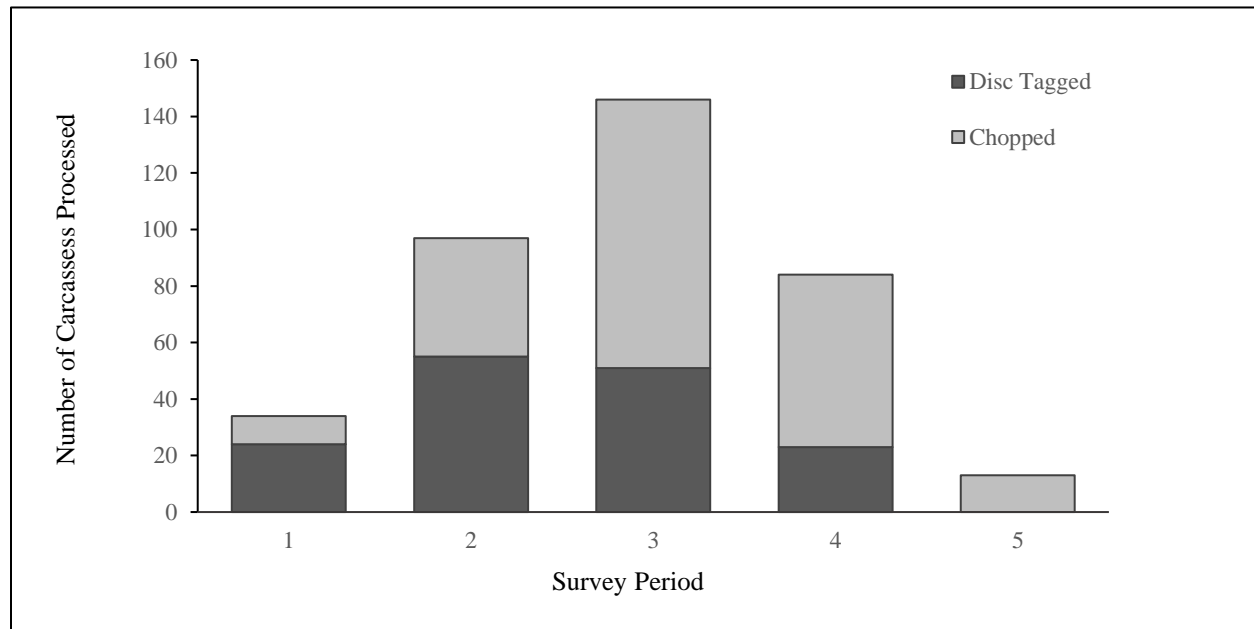


Figure 8: Temporal distribution of marked and chopped mortalities processed during the 2021 carcass survey on Butte Creek.

Length Composition

A total of 374 carcasses were processed for fork length and sex determination (Table 10, Figure 9). Male carcasses accounted for 21% of processed carcasses (n=77). Fork length ranged from 63 cm to 85 cm with a mean fork length of 74.3 cm (± 5.67). Female carcasses accounted for 20% (n= 76) of observed totals and fork lengths ranged from 60 cm to 76 cm with a mean fork length of 70.4 cm (± 4.35) (Figure 9).

Table 10. Summary of total number of mortalities processed over duration of SRCS carcass survey.

Survey Period	Female	Male	Chopped	Total
1	13	11	10	34
2	33	22	42	97
3	16	35	95	146
4	14	9	61	84
5	0	0	13	13
Total	76	77	221	374
% Total	20%	21%	59%	100%

