State of California
Department of Fish and Wildlife

Memorandum

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Subject: 2022 Tuolumne River Fall Chinook Salmon Escapement Survey

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NOTE TO THE READERS

2022 Tuolumne River Fall Chinook Salmon Escapement Survey summarizes our annual Chinook (*Oncorhynchus tshawytscha*) salmon escapement survey and analyzes fishery and environmental data on the Tuolumne River. The report documents salmon migration timing, spawning temporally and spatially, and estimates 2022 fall Chinook salmon spawning population in the Tuolumne River. The report discusses challenges faced during our survey.

Information collected is used in the Department's Ocean Salmon Project Coded-Wire Tags recovery report and California Central Valley Chinook Population Database Report known as GrandTab.

All data is reviewed by Ryan Kok and Vanessa Kollmar, Central Region, Lower San Joaquin River Research and Restoration, PO Box 10 La Grange, CA 95329.

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1 INTRODUCTION

The San Joaquin fall-run Chinook salmon is currently a species of concern under the federal Endangered Species Act. Population levels in the Tuolumne River, as measured by escapement of returning adults, has declined in the latter half of the 20th century from a high of approximately 130,000 returning adults in 1944 (Fry 1961) to a low of 77 in 1991 (Neilands et al. 1993). In 2000 population levels increased to 17,873 (Vasques 2001) indicating some recovery; however, by 2009 and 2015 the salmon population had reached all time lows of 124 and 113 fish, respectively. The causes of this species decline can be attributed to many factors which include the reduction of spawning and rearing habitat, which in combination with stream flow management practices are thought to be the major factors limiting overall population numbers. Numerous additional in river factors, many related to flow, such as lack of water, streambed alteration, land use practices, toxic substances, predation, diversion, and gravel mining, have affected the population. In addition to in-river factors, ocean angler harvest and ocean conditions contribute to the complex web of factors which affect the population dynamics of fall-run Chinook salmon within the Tuolumne River.

The California Department of Fish and Wildlife (CDFW), formerly California Department of Fish and Game, has conducted escapement surveys on the Tuolumne River since 1953. Mark-Recapture methods have been used since 1971 to estimate escapement and estimates are available in past annual reports from Turlock Irrigation District (TID) and Modesto Irrigation District (MID). Various population models have been used including Schaefer (1951), Jolly-Seber (1973), Adjusted Peterson (Ricker 1975) and the Cormack-Jolly-Seber (Bergman et al. 2011). This year the Cormack-Jolly-Seber model was used, this population model assumes an open population and calculates the direct maximum likelihood estimates of population size for each survey period which are then used to estimate the total population (Bergman et al. 2011). CDFW escapement surveys have also been used as part of the New Don Pedro FERC Project No. 2299 license monitoring program and annual reporting.

The primary objectives of the Tuolumne River escapement survey are to:

- Estimate the escapement of fall run Chinook salmon on the Tuolumne River.
- Evaluate the distribution of spawning throughout the study area.
- Collect fork length and sex data.
- Collect and analyze coded wire tag data from hatchery fish.
- Collect scale and otolith samples for age determination, and subsequent cohort analysis.

2 METHODS

General Information

Chinook salmon escapement surveys on the Tuolumne River typically begin around the first week of October and extend into the end of December or early January. The study area is surveyed weekly to monitor the distribution of spawning and to record the number of carcasses found within the study area. Crew members float downstream in a drift boat searching for carcasses, counting live fish and documenting redds in each riffle and subsequent pool. Occasionally, crew members get out of the boat to walk along the sides of the river in search of carcasses that may be difficult to see from the boat. When a carcass is located, it is gaffed out of the water and held on the boat until the entire riffle section (riffle and adjacent downstream pool) has been completely surveyed. All carcasses found within a riffle section are processed after the area has been completely searched. "Processing" involves the determination of condition, sex, and fork length, along with retrieval of scale, otolith samples, and the head of adipose clipped fish to extract coded-wire tags. Once all carcasses found within a riffle section have been processed and returned to the tail end of the riffle, the survey crew resumes floating downstream. The same procedures are followed for each subsequent riffle/pool combination until the entire river section has been completed.

The duration of the survey depends on the presence of new carcasses in the river. Tagging continues until there are less than five new carcasses found in a survey week. After tagging has ceased, surveys continue for two more "recovery" weeks. Data collection remains the same for the "recovery" weeks.

Study Area

A total of 30.5 river miles were surveyed as part of the Tuolumne River carcass survey (Figure 1). The survey area was divided into five sections with Section 1 being the upstream most reach. Section 1, also referred to as the primary spawning reach, extends from riffle A1 at river mile 52.0 near La Grange Dam downstream to Basso Bridge at river mile 47.5. Section 2 extends from Basso Bridge down to the Turlock Lake State Recreation Area (TLSRA) at river mile 41.9. Section 3 extends from TLSRA to riffle S1 at river mile 34. Section 4 extends from riffle S1 downstream to Fox Grove Fishing Access at river mile 26. Section 5 extends from Fox Grove Fishing Access to Santa Fe Rd. at river mile 21.5 however this section was not surveyed in 2022.

Riffle Identification

All riffles in the study area have been identified and mapped using a Trimble GPS unit and the GIS computer program ArcView. Each riffle was systematically re-named in 2001 from upstream to downstream using sequential letter/number designations for river mile and riffle number within each river mile, respectively. For example, the first riffle surveyed below La Grange Dam in the first river mile (51) is named A1. This numbering system is a departure from the historical riffle numbering system; the new riffle identification system is more conducive to editing and tracking riffles as river morphology changes. Changes in riffle locations, which may occur during high flow periods, will affect riffle names only within a river mile. Riffles were re-catalogued after the 2017 survey season (Table 1).

Redd and Live Fish Counts

Weekly redd and live fish counts are conducted during the entire duration of the carcass survey. These counts use the riffle identification system noted above. Counts are made using tally counters as the field crew floats downstream through each riffle, but no efforts are made to survey the entire riffle for redds, nor are there any efforts to avoid counting the same redd over multiple weeks. The single pass method is used for conducting redd and live fish counts. Generally, one person remains responsible for redd counting throughout the entire season because, in doing so, there is less variability in the data. Live fish are counted once they swim upstream past the boat to prevent double counting.

Carcass Condition

The condition of each carcass dictates how each fish will be processed. Fresh and decayed carcasses are tagged and used for sample collection while skeletons are only counted and checked for an adipose clip. A carcass with at least one clear eye is classified as “fresh” (Figure 2). Carcasses that have cloudy eyes are considered “decayed” (Figure 2). “Skeletons” are carcasses judged to be in such an advanced state of decay that they are unlikely to have the same probability of recapture as fresh or decayed specimens (Figure 3). Skeleton condition ranges from a fungus covered carcass to an actual skeleton. Fish with obvious marks of predation are also considered skeletons and identified as such on the datasheet. Skeletons are enumerated and then chopped in half before returning to the river to avoid double counting. Carcasses with an aluminum jaw tag are considered “recoveries” indicating they have previously been caught and sampled, so only the jaw tag number is recorded.

Assignment of Unique Identification Number

Each carcass, except for skeletons, is assigned a unique identification number using a numbered metal tag, which is affixed to the bottom jaw (Figure 4). This number identifies each individual carcass throughout the season so that it can be identified if found again at a later date. Newly processed carcasses are returned to moving water at the tail end of the riffle above the pool from which they were collected, for recovery in subsequent weeks.

Tag Recoveries

Carcasses are considered recoveries if they are found with a jaw tag from subsequent weeks of tagging. Each recovery tag number is recorded by the unique jaw tag number before returning the carcass back into the water at the bottom end of the riffle. Recovery totals are essential in calculating annual population estimates because they determine the overall success rate of the field crew’s ability to locate carcasses in the river.

In past years’ escapement surveys, previously tagged carcasses were chopped in half upon recovery to prevent multiple recaptures. Since 2008, tagged carcasses were recovered as many times as they were found, and returned to the water intact. Tagged carcasses were chopped when the carcass no longer passed the “shake test”, or signs of predation were found. A shake test is performed by lifting a carcass out of water by the lower jaw using a hay hook. If the lower jaw begins to detach then the fish is chopped. This multiple recapture data is used to determine the longevity of carcass retention within the river system. Multiple recoveries are also used to generate a unique capture history for all tagged fish which is used in the Cormack-Jolly-Seber super-population estimate.

