Juvenile Salmonid Emigration Monitoring in the Lower American River, California

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By

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Acronyms and Abbreviations

Acronym	Definition
NFH	Nimbus Fish Hatchery
CVPIA	Central Valley Project Improvement Act
CAMP	Comprehensive Assessment and Monitoring Program
AFRP	Anadromous Fish Restoration Program
km	kilometers
RST	rotary screw trap
CDFW	California Department of Fish and Wildlife
NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Service
m	meters
USBR	United States Bureau of Reclamation
CFS	cubic feet per second
rkm	river kilometer
ft	foot
cm	centimeter
RPM	revolutions per minute
USGS	United States Geological Survey
L	liter
mm	millimeter
g	gram
LAD	length-at-date
USFWS	United States Fish and Wildlife Service
SNP	single-nucleotide polymorphism
BBY	Bismarck Brown Y
VIE	Visual Implant Elastomer
GAM	generalized additive model

Acronym	Definition
C	Celsius
NTU	Nephelometric Turbidity Units
m/s	meters per second
DO	Dissolved oxygen
mg/L	milligrams per liter

Abstract

Operation of rotary screw traps on the lower American River in 2019 is part of a collaborative effort by the U.S. Fish and Wildlife Service's Comprehensive Assessment and Monitoring Program, Pacific States Marine Fisheries Commission, and the California Department of Fish and Wildlife. The primary objectives of the study are to collect data that can be used to estimate the passage of juvenile fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and to quantify the raw catch of steelhead/rainbow trout (*Oncorhynchus mykiss*) as well as winter, spring, and late fall Chinook salmon. Secondary objectives of the trapping operations focus on collecting fork length and weight data for juvenile salmonids and gathering environmental data that will eventually be used to develop models that correlate environmental parameters with salmonid size, temporal presence, abundance, and production.

For the 2019 survey season, two 2.4 meter (8 foot) rotary screw traps (RSTs) were operated downstream of the Watt Avenue Bridge. Sampling occurred on 68 of the 113 day season beginning the 9 January and concluding on the 1 May. A total of 15,056 fall-run, nine spring-run, and 18 winter-run juvenile Chinook salmon were captured. The passage of juvenile fall-run Chinook salmon peaked between 19 March and 25 March, when 28.99 percent of the total (n = 4,364) was captured. The majority of the captured juvenile fall-run Chinook salmon was identified as button-up fry life stage; yolk-sac fry, parr, silvery parr and smolt life stages were also captured. Two trap efficiency tests were used to estimate the passage of juvenile fall-run Chinook salmon. Trap efficiencies during these two tests ranged 0.46 to 1.00 percent, with an average efficiency of 0.73 percent. The number of juvenile fall-run Chinook salmon that were estimated to have emigrated past the Watt Avenue trap site during the 2019 survey season was 348,100 individuals (95 percent confidence intervals = 265,900 to 466,700). Finally, 1,872 individuals belonging to 22 different identifiable non-salmonid species were captured, as well as 112 non-salmonid individuals unable to be identified to species. Production for steelhead, the other non-fall Chinook salmon runs, and non-salmonid fish taxa were not estimated.

Due to flow fluctuations, sampling was suspended between 7 February and 21 February and 26 February and 13 March causing an unknown and potentially substantial percentage of the emigrating population to remain unobserved. Additionally, due to an anchor line failure traps were removed on 1 May and the 2019 survey season was terminated prior to the end of the emigration period. Backflow from the Sacramento River, which slows cone rotations and creates irregular cone rotation rates, also hindered the success of sampling in the 2019 season. Sampling was suspended on five days due to backflow between 21 January and 4 February. Between 26 March and 4 April backflow impaired successful sampling however the traps

remained online. Therefore, the passage estimate for juvenile fall-run Chinook salmon in 2019 is likely biased low.

This annual report also includes eight appendices. Five of those appendices describe different environmental variables and studies related to the trap site or rotary screw trap operations during the 2019 survey season.

Introduction

The American River is the southernmost major tributary to the Sacramento River in California's Central Valley. Historically, the American River supported three runs of Chinook salmon, including fall-, spring-, and possibly late-fall-run Chinook salmon (Yoshiyama et al. 2001). However, during the California Gold Rush in the mid- to late 1800s, hydraulic mining devastated salmon spawning habitat in the upper and lower reaches of the American River (Fisher 1994). Additionally, the construction of Folsom and Nimbus dams in 1955 made it impossible for spring-run Chinook salmon to migrate to the cool water pools they historically used in the upper portions of the American River watershed. To mitigate for the loss of Chinook salmon and steelhead spawning and rearing habitat, the Nimbus Fish Hatchery (NFH) was built in 1958, 0.80 kilometers (km) downstream of the Nimbus Dam. The NFH produces large numbers of fall-run Chinook salmon and steelhead. However, over-harvest, hydropower implementation, introduced species, water diversions and other factors continued to contribute to the decline of these fish populations (Yoshiyama et al 2000, Lindley et al 2006, NMFS 2009). Today, the portion of the American River below Nimbus Dam, known as the Lower American River, provides the only spawning and rearing habitat in the American River watershed for Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*), the anadromous form of rainbow trout.

In order to help protect, restore, mitigate and improve the natural production of juvenile Chinook salmon and steelhead in the Central Valley, the Central Valley Project Improvement Act (CVPIA) was established in 1992. One of the primary goals of that legislation was to facilitate efforts that enhance and restore the natural production of juvenile Chinook salmon and steelhead. Pursuant to that act, several programs were established to help recover salmonid populations. In 1997 the Comprehensive Assessment and Monitoring Program (CAMP) Implementation Plan was developed to evaluate the effectiveness of CVPIA actions in restoring anadromous fish production. The CVPIA programs currently engaged in habitat restoration activities within the American River watershed include the Anadromous Fish Restoration Program (AFRP), Dedicated Project Yield Program, and Spawning Gravel Program.

In an effort to improve salmonid spawning habitat on the Lower American River, the U.S. Bureau of Reclamation (USBR), the California Department of Fish and Wildlife (CDFW), and the CVPIA's AFRP and Spawning Gravel Program have collaborated to implement the Lower American River Gravel Augmentation and Side-Channel Habitat Enhancement Project. This project is ongoing and has in part been integral in increasing and restoring the adult spawning and juvenile rearing habitat that was adversely affected by the construction of the Folsom and Nimbus dams. Habitat restoration activities are ongoing and have occurred at ten sites from the base of Nimbus Dam (Nimbus Basin) downstream to River Bend at river kilometer (rkm) 20.9 (USBR 2019).

In addition, the CVPIA's Dedicated Project Yield Program Section (b)(2), commonly referred to as "(b)(2) water", authorizes a portion of the Central Valley Project water yield to be dedicated and managed for the benefit of fish and wildlife. As it pertains to the Lower American River, (b)(2) water can be utilized to augment base flows out of Nimbus Dam to provide improved in-stream conditions for fall-run Chinook salmon and Central Valley steelhead during critical life stage periods such as spawning, egg incubation, fry emergence, juvenile rearing, and emigration. The (b)(2) water's flow augmentation may also contribute towards the AFRP Final Restoration Plan flow objectives for the Lower American River.

Despite all efforts put forth on the Lower American River, continuous restoration, management, and monitoring activities are needed to further aid in the recovery of Chinook salmon and steelhead populations. To this end, in 2014 the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) developed a recovery plan for California Central Valley salmon and steelhead which put a high priority on habitat restoration activities in the American River.

Rotary screw traps (RSTs) are commonly used to monitor the abundance of emigrating juvenile salmonids and their biological response to such habitat restoration activities. This report describes efforts to monitor juvenile salmonid abundance with RSTs on the lower American River in 2019 as part of a larger effort to determine if habitat restoration activities and flow management practices are positively impacting the Chinook salmon and steelhead production in the American River. Furthermore, this report presents monitoring data assessing the temporal variability in steelhead abundance, as well as providing data that describe the size and abundance of salmonids and other native and non-native fish species in relation to the time of year, river discharge, and environmental conditions.

The 2019 survey season was the continuation of a multi-year juvenile Chinook salmon emigration survey. In 2019, California experienced an above average snowpack and reservoir levels resulting in high river flows throughout the season on the lower American River. Many different water years and operational procedures can be compared to surmise which scenarios may be the most productive for juvenile Chinook salmon in the lower American River. In addition to current management practices and fish recovery projects, the RST data collected during the past seven years may help to better understand the drought and whether coinciding drought management and flow strategies impact salmonids and other threatened species on the American River.

Study Area

The American River watershed covers an area of 4,900 square kilometers (km^2), and the upper-most headwaters reach an elevation of 3,170 meters (m) on the western slopes of the Sierra Nevada range (James 1997). This river contains three major forks, including the North, Middle, and South forks that ultimately converge at Folsom Reservoir, which is impounded by the Folsom Dam 32 km northeast of the city of Sacramento (USACE 1991). The water exiting Folsom Reservoir flows immediately into Lake Natoma, which is impounded by Nimbus Dam. The USBR regulate water management activities for these two dams including river discharge and water temperature of the American River to help administer flood protection, provide municipal and agricultural water supplies, generate hydroelectric power, and maintain fish and wildlife habitats.

Water exiting Nimbus Dam flows downstream for 36 km until it reaches the confluence with the Sacramento River. This lower stretch of the American River is currently the only portion that Chinook salmon and steelhead are able to access. Historically ranging in flow from 500 cubic feet per second (CFS) to upwards of 164,035 CFS, it is now constricted and straightened by a levee system that was engineered for flood control during the urban development of Sacramento County. The river contains gravel bar complexes and islands, flat water areas, and side-channel habitat characteristics (Merz and Vanicek 1996). However, only a small portion of the lower American River possesses suitable substrate for anadromous salmonid spawning activities. The primary salmonid spawning grounds are relegated to the uppermost portion of the lower American River between Sailor Bar (rkm 34.7) and the Lower Sunrise Recreational Area (rkm 31.1) (Phillips and Gahan 2014). A site below the Watt Avenue Bridge (rkm 14.6) was selected by CDFW (Snider and Titus 2001) as the location to install and operate RSTs due to its location downstream of most of this Chinook salmon and steelhead spawning activities in the lower American River yet far enough upstream to not be influenced by tidal fluctuations, or Sacramento River discharges. A summary of the abovementioned points of interest on the lower American River is shown in Appendix 1.

