

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



# Butte Creek Spring-Run Chinook Salmon Annual Adult Monitoring Report 2022



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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 is one of three remaining Sacramento River tributaries that harbors 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 occupying riffle complexes with substrate conducive to redd development and spawning.

This report provides a summary of the 2022 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 May 2022. The Vaki Riverwatcher detected a partial count of 5,463 salmon traveling through the fish ladder during their migration to summer holding habitat upstream. Subsequently, the annual 2022 Butte Creek SRCS snorkel survey was conducted over five days on July 15, 19-21, and August 9 and estimated 2,852 adult SRCS within the holding habitat (Henley 2022). From June 16 through September 22, a total of 293 mortalities were encountered during the pre-spawn mortality mark-recapture survey producing an estimated 788 SRCS pre-spawn mortalities. This estimate was based on an expansion rate generated from the post-spawn carcass survey Cormack Jolly-Seber (CJS) model and applied to the pre-spawn mortality recapture rate (Bergman et al. 2012). The post-spawn mark-recapture based carcass survey was conducted over five weeks from September 27 to October 27. The estimated 2022 Butte Creek SRCS spawning population was 2,900 based on the modified CJS model. The total 2022 Butte Creek SRCS escapement estimate was 3,688 which includes 788 SRCS pre-spawn mortalities.

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## Acronyms and Abbreviations

BCK	Butte Creek near Chico gauge
CDFW	California Department of Fish and Wildlife
CDEC	California Data Exchange Center
CDWR	California Department of Water Resources
CESA	California Endangered Species Act
CHD	Centerville Head Dam
CJS	Cormack Jolly-Seber
CWT	coded wire tag
HRCB	Honey Run Covered Bridge
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 is one of three remaining tributaries that harbor self-sustaining populations of Central Valley SRCS. The anadromous portion of Butte Creek extends 90-miles from the base of the Centerville Head Dam (CHD) downstream to the confluence of the Sacramento River. Butte Creek enters 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 Quartz Bowl Pool downstream to Parrott-Phelan Diversion Dam (PPDD). Although Quartz Bowl Pool is a natural barrier for adult salmon migration in most water years, adults have been observed above the pool in years with very high flows. Therefore, each year, CDFW surveys the reach from CHD to Quartz Bowl Pool for holding adult SRCS.

Since 1991, CDFW has consistently monitored and estimated adult SRCS populations in Butte Creek using snorkel surveys and throughout the years have added additional monitoring to better document size of spawning populations and pre-spawn mortalities (Ward et al.2004). This report provides a summary of the 2022 SRCS adult monitoring activities conducted by CDFW. Monitoring efforts include:

- Passage monitoring to estimate adults migrating into upper Butte Creek using a Vaki Riverwatcher (Vaki) fish counter.
- A 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 carcass surveys since 2001 and a Vaki installed at Durham Mutual

Diversion Dam Fish Ladder since 2014 to estimate the adult SRCS population on Butte Creek (Garman 2018). Resulting estimates are evaluated along with the holding snorkel surveys. Each survey provides valuable information on adult SRCS including migrating timing, level of pre-spawn 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 provides 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*

The Vaki combines both infrared scanning and video technology to passively monitor adult SRCS passage during the migration season, 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 California Department of Water Resources (CDWR) California Data Exchange Center (CDEC) Butte Creek near Chico (BCK) gauge station to compare SRCS passage with flow and temperature.

The goals of the Vaki monitoring include:

- Produce a passage estimate of adult SRCS migrating into upper Butte Creek holding habitats.
- Document temporal distribution of adult SRCS passage.
- Comparison of adult SRCS passage data with water temperature and flow conditions within Butte Creek.
- Comparison of annual trends and timing of migration patterns of adult SRCS.

### 2.1 *Snorkel Survey*

SRCS adult holding snorkel surveys are conducted annually, generally in July, to estimate the number of SRCS adults successfully returning and holding in Butte Creek over summer prior to spawning in the fall. This survey also provides information regarding the distribution of holding adults. Holding surveys are conducted using standard snorkel methodology within Butte Creek from Quartz Bowl Pool downstream to PPDD.

Data collection and analysis methodologies for this survey were standardized in 2001<sup>1</sup> to provide a total annual escapement estimate by summing the average observed fish count for each pool.

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<sup>1</sup> 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.

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.

## ***2.2 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 starting in June and continue weekly until the first redd is detected in September. Pre-spawn mortality surveys are conducted using standard snorkel survey methodology within Butte Creek from Quartz Bowl Pool downstream to PPDD (Table 1). The pre-spawn 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 “Honey Run 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 spring-run Chinook salmon pre-spawn mortality survey reach locations and length of each reach. \* Note some location names have been changed from previous reports to provide a more accurate description, but physical location has remained the same since 2001.**

<b>Reach</b>	<b>Location*</b>	<b>Miles</b>
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 Honey Run Covered Bridge	1.71
Covered Bridge to Parrott-Phelan Diversion Dam	Honey Run Covered Bridge to Parrott-Phelan Diversion Dam	3.41
<b>TOTAL</b>		<b>14.57</b>

All Chinook salmon carcasses encountered during the survey are collected and evaluated for their status of decomposition and the presence of an adipose fin (which would indicate whether the fish was of natural or hatchery origin). 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  $\geq 600$  mm are classified as adult fish, while fork lengths  $\leq 600$  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. For any carcasses encountered that are missing an adipose fin, the head would be retained for extraction of a coded wire tag (CWT), which indicates the hatchery of origin.

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).

### ***2.3 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 when the first redd is detected in September and extending through October (approximately seven weeks) by walking and snorkeling six stream reaches between Quartz Bowl Pool and PPDD (Table1).

All Chinook salmon carcasses encountered while conducting the survey are collected and evaluated for their status of decomposition and the presence of an adipose fin. 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  $\geq 600$  mm are classified as adult fish, while fork lengths  $\leq 600$  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. For any carcasses encountered that are missing an adipose fin, the head would be retained for extraction of a CWT, which indicates the hatchery of origin.

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 4.1.1).