Coded-Wire Tags

Each salmon carcass encountered, including skeletons, is checked for the presence or absence of an adipose fin. Individuals lacking an adipose fin were raised in a hatchery and usually have a metal, coded-wire tag (CWT) implanted inside their head. Coded-wire tags are collected and later analyzed as part of survival testing of marked out-migrating smolts. Coded-wire tag returns provide information on hatchery contribution rates and can be used to analyze the incidence of straying from other river systems. Coded-wire tag data is also being used to validate scale and otolith age determination work.

Survey crews remove the upper portion of the heads of carcasses and skeletons with adipose clips while in the field. The lower jaw of the carcass remains attached to the rest of the body so that a metal “jaw tag” can still be affixed. Once the head has been removed, it is placed in a labeled “head bag” and catalogued by the unique jaw tag number so that it can be referenced to a specific date and riffle number. Skeletons, which have no unique number, are tracked by the collection date and riffle number. The extraction and analysis of CWT’s is conducted at the Department’s Central Valley Tissue Archive.

Tissue Collection

Scale and otolith samples are taken from as many carcasses as possible. Generally, otolith samples can be obtained from most carcasses, while some individuals may be too badly decomposed to collect scale samples. All samples are catalogued with the unique jaw tag number which allows the samples to be referenced to the specific date and riffle of collection.

Otoliths are extracted from most carcasses found on the river. A horizontal incision is made above the eyes and nostrils towards the posterior end of the head ending above the operculum. The incision is made so that the top of the head can be removed, and the brain capsule exposed. A pair of tweezers are then used to reach inside and extract the otoliths which are the only hard structures found within the capsule. Any adhering tissue is removed from each otolith before placing the pair inside an individual vial labeled with the jaw tag number for later analysis.

Scale samples are collected from the left side of the fish, behind the dorsal fin and above the lateral line. Samples are obtained by using a clean knife to scrape back and forth along the side of the carcass. Approximately twenty or more scales are collected from each carcass which are used to determine the age composition of annual spawning runs. At the end of the season technicians clean approximately 20 individual scales using an ultrasonic cleaner (Cole-Parmer Model 8891 Ultrasonic cleaner). Once the scales are cleaned a trained technician will individually mount 10 “good” (clean, clear focus) scales onto a slide, number the scales and affix a cover slide. Scales are then aged by two trained technicians using microfiche readers. If the two ages disagree a third technician will perform a separate read to help determine the age.

Tissue samples were collected during 2022 from both natural and adipose clipped carcasses at the beginning of the survey until the end of October due to the suspicion of spring run Chinook. One sample, roughly 1 cm^2 was collected from the pectoral fins of carcasses and the least decayed flesh was selected. Fin clips were placed individually in filter paper to dry. Alternative samples were collected from the operculum if there was no tissue left on the fins to sample. All samples were later sent off to be examined off site.

Data Management/Analysis

Datasheets are reviewed by a data entry technician prior to being entered into a Microsoft Access database. All newly entered data goes through a quality control process in which a second individual prints out “line-by-lines” to check for any data entry errors. The biologist receives a copy of the database after all data entry errors have been corrected. Most data analysis is done using Microsoft Excel but the population estimate is calculated using a package written by West Inc. for the statistical program R. Escapement reports generate annual population estimates but also analyze other factors such as population composition, egg production estimates, and distribution of spawning within the river.

CDFW has used a variety of population models since escapement surveys began in 1953. This year the Cormack-Jolly Seber super-population model was used. This model uses recapture histories, number of skeletons per week and covariates (fork length, sex) to estimate escapement. The Cormack-Jolly Seber model assumes an open population (carcasses moving into and out of the population) and allows for a bias in capture probabilities (i.e., large fish are more likely to be captured than smaller ones) (Bergman et al. 2011). Finally, the Cormack-Jolly Seber super-population model can calculate uncertainty in the population estimate (Bergman et al. 2011). Population estimates were calculated using R version 3.3.0 and Cormack-Jolly Seber super-population model version 2.11.R.

3 RESULTS

Survey Duration

The 2022 CDFW Tuolumne River Carcass survey lasted a total of 12 weeks. Surveys were conducted between September 26th, 2022, and December 12th, 2021. Drift boat surveys were conducted weekly between the La Grange Dam and Fox Grove (sections 1-4) for all 12 weeks of the survey except week 12, when only section 1 and 2 were surveyed. Section 5 (between Fox Grove Fishing Access and Santa Fe Road) was not surveyed due to staff constraints. Carcasses were tagged for 12 survey weeks. The survey was terminated on December 12th, 2022 due to staff restrictions related to COVID-19 infections.

Escapement Estimate

A total of 154 carcasses were tagged during the 2022 Tuolumne River escapement survey. An additional 95 skeletons were tallied and chopped, giving a total of 249 individual Chinook salmon handled during the escapement survey.

The Cormack-Jolly Seber super-population model utilizes recapture histories for each fish; these histories include initial tagging, any recaptures, and chops. This model accounts for covariates such as sex and fork length of each fish as well as a weekly count of skeletons. The overall recovery rate for the 2022 escapement survey was about 38.31%.

Based on the Cormack-Jolly Seber model, the 2022 escapement estimate was 466 salmon using the bootstrap method (5,000 replicates), a model which assumes capture probability was related to sex and survival probability was related to length (Figure 5). The 95% confidence interval is 398-526. Male and females accounted for 51.30% and 48.70% respectively of the total tagged fish on the Tuolumne River. Table 2 and Figure 6 show historical Tuolumne River escapement estimates from 1979 to 2022. Table 3 shows weekly totals for tags, skeletons, recoveries, and adipose clipped carcasses.

Live Salmon and Redd Counts

The observation of live fish peaked at week 8, with 259 fish observed, then demonstrated an overall decline throughout the remainder of the survey. Redd counts peaked in week 9 with a total of 286 redds counted and then steadily declined for the remainder of the study period. The maximum number of redds counted for individual riffles is presented in Table 5. Total carcass counts peaked in week 9, at 116 (Table 4 and Figure 7).

Distribution of Spawning

The distribution of spawning is assessed through redd counts, which are conducted in a single pass per week while crews are navigating the riffle and one effort is made to survey the entire riffle is for redds. Redd counts are strongly affected by time of day, visibility, sunlight, wind rippling the water surface, redd superimposition, and other physical factors as well as the natural variability between observers. The limitations of the single pass method for redd counts suggest a more intensive approach should be used but is beyond the funding and scope of this study which is designed to calculate adult escapement and collect biological samples.

Maximum weekly redd counts are used when analyzing the distribution of spawning because no effort is made to avoid counting the same redd every time a riffle was surveyed. Therefore, maximum weekly redd counts provide the minimum estimation of overall spawning within a riffle. The total number of maximum redds observed during the 2022 escapement survey was 365 (Table 5). The results of weekly maximum redd counts indicated that approximately 143 redds or 39.18% of the spawning activity was concentrated in the riffles of Section 1 (Figure 8). Sections 1, 2 and 3, combined, accounted for about 93.97% of the total spawning activity in 2022. The overall percentage of maximum redd counts for sections 2, 3 and 4 were 27.67%, 27.12% and 6.03% respectively. Section 5 was not sampled during the 2022 survey. Section 4 was stopped early at Riffle U1 due to hyacinth limiting any boat passage downstream. This may account for the lower numbers of redds observed in section 4. Maximum weekly redd counts for each riffle over the course of the season is listed in table 5. Figure 9 shows maximum weekly redds observed by river mile.

Population Composition

The total composition for fall-run Chinook salmon population, sampled as carcasses, in the Tuolumne River was 34% natural females, 41% natural males, 15% adipose clipped females, and 10% adipose clipped males (Figure 10). Table 6 shows the yearly percent composition of fall-run Chinook salmon on the Tuolumne River since 1992. Hatchery reared fish with coded wire tags comprised approximately 25% of the total tagged carcasses. In 2022 skeletons were examined for adipose clips, and heads were collected, comprising of 5 fish or 5.26% of the total skeletons handled (95). The total of adipose clipped Chinook (43) makes up 17.26% of all carcasses handled (249). The actual percentage of adipose clipped skeletons is likely higher than observed, particularly since some skeletons lack skin to check for adipose clips. Table 7 shows the tag code, brood year, release year, and release location for all hatchery reared CWT fish collected in the Tuolumne River in 2022. It is important to note that spring run Chinook were encountered this year and this batch of fish is clipped at 100% production rate therefore the proportion of hatchery fish available to be captured was also higher and may not reflect true hatchery origin fish abundance from year to year.