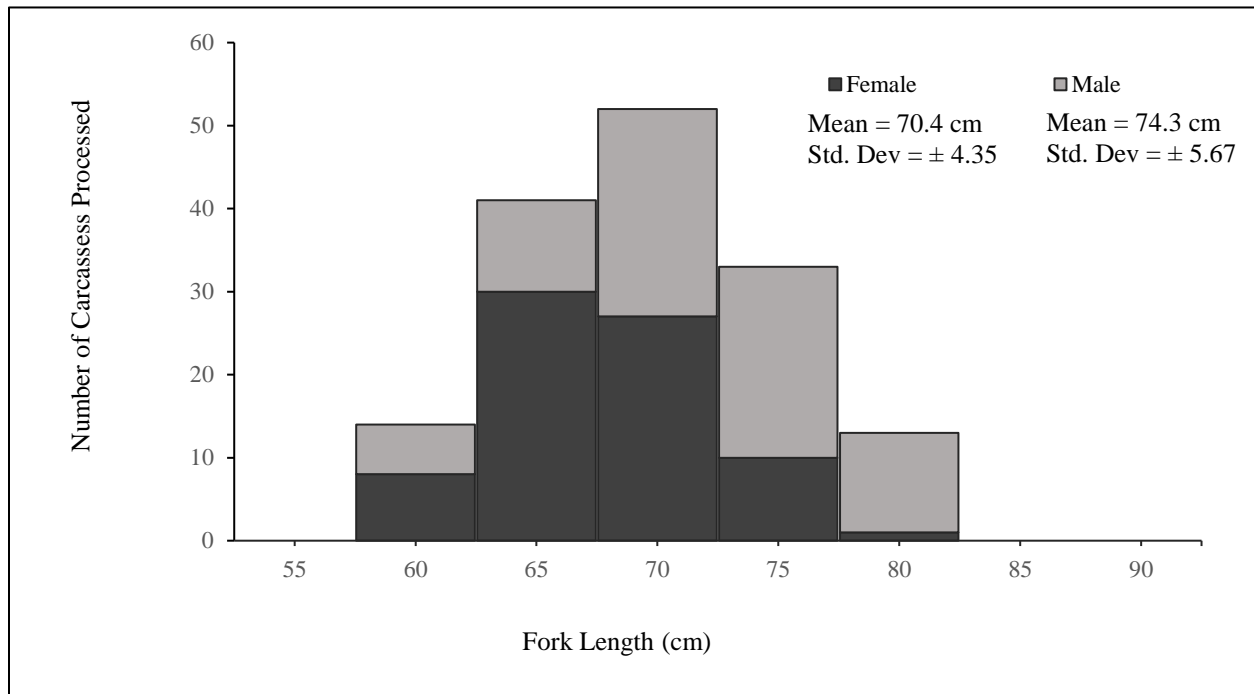


Figure 9: Fork length distribution of male and female mortalities processed during the carcass survey.

Spatial Distribution

Reach A accounted for 32% of total observed carcasses (n=118) followed by Reach C at 28% (n=105) (Table 11). Additionally, 65% of the total number of carcasses were processed between survey periods 2 and 3 (Table 11).

Table 11. Summary of the spatial distribution of SRCS carcasses processed by reach and survey period.

Survey Period	A	B	C	D	E	Total	% Total
1	21	3	10	0	0	34	9%
2	26	29	29	8	5	97	26%
3	47	32	51	12	4	146	39%
4	21	30	11	18	4	84	22%
5	3	3	4	2	1	13	3%
Total	118	97	105	40	14	374	100%
% Total	32%	26%	28%	11%	4%	100%	

Estimate of SRCS Spawning Population

The CJS model was used to estimate the number of SRCS that survived to spawn (Cormack 1964, Bergman et al. 2012). Three matrix files were created to run the model: a capture history, a chops history, and covariate data. The CJS model was run using the escape MR package in RStudio (Version 1.3.1093). Upon analysis, the model with the lowest QAICc was N= 1,807. The bootstrap estimate of the standard error of the modeled population was 451.144 (n=1,000 bootstrap iterations). With 95% confidence intervals, the 2021 Butte Creek SRCS spawning population is estimated between 1,184–2,849. (Figure 10).