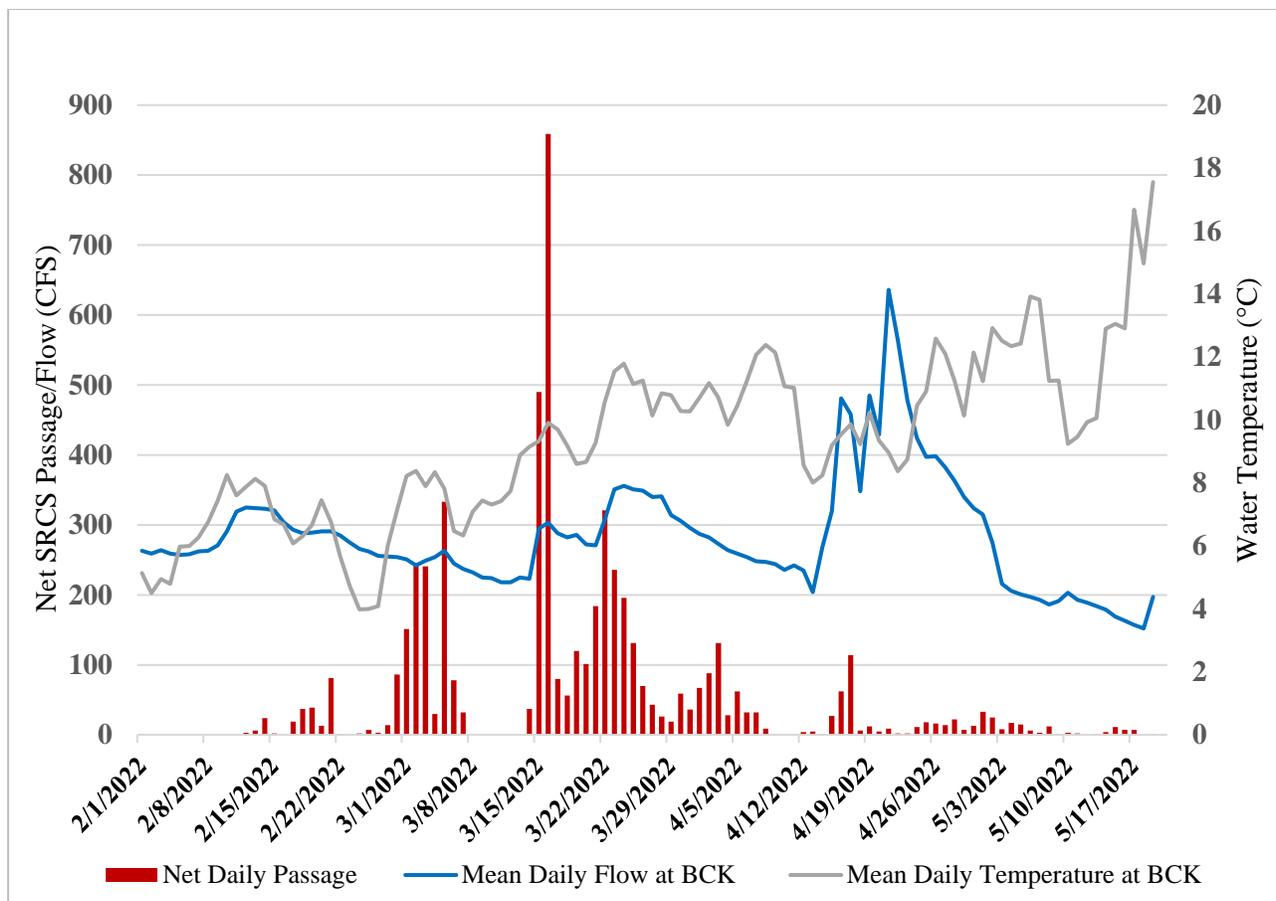
## ***2.4 Environmental Conditions***

Flow data is obtained during both the pre-spawn mortality and post-spawn carcass survey periods from the CDEC BCK gauge station. Additionally, water temperature data is collected from two 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 2022 migration season occurred on February 1 (Figure 2). The peak daily number of salmon passing through the Vaki occurred on March 16 with a total of 859 salmon. Vaki operation ended on May 18 due to a component failure, which resulted in an incomplete passage estimate. Throughout the majority of the SRCS migration season, the Vaki experienced camera issues which resulted in identification only by silhouette data which can be less accurate than the combination of silhouette and video data. Prior to equipment failure, the Vaki counted 5,463 salmon traveling upstream through the ladder and migrating into the summer holding habitat. 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. Butte Creek adult spring-run Chinook salmon daily passage estimates from Vaki Riverwatcher counts in 2022 along with water temperature and flow data taken from the CDEC Butte Creek near Chico gauge.**

### 3.2 Snorkel Survey

The annual Butte Creek SRCS holding snorkel survey was conducted over five days on July 15, 19-21, and August 9, 2022, from CHD downstream to PPDD (Figure 1). One reach between the Honey Run Covered Bridge (HRCB) and PPDD was surveyed on July 15 and three reaches between Quartz Bowl Pool and HRCB were surveyed on three consecutive days, July 19-21. A fifth reach from CHD to Quartz Bowl Pool was surveyed on August 9.

The 2022 snorkel survey estimated 2,852 adult SRCS returned to Butte Creek to hold over summer prior to spawning in the fall (see Henley 2022). 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 occurring before the snorkel survey were not included in the estimate, and the snorkel survey provides a snapshot in time of the estimated number of live adult SRCS in Butte Creek and their holding patterns at the time of the survey.

**Table 2. Range and average number, and percent total of adult spring-run Chinook salmon observed in each survey reach during the 2022 Butte Creek spring-run Chinook salmon snorkel survey.**

Date	Reach	SRCS Observed (Range)	SRCS Observed (Average)	% Of Total
8/9	Centerville Head Dam to Quartz Bowl Pool	0	0	0%
7/19	Quartz Bowl Pool to Whiskey Flat	1,458 - 2,291	1,846	64.73%
7/20	Whiskey Flat to Centerville Powerhouse	820 - 1,083	936	32.82%
7/21	Centerville Powerhouse to Honey Run Covered Bridge	66 - 73	70	2.45%
7/15	Covered Bridge to Parrot-Phelan Diversion Dam	0	0	0%
Totals		2,344 – 3,447	<b>2,852</b>	100%

### 3.3 Pre-Spawn Mortality Survey

#### Survey Periods

The Butte Creek SRCS adult pre-spawn mortality survey was conducted over fifteen survey periods from June 16 to September 22, 2022 (Table 3).

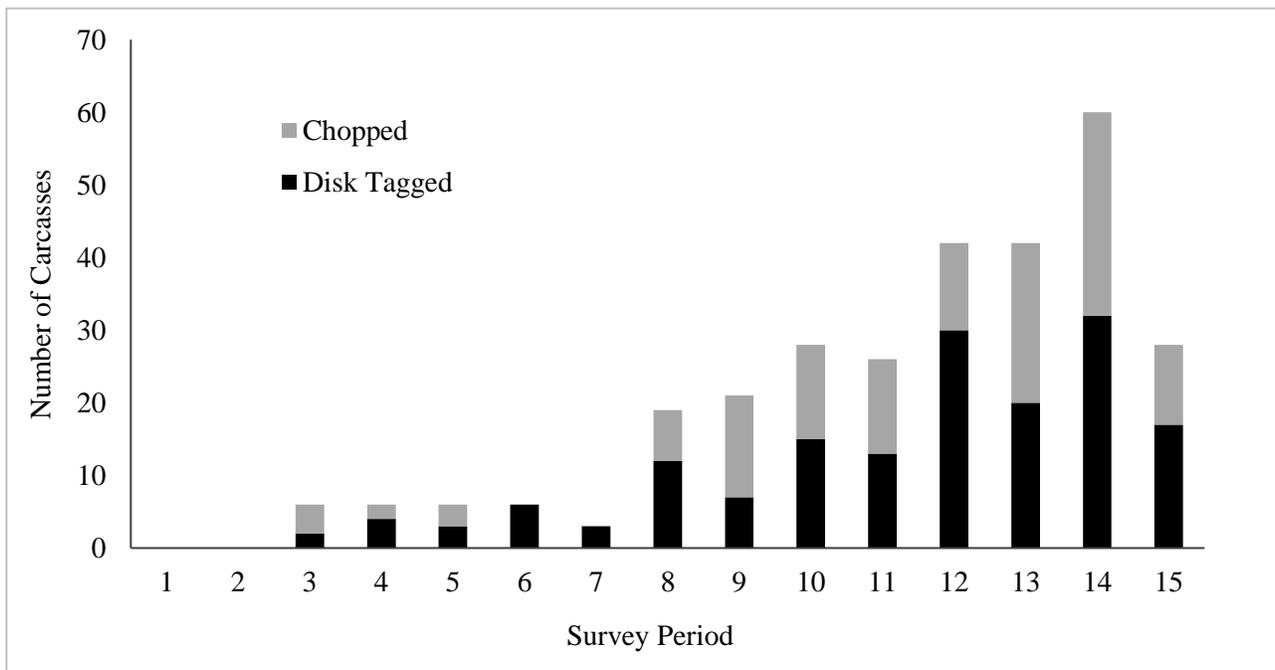
**Table 3: Summary of survey periods and corresponding date ranges for the 2022 Butte Creek spring-run Chinook salmon pre-spawn mortality mark-recapture survey.**

<u>Survey Period</u>	<u>Date Range</u>
1	June 16–17
2	June 21–23
3	June 28–30
4	July 5–7
5	July 12–14
6	July 19–21
7	July 26–28
8	August 2–4
9	August 9–11
10	August 16–18
11	August 23–25
12	August 30–Sept. 1
13	September 6–8
14	September 13–15
15	September 20–22

A total of 293 SRCS carcasses were either marked for recapture or chopped during the pre-spawn mortality survey (Table 4 and Figure 3).