Seventy-five female carcasses, with fork lengths ranging between 58cm and 84cm (average 72.9 cm) were jaw tagged in 2022. Seventy-nine male carcasses were jaw tagged with fork lengths ranging between 48cm and 98cm (average 74.4 cm). Figure 11 shows a length frequency histogram for all female Chinook salmon tagged in 2022 while figure 12 shows length frequency for all male Chinook salmon tagged in 2022. Grilse composition was determined using breakpoints between grilse and adult which were determined from basin-wide fork length data and applied to Tuolumne River fork length data. The breakpoints used in 2022 were female salmon smaller than or equal to 61 cm and male salmon smaller than or equal to 70 cm. Twenty-seven males and three female were considered grilse using the grilse breakpoint in 2022. For all examined fish, total grilse composition was 19.48%. Scale samples will be read from coded wire tagged Chinook to verify hatchery grilse age.

Scale and Otolith Collection

Scale and otolith samples were collected from all tagged carcasses (154 scale, and 154 otolith samples). Tissue and otolith samples were not collected from skeletons due to the advanced state of decomposition unless they were hatchery origin with an adipose clip. A total of 5 skeletons were sampled of hatchery origin. In some cases, all scales collected were too damaged to read so no age was determined for those fish. Scale and otolith samples are used in the CDFW age determination program and for subsequent cohort analysis of the San Joaquin River Basin Chinook salmon populations. Of the 159 samples, 156 scale samples were useable samples for determining age composition.

In past years age breakdown was only separated by grilse and adult Chinook. In 2022 scale analysis was completed and age composition was able to be determined. For all sampled carcasses the proportion of age 2-, 3-, and 4-year-old fish was 18%, 79% and 3% respectively. The grilse cutoff showed an age 2 composition of 19.48% by using fork lengths which is similar to the known age determination using scale analysis. As assumed by CDFW, the majority of fish returning as adults are 3-year-old fish.

Egg Production Estimation

An estimate for the number of eggs produced by the 2022 fall-run was generated using a standard regression equation (158.45 * fork length cm – 6138.91 = number of eggs). This fork length-fecundity relationship was determined using 48 San Joaquin fall-run Chinook salmon females ranging from 62.5 to 94.0 cm fork length (Loudermilk et al. 1990). The number of eggs was calculated for all tagged females (adipose clipped and natural) and expanded by the ratio method. The average fork length for all females in 2022 was 72.9 cm. An estimated 405,986 eggs were produced by natural and adipose clipped female Chinook (75). Adipose clipped females (23) were estimated to have produced 129,913 eggs. Natural females (52) were estimated to have produced 376,073 eggs. This estimate is an under representation of the entire spawning population because no egg production estimate can be produced for skeletons, and this only represents the female carcasses found. If the egg estimation is expanded for whole female proportion (48.70%) and the overall estimate of 466 total chinook, the egg production may be closer to 1,228,232 eggs.

Tuolumne River Flows

The Tuolumne River flows, recorded at the La Grange gauge, for the period of September 25, 2022 through January 15, 2023 are shown in figure 13 (preliminary data obtained from the California Data Exchange Center**)**. Based on the DWR 60-20-20 index, Tuolumne river fell under a Median Critical water year type (WYT). The flow schedule allows for 150 cfs base flow between October 16 and May 31. The average base flow for the time period surveyed was 173 cfs. There were two flow releases during the survey period on October 17 and October 25 spanning up to 6 days and reaching 1,380 cfs at the peak flow.

Water temperature on the Tuolumne River is recorded using Onset temperature monitors at locations throughout the river. Figure 13 shows Tuolumne River water temperatures recorded at riffle A1 (RM 51.6) and K1 (RM 41.7). These water temperatures are plotted verses flow, maximum thermal limit of 13.3 °C for successful egg incubation (US Fish and Wildlife Service 1995), live fish and redd counts.

Multiple Recaptures

In past years' escapement surveys, tagged carcasses were chopped in half upon recovery to prevent multiple recaptures. Since 2008, tagged carcasses were recovered as many times as they were found, and returned to the water intact each time. This technique was initially used to determine the longevity of carcass retention within the river system. In 2022 multiple recapture data was used for the population estimate in the form of individual recapture histories as part of the Cormack-Jolly Seber super-population model. There were 59 carcasses recaptured, of those, 54 were recovered once and five were recovered twice (Figure 14).

Pre-spawn/Partial Spawn Mortality

In 2022 fish were checked for evidence of incomplete spawning. Incomplete spawning is generally most notable in female fish but may also occur in males. Female pre-spawn mortalities were characterized by fish with unripe eggs or still very full, while partial spawn fish still contained a portion of their eggs. Males were considered to have incomplete spawning when milt was easily expressed while collecting scales or other data. There were no pre-spawn females found in 2022.

Turbidity

Secchi disk measurements at the same locations from the past 5 years, during the first week of October, have consistently been to the bottom of the pool, between 16 and 19 feet in depth. Visibility was consistently between 13 and 17 feet, throughout the study period, with rain in weeks 12 creating less than ideal conditions in the last two sections. On December 10th, 2022, the turbidity in the Lower Tuolumne River increased due to nearly an inch of rain in the basin. Visibility was near 2 feet for the surveys during week 12. (Table 8). This may have an impact on the ability to observe redds, live fish or carcasses. Other than during week 12 visibility remained consistent and high, shown by the secchi disk still being visible at the river bottom.

River Hazards

When the New Don Pedro dam was built Turlock and Modesto irrigation districts built 2 temporary haul roads over the Tuolumne River to collect dredger tailings to use as fill for the dam. When the dam was completed the decks of the bridges were removed, but many of the structural supports remained. At one of these sites there is only a narrow opening to pass the drift boat through and any small errors result in collision with an I beam. This section is passable by boat, but it must be maneuvered in tight quarters. Future restoration projects may want to focus on removing these obstructions from the channel.

4 DISCUSSION

The 2022 escapement estimate of 466 salmon is consistent to the number of returning Chinook salmon during the 2014 escapement survey (438) but is higher than the previous two years return (Table 2 and Figure 6). The 2014 survey may be comparable because of similar WYTs, drought conditions, and flow requirements. The consistent low numbers of returning adults is some cause for concern since numbers on the Tuolumne River are still critically low compared to 2000 escapement numbers of 17,873 and have been on the decline ever since. This cohort of adults would have been from the offspring in 2019 during a wetter year where survival may have been greater during juvenile outmigration, resulting in a larger escapement than the previous years. In 2022 the Cormack-Jolly-Seber superpopulation model was used to estimate escapement for a variety of reasons which include the assumption of an open population (carcasses are added and removed from the population) and the use of covariates in the analysis (Bergman et al. 2011).

Sex composition of tagged carcasses was 49% for females and 51% for males. There were an additional 95 skeletons collected during the survey that were not sampled for sex. Due to the nature of female behavior while protecting a redd, it is likely that ratio of females to males would be higher than the actual population. A study done on the Elk River in Oregon also found that females and larger fish had a higher probability of recovery on the spawning grounds compared with males of similar size groups (Pollock 2020). Male carcasses may tend to be washed downstream faster than females since females will guard a redd until unable to physically. females had a higher probability of recovery on the spawning grounds compared with males.

Stream flow dynamics affect the likelihood of collecting carcasses because it affects both how carcasses are distributed in the system and the effectiveness of carcass recovery by field crews. The overall recovery rate is the percentage of carcasses that were recovered at least one time during the carcass survey. The 2022 tag recovery rate of 38.31% was similar to the 2017 tag recovery rate of 38% (Murphey 2017)

Redd counts were conducted with a single pass as opposed to a more complete intensive systematic approach in which crew members stop at each riffle and survey the entire area documenting redds, which is beyond the scope of current funding. Redd counts are affected by time of day, visibility, sunlight, wind rippling the water surface, redd superimposition, and other physical factors as well as the natural variability between observers. Maximum weekly redd distribution of section one to section four was 39.18%, 27.67%, 27.12%, and 6.03%, of total observed redds.

There were 43 adipose clipped (hatchery reared with CWT) carcasses, encountered during the escapement survey in 2022, five of which were classified as a skeleton with limited data taken. Coded wire tags were recovered from all 43 of the adipose clipped carcasses. Adipose clipped females made up 15% of the returning adult population, while the percentage of adipose clipped (hatchery reared with CWT) males returning to the Tuolumne in 2022 was 10%. Skeletons were checked for adipose clips and found to be about 5.26% of all the skeletons handled. Adipose clips of tagged fish and skeletons comprised 17.26% of all 249 Chinook handled. The percentage of skeletons with adipose clips is likely artificially low because in some cases skeletons lacked skin to check for an adipose clip.