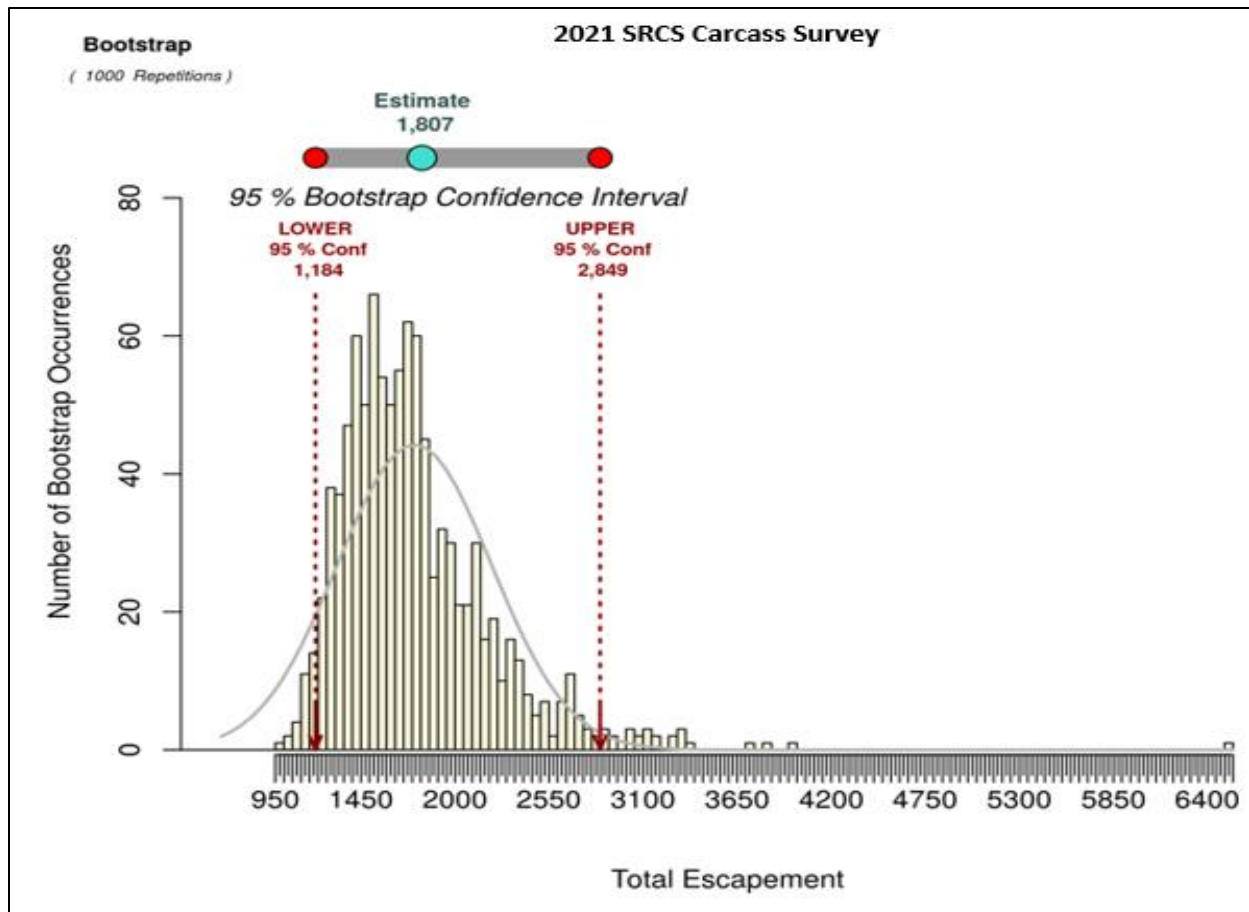


Figure 10: Modified Cormack Jolly-Seber (CJS) histogram of 1,000 bootstrap iterations and 95% confidence intervals.

3.5 Environmental Conditions

Butte Creek water temperature was recorded for a majority of the carcass survey using Hobo Onset loggers and were deployed and retrieved on a weekly basis. Beginning October 21, heavy precipitation resulted in a high flow event. Flows reached levels unsafe for field work and the remainder of the survey for 2021 was canceled (Figure 11). Water temperature data demonstrates a gradual decline throughout the carcass survey with small increasing fluctuations the first and third weeks of October. Mean water temperature for the duration of the carcass survey was 12.1°C (± 0.44), with minimum and maximum temperatures of 8.34 °C and 15.0 °C respectively (Figure 10). Butte Creek flows remained fairly consistent until October 21. Prior to the rain event, mean flow was 73.6 cfs (± 9.9). Maximum flow recorded during the carcass season was 2,304 cfs on October 24 (Figure 11).