The lower American River RST site is located 0.20 rkm downstream of the Watt Avenue Bridge (Figure 1). During typical flow years, the American River at this location separates into two channels that pass on either side of a gravel island. The north channel carries the majority of the water volume and becomes the only channel with flowing water during flows of less than approximately 500 CFS. This north channel reach possesses a steep gradient that causes relatively high water velocities, while the south channel has a flatter gradient and lower water velocities. During flows above approximately 10,000 CFS the gravel island separating the north and south channels becomes submerged and the American River below Watt Avenue becomes one channel. A pictorial comparison of the lower American River RST site in different flow conditions is provided in Appendix 8.

Figure 1: Lower American River rotary screw trap sites in the north and south channels. Inset map illustrates the trapping location in the state of California.

Two 2.4 meter (8 foot) diameter RSTs were deployed in the north channel in 2019 and were designated as Trap 8.1 and Trap 8.2 (Figure 2). Trap 8.1 was set closer to the north side of the north channel, while Trap 8.2 was closer to the south side of the north channel.

Figure 2: The two north channel 8 foot traps (8.1 and 8.2) on the lower American River just downstream of the Watt Avenue overcrossing.

Methods

Trap Operations

Monitoring activities for the 2019 survey season started on 9 January and ended on 1 May. The two 8 foot (ft) RSTs were fished in a side-by-side configuration in the north channel. Traps were anchored to large concrete blocks set into the cobble substrate in the river channel using 0.95 centimeter (cm) nylon coated galvanized cable and a 0.95 cm chain bridal attached to the front of each trap's pontoons.

Trap checks were conducted at least once every 24-28 hours when traps were actively fishing in a cone-down configuration. During large storm events or measurable river flow increases, trap functionality could be hindered by larger sized or higher quantities of debris, creating a high potential for fish mortality. Therefore, in cases where a storm or flow increase was deemed severe enough, traps were taken out of service for an indefinite amount of time until the conditions improved. When traps were out of service, trap cones were raised, live well screens were removed, and sampling was temporarily suspended.

The number of cone rotations between trap visits was monitored using an electronic hubometer (Veeder-Root RT 1000-000) mounted to the axle of the cone inside of the live well; this data was used to determine how well traps functioned between trap visits. The effect of debris buildup on trap cone rotation rates was quantified by counting the number of revolutions per minute (RPM) before and after each cone was cleaned each day. Cleaning of the cones relied on the use of a scrub brush to clear off algae and other vegetation, and the field crew occasionally had to stop the rotation of a trap cone to remove larger debris. For each trap visit, the extent of cone intake obstruction caused by debris was assigned a category of "none", "partially blocked", "completely blocked", or "backed up into cone."

Safety Measures

All crew members were trained in RST and boat operation safety. Personal flotation devices were worn at all times when crew members were on the boat or the RSTs. For night operations, crew members were required to attach a strobe light to their personal flotation devices that turned on automatically when submerged in water. Two 12-volt, 1260 lumens, LED flood lights were affixed to each trap. On the jet-boat, navigation lights and a bow mounted 55-watt halogen driving light were also installed for safety during night operations. A coast guard approved flare kit was carried on the boat at all times.

In addition, a variety of devices were installed to keep the public safe and away from the traps. “Keep Away” signs in English and Spanish were installed on the traps, as well as a flashing amber construction lights to alert anyone utilizing the river at night that there was a potential navigation hazard. Orange reflective buoys were also placed on the chain bridals to prevent boaters from crossing in front or over the anchor lines.

Environmental Parameters

During trap visits when fish were processed, the following environmental data were taken and recorded once per visit. Temperature and dissolved oxygen were measured using a YSI dissolved oxygen meter (YSI; Model 55), velocity in front of each cone was recorded using a Hach flow meter (Hach; Model FH950), and turbidity was measured using a Eutech portable turbidity meter (Eutech; Model TN-100). When water depth was 300 cm or below, a depth rod was used to measure water depth underneath the trap to the nearest centimeter on the port and starboard sides of the two-trap array, in line with the front of the trap cones. Average daily river discharge for the American River was determined using data acquired from the American River at Fair Oaks monitoring station maintained by the U.S. Geological Survey (USGS) (USGS station number 11446500). Average daily temperature was measured 150 m upstream of the RSTs using data from the USGS American River below Watt Avenue Bridge station (USGS station number 11446980).

Catch and Fish Data Collection

After environmental data was collected, the process of clearing out each RST’s live well and working-up the fish began. First, all debris was removed from the live well and placed into 68.14 liter (L) tubs where crew members sifted through debris and set aside or enumerated any fish, alive or dead. After all debris was removed, an assessment of debris type and volume was recorded. Next, the crew netted any remaining fish from the live well and placed them in 18.93 L buckets with lids, segregating salmonids from non-salmonids or potential predators. During periods of hot weather, fish were placed in buckets with aerators to provide them with oxygen and an ice pack to keep the water temperature at a safe level. In addition, buckets of fish were placed underneath shade umbrellas, if necessary, to avoid additional heat from direct sunlight. If fish were held in buckets for a prolonged period of time, oxygen-depleted water was regularly exchanged with fresh river water.

On days when less than 100 Chinook salmon were caught per trap, the fork length of each salmon from each trap was measured to the nearest millimeter (mm), their life stage was assessed using the smolt index rating (Table 1), the presence of marks applied during trap efficiency tests or the absence of adipose fin were noted, and fish mortality status (live or dead) was assessed. If Chinook salmon were ≥ 40 mm in fork length, the first 25 salmon from each trap were weighed to the nearest 0.1 gram (g).

When more than 100 Chinook salmon were caught in a trap, a random sample of 100 live salmon from each trap was collected. The fork length, life stage, mark status, and fin clip status for each of the 100 salmon was assessed. Again, if the individuals were ≥ 40 mm in fork length, the first 25 salmon from each trap were weighed to the nearest 0.1 g after they were measured and assessed for life stage. Live salmon were preferentially used for the random sample of 100, when possible, since decomposition which alters body size, weight, and color, makes deceased salmon more difficult to accurately measure and identify to life stage. In those cases, mortalities were considered to be a “mort plus-count”; an unassigned life stage category.

A random sample was achieved by placing a net full of Chinook salmon from the live well into a 68.14 L tub. Debris was removed from the tub with salad tongs/probes, leaving only the subsampled salmon. Then, a random net full of salmon was taken from the tub and placed in a bucket designated for Chinook salmon subsampling. From the subsampled bucket, 100 fall-run Chinook salmon were randomly selected for further analysis. Any remaining fall-run Chinook salmon were checked for marks, enumerated, and designated as either a “live plus count tally” or “mort plus count tally” on the data sheet. A “plus-count tally” was defined as the total number of fish that were caught in a trap on a given day, and that were not measured, weighed, or assigned a life stage. If the plus-count capture included spring-, winter-, or late-fall-run salmon that differed in size from fall-run Chinook salmon based on length-at-date criteria, individuals belonging to those three salmon runs were counted separately and up to 100 of each run were assessed for fork length, life stage, and color/fin clip mark status. Since Central Valley spring- and winter-run Chinook salmon are federally listed as threatened or endangered taxa, trapping activities attempted to identify every spring- and winter-run Chinook salmon that was captured so those data could be reported to NMFS.

When steelhead were captured, each individual was counted, fork lengths were measured to the nearest mm, life stage was assessed using the smolt index rating (Table 1), and condition was recorded. In addition, each steelhead was checked for the presence or absence of a mark (i.e., adipose fin clipped) and the weights of each individual ≥ 40 mm in fork length were recorded.

Table 1: Smolt index rating for assessing life stage of Chinook salmon and steelhead.

Smolt Index	Life Stage	Morphological Criteria
1	Yolk-sac fry	* Newly emerged with visible yolk-sac
2	Fry	* Recently emerged with yolk sac absorbed (button-up fry) * Seam along mid-ventral line visible * Pigmentation undeveloped
3	Parr	* Seam along mid-ventral line not visible * Scales firmly set * Darkly pigmented with distinct parr marks * No silvery coloration
4	Silvery Parr	* Parr marks visible but faded * Intermediate degree of silvering
5	Smolt	* Parr marks highly faded or absent * Bright silver or nearly white coloration * Scales easily shed (deciduous) * Black trailing edge on caudal fin * Body/head elongating
6	Adult	* $\geq$ 300mm

All other individuals belonging to non-salmonid taxa were enumerated and identified to species. For each trap, fork lengths or total lengths (species dependent) of up to 50 randomly selected individuals of each species were recorded to the nearest mm and their mortality status was assessed. Because multiple entities in the Central Valley have a special interest in juvenile lamprey, an effort was made to distinguish between river lamprey and Pacific lamprey. To distinguish between the two species, the number of lateral circumorals in the mouth was observed. River lampreys have three lateral circumorals, while Pacific lampreys have four (Reid 2012). Because the lateral circumorals in the larval stage of ammocoetes are not well developed, they were not identifiable to species.

Prior to collecting fish fork lengths and weights, individuals were anesthetized with sodium bicarbonate tablets (Alka-Seltzer Gold) to reduce stress as they were processed. One Alka-Seltzer tablet was added to one liter of water. Approximately eight to 10 fish were placed in a solution of river water and Alka-Seltzer, then measured and weighed. The crew routinely observed the gill activity of fish immersed in the solution, with reduced gill activity indicating fish were ready to be processed. After fish were measured and weighed, they were placed in an 18.93 L bucket with a mixture of fresh river water and stress coat additive (Poly-Aqua) to help replenish their slime coat as the fish recovered from the anesthetic. As soon as it was determined that the fish had fully recovered from the anesthesia, all fish were then released well downstream of the traps to prevent recapture.