The fork lengths of all salmon examined in the San Joaquin River Basin was used to determine grilse breakpoints. A total of twenty-seven males were considered grilse based on fork lengths of 70 cm or less. Three females had fork lengths of 61 cm or less and were also considered grilse. The total percentage of grilse examined in the Tuolumne River was 19.48% of all examined fish.

The escapement estimate of 466 individuals in 2022 is similar to the 2014 estimates (438) but larger than the 2020 estimate of 271. Although alarming, these results may be lower than the actual spawning population. The survey season ended during week 12 on December 12th to reduce the risk of COVID-19 infection spreading among the crew members. Surveys were started at the end of September because possible spring-run Chinook were observed at the powerhouse at La Grange Dam. The last Chinook was observed passing through the FISHBIO fish counting station on January 6th. There are many unanswered questions as to why the once healthy population has dropped to such dramatically low numbers. A complex web of factors including drought, flow management practices, predation by non-native species, a reduction of spawning and rearing habitat, disease, streambed alteration, pump diversion, gravel mining, land use practices, ocean angler harvest and poor ocean conditions affect the population dynamics of Chinook salmon in the Tuolumne River.

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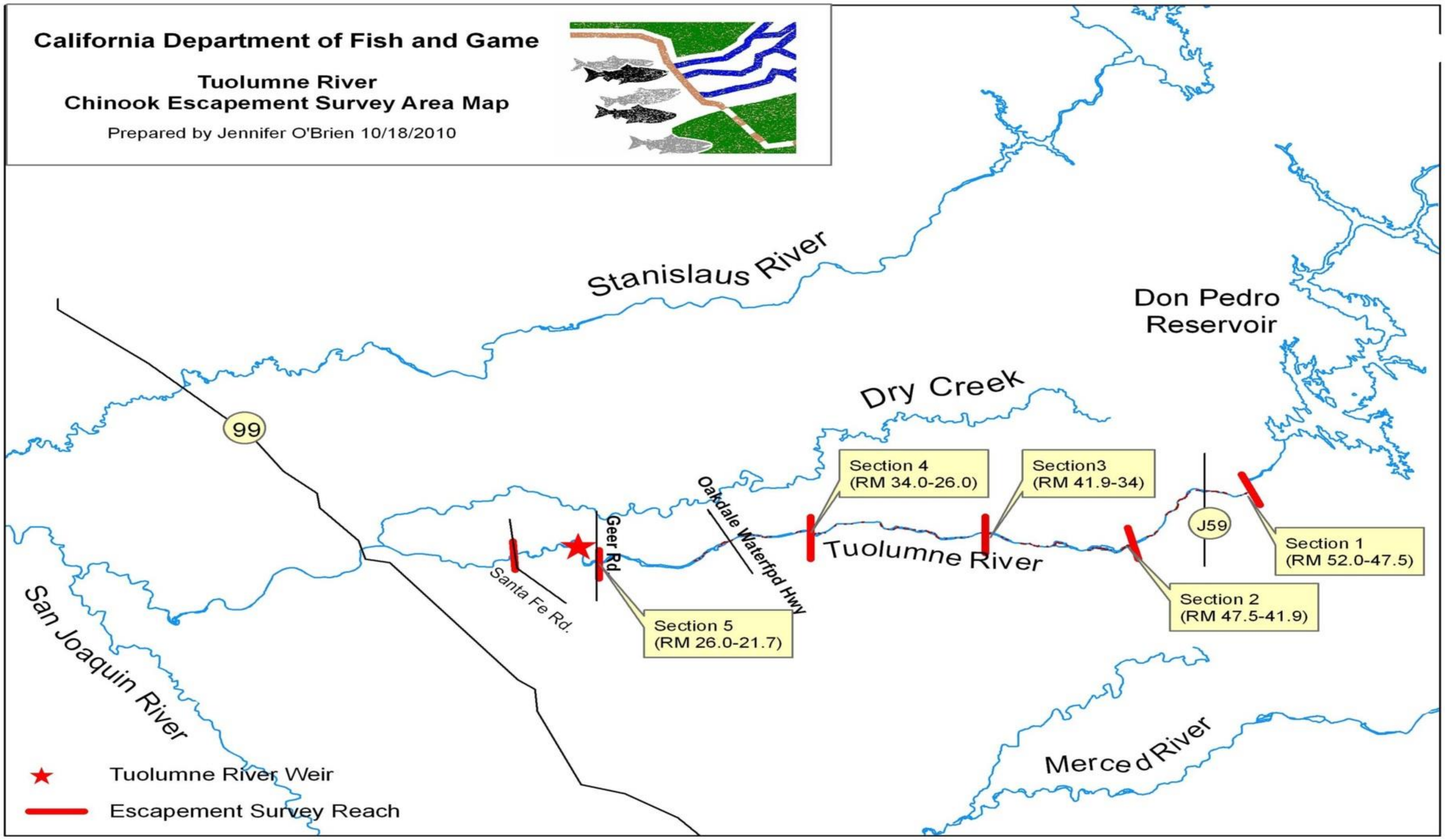

Figure 1. Tuolumne River Escapement Survey Section Map

Figure 2. Left-Fresh carcass indicated by a clear eye. Right- Decayed carcass indicated by cloudy eyes.

Figure 3. “Skeletons” are in the advanced state of decomposition and are chopped in half to avoid double counting.

Figure 4. Each carcass is assigned a unique identification number by affixing a metal, numbered tag to the bottom jaw.

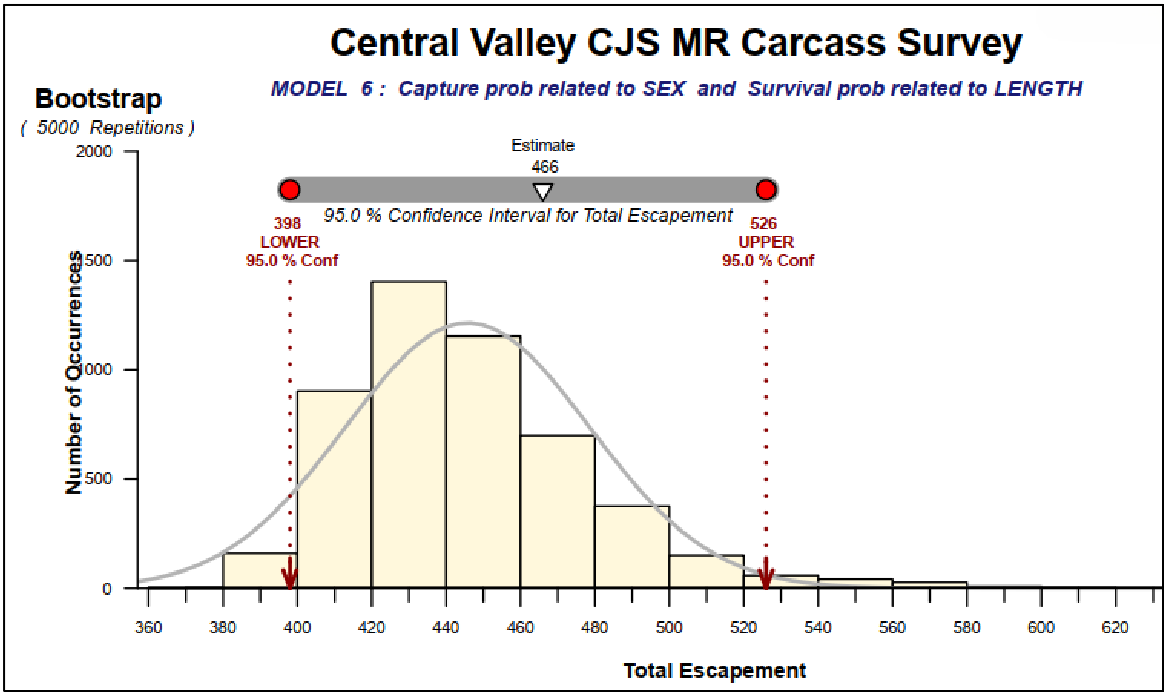

Figure 5. Results of CJS analysis using Model which assumes capture probablity is constant and survival probability is related to length. The model was run with with 5,000 bootstrap repetitions.