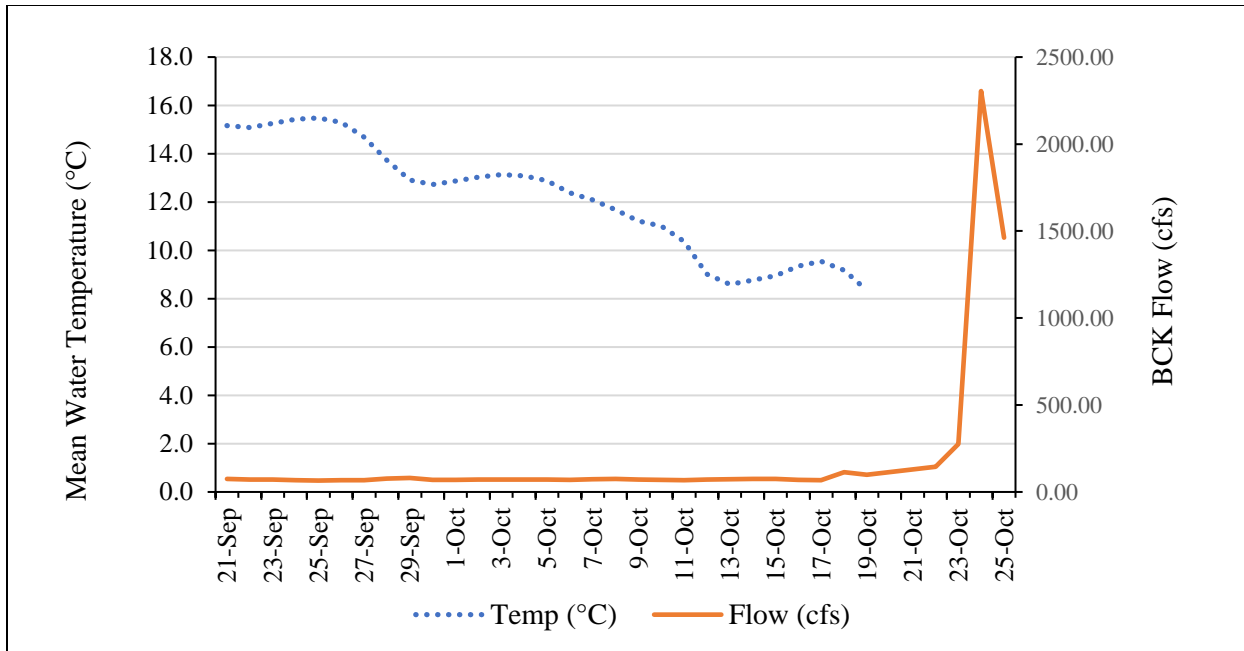


Figure 11: Mean daily river flows (cfs) and water temperatures (°C) observed during the 2021 Butte Creek carcass survey.

4.0 Conclusion

The magnitude of SRCS pre-spawn mortalities that occurred in Butte Creek in 2021 was historical. The only other known SRCS pre-spawn mortality event recorded of similar size in Butte Creek occurred in 2003. Similar to 2021 events, the conditions leading up to the high mortalities observed included sustained warm water temperatures (20.9°C (69.6°F) in Quartz Bowl Pool) and pathogen outbreak resulting in a total pre-spawn mortality estimate of 11,231 SRCS (Ward et al. 2004). The 2021 adult SRCS returning cohort was estimated at over 21,580, and based on field observations and survey estimates, the density of the population in the upper reaches of the holding habitat likely exacerbated the spread of pathogen transmission and contributed to the rapid spike in pre-spawn mortality. Adult SRCS populations returning to Butte Creek will continuously seek cool water to hold over the summer. As water temperatures rise due to drought conditions and climate change, the spatial distribution of holding populations will become more and more compacted within the coolest reaches, increasing the potential for larger pathogen outbreaks and mortality events in future years. CDFW will continue to coordinate efforts with resource agencies and stakeholders to provide the best possible conditions for adult SRCS holding over summer in Butte Creek to help increase their chance of survival to the fall to spawn.