Chinook salmon were assigned a salmon run at the time of capture using length-at-date (LAD) criteria that were developed for the Sacramento River by Greene (1992). When Chinook salmon appeared to be winter- or spring-run salmon using the LAD criteria, one to two mm samples were commonly taken from the upper lobe of the caudal fin. These samples were then sent to the staff at the U.S. Fish and Wildlife Service's (USFWS) Abernathy Fish Technology Center to perform genetic run assignments using the panel of single-nucleotide polymorphism (SNP) markers described by Clemento et al. (2014). This panel of SNPs was developed by staff from NOAA Fisheries, and is now used for several applications by the USFWS and several partner groups (Christian Smith, USFWS, pers. comm.). Detailed methods for DNA extraction, genotyping, and run assignment are described in Abernathy Fish Technology Center Standard Operating Procedure #034.

The accuracy of genetic run assignments made using the SNP baseline was evaluated using self-assignment tests, and it was reported that winter-run were correctly assigned to run 100 percent of the time, fall-run were correctly assigned to run 85-95 percent of the time, and spring-run were correctly assigned to run 78-93 percent of the time (Clemento et al. 2014). For the purposes of this report, the SNP panel providing the "Genetic Call to three lineages" probability was used, and an arbitrary 50 percent probability threshold was employed to assign the final salmon runs as follows:

1. Individuals for which the probability of assignment was < 50 percent were not assigned based on the genetic data, i.e., assignments based on the LAD criteria were used to assign the final run.
2. Individuals for which the probability of assignment was ≥ 50 percent were assigned based on the genetic data, i.e. if LAD and genetic assignments conflicted, and then final run was assigned using the genetic markers.

Six salmon that had a LAD salmon run assignment of fall at the time of capture were genetically sampled to compare their LAD assignments with run assignments determined using the SNPs. That procedure was implemented to evaluate the similarity between LAD and SNP assignments when the LAD run assignment at time of capture was fall-run.

Trap Efficiency

Trap efficiency trials were conducted to quantify the proportion of the emigrating fall-run Chinook salmon that were passing through the river and were collected by the RSTs; these data were then used to estimate the total number of fall-run Chinook salmon migrating past the RSTs. Trap efficiencies were assessed using two different marking methods.

One method of marking consisted of dying the whole body of a fall-run Chinook salmon with Bismarck Brown Y (BBY) stain when a majority of the juvenile salmon had a fork length that was < 50 mm. At least 500 salmon were needed to conduct trials with BBY stain. When < 500 Chinook salmon were caught on a given day, they were held overnight and salmon caught the next day were added to the previous day's catch to achieve the minimum number of Chinook salmon required for a trap efficiency test. If the minimum number of salmon needed to conduct a trap efficiency trial were not captured within a 48-hour period, they were not used for an efficiency trial and were released downstream of the traps. If daily catch totals were low, fall-run Chinook salmon were provided by the Nimbus Fish Hatchery.

Once enough in-river produced Chinook salmon were available to conduct a trap efficiency trial, they were placed in a 68.14 L tub and stained using a solution of 0.6 g of BBY for every 20 L of river water. The actual amount of stain used varied depending on water turbidity and the number of salmon being stained. Salmon were stained for approximately two hours, and their condition was constantly monitored during the staining process. After staining, salmon were rinsed with fresh river water and placed in a 68.14 L live car and held until twilight when they were released using the technique described below.

The other method of marking used was a Visual Implant Elastomer (VIE) tag which consisted of inserting a syringe loaded with elastomer and hardener at a ratio of 10 parts elastomer to one part hardener into the snout of an anesthetized fall-run Chinook salmon and injecting a small amount of the liquid fluorescent elastomer just under the skin. The elastomer then hardens and a tag retention test was done after each tagging session. This marking method is performed on fish with a fork length >50 mm. Tagging supplies, mixing procedures and protocols for VIE tags were provided by Northwest Marine Technology, Inc.

To evaluate the potential that the size distribution of marked and released vs. recaptured in-river produced salmon used during trap efficiency tests was different, 100 fork lengths from the day the in-river produced fish were captured and marked were used as a baseline to compare to the lengths of recaptured salmon.

The trap efficiency release site was approximately 1.29 rkm upstream of the traps. To avoid schooling when Chinook salmon were released, they were scattered across the width of the river channel using small dip nets. When river flows were relatively low (e.g., < 1,250 CFS), the fish were released by wading across the river, which did not occur during the 2019 season. When higher river discharges occurred, a boat was used to release the marked fish, keeping the motor upstream of the released fish while a crew member released fish downstream. Every release of marked Chinook salmon occurred close to dusk to mimic natural migration patterns and to avoid predation.

Due to the proximity of the release location to the RSTs, the majority of released fish were found to migrate past the RST location within the first four days following a release. As a result, trial periods were designated as a minimum of four days.

On trap visits following each trap efficiency release, crew members looked carefully for any marked fish in the RST live wells. A random sample of up to 100 recaptured Chinook salmon from each trap efficiency test were measured for fork lengths, assessed for life stage, and evaluated for mortality status. If more than 100 recaptures from a trap efficiency test were found in a RST live well, the marked salmon in excess of 100 were enumerated and classified as a “live recap plus-count tally” or “mort recap plus-count tally”.

Passage Estimates

Fall-run Chinook salmon passage estimates were developed using an enhanced efficiency model developed by West Inc. The following model description was excerpted from a West Inc. document sent to those who implement the model.

> *The CAMP Rotary Screw Trap platform utilizes a trap efficiency model to adjust upward the number of captured fish for those that were not captured. Prior to implementation of enhanced efficiency models, the Platform estimated daily passage by dividing daily catch by a daily estimate of efficiency derived from efficiency trials conducted during the season. To estimate efficiency every day of the season, the Platform utilized a b-spline smoothing method to model daily efficiency.*
>
> *Recently, the Platform added an option to use an enhanced model of trap efficiency in passage estimation. The enhanced efficiency models utilized efficiency trials conducted during multiple seasons and covariates such as stream flow and temperature to estimate efficiency.*

This document describes methods used to estimate the enhanced efficiency models, as well as the final models being used in the latest version of the Platform.

Methods

Catch Estimation

To estimate catch within a fishing year, all valid fishing durations are recorded and tabulated. Within each fishing episode (typically one day), catch is counted, measured, assigned a size class, and assigned a run. In cases when a large number of fish are captured, a subsample of the catch may be counted instead, with proportions of size class and run applied to the bulk of uncounted fish, so as to obtain a so-called "plus-count," which is then added to that day's count of catch.

In order to estimate passage for days when fishing did not take place, a daily catch estimate is imputed from the catch data. Catch is assumed to follow a Poisson distribution from which a generalized linear model is fit. The resulting curve of catch over time is then used to impute catch for days with missing data. Typically, the number of missing catch days is few and only missing days use imputed catch. Actual catch is used for all other days.

Simple Efficiency Estimation

Typically, only a few efficiency trials are available at any one site or sub-site. To estimate simple efficiency models, only efficiency trials conducted within a fishing year are utilized. For each efficiency trial, both the number of released fish and captured fish are tabulated. Efficiency (proportion of fish passing that are caught) is assumed to follow a binomial distribution, with the number of released fish the number of independent Bernoulli trials and the number of caught fish from the release group as a Bernoulli "success". If at least ten efficiency trials were conducted in a year, the Platform's simple efficiency model is estimated using a logistic regression (binomial generalized linear) model that contains b-spline-derived smoothing splines. If fewer than ten trials were conducted, the smoothing splines are dropped and a constant (intercept-only) model is estimated. The resulting curve of efficiency over time is then used to impute efficiency on every day of *the season. Efficiency models are fit for each sub-site for which efficiency-trial data are available.*

Enhanced Efficiency Estimation

Enhanced efficiency models incorporate two additional pieces of information into the model, when compared to simple models. First, efficiency-trial data from all years at a site are used to estimate the model. Collapsing efficiency-trial data from multiple years dramatically increases sample sizes for model estimation. Second, the enhanced models incorporate environmental covariates measured at the time of each trial. Like simple efficiency models, enhanced efficiency logistic regression models were fit to data from each sub-site when possible. Different models were allowed at different sub-sites to incorporate different covariates and effects at distinct sites.

Covariates considered for inclusion in the enhanced models are one of four types: efficiency-trial, environmental, CAMP, and percent-Q. Each covariate type, along with included variables, is described below. Backwards variable selection was used to establish the best fitting and hence enhanced efficiency model used in passage estimation. Backwards variable selection proceeded as follows. Initially, all covariates were included in the enhanced efficiency logistic regression model. The predictive utility associated with each covariate in the model was then assessed by computing the number of standard deviations away from zero of each coefficient estimate (i.e., the coefficient's Wald t-ratio) and associated p-value from the t-distribution. The covariate associated with the highest p-value greater than 0.10 was removed and the model was re-fit. The same drop-one procedure was repeated until p-values of all covariates were less than 0.10. Covariates utilized daily values coincident with enhanced-efficiency trial days. When a covariate was not available on the day of an efficiency trial, its historical mean was used instead.

Efficiency-trial Covariates

Efficiency-trial covariates included mean fork-length, proportion of time spent fishing during night-time, and proportion of time spent fishing during moon-time. Here, moon-time reflects the portion of a day when the moon was above the horizon, and it varies by day through the year. For estimation, values for these three covariates were calculated over the *duration of each efficiency trial, typically a week, via weighted means, so as to obtain a daily estimate coincident with an efficiency trial.*

Environmental Covariates

Environmental covariates included water temperature and flow, as measured at stream gauges operated by either the United States Geological Survey (USGS) or California Data Exchange Center (CDEC). The particular USGS or CDEC gauge used to derive temperature and flow varied by sub-site. Some gauges recorded daily values while other recorded hourly flow and temperature. To ensure consistency across fitted models, as well to fill gaps in the USGS or CDEC data, a smoothing spline was fit to both the temperature and flow data series. The optimal number of smoothing splines to include in the temperature and flow model was chosen by cross-validation. The smoothed data series of temperature and flow were used in all subsequent modeling.