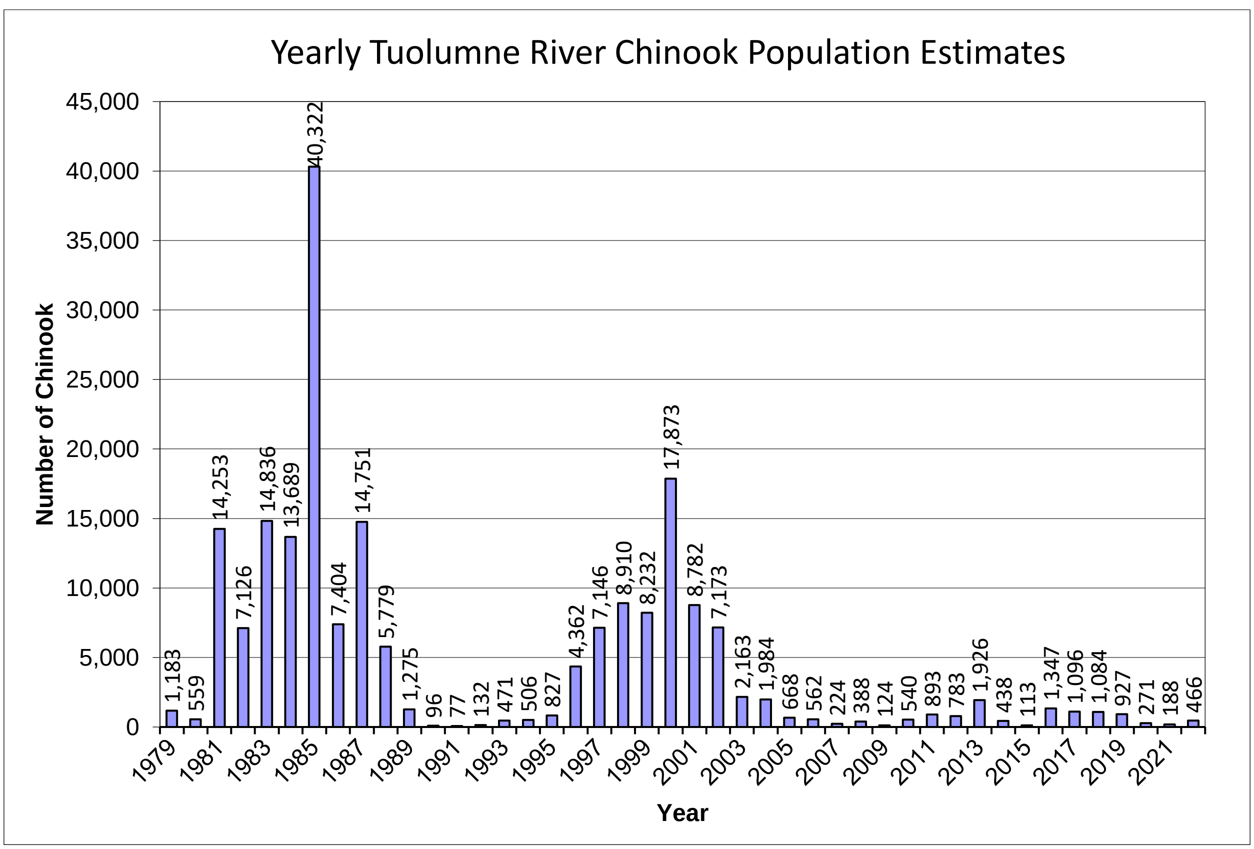

Figure 6. Yearly Tuolumne River Chinook Population Estimates. 1979-2022 estimates obtained from GrandTab (CDFW 2022)

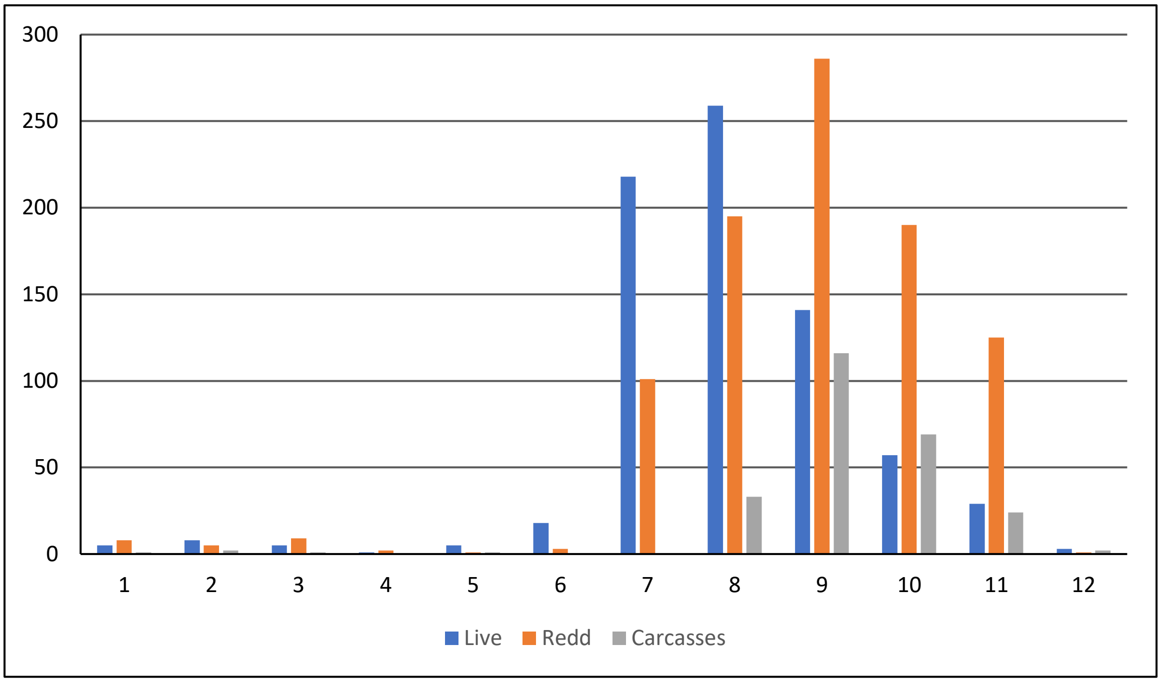

Figure 7. Live fish observations, redds, and carcasses* counted by week.
*Carcasses include all tagged carcasses and skeletons but does not include recoveries.

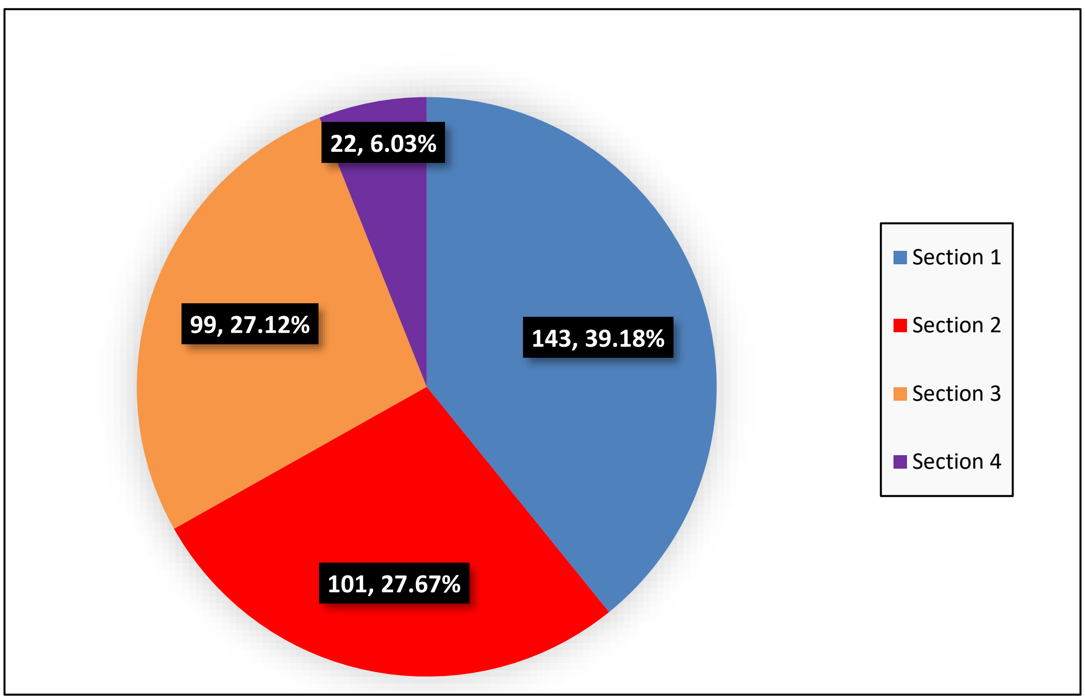

Figure 8. Pie graph of maximum redds observed by river section.