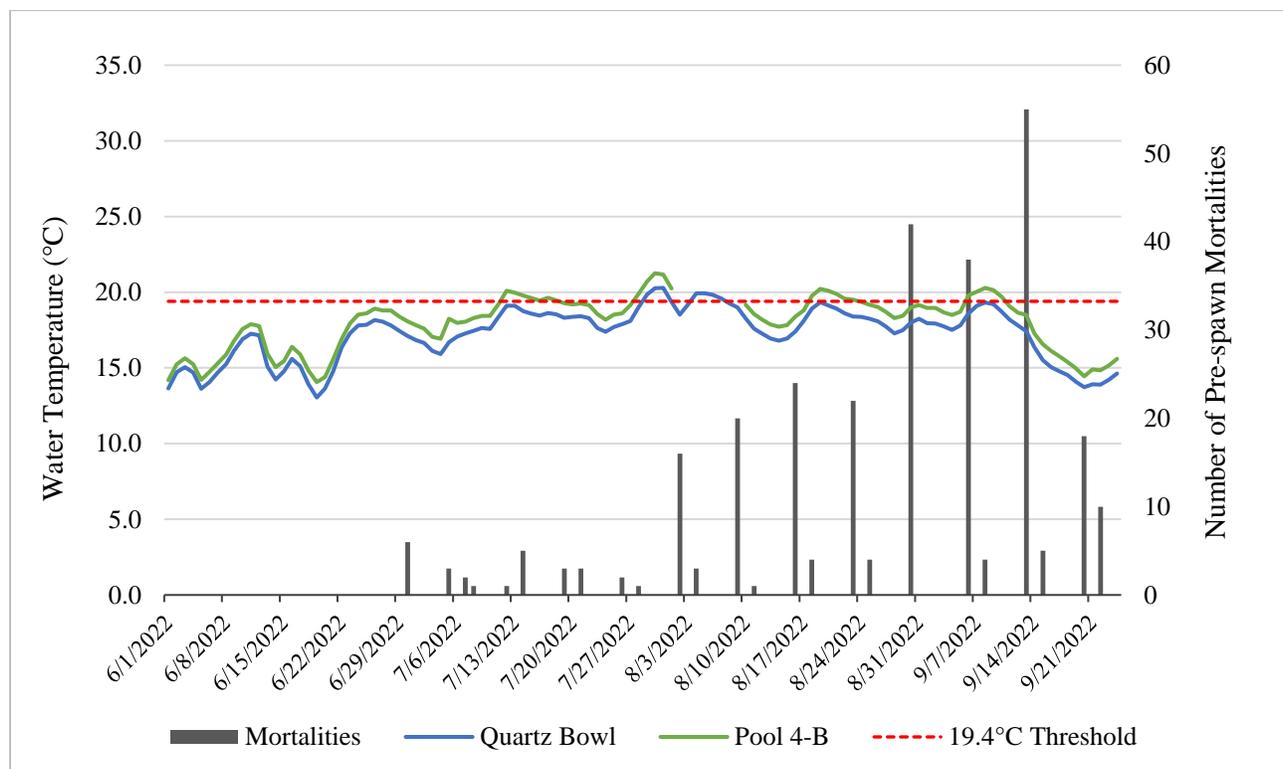
**Table 4. Summary of carcasses processed by survey period during the 2022 Butte Creek spring-run Chinook salmon pre-spawn mortality survey, including the number of carcasses disc tagged and chopped, and the percent of the pre-spawn mortality total.**

Survey Period	Date Range	Disc Tagged	Chopped	Total Pre-spawn Carcasses	Percent Total (%)
1	June 16-17	0	0	0	0
2	June 21-23	0	0	0	0
3	June 28-30	2	4	6	2.05
4	July 5-7	4	2	6	2.05
5	July 12-14	3	3	6	2.05
6	July 19-21	6	0	6	2.05
7	July 26-28	3	0	3	1.02
8	August 2-4	12	7	19	6.48
9	August 9-11	7	14	21	7.17
10	August 16-18	15	13	28	10.56
11	August 23-25	13	13	26	9.87
12	August 30-Sept. 1	30	12	42	14.33
13	September 6-8	20	22	42	14.33
14	September 13-15	32	28	60	20.48
15	September 20-22	17	11	28	9.56
<b>Total</b>		<b>164</b>	<b>129</b>	<b>293</b>	<b>100</b>



**Figure 3. Temporal distribution of marked and chopped carcasses processed during the 2022 pre-spawn mortality survey on Butte Creek.**

The greatest number of processed carcasses occurred during survey period 14 (September 13–15) when a total of 60 carcasses were tagged or chopped to prevent from recounting. Mean daily water temperature was recorded in Quartz Bowl (Reach A) and Pool 4 (Reach B) within the holding habitat during the survey period with the exception of Pool 4 during week 8 due to logger malfunction (Figure 4). Historical temperature monitoring at Quartz Bowl (Reach A) has shown that a mean daily temperature of 19.4°C or higher likely increases the number of pre-spawn mortalities that occur (Ward et al. 2004). Mean daily temperature at Quartz Bowl (Reach A) reached or exceeded the 19.4°C threshold for a total of eight days during the holding period in 2022. Peak mean daily water temperatures occurred in both pools during July 31 with temperature reaching 20.3°C and 21.2°C in Quartz Bowl and Pool 4 respectively (Figure 4).



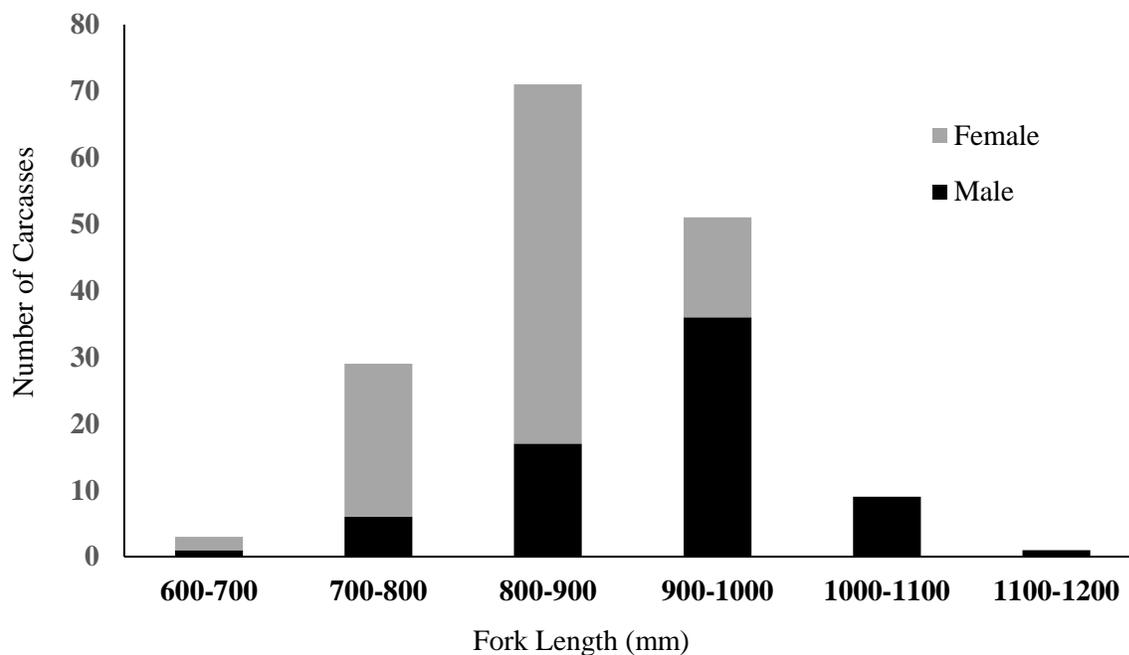
**Figure 4. Recorded mean water temperature (°C) within Quartz Bowl in survey reach A and Pool 4 in survey reach B along with numbers of pre-spawn mortalities recorded throughout the pre-spawn mortality survey. The 19.4°C temperature threshold is indicated on the graph by the dotted red line.**

#### Length Composition

A total of 164 pre-spawn carcasses were processed for fork length and sex determination (Table 5, Figure 5).