CAMP Covariates

CAMP covariates included flow, water depth, air temperature, turbidity, water velocity, water temperature, and light penetration. These covariates generally reflected environmental conditions at the time of a rotary-screw trap visit and were collected by biologists at the sub-site. The number of CAMP covariates available for enhanced model estimation varied from sub-site to sub-site. When flow or water-temperature data were collected by CAMP biologists at the time of their visit, but USGS or CDEC data were available, the USGS or CDED data were used for modeling. Similar to the two environmental covariates, smoothing splines were applied to all CAMP covariates collected at a sub-site in order to estimate missing values and to dampen measurement error. The smoothed versions of all variables were then used in subsequent modeling efforts.

Percent-Q Covariates

At the Red-Bluff Diversion Dam (RBDD), percent-Q was computed and utilized as a potential covariate in each sub-site's enhanced-efficiency model. Different sub-sites, or dam Gates in the case of the RBDD, may or may not include percent-Q as a potential covariate, depending on whether percent-Q was chosen in the final model by backwards selection. Because percent-Q depends on both stream velocity and flow, these two covariates were not *considered as covariates in enhanced efficiency models developed for RBDD Gates. Estimates of percent-Q incorporate water loss due to both the Colusa and Tehama canal diversions.*

Application of Enhanced Efficiency Models

Ultimately, a unique enhanced efficiency model was estimated for each sub-site based on its own data (Table 1). Estimation of passage utilized daily efficiency from these sub-site specific enhanced efficiency covariate models to adjust daily catch at the sub-site. In this way, passage estimates utilized year-specific catch data but efficiency estimates used data obtained from all available information at the sub-site.

Table 1: Final enhanced efficiency logistic regression covariate models established for use at each sub-site in the Platform. Temporal splines not included.

Stream	*Name (Sub-site)*	*Covariate Model*
American	*North Channel 8.1 (57001)*	*–5.459 + 4.539(night proportion) + 0.03(forklength) – 0.0009(flow)*
	North Channel 8.2 (57004)	*–4.698 + 0.048(forklength) – 0.0004(flow)*

Note: The above description of the enhanced efficiency model is excerpted from West Inc.'s description of the model. Further questions about this model should be sent to Trent McDonald at West Inc.

Retention in Analysis

For every sampling period, a determination was made whether to include or exclude the period from analysis. Factors that influenced this decision included success of fishing based on trap functionality, or other factors that might have adversely affected catch.

If fishing was unsuccessful, a calculation was conducted using the clicker total and after cleaning RPMs to estimate the amount of time the trap had been functioning normally. If this calculation indicated the trap had likely been functioning normally for at least 70 percent of the sampling period, the sampling period was kept in analysis. If the trap was estimated to have been functioning normally for less than 70 percent of the sampling period, the period was excluded from analysis. Sampling periods excluded from analysis were treated by the CAMP platform like periods not fished and a catch estimate was produced based on Method #2, as described above. This estimated catch was then compared to the actual catch encompassing that sampling period. Under the assumption that abnormal trap function adversely affects catch, the higher of the two was considered to more accurately represent what would have been caught under normal trap function. Therefore, any period with abnormal trap function was only excluded from analysis if the catch estimate produced was higher than what had actually been caught. Furthermore, if an unsuccessful trapping period was the first or last of the season, or if there were seven or more consecutive days of unsuccessful trapping the CAMP platform was unable to impute catch. Therefore, the actual catch was assumed to be more accurate and the period was included in analysis.

Confidence Interval Estimates

Confidence intervals were computed using parametric bootstrap or Monte Carlo methods as described in the "Feasibility of Unified Analysis Methods for Rotary Screw Trap Data in the California Central Valley," by McDonald and Banach (2010).

Fulton's Condition Factor

Fall-run Chinook salmon condition was assessed using the Fulton's condition factor. The first 25 Chinook salmon larger than 40 mm captured each day were measured for weight and fork lengths. The ratio of the two was used to calculate their condition factor:

$$K = \left(\frac{W}{FL^3}\right)100{,}000$$

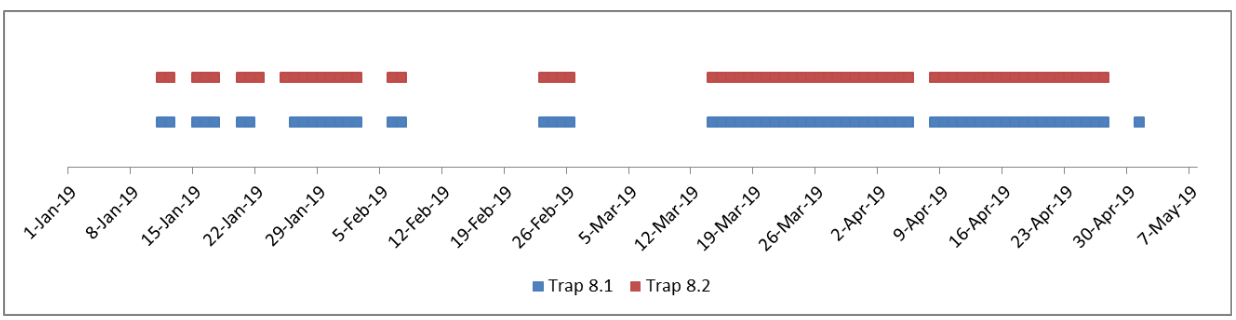
where *K* was the Fulton's condition factor, *W* was the weight in grams, and *FL* was the fork length in mm.

Results

Trap Operations

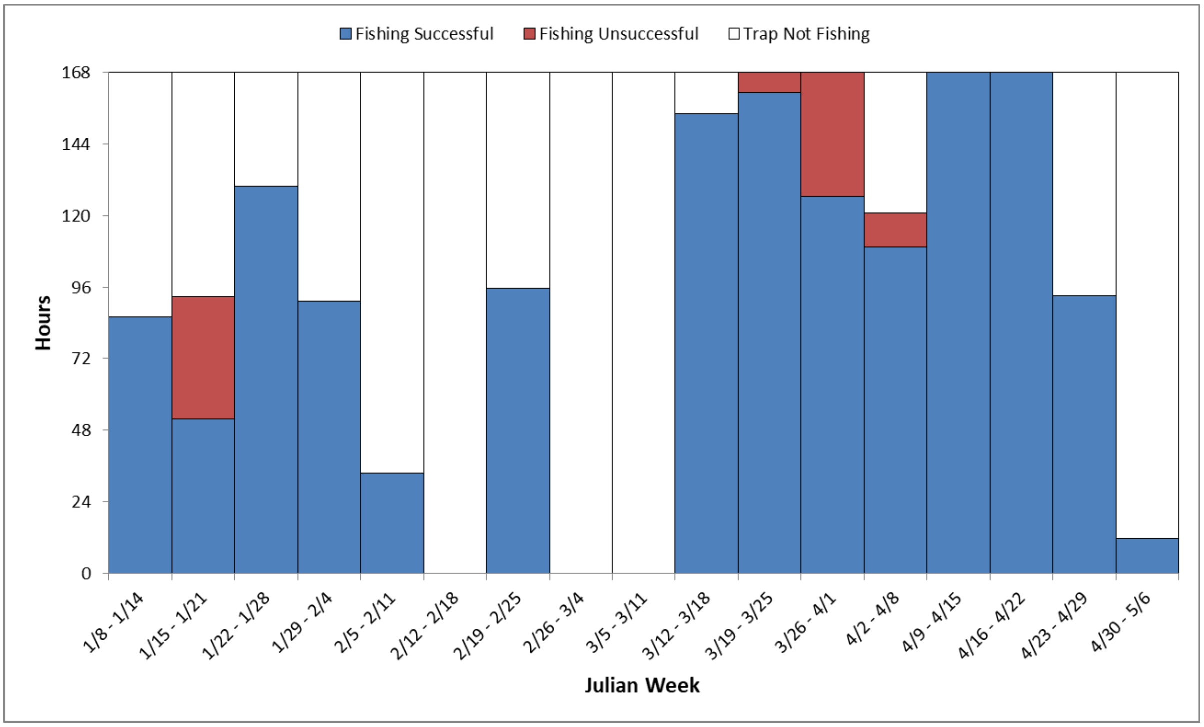
Sampling for the 2019 survey season began on 9 January at river flows of approximately 1,750 cfs. At this time, two 8ft RSTs were deployed into the north channel of the Watt Avenue trapping site. Several times throughout the season sampling was suspended due to high river flow conditions creating greater potential for fish mortality and reduced safety for the field crew. Trap operations ceased twice under these conditions for greater than 7 days. The first occurred 7 February and lasted through 21 February totaling 15 days. The second occurrence was 26 February through 12 March totaling 15 days. Sampling for both traps was suspended temporarily on 17 and 18 January as well as 5 and 6 April to allow debris to flush out of the system created by weather events. Backflow from the Sacramento River also hindered 2019 operations. As a result, sampling was suspended on 22 and 23 January and 2 February through 4 February. Lastly, staff availability and public safety necessitated suspension of operations on 12 and 13 January as well as 27 through 29 April. Trapping operations for the 2019 survey season ended on 1 May after an anchor line securing the traps in place, snapped and created unsafe work conditions. The anchor is only accessible during periods of low flow on the Lower American River. Low flows would not be seen until September therefore trapping was concluded for the season. The dates each trap sampled is depicted in Figure 3.

Figure 3: Dates sampling occurred per trap during the 2019 lower American River rotary screw trap survey season.



Throughout the 2019 survey season, between 9 January and 1 May, sampling took place on 67 of 111 days. During this time, the traps fished unsuccessfully (defined as a period of time during which the trap was fishing, but catch was determined to be adversely affected by abnormal trap function) for approximately 101 hours. Traps fished successfully for approximately 1,480 hours and did not fish for approximately 1,275 hours (Figure 4).