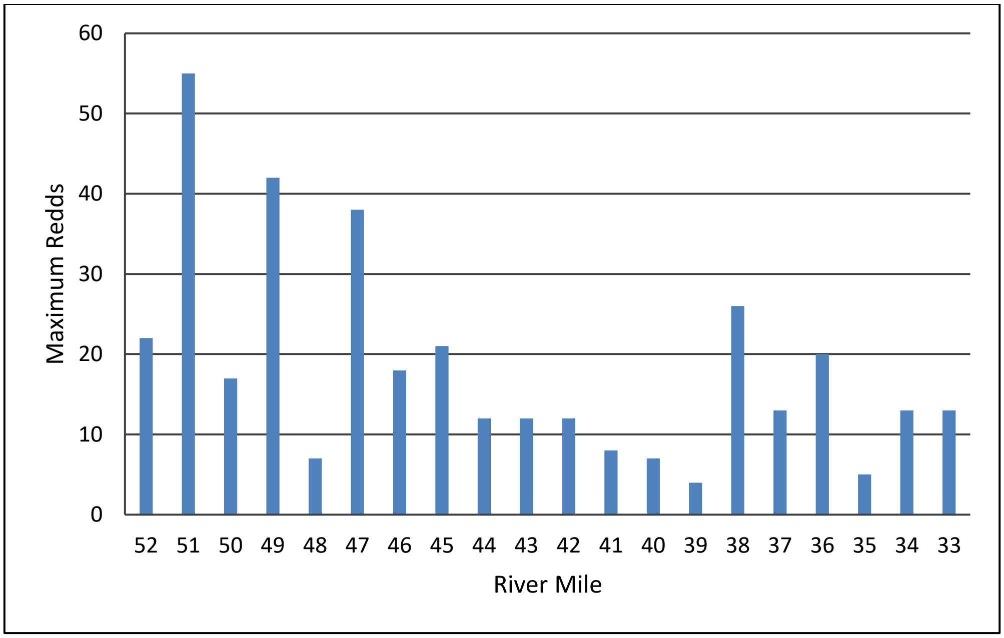

Figure 9. Maximum redds observed by river mile.

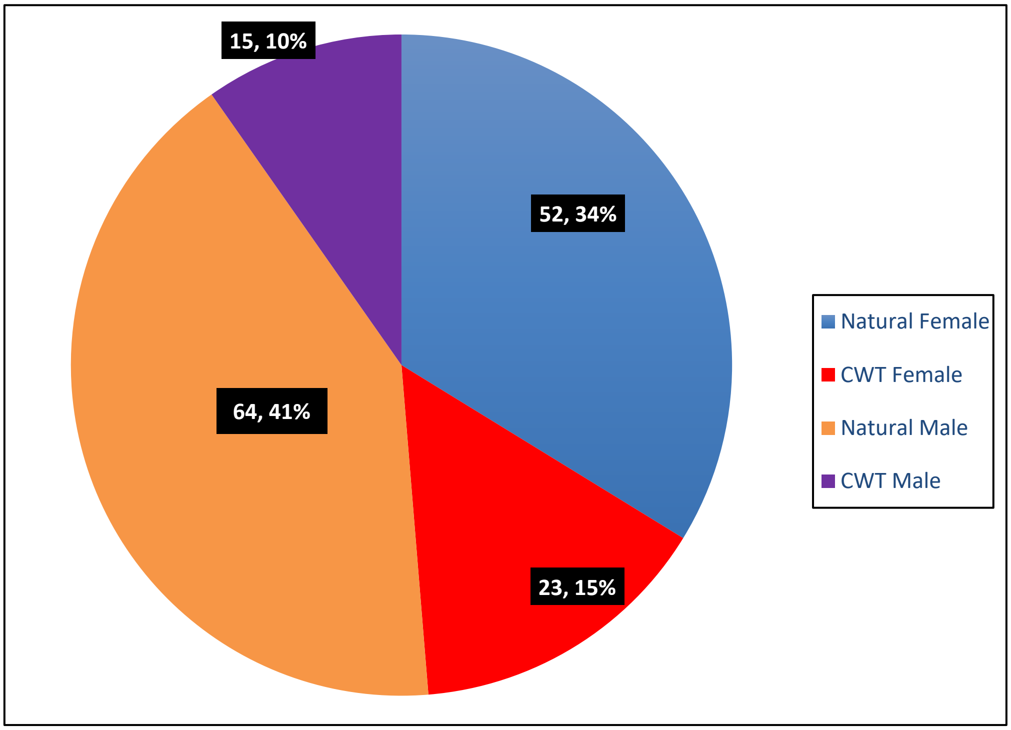

Figure 10. Composition of natural female, CWT female, natural male, and CWT male found in the 2022 Tuolumne River escapement survey. Includes tagged fish only.

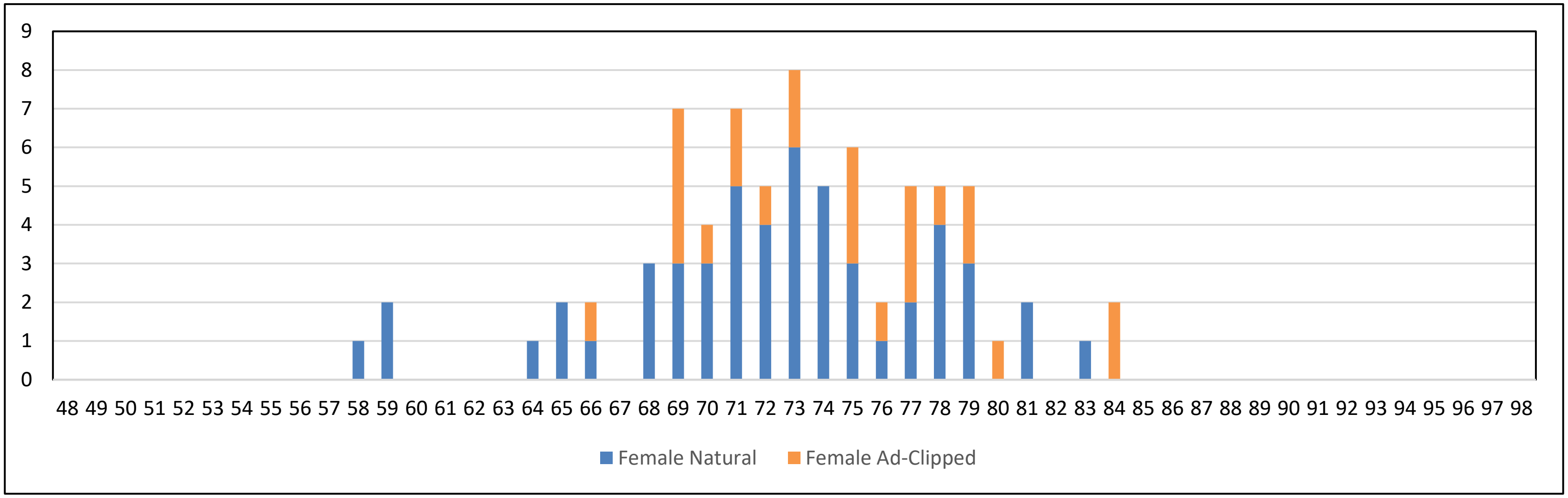

Figure 11. Length frequency histogram of female Chinook salmon tagged in the 2022 Tuolumne Escapement Survey.