**Table 5. Summary of the total number of carcasses processed during the 2022 Butte Creek spring-run Chinook salmon pre-spawn mortality survey, including the numbers of fresh females versus males and number chopped by survey period.**

<b>Survey Period</b>	<b>Female</b>	<b>Male</b>	<b>Chopped</b>	<b>Total</b>
1	0	0	0	0
2	0	0	0	0
3	2	0	4	6
4	3	1	2	6
5	1	2	3	6
6	3	3	0	6
7	2	1	0	3
8	7	5	7	19
9	5	2	14	21
10	9	6	13	28
11	7	6	13	26
12	17	13	12	42
13	14	6	22	42
14	17	15	28	60
15	7	10	11	28
<b>Totals</b>	<b>94</b>	<b>70</b>	<b>129</b>	<b>293</b>



**Figure 5: Fork length distribution of fresh male and female carcasses processed during the 2022 Butte Creek spring-run Chinook salmon pre-spawn mortality mark-recapture survey.**

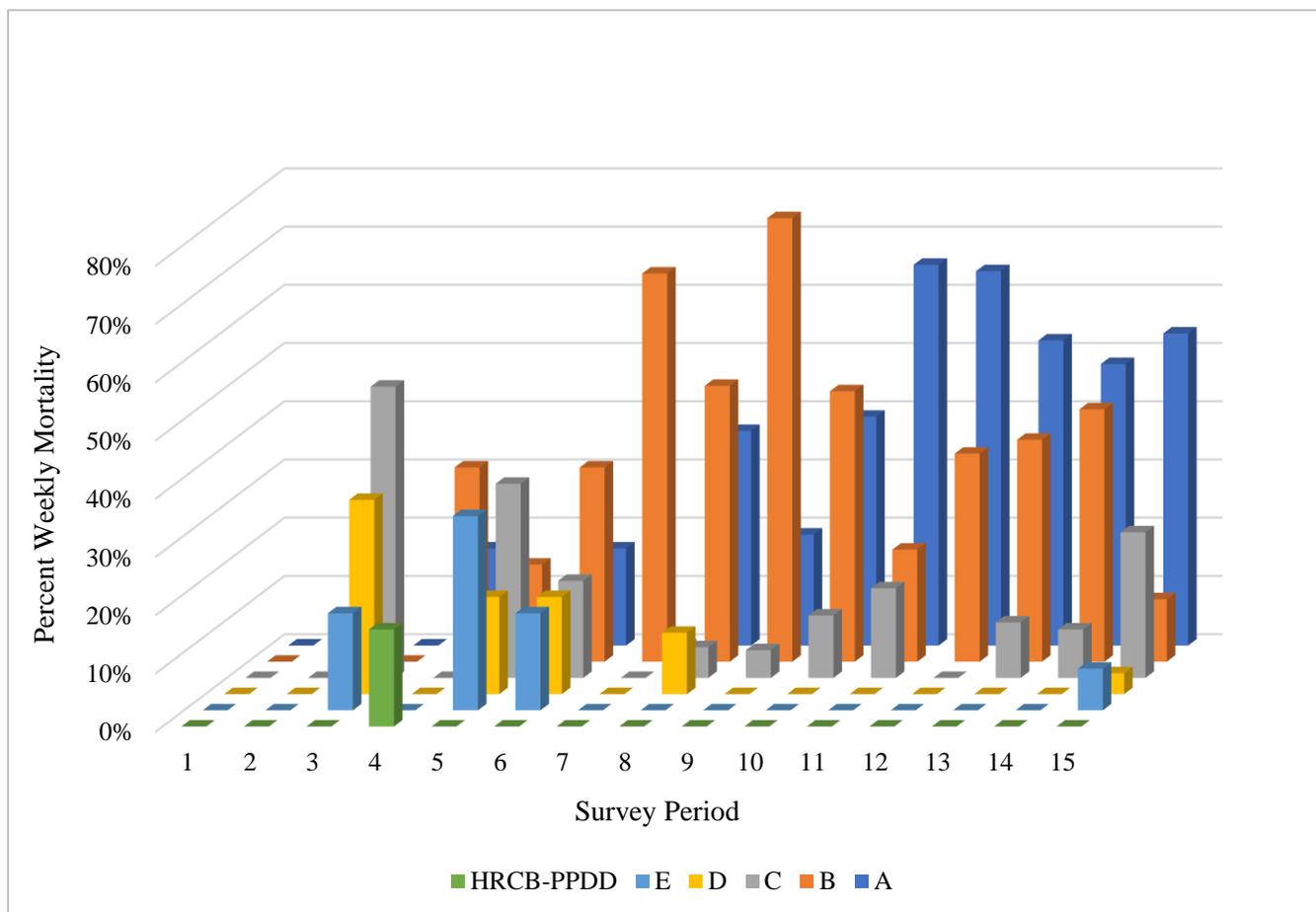
Females accounted for 57% (n=94) of processed pre-spawn carcasses with fork lengths ranging from 630 mm to 990 mm with a mean fork length of 838 mm. Males accounted for 43% (n= 70) of processed pre-spawn carcasses with fork lengths ranging from 660 mm to 1105 mm with a mean fork length of 919 mm (Table 6, Figure 5).

#### Spatial Distribution

Reaches A and B accounted for over 83% of observed pre-spawn mortalities (n= 144) during the survey (Table 6). These results correspond with the SRCS spatial distribution observed during the holding snorkel survey where approximately 97% of SRCS were holding in these reaches (Table 2). Figure 6 demonstrates the percent weekly mortality contribution by survey reach for the 2022 Butte Creek SRCS pre-spawn mortality survey.

**Table 6. Summary of spring-run Chinook salmon pre-spawn carcasses (and percent totals) observed by survey reach and period during the 2022 Butte Creek spring-run Chinook salmon pre-spawn mortality survey.**

<b>Survey Period</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>	<b>HRCB-PPDD</b>	<b>Total</b>	<b>Percent Total (%)</b>
1	0	0	0	0	0	0	0	0.00
2	0	0	0	0	0	0	0	0.00
3	0	0	3	2	1	0	6	2.05
4	1	2	0	2	0	1	6	2.05
5	0	1	2	1	2	0	6	2.05
6	1	2	0	1	1	0	6	2.05
7	0	2	0	1	0	0	3	1.02
8	7	9	1	2	0	0	19	6.48
9	4	16	1	0	0	0	21	7.17
10	11	13	3	1	0	0	28	9.56
11	17	5	4	0	0	0	26	8.87
12	27	15	0	0	0	0	42	14.33
13	22	16	4	0	0	0	42	14.33
14	29	26	5	0	0	0	60	20.48
15	15	3	7	1	2	0	28	9.56
<b>Totals</b>	<b>134</b>	<b>110</b>	<b>31</b>	<b>11</b>	<b>6</b>	<b>1</b>	<b>293</b>	<b>100</b>
% Total	45.73	37.54	10.58	3.75	2.05	0.34	100	



**Figure 6. Percent total of weekly carcasses recorded by survey reach during the 2022 Butte Creek spring-run Chinook salmon pre-spawn mortality survey.**

Estimate of SRCS Pre-spawn Mortality

Due to a low mark/recapture rate, it was not possible to generate a Cormack Jolly-Seber (CJS) estimate for total pre-spawn mortality (Cormack 1964, Bergman et al. 2012). An expansion rate of 2.69 generated from the post-spawn carcass survey CJS model was used which resulted in an estimate of 788 pre-spawn mortalities during the 2022 holding period.

**3.4 Post-Spawn Carcass Survey**

Survey Periods

The post-spawn carcass survey was conducted over five weeks from September 27–October 27 (Table 7). All carcasses encountered were processed. Fresh carcasses were marked for recapture and non-fresh carcasses were chopped to prevent from recounting. During survey period three, reach A was not surveyed due to unexpected property access issues.