Figure 4: Weighted average hours per Julian week that both traps fished successfully, fished unsuccessfully, or did not fish during the 2019 lower American River rotary screw trap survey season.



Environmental Summary

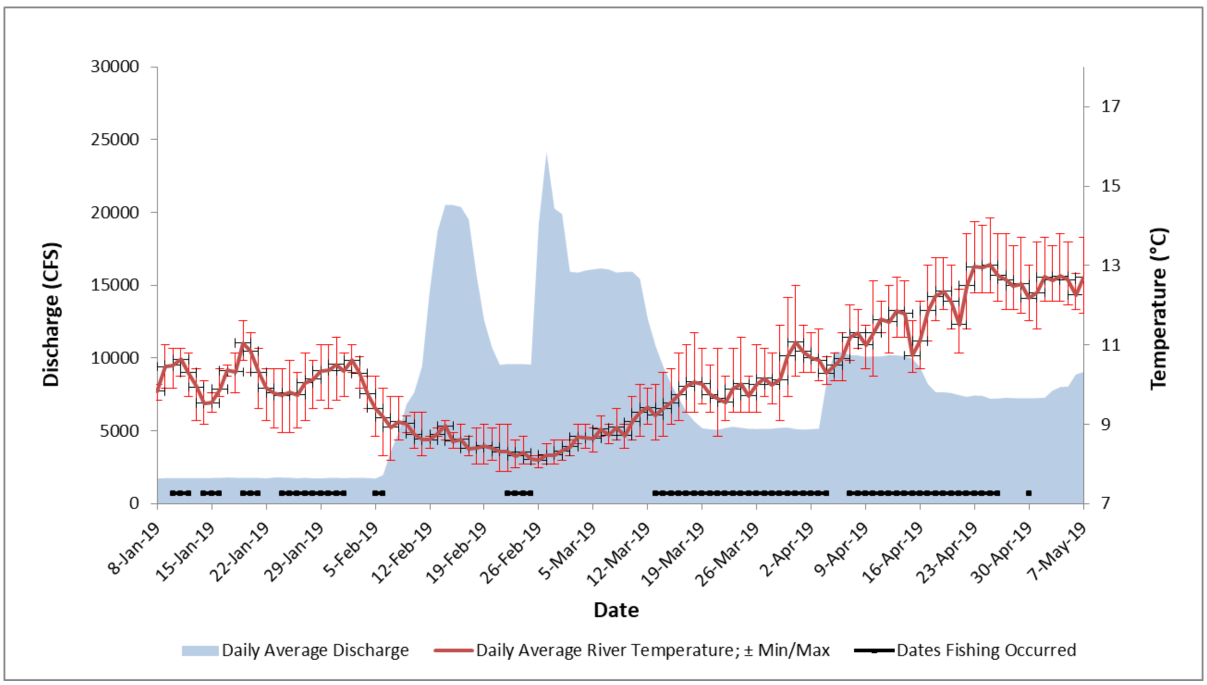
Appendix 2 provides a summary of the environmental conditions, averaged by Julian week, starting on January 8 and spanning until the last Julian week of the 2019 survey season. Trapping for the 2019 survey season did not occur throughout this entire date range.

Measurements taken in the field, such as dissolved oxygen content, water turbidity and water velocity reflect only the 2019 survey season (i.e. time period between 9 January, when the traps were first deployed, and 1 May when sampling concluded) and may not contain data on days when the traps were not sampling. Maximum and minimum environmental data values quantified below also reflect only the date range of the 2019 survey season, between 9 January and 1 May.

River discharge data, recorded in 15 minute increments, was acquired from the USGS Fair Oaks gaging station on the American River, 21 rkm upstream of the RSTs. River temperature, also recorded in 15 minute increments, was acquired from the USGS Watt Avenue

Bridge station on the American River, 0.16 rkm upstream of the RSTs. During the 2019 survey season, between 9 January and 1 May, river discharge reached a high of 25,700 CFS on 26 February and a low of 1,630 CFS on 8 January. Temperatures between 9 January and 1 May ranged from a low of 7.8° Celsius (C) on 21 February, to a high of 14.2° C on 22 April. River discharge and water temperature averaged by day throughout the 2019 survey season are shown in Figure 5.

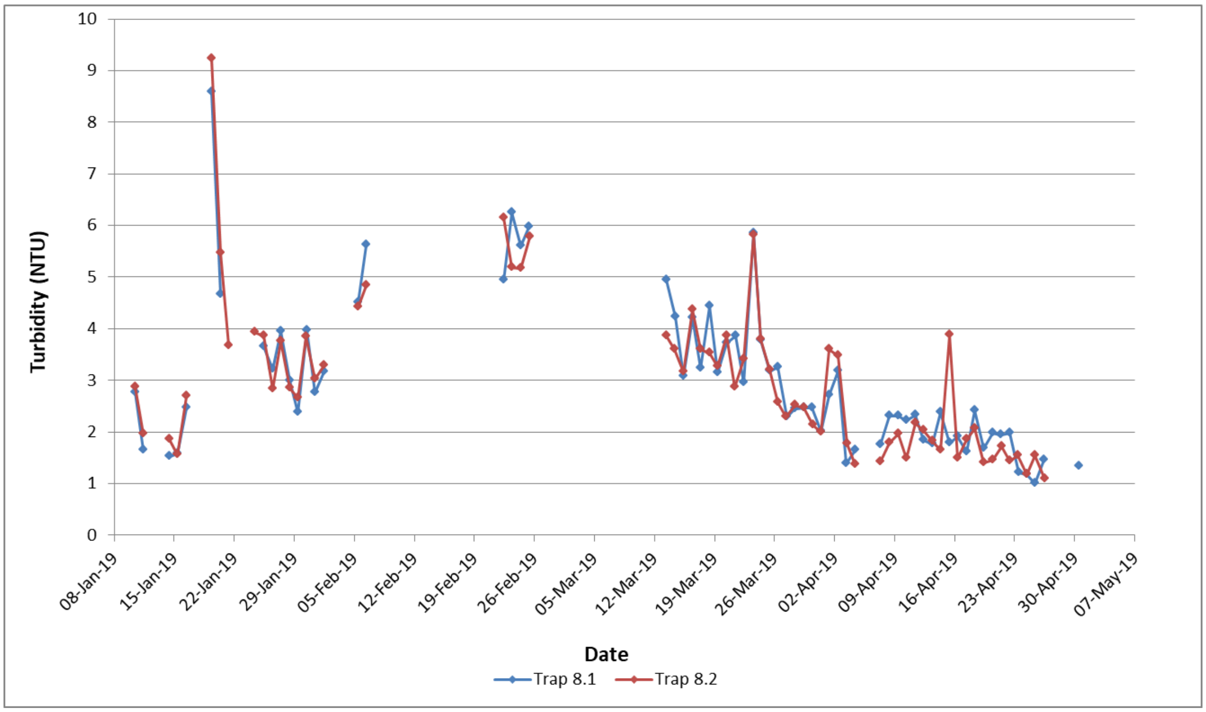
Figure 5: Average daily discharge (CFS) measured at Fair Oaks, and average daily water temperature (°C) measured at Watt Avenue during the 2019 lower American River rotary screw trap survey season.



Note: Discharge and water temperature data for the 8 January to 28 May time period were acquired from the USGS website at http://waterdata.usgs.gov/ca/nwis/uv.

River turbidity was measured in the field, from water samples taken daily from each trap, and remained similar between the two traps (Figure 6). Turbidity for both traps reached a season maximum on 19 January, with 9.23 Nephelometric Turbidity Units (NTU) for Trap 8.2 and 8.59 NTU for Trap 8.1. Turbidity declined to a low of 1.08 NTU for Trap 8.2 on 26 April, and a low of 1.00 NTU for Trap 8.1 on 25 April. Weekly average turbidity, averaged by Julian week, is shown in Appendix 2. Weekly average turbidity reached a high of 5.63 NTU during the week of 19 February and declined to a weekly average low of 1.27 NTU during the week of 23 April.

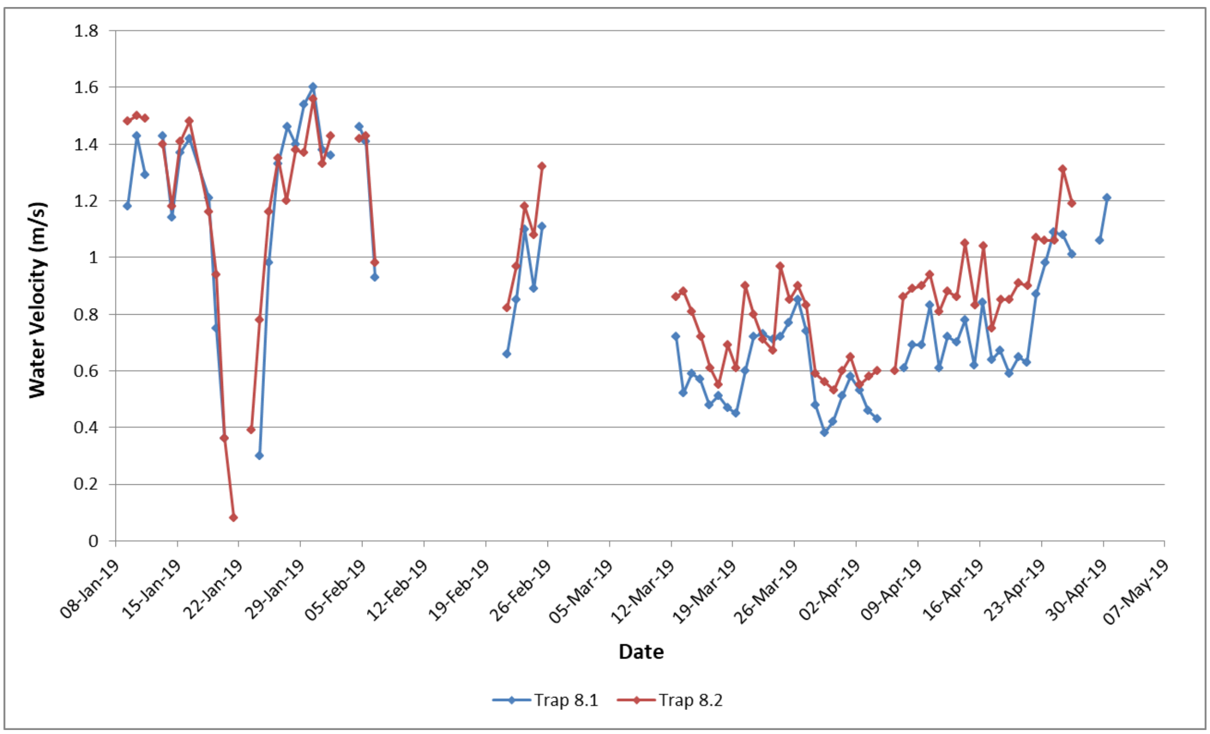
Figure 6: Comparison of daily turbidity measured in the field for each trap, during the 2019 lower American River rotary screw trap survey season.