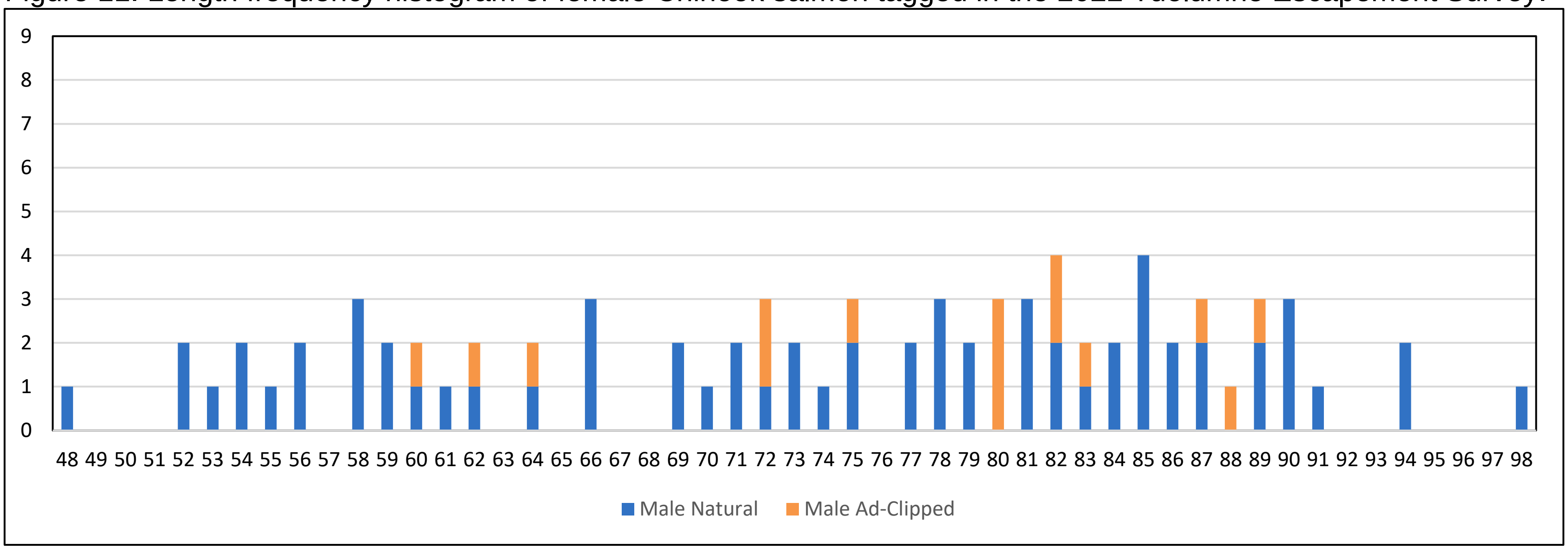

Figure 12. Length frequency histogram of male Chinook salmon tagged in the 2022 Tuolumne Escapement Survey.

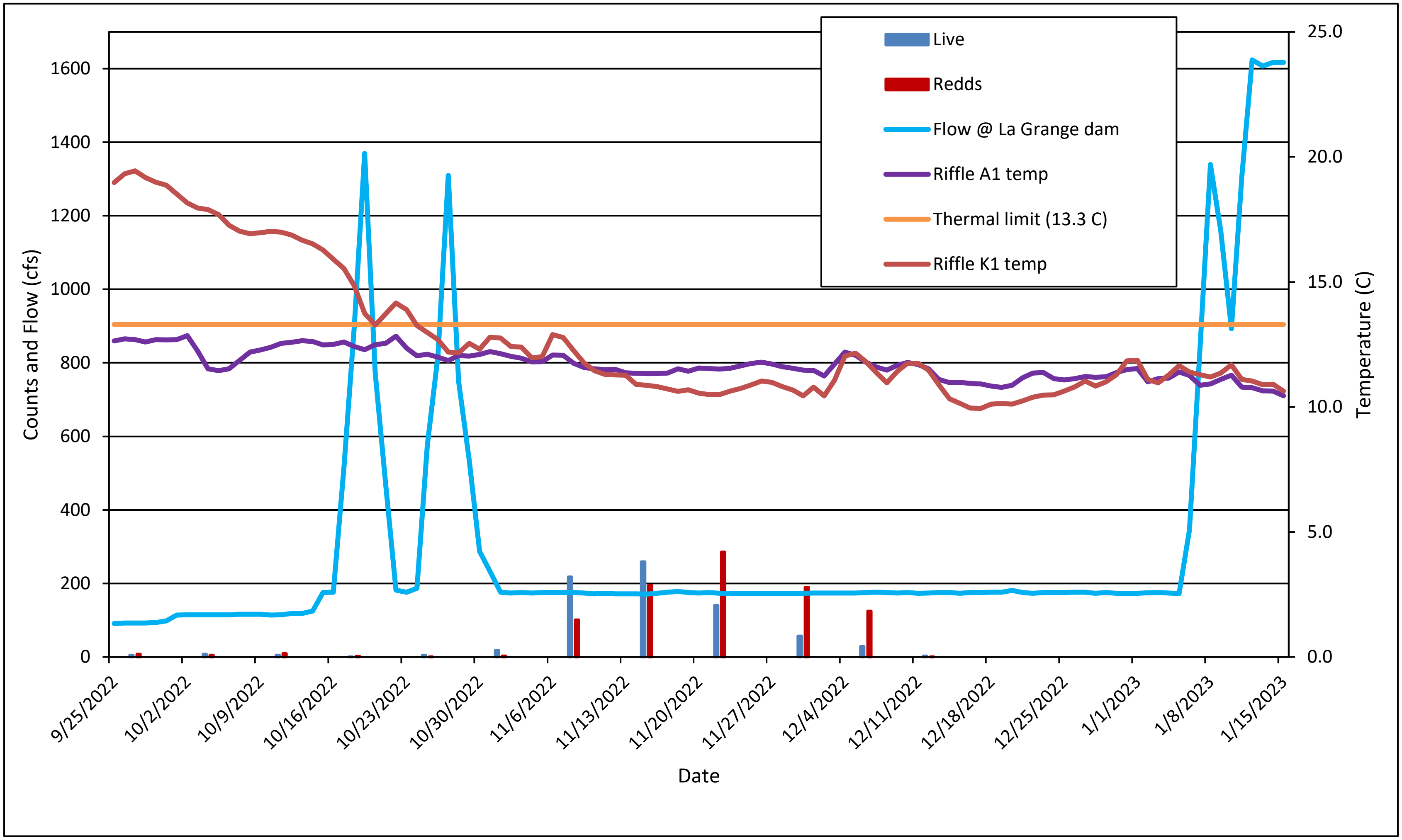

Figure 13. Tuolumne River flows (cfs) at the La Grange gauge, temperature at Riffle A1 (RM 52.6), Riffle K1 (RM 41.7), upper thermal limit for successful egg incubation (13.3°C) and number of live fish and redds counted.

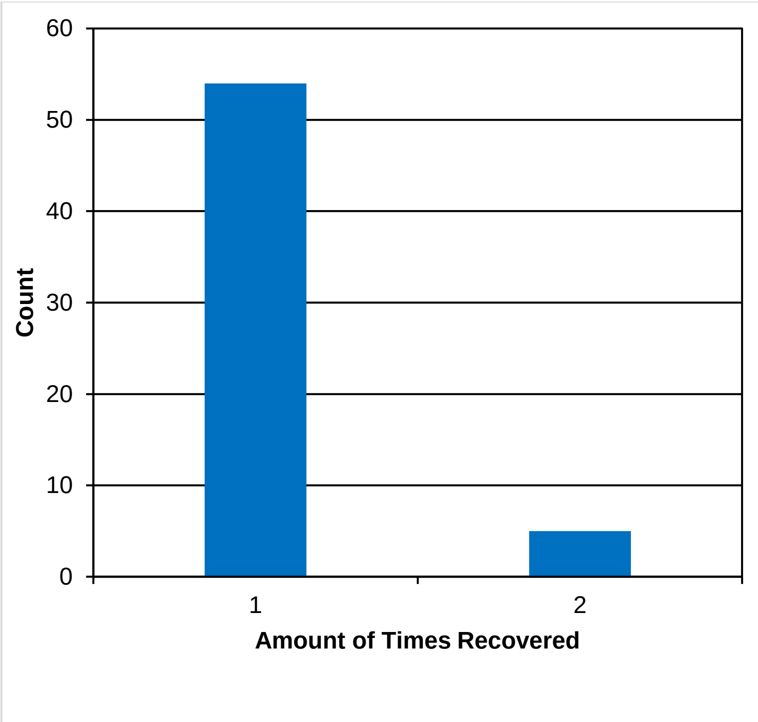

Figure 14. Recapture data for the 59 carcasses recovered in 2022.

Figure 15. Example of a male fish considered a partial spawn

Table 1. Tuolumne River riffle identification cross-reference Section 5 was not updated nor surveyed in 2022.