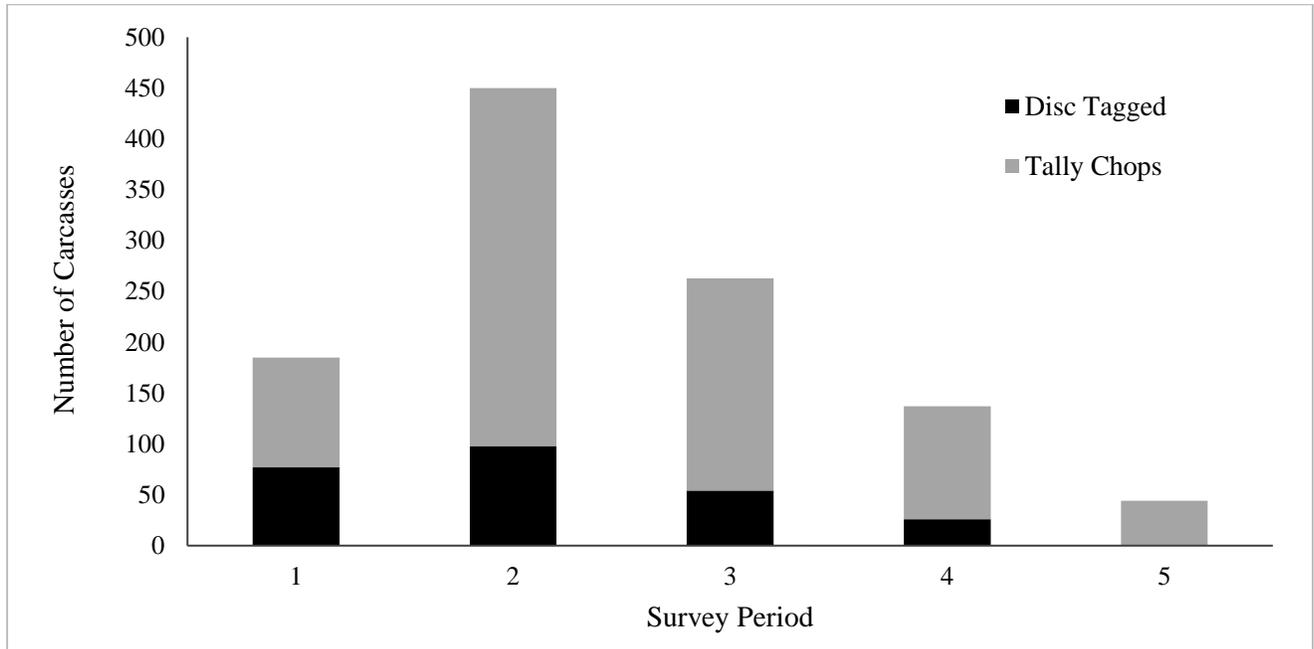
**Table 7. Summary of survey periods (dates) for the 2022 Butte Creek spring-run Chinook salmon post-spawn carcass mark-recapture survey.**

<b>Survey Period</b>	<b>Dates</b>
1	September 27-29
2	October 4-6
3	October 11-13
4	October 18-20
5	October 25-27

A total of 1,079 carcasses were processed during the 5-week survey. Disc-tagged fresh carcasses accounted for 24% of carcasses (n=255), while the remaining 76% were categorized as non-fresh and chopped to prevent recounting (n=824). Survey period 2 observed the largest number of processed carcasses within a single survey week (October 4 – October 7) (Table 8, Figure 7).

**Table 8. Summary of the total carcasses processed by survey period during the 2022 Butte Creek spring-run Chinook salmon post-spawn carcass survey. The number of carcasses disc tagged and tally chopped are listed by survey period.**

<b>Survey Period</b>	<b>Dates</b>	<b>Disc Tagged</b>	<b>Tally Chops</b>	<b>Total Carcasses Processed</b>
1	September 27-29	77	108	185
2	October 4-6	98	352	450
3	October 11-13	54	209	263
4	October 18-20	26	111	137
5	October 25-27	0	44	44
	<b>Total</b>	<b>255</b>	<b>824</b>	<b>1,079</b>
	% Total	24%	76%	100%



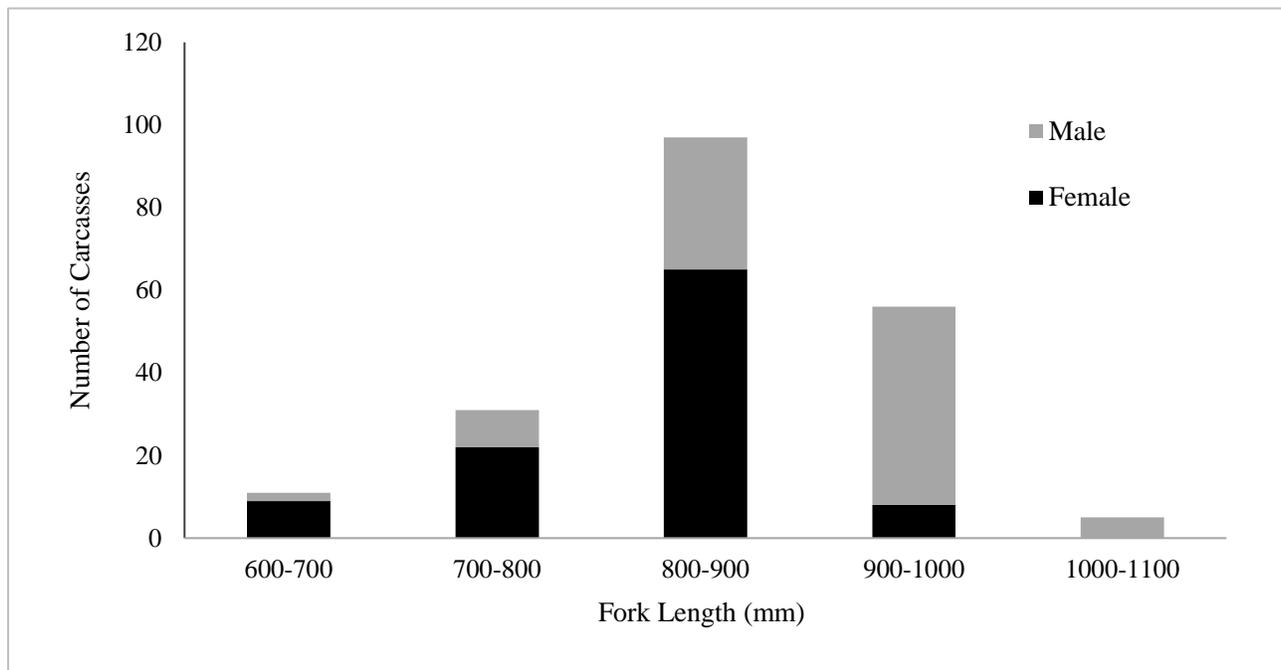
**Figure 7: Temporal distribution of marked and chopped carcasses processed during the 2022 Butte Creek spring-run Chinook salmon post-spawn carcass survey.**

#### Length Composition

A total of 200 carcasses were processed for fork length and sex determination (Table 9, Figure 8). Male carcasses accounted for 48% of processed carcasses (n=96) with fork lengths ranging from 655 mm to 1,035 mm and a mean fork length of 879 mm. Female carcasses accounted for 52% (n= 104) of processed carcasses with fork lengths ranging from 628 mm to 945 mm and a mean fork length of 820 mm (Figure 8).