Adult SRCS face many challenges during their journey through the 90-mile migration corridor towards their spawning grounds in upper Butte Creek. Reduced flows and accumulated invasive aquatic vegetation and debris in the Sutter Bypass create poor habitat conditions and can obstruct passage.

Similarly, upstream of the Sutter Bypass, log/debris jams create passage impediments and force adult SRCS to find alternate routes through the Butte Sink, increasing their risk of mortality. Operational constraints of BSOG pose passage challenges for adult SRCS trying to enter Butte Creek through Butte Slough, resulting in large numbers of fish stacked up at BSOG waiting to pass, which contributes to increased poaching opportunities. Additionally, numerous diversions, weirs, and fish ladders are present throughout the migration corridor, which requires returning SRCS adults to expend additional energy to navigate these facilities.

Numerous adult SRCS passage issues were identified by CDFW during the spring of 2021. Large schools of adult SRCS (100 or more) trying to enter Butte Creek at BSOG were documented from March 3, 2021 through April 21, 2021 (McReynolds 2021). In addition to facility adjustments, storm flows helped facilitate passage through BSOG during March, reducing the numbers of adult SRCS milling around the facility in subsequent months. However, during years with low flows in Butte Creek and in absence of spring storms, passage at BSOG will likely continue to be a concern until facility design issues are resolved. On April 18, 2021, CDFW responded to an adult SRCS mortality event at Weir 1 in the Sutter Bypass (Huneycutt 2021). CDFW observed approximately 100 adult SRCS carcasses and 100 live adult SRCS above and below the weir/ladder facility. Based on CDFW's evaluation of the site, the fish ladder at Weir 1 was determined to be impassable to adult salmon due to low flows through the facility. CDFW placed boards in the weir structure and sandbags on the opposite side of the channel to route additional flow towards Weir 1 and into the fish ladder to provide passable flow conditions. CDFW has responded to similar events at Weir 1 in previous years (see Garman 2012 and 2013). Passage concerns for SRCS salmon are likely to continue at Weir 1 in subsequent years during periods of low flow until facility design issues are resolved.

The historic pre-spawn mortality event of Butte Creek SRCS in 2021 along with passage challenges throughout the Butte Creek migration corridor, highlight the negative impacts of repeated low water years, in-stream obstructions, poor habitat conditions, and warming water temperatures. The urgency is greater than ever to collaboratively mitigate passage challenges and adaptively manage flows to reduce mortality and improve survival for one of the last remaining self-sustaining SRCS populations in California. In 2022, CDFW has implemented several different projects with numerous stakeholders in the Butte Creek watershed to better understand and coordinate water management throughout the system, enhance monitoring of SRCS to increase knowledge of their life history, improve habitat conditions for migrating adult and juvenile SRCS, and identify and mitigate passage impediments for adult SRCS.

CDFW partnered with the California Department of Water Resources in March and April of 2022 to remove approximately 15,272 linear feet (2.89 miles) of invasive aquatic vegetation mats within a 10-

mile section of the Sutter Bypass to improve water quality and migration conditions for adult and juvenile SRCS. CDFW also increased monitoring efforts at BSOG and Weir 1 throughout spring 2022 to ensure adult SRCS migration was not impacted by these facilities. Additionally, CDFW is working with landowners in the Butte Sink to identify adult SRCS passage obstructions in Butte Creek caused by accumulated logs and debris and facilitate removal. Further, CDFW has formed a multi-stakeholder group to work collaboratively on water management issues and SRCS passage concerns throughout the Butte Creek watershed. In the near future, CDFW is planning to conduct research investigating thiamine deficiency complex in the Butte Creek SRCS population to gain a better understanding of how this condition contributes as a stressor to wild SRCS, particularly the Butte Creek population, and influences prespawn mortality events. These efforts and studies will provide CDFW and other agencies and stakeholders with the ability to develop tools and strategies to better manage the SRCS population in Butte Creek.

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