Note: See Figure 3 for dates sampling occurred.

Water velocities were also measured for each trap on a daily basis, and were taken from in front of each cone. Velocities for both traps were similar throughout the survey season (Figure 7), with velocities for Trap 8.2 slightly higher than for Trap 8.1. Water velocity for Trap 8.1 reached a low of 0.30 meters per second (m/s) on 24 January, while water velocity for Trap 8.2 reached a low of 0.08 m/s on 21 January. Water velocities for both traps reached highs on 30 January with Trap 8.1 recording a value of 1.60 m/s and Trap 8.2 recording a value of 1.56 m/s. Weekly average water velocity between both traps, averaged by Julian week, is shown in Appendix 2. Weekly average water velocity reached a high of 1.45 m/s the week of 29 January and fell to a low of 0.62 m/s the week of 26 March.

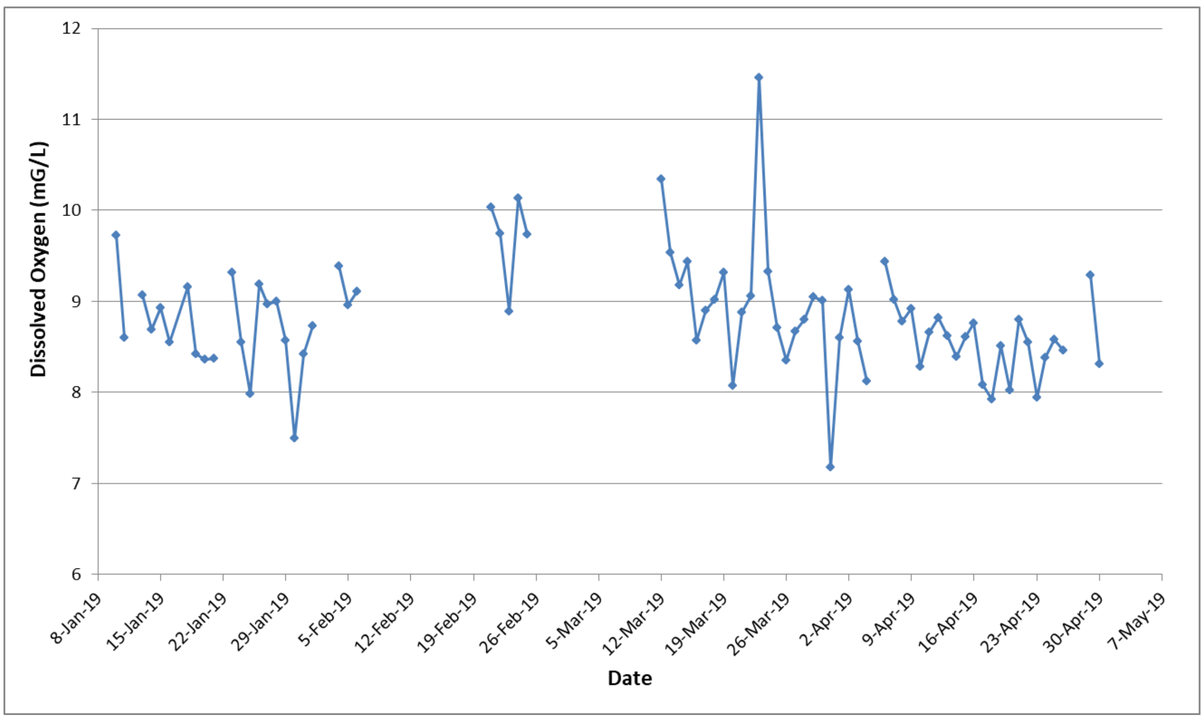
Figure 7: Comparison of daily water velocities, measured in the field in front of each trap, during the 2019 lower American River rotary screw trap survey season.



Note: See Figure 3 for dates sampling occurred.

Dissolved oxygen (DO) in the river water (Figure 8) was taken in the field as a single daily measurement, and ranged from a high of 11.46 milligrams per liter (mg/L) on 23 March to a low of 7.18 mg/L on 31 March. Weekly average DO, averaged by Julian week (Figure 2), reached a high of 9.71 mg/L the week of 19 February and had a weekly average low of 8.31 mg/L the week of 30 April however only one day of sampling occurred during this week. Of the weeks where sampling occurred more than one day, the week of 16 April had the lowest average with a value of 8.38 mg/L.

Figure 8: Daily dissolved oxygen content measured in the field during the 2019 lower American River rotary screw trap survey season.



Note: See Figure 3 for dates sampling occurred.

Catch

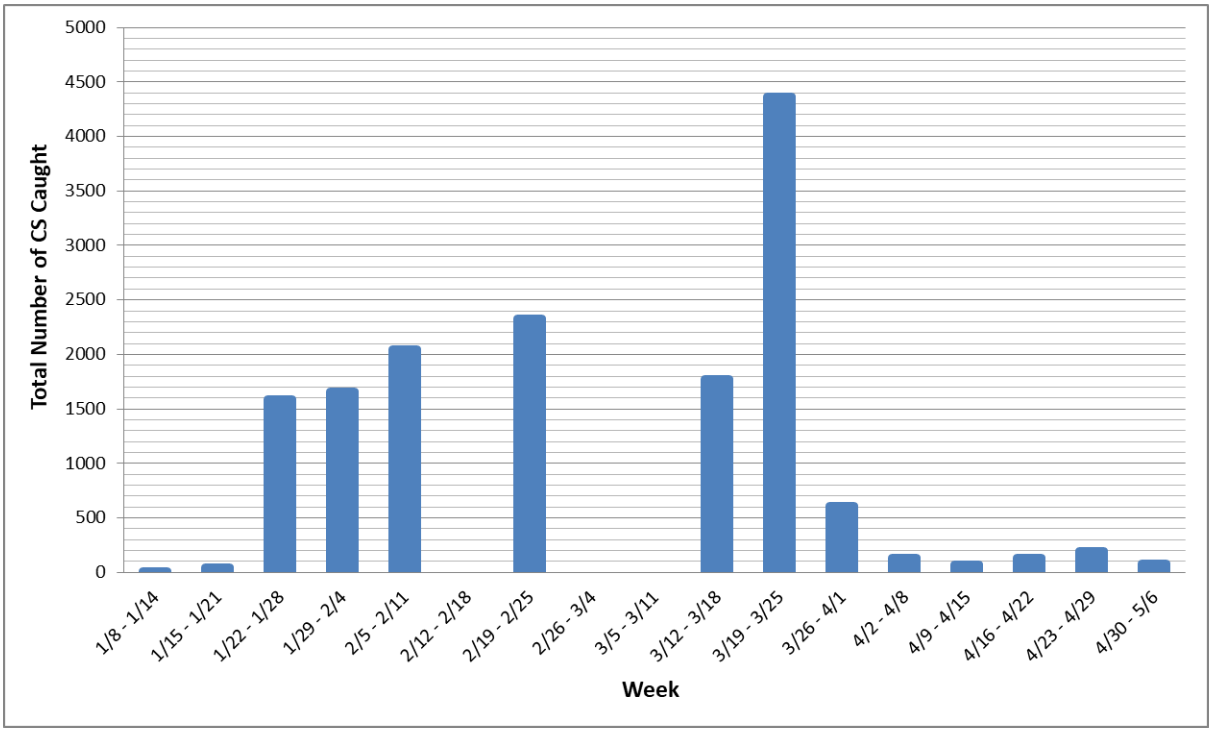
The two rotary screw traps deployed during the 2019 survey season captured a total of 17,608 fish, including 204 hatchery-produced salmonids. Trap 8.1 captured 43.55 percent (n = 7,668) of these fish, and Trap 8.2 captured 56.45 percent (n = 9,940). Salmonid species captured included steelhead and fall-, late-fall-, spring- and winter-run Chinook salmon by length-at-date criteria. However, genetic analysis revealed that the Chinook salmon runs captured did not include late fall-run Chinook salmon (Appendix 4). Twenty-two identified non-salmonid species as well as 112 non-salmonid individuals unable to be identified to species (Appendix 3) were also captured.

Fall-run Chinook salmon

A catch total of 15,056 unmarked Chinook salmon were determined to be fall-run based on the genetic analysis results. As these fish did not have an adipose fin clip, they were presumed to be of in-river production. Catch of in-river produced, unmarked fall-run Chinook salmon peaked between 19 March and 25 March, when 28.99 percent (n =4,364) of the season's total was captured (Figure 9).

Of the in-river produced, unmarked juvenile Chinook salmon captured during the 2019 survey season, a total of 8,406 were unmeasured plus-count tallies and may have included both LAD fall- and late fall-run Chinook salmon. However, by genetic analysis all LAD late fall-run Chinook salmon captured were determined to be fall-run Chinook salmon by proration of genetic analysis results, therefore all 8,406 unmeasured plus count tallies were determined to be fall-run Chinook salmon.