**Table 9. Summary of the total number of carcasses processed during 2022 Butte Creek spring-run Chinook salmon post-spawn carcass survey, including the number of fresh females versus males, and number of carcasses chopped.**

Survey Period	Female	Male	Chopped	Total
1	41	36	108	185
2	18	25	407	450
3	33	21	209	263
4	12	14	111	137
5	0	0	44	44
<b>Total</b>	<b>104</b>	<b>96</b>	<b>879</b>	<b>1079</b>
% Total	10%	9%	81%	100%



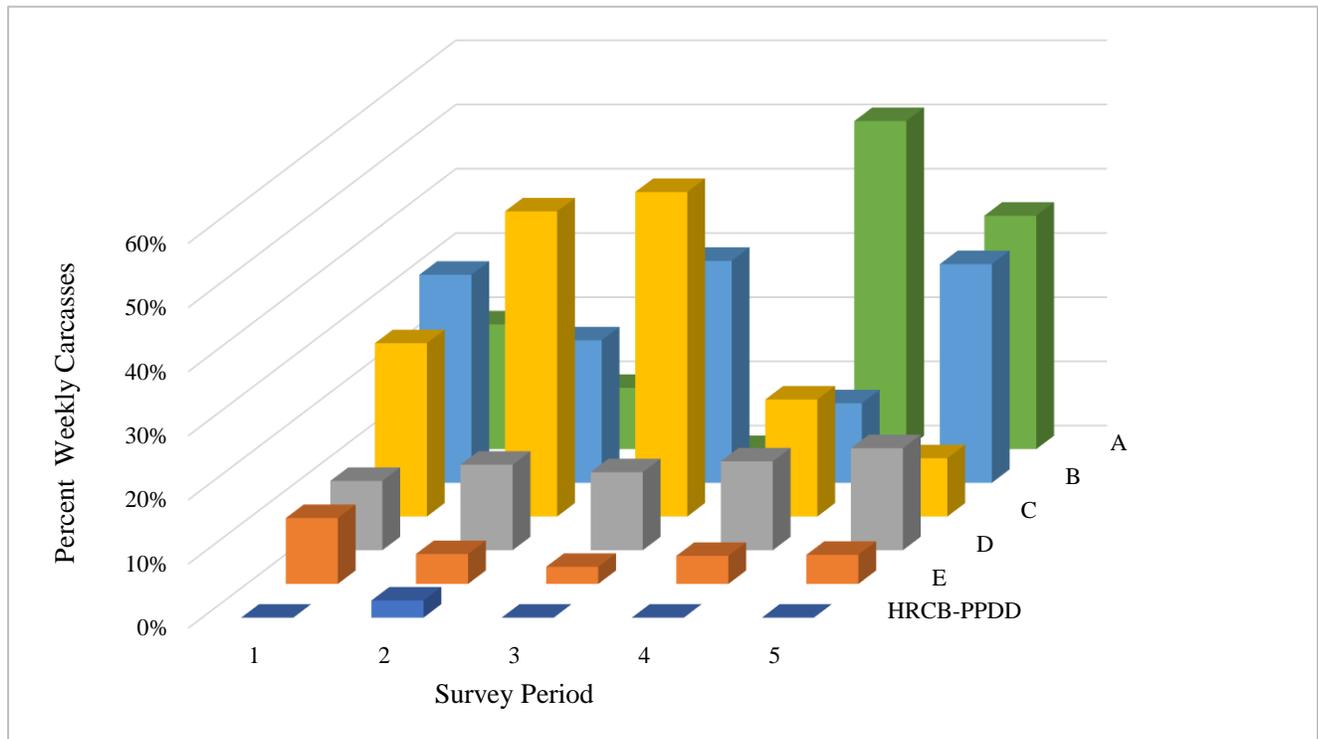
**Figure 8. Fork length distribution of male and female carcasses processed during the 2022 Butte Creek spring-run Chinook salmon post-spawn carcass survey.**

### Spatial Distribution

Reach C accounted for approximately 40% of total observed carcasses (n=426) followed by Reach B at approximately 26% (n=283) (Table 10, Figure 9). Additionally, 65% of the total number of carcasses were processed between survey periods 2 and 3 (Table 10, Figure 9).

**Table 10. Summary of the spatial distribution and percent total of carcasses processed by survey reach and period during the 2022 Butte Creek spring-run Chinook salmon post-spawn carcass survey.**

Survey Period	A	B	C	D	E	HRCB-PPDD	Total	Percent Total (%)
1	36	60	50	20	19	0	185	17.15
2	43	100	214	60	21	12	450	41.71
3	N/A	91	133	32	7	0	263	23.37
4	70	17	25	19	6	0	137	12.70
5	16	15	4	7	2	0	44	4.08
<b>Totals</b>	<b>165</b>	<b>283</b>	<b>426</b>	<b>138</b>	<b>55</b>	<b>12</b>	<b>1079</b>	<b>100</b>
<b>% Total</b>	<b>15.29</b>	<b>26.23</b>	<b>39.48</b>	<b>12.79</b>	<b>5.10</b>	<b>1.11</b>	<b>100</b>	

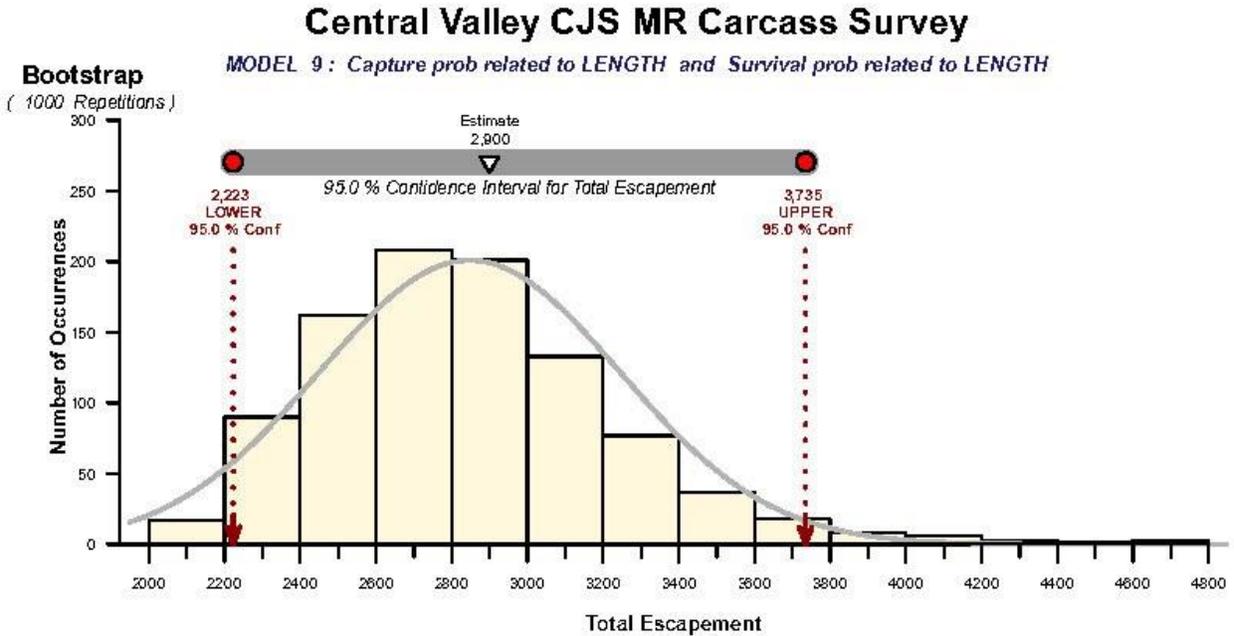


**Figure 9: Percent total of weekly carcasses recorded by survey reach during the 2022 Butte Creek spring-run Chinook salmon post-spawn carcass survey.**

Estimate of SRCS Spawning Population

To estimate the 2022 Butte Creek SRCS spawning population, a CJS model was used (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 4.1.1). Upon analysis, a model was chosen that related capture and survival probability to length, resulting in an estimate of 2,900. With 95% confidence intervals, the 2022 Butte Creek SRCS spawning population was estimated