Section 1		Section 2		Section 3		Section 4		Section 5	
2017	2019	2017	2019	2017	2019	2017	2019	2009	2013
A1	A1	F1	F1	K1	K1	S2	S2	ZA1	AA1
A2	A2	F2	F2	K2	K2	S3	S3	ZA2	AA2
A3	A3	F3	F3	K3	K3	S4	S4	ZA3	AA3
B1	B1	G1	G1	L1	L1	T1	T1	ZA4	AA4
B2	B2	G2	G2	L2	L2	T2	T2	ZA5	AA5
B3	B3	G3	G3	L3	L3	T3	T3	ZA6	AA6
C1	C1	G4	G4	L4	L4	T4	T4	ZA7	AA7
C2	C2	none	G5	M1	M1	T5	T5	ZB1	AB1
D1	D1	H1	H1	M2	M2	U1	U1	ZB2	AB2
D2	D2	H2	H2	N1	N1	U2	U2	ZB3	AB3
D3	D3	H3	H3	O1	O1	V1	V1	ZB4	AB4
D4	D4	H4	H4	O2	O2	V2	V2	ZB5	AB5
D5	D5	H5	H5	O3	O3	V3	V3	ZB6	AB6
E1	E1	H6	H6	O4	O4	V4	V4	ZC1	AC1
		H7	H7	O5	O5	V5	V5	ZC2	AC2
		I1	I1	O6	none	W1	W1	ZC3	AC3
		I2	I2	P1	P1	W2	W2	ZC4	AC4
		I3	I3	P2	P2	W3	W3	ZD1	AD1
		I4	I4	P3	P3			ZD2	AD2
		J1	J1	P4	P4			ZD3	AD3
		J2	J2	P5	P5				
		J3	J3	P6	P6				
		J4	J4	P7	P7				
		J5	J5	Q1	Q1				
		J6	J6	Q2	Q2				
		J7	J7	Q3	Q3				
		J8	J8	R1	R1				
				R2	R2				
				S1	S1				

Table 2. Yearly escapement estimates

Year	Tuolumne River Estimate
1979	1,183
1980	559
1981	14,253
1982	7,126
1983	14,836
1984	13,689
1985	40,322
1986	7,404
1987	14,751
1988	5,779
1989	1,275
1990	96
1991	77
1992	132
1993	471
1994	506
1995	827
1996	4,362
1997	7,146
1998	8,910
1999	8,232
2000	17,873
2001	8,782
2002	7,173
2003	2,163
2004	1,984
2005	668
2006	562
2007	224
2008	388
2009	124
2010	540
2011	893
2012	783
2013	1,926
2014	438
2015	113
2016	1,347
2017	1,096
2018	1,084
2019	927
2020	271
2021	188
2022	466

1979-2022 estimates from GrandTab (CDFW 2022)

Table 3. Weekly Totals

Week	Total Tagged	Skeletons	Single Recoveries	Total Recoveries	Total Counted *	Ad Clipped**
1	1	0	0	0	1	1
2	1	1	0	0	2	2
3	0	1	0	0	1	1
4	0	0	0	0	0	0
5	0	1	0	0	1	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	26	7	0	0	33	3
9	76	40	13	13	129	22
10	40	29	30	34	103	10
11	9	15	16	17	41	4
12	1	1	0	0	2	0
Total	154	95	59	64	313	43

*Includes total tagged, skeletons, and all recoveries.
** Ad Clipped includes tagged carcasses and skeletons

Table 4. Total live fish, redds, and carcass counts by survey week

Week	Live	Redd	Carcasses*
1	5	8	1
2	8	5	2
3	5	9	1
4	1	2	0
5	5	1	1
6	18	3	0
7	218	101	0
8	259	195	33
9	141	286	116
10	57	190	69
11	29	125	24
12	3	1	2

*Carcasses include all tagged carcasses and skeletons but does not include recoveries.

Table 5. Maximum weekly redd count for each riffle by section.

Section 1		Section 2		Section 3		Section 4	
Riffle	Max. # of Redds	Riffle	Max. # of Redds	Riffle	Max. # of Redds	Riffle	Max. # of Redds
A1	6	F1	14	K1	1	S2	6
A2	5	F2	16	K2	3	S3	0
A3	11	F3	8	K3	8	S4	3
B1	22	G1	7	L1	4	T1	4
B2	28	G2	5	L2	0	T2	5
B3	5	G3	5	L3	1	T3	1
C1	8	G4	0	L4	3	T4	1
C2	9	G5	1	M1	4	T5	2
D1	7	H1	7	M2	3	U1	N/A
D2	11	H2	1	N1	4	U2	N/A
D3	3	H3	3	O1	2	V1	N/A
D4	11	H4	4	O2	0	V2	N/A
D5	10	H5	3	O3	6	V3	N/A
E1	7	H6	1	O4	8	V4	N/A
		H7	2	O5	10	V5	N/A
		I1	2	P1	2	W1	N/A
		I2	4	P2	4	W2	N/A
		I3	5	P3	1	W3	N/A
		I4	1	P4	1		
		J1	2	P5	2		
		J2	0	P6	3		
		J3	0	P7	0		
		J4	0	Q1	3		
		J5	1	Q2	11		
		J6	2	Q3	6		
		J7	2	R1	3		
		J8	5	R2	2		
				S1	4		
Sub Total	143		101		99		22
Total				365			

Table 6. Yearly percent composition of fall-run Chinook salmon on the Tuolumne River.

Year	%Female	% Male	% Unknown
1992	41.70%	56.30%	2.10%
1993	57.40%	42.60%	0.00%
1994	42.40%	42.90%	14.70%
1995	52.00%	47.50%	0.50%
1996	33.50%	66.30%	0.20%
1997	57.30%	42.70%	0.00%
1998	50.60%	49.30%	0.10%
1999	45.90%	54.10%	0.00%
2000	62.80%	37.10%	0.00%
2001	54.00%	45.90%	0.10%
2002	54.50%	45.50%	0.00%
2003	59.80%	40.20%	0.00%
2004	59.00%	40.60%	0.40%
2005	66.50%	33.50%	0.00%
2006	47.90%	52.10%	0.00%
2007	37.80%	62.20%	0.00%
2008	57.10%	42.90%	0.00%
2009	56.80%	43.20%	0.00%
2010	32.90%	67.10%	0.00%
2011	41.21%	58.78%	0.00%
2012	49.57%	50.42%	0.00%
2013	52.83%	47.16%	0.00%
2014	54.54%	45.45%	0.00%
2015	25.00%	75.00%	0.00%
2016	48.82%	51.17%	0.00%
2017	52.61%	47.38%	0.00%
2018	54.31%	45.69%	0.00%
2019	59.52%	40.48%	0.00%
2020	63.23%	36.77%	0.00%
2021	43.90%	56.10%	0.00%
2022	48.70%	51.30%	0.00%

Table 7. CWTs Recovered from the Tuolumne River in 2022

CWT	Carcass	Skeleton	Brood Year	Release Year	Age	Hatchery Location
060767	1	0	2019	2020	3	SAN JOAQ R CONSERVAT HATCH
060768	0	1	2019	2020	3	SAN JOAQ R CONSERVAT HATCH
061410	0	1	2018	2019	4	SAN JOAQ R CONSERVAT HATCH
061531	1	0	2019	2020	3	MOK R FISH INS
061578	1	0	2019	2020	3	MOK R FISH INS
061581	1	0	2020	2021	2	MOK R FISH INS
061964	1	0	2018	2019	4	SAN JOAQ R CONSERVAT HATCH
062006	4	0	2019	2020	3	MERCED R FISH FACILITY
062058	1	0	2019	2020	3	MOK R FISH INS
062059	2	1	2019	2020	3	MOK R FISH INS
062062	4	0	2019	2020	3	MOK R FISH INS
062063	2	0	2019	2020	3	MOK R FISH INS
062064	3	1	2019	2020	3	MOK R FISH INS
062065	1	0	2019	2020	3	MOK R FISH INS
062066	1	0	2019	2020	3	MOK R FISH INS
062067	3	0	2019	2020	3	MOK R FISH INS
062068	7	0	2019	2020	3	MOK R FISH INS
062069	2	0	2019	2020	3	MOK R FISH INS
062350	1	1	2020	2021	2	MOK R FISH INS
062351	1	0	2020	2021	2	MOK R FISH INS
062361	1	0	2020	2021	2	MOK R FISH INS

Table 8. Survey weeks and secchi measurements. Due to the depth of the river secchi can only be measured in specific locations. Note: measurements with a + indicate the secchi disk could still be seen at the bottom

Secchi measurements (feet)			
Week	**Section 1/2**	**Section 3/4**	**Comments**
1	15.5+	15.5+	
2	15.5+	15.5+	
3	15.5+	15.5+	
4	13+	8	
5	17+	16+	
6	14+	14+	
7	15+	15+	
8	13+	13+	
9	17+	17+	
10	15+	15+	
11	10	13+	
12	2	NA	Very Turbid