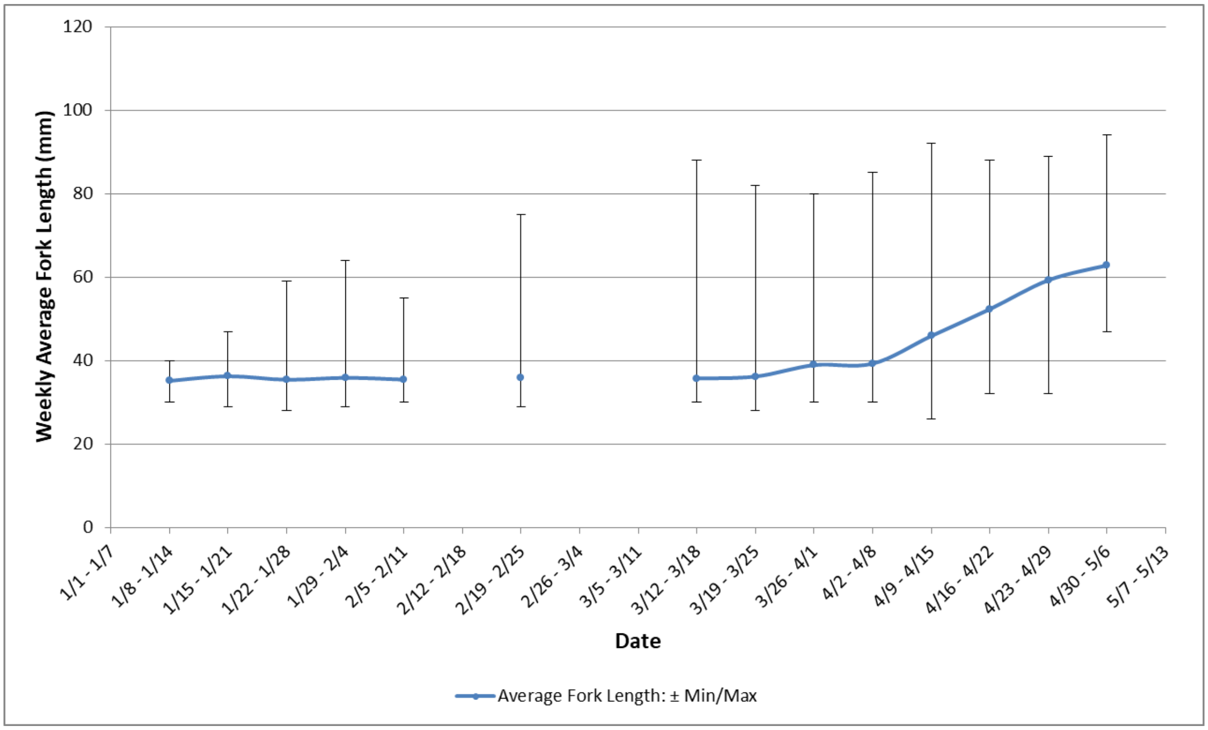
Figure 9: Weekly catch distribution of in-river produced, unmarked fall-run Chinook salmon during the 2019 lower American River rotary screw trap survey season.



Note: Plus-counted Chinook salmon and mortalities are included in the graph. See Figure 3 for dates sampling occurred.

A total of 6,650 in-river produced, unmarked fall-run Chinook salmon was measured for fork length. Weekly average fork lengths throughout the 2019 survey season are depicted in Figure 10 and Table 2. The lowest weekly average fork length was 35 mm, which was seen during the first week of sampling. The highest weekly average fork length was 63 mm, which occurred during the last week of sampling.

Figure 10: Average weekly fork length for fall-run Chinook salmon during the 2019 lower American River rotary screw trap survey season.



Note: See Figure 3 for dates sampling occurred.

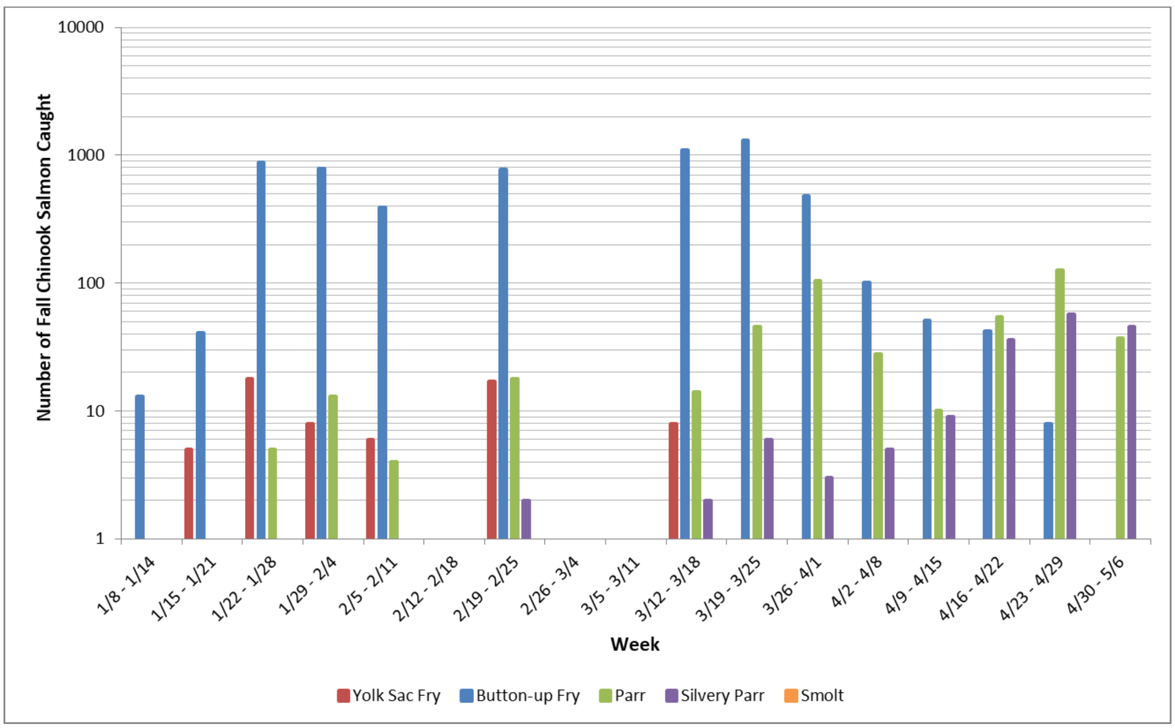
Table 2: Average, minimum, maximum and standard deviations of fork lengths (mm) per week for fall-run Chinook salmon during the 2019 lower American River rotary screw trap survey season.

Julian Week	Fork Length Average	Min	Max	St. Dev.
1/8 - 1/14	35	30	40	2.80
1/15 - 1/21	36	29	47	4.34
1/22 - 1/28	35	28	59	2.37
1/29 - 2/4	36	29	64	2.87
2/5 - 2/11	35	30	55	2.71
2/12 - 2/18				
2/19 - 2/25	36	29	75	4.06
2/26 - 3/4				
3/5 - 3/11				
3/12 - 3/18	36	30	88	3.49
3/19 - 3/25	36	28	82	4.80
3/26 - 4/1	39	30	80	7.41
4/2 - 4/8	39	30	85	9.38
4/9 - 4/15	46	26	92	17.78
4/16 - 4/22	52	32	88	14.18
4/23 - 4/29	59	32	89	10.21
4/30 - 5/6	63	47	94	8.01

Note: See Figure 3 for dates sampling occurred.

The fall-run Chinook salmon measured for fork length, were also assessed for life stage (Figure 11 and Table 3). The majority of this total was salmon identified as button-up fry life stage, which accounted for 89.58 percent (n = 5,957) of the assessed catch. Salmon identified as yolk sac fry comprised 0.96 percent (n = 64), parr made up 6.93 percent (n = 461), silvery parr were 2.51 percent (n = 167), and smolt were 0.02 percent (n = 1).

Figure 11: In-river produced, unmarked fall-run Chinook salmon catch by life stage during the 2019 lower American River rotary screw trap survey season.



Note: Since the *y*-axis scale is logarithmic, weeks where one Chinook salmon of a given life stage was captured do not appear in the graph. See Table 3 for weeks with a catch total of one. Plus-counted fall-run Chinook salmon are not included in the graph. See Figure 3 for dates sampling occurred.

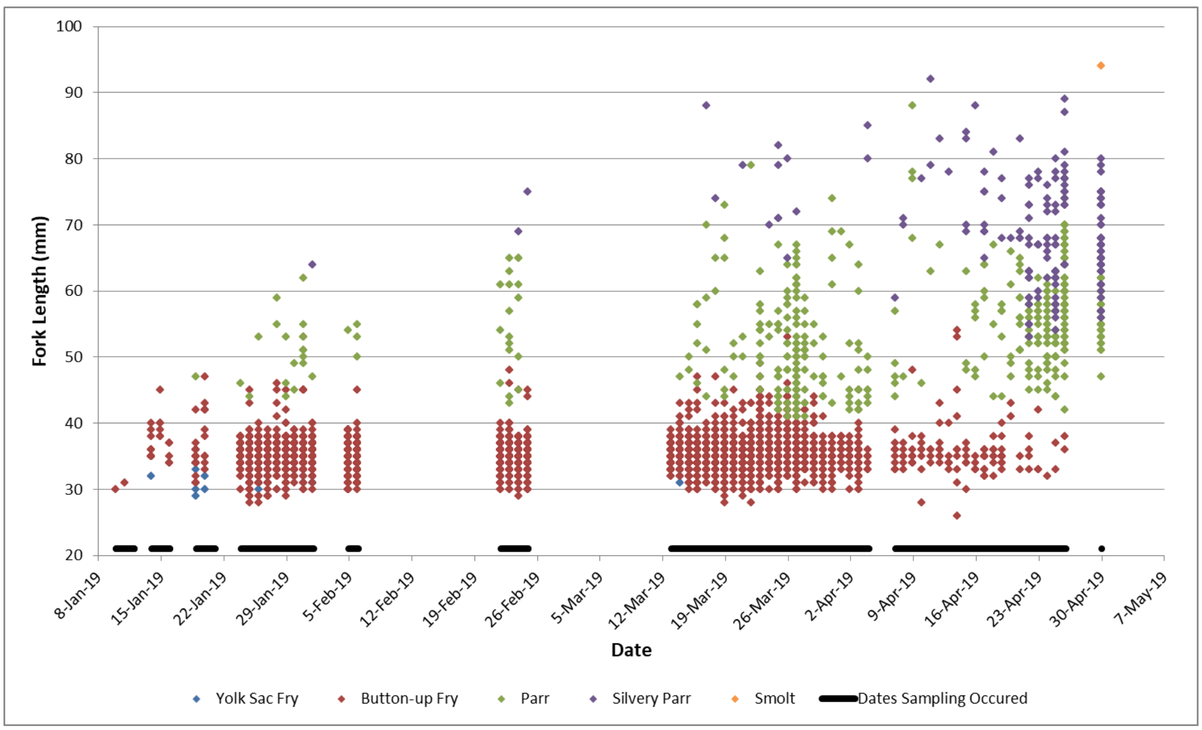
Table 3: Total of in-river produced, unmarked fall-run Chinook salmon by life stage or unassigned life stage during the 2019 lower American River rotary screw trap survey season.