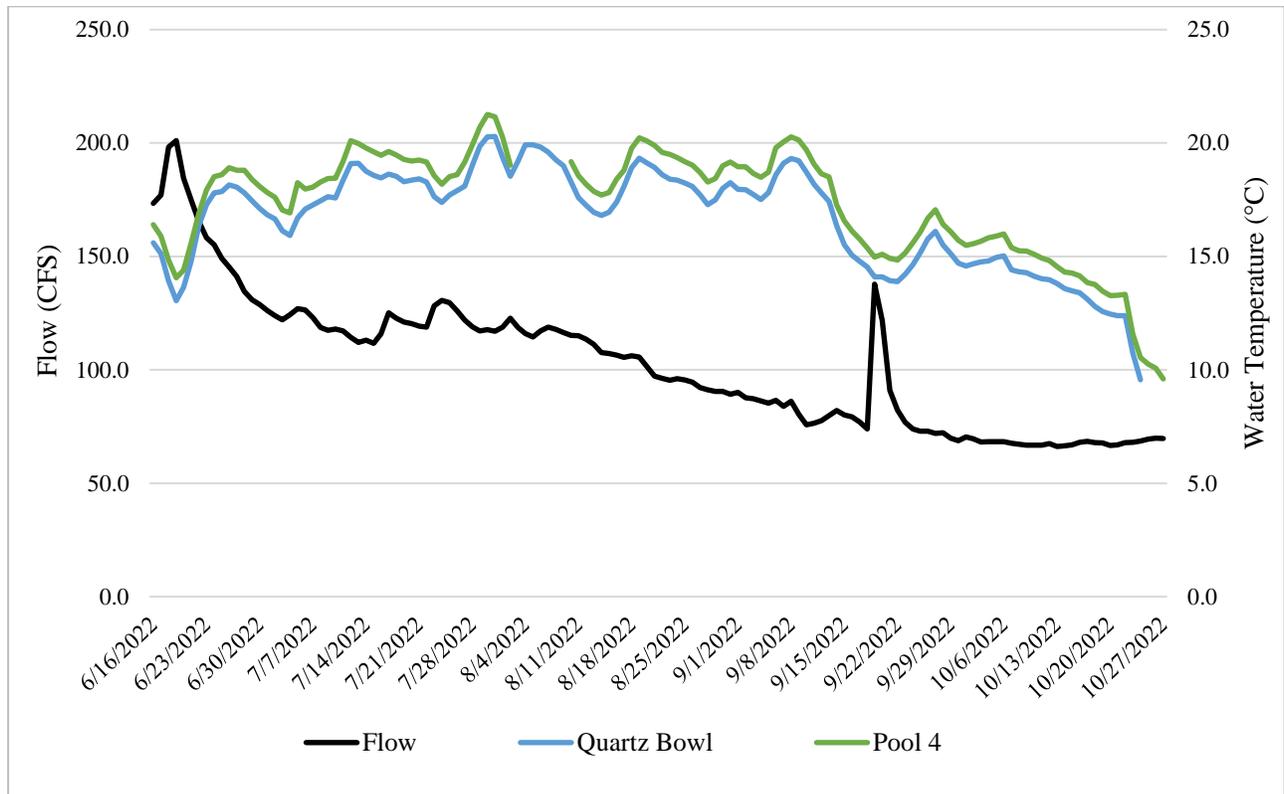
between 2,223 and 3,735. (Figure 10). Combining the pre-spawn mortality estimate (n=788) and the spawning population estimate (n=2900) results in a total escapement estimate of **3,688** SRCS returning from the ocean to Butte Creek in 2022.



**Figure 10: Modified Cormack Jolly-Seber (CJS) histogram of 1,000 bootstrap iterations and 95% confidence intervals. The estimated 2022 Butte Creek spring-run Chinook salmon population was estimated between 2,223 and 3,735 adults.**

### 3.5 Environmental Conditions

Butte Creek water temperature was recorded for a majority of the 2022 Butte Creek pre-spawn mortality and post-spawn carcass survey periods in Quartz Bowl (survey reach A) and Pool 4 (survey reach B) using Onset Hobo loggers and were deployed and retrieved on a weekly basis. Mean daily water temperature during the pre-spawn mortality survey fluctuated throughout the survey period with low temperatures of 13°C and 14.1°C recorded on June 19 in Quartz Bowl and Pool 4, respectively. High temperatures during the pre-spawn survey were recorded on July 30 with Quartz Bowl reaching 20.3°C and Pool 4 reaching 21.3°C. Temperatures during the post-spawn carcass survey ranged from a high of 16.1°C and 17.1°C at Quartz Bowl and Pool 4, respectively, on September 27, to a low of 9.6°C in Quartz Bowl and Pool 4 on October 24 and 27, respectively. During the pre-spawn mortality and post-spawn carcass survey periods, Butte Creek flow ranged from a high of 201.1 cfs to a low of 66.2 cfs, gradually decreasing during the survey periods (Figure 11).



**Figure 11. Observed mean daily river flow (cfs) in Butte Creek, and water temperature (°C) in Quartz Bowl (survey reach A) and Pool 4 (survey reach B) during the 2022 Butte Creek spring-run Chinook salmon pre-spawn mortality and post-spawn carcass surveys.**

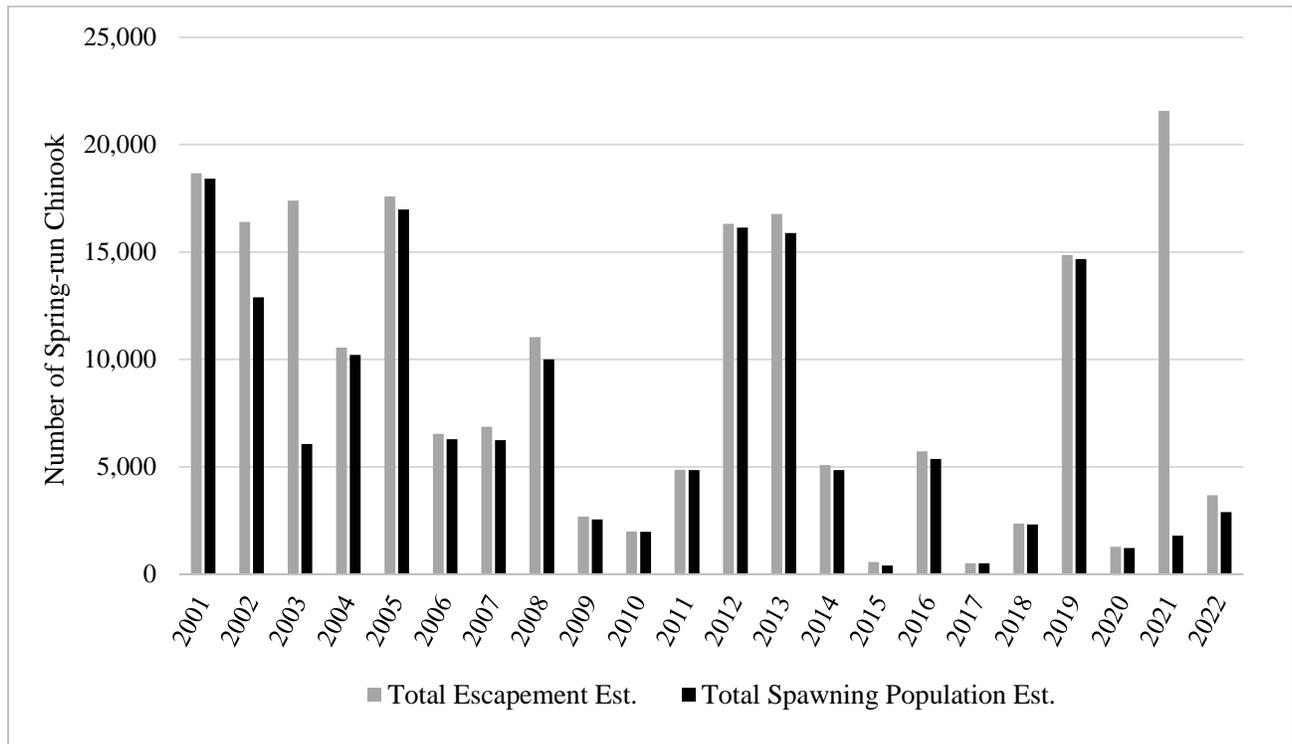
#### 4. Discussion

Throughout the 2022 adult SRCS migration season, the Vaki experienced camera issues, which restricted the identification of SRCS and other fishes solely to inferred scans during passage monitoring. Identification using inferred scans alone can make differentiating SRCS from other large fish in Butte Creek (i.e., Sacramento Pikeminnow and Sacramento sucker) difficult compared to using a combination of scans and video. This potential misidentification of SRCS may have inflated the total Vaki estimate and could explain the difference in the escapement estimate derived from the Vaki (n=5,463) versus the post-spawn carcass survey (maximum n=3,735).

Pre-spawn mortality for 2022 was estimated to be 788 which represented 21.4% of the total escapement estimate. Although not as high as the estimated percent of the population lost to prespawn mortality in 2021 of 91% (see Nichols 2022), this estimate is higher than the average prespawn mortality rate in Butte Creek of 13% since 2001. Warm water temperature is assumed to be a major contributing factor to SRCS prespawn mortality in Butte Creek indicated by spikes in temperature that reach or exceed 19.4°C at Quartz Bowl (survey reach A) as observed during historical surveys (Ward et al. 2004). During the 2022 summer holding

period, the 19.4°C temperature threshold was exceeded on seven days during July and August, followed by an increase of prespawn carcasses encountered during subsequent survey periods (Figure 4). Prespawn mortality may also be attributed to other factors including pathogens and/or stress incurred prior to the holding period (i.e., during upstream migration). No evidence of disease outbreak was noted in 2022 during the summer holding period. As discussed further below, low flow conditions in the creek may have contributed to decreased fitness of SRCS adults migrating upstream in Butte Creek, resulting in prespawn mortality during the summer holding period.

A total of 1,079 carcasses were handled during the post-spawn carcass survey with 255 marked for recapture (Table 8). The CJS model estimated a total of 2,900 adult SRCS survived the summer holding period to successfully spawn during the fall of 2022. Combining the spawning population estimate of 2,900 with the pre-spawn mortality estimate of 788 results in a total adult SRCS escapement estimate of 3,688 in Butte Creek for 2022. Since 2001, the maximum and minimum escapement estimates for Butte Creek SRCS are 21,580 and 515 in 2021 and 2015, respectively, with an average escapement of 9,246, placing 2022 well below the 21-year survey average (Figure 12).



**Figure 12. Estimated escapement and spawning population for Butte Creek spring-run Chinook salmon based on surveys conducted from 2001 through 2022.**

The adult SRCS that returned to Butte Creek in 2022 represent offspring from the 2019 adult SRCS spawning population (brood year (BY) 2019) which was estimated to be 14,679, indicating a very low cohort

replacement rate for 2022. The low adult SRCS spawning population in Butte Creek in 2022 may be contributed to several factors, most notably drought and thiamine deficiency complex (TDC) as discussed below.

Butte Creek juvenile SRCS spawned from BY 2019 adults emigrated to the ocean as juveniles during Water Year (WY) 2020, a dry year, and then returned to Butte Creek from the ocean as adults in WY 2022, a critically dry year; both WYs were concurrent with the most recent California drought. Dry and critically dry water years and drought are generally associated with low instream flows in the Butte Creek watershed, which creates poor habitat and migratory conditions for both juvenile and adult SRCS. Juvenile SRCS that migrated in low water conditions in the Butte Creek watershed in WY 2020 were likely subjected to poor water quality conditions, including high temperature, low dissolved oxygen, and reduced turbidity, which may reduce rearing opportunities, impact prey availability, reduce predator avoidance, and alter routing and emigration timing, which can result in stress and mortality. Additionally, juveniles may also become stranded in unscreened agricultural diversions and canals in low water conditions which can ultimately lead to mortality. Adult SRCS migrating upstream through the Butte Creek watershed in WY 2022 encountered fish ladders, weirs, diversions, and natural obstructions (e.g., log jams and mats of invasive aquatic vegetation) in low water conditions, which created passage impediments and routed fish into areas disconnected from the creek, all of which may have contributed to delayed migration, stress, and mortality.

TDC may also be a contributing factor to the decreased number of adult SRCS returning to Butte Creek to spawn in 2022. TDC was first documented in Central Valley hatcheries in early 2020 when juvenile Chinook salmon (spawned from BY 2019 adults) were observed swimming in corkscrew patterns and dying at unusually high rates. TDC is linked to the ocean diet of adult salmon, which when high in anchovies can create thiamine deficiency in adults and thence their eggs and juveniles (NOAA Fisheries 2021). TDC causes loss of equilibrium, abnormal swimming patterns, lethargy, and early life-stage mortality in juvenile salmon (Mantua et al. 2021). Juvenile salmon spawned from thiamine deficient adults may die as eggs during incubation or shortly after emergence, or as emigrating juveniles which have inhibited swimming behavior and are more vulnerable to predation on their journey to the ocean. Based on this information, it is possible the low numbers of returning SRCS adults to Butte Creek in 2022 is a result of decreased survival of BY 2019 eggs or juveniles in 2019 and 2020 due to TDC.

During the spring of 2022, CDFW implemented several actions in Butte Creek and the Sutter Bypass to offset poor habitat and migratory conditions for SRCS exacerbated by the ongoing drought, and potential survival impacts due to TDC. In a cooperative effort, CDFW and DWR removed extensive mats of floating invasive aquatic vegetation from a 10-mile stretch of the east borrow canal of the Sutter Bypass to improve

passage conditions for adult SRCS. Additionally, debris and log removal were conducted by CDFW at multiple locations along Butte Creek and its tributary Angel Slough to alleviate passage impediments for adult SRCS passage into the upper watershed and for juvenile SRCS emigration through the lower watershed. Further, CDFW formed the ongoing multi-stakeholder Butte-Sutter Bypass Coordinated Operations Group (BSBCOG) with the intent to coordinate water diversions and operations throughout Butte Creek and the Sutter Bypass in an effort to improve salmon passage and survival while maintaining existing water supply needs.

## References

- Bergman, J. M., R. M. Nielson, and A. Low. 2011. California Central Valley Chinook salmon escapement monitoring plan. Pacific States Marine Fisheries Commission and California Department of Fish and Game.
- California Department of Water Resources (CDWR). 2022. California Data Exchange Center (CDEC).<http://cdec.water.ca.gov/>.
- Cormack, R.W. 1964. Estimates of survival from the sighting of marked animals. *Biometrika* 51(3/4): 429-438.
- Garman, C. 2018. Butte Creek Spring-run Chinook Salmon Escapement Survey. California Department of Fish and Wildlife.
- Henley, G. 2022. 2022 Butte Creek Spring-run Chinook Salmon Snorkel Survey Memorandum. California Department of Fish and Wildlife.
- Mantua, N., Johnson, R., Field, J., Lindley, S., Williams, T., Todgham, A., Jeffres, C., Bell, H., Cocherell, D., Rinchard, J. and Tillitt, D., 2021. Mechanisms, impacts, and mitigation for thiamine deficiency and early life stage mortality in California's Central Valley Chinook Salmon. North Pacific Anadromous Fish Commission Technical Report, 17, pp.92-93.
- National Oceanic and Atmospheric Association Fisheries (NOAA Fisheries). 2021. Monitoring thiamine deficiency in California salmon. September 28, 2021. NOAA Fisheries West Coast Region Science and Data. Retrieved January 11, 2023, from: <https://www.fisheries.noaa.gov/west-coast/science-data/monitoring-thiamine-deficiency-california-salmon>.
- Nichols, J. 2022. Butte Creek Spring-run Chinook Salmon Adult Monitoring Annual Report 2021. California Department of Fish and Wildlife.
- RStudio Team (2022). RStudio: Integrated Development for R. RStudio, PBC, Boston, MA. URL <http://www.rstudio.com/>.
- Ward, P. McReynolds, T. Garman, C. 2004. Butte Creek Spring-Run Chinook, *Oncorhynchus tshawytscha* Pre-Spawn Mortality Evaluation 2003. California Department of Fish and Game.