Julian Week	Yolk Sac Fry	Button-up Fry	Parr	Silvery Parr	Smolt	Unassigned Life Stage	Total
1/8 - 1/14	1	13	0	0	0	0	14
1/15 - 1/21	5	41	1	0	0	0	47
1/22 - 1/28	18	879	5	0	0	689	1,591
1/29 - 2/4	8	787	13	1	0	846	1,655
2/5 - 2/11	6	393	4	0	0	1,648	2,051
2/12 - 2/18							
2/19 - 2/25	17	774	18	2	0	1,518	2,329
2/26 - 3/4							
3/5 - 3/11							
3/12 - 3/18	8	1,091	14	2	0	662	1,777
3/19 - 3/25	1	1299	46	6	0	3012	4,364
3/26 - 4/1	0	478	104	3	0	28	613
4/2 - 4/8	0	101	28	5	0	2	136
4/9 - 4/15	0	51	10	9	0	1	71
4/16 - 4/22	0	42	54	36	0	0	132
4/23 - 4/29	0	8	127	57	0	0	192
4/30 - 5/6	0	0	37	46	1	0	84
Total	64	5957	461	167	1	8406	15,056

Note: Unassigned life stage includes plus-counts. See Figure 3 for dates sampling occurred.

As shown in Figure 12, Chinook salmon identified as yolk sac fry were captured between 14 January and 19 March. Chinook salmon identified as button-up fry were captured beginning on the first survey day of the 2019 season on 10 January until 26 April. Chinook salmon identified as parr life stage were caught between 19 January and 30 April, salmon identified as silvery parr life stage were captured starting 1 February to the last day of the sampling on 30 April, and one salmon identified as smolt life stage was caught on 30 April.

Figure 12: Daily fall-run Chinook salmon fork lengths during the 2019 lower American River rotary screw trap survey season.



For each identified life stage of measured fall-run Chinook salmon, fork length distributions varied (Table 4). Yolk-sac fry life stage had a fork length distribution between 29 mm and 36 mm, while button-up fry ranged from 26 mm to 54 mm. Parr life stage ranged from 41 mm to 88 mm, and silvery parr ranged between 53 mm and 92 mm. One individual was identified as smolt life stage and measured 94 mm.

Average weekly fork lengths generally increased by life stage progression with yolk-sac fry life stage having the lowest average weekly fork lengths, and smolt life stage having the largest average weekly fork lengths. Overall average fork length for each life stage also increased according to life stage progression. Salmon identified as yolk-sac fry life stage had a season average fork length of 32 mm and button-up fry had an average folk length of 36 mm. Salmon identified as parr life stage had an average of 52 mm, silvery parr had an average of 73 mm and smolt had an average of 94 mm.

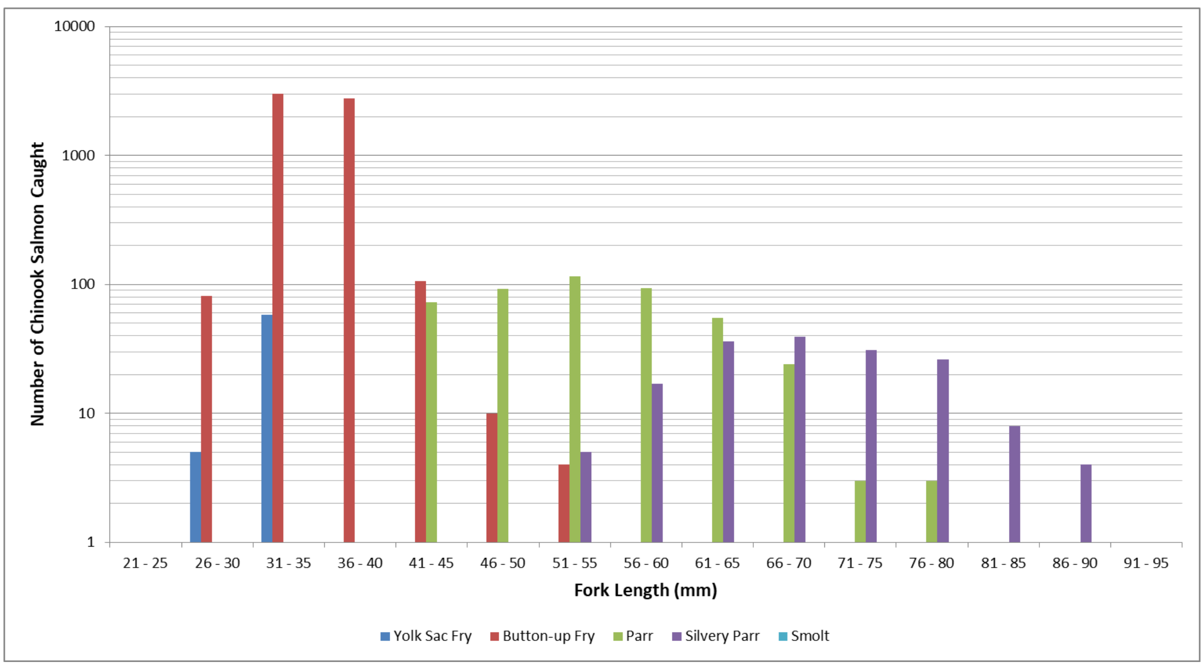
Table 4: Average, minimum and maximum fork lengths (mm) per week for each stage of fall-run Chinook salmon during the 2019 lower American River rotary screw trap survey season.

Julian	Yolk Sac Fry			Button-up Fry			Parr			Silvery Parr			Smolt		
Week	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
1/8 - 1/14	32	32	32	35	30	40									
1/15 - 1/21	31	29	33	37	31	47	47	47	47						
1/22 - 1/28	32	30	34	35	28	46	51	44	59						
1/29 - 2/4	32	31	34	36	29	53	50	44	62	64	64	64			
2/5 - 2/11	33	31	34	35	30	45	53	50	55						
2/12 - 2/18															
2/19 - 2/25	33	32	36	35	29	48	55	43	65	72	69	75			
2/26 - 3/4															
3/5 - 3/11															
3/12 - 3/18	33	31	34	35	30	47	55	44	70	81	74	88			
3/19 - 3/25	34	34	34	35	28	49	52	42	79	75	70	82			
3/26 - 4/1				36	30	53	51	41	74	72	65	80			
4/2 - 4/8				35	30	45	48	42	67	73	59	85			
4/9 - 4/15				36	26	54	65	46	88	79	69	92			
4/16 - 4/22				35	32	43	55	44	67	68	53	88			
4/23 - 4/29				36	32	42	56	42	74	69	54	89			
4/30 - 5/6							57	47	65	67	56	80	94	94	94

Note: See Figure 3 for dates sampling occurred.

Catch totals of measured in-river produced, unmarked fall-run Chinook salmon divided into 5 mm fork length size classes are shown in Figure 13 and Table 5. Chinook salmon measuring between 31 mm and 40 mm were captured most frequently during the 2019 survey season, encompassing 87.44 percent (n = 5,815) of the season's measured salmon catch. The size class between 31 mm and 35 mm comprised 46.04 percent (n =3,062) of the season's catch and included Chinook salmon identified as yolk sac fry and button-up fry life stages. The size class between 36 mm and 40 mm comprised 41.40 percent (n =2,753), and included Chinook salmon identified as yolk-sac fry, and button-up fry life stages.

Figure 13: Distribution of fall-run Chinook salmon life stage by fork length during the 2019 lower American River rotary screw trap survey season.



Note: Plus-counted fall-run Chinook salmon are not included in the graph. Since the *y*-axis scale is logarithmic, fork length categories containing only one salmon are not shown in the graph. See Table 5 for fork length categories that contain only one individual.

Table 5: Distribution of fall-run Chinook salmon life stage by fork length size class during the 2019 lower American River rotary screw trap survey season.

Fork Length Size Class	Yolk Sac Fry	Button-up Fry	Parr	Silvery Parr	Smolt	Total
21 - 25	0	0	0	0	0	0
26 - 30	5	81	0	0	0	86
31 - 35	58	3,004	0	0	0	3,062
36 - 40	1	2,752	0	0	0	2,753
41 - 45	0	106	73	0	0	179
46 - 50	0	10	92	0	0	102
51 - 55	0	4	116	5	0	125
56 - 60	0	0	94	17	0	111
61 - 65	0	0	55	36	0	91
66 - 70	0	0	24	39	0	63
71 - 75	0	0	3	31	0	34
76 - 80	0	0	3	26	0	29
81 - 85	0	0	0	8	0	8
86 - 90	0	0	1	4	0	5
91 - 95	0	0	0	1	1	2
96 - 100	0	0	0	0	0	0
101 - 105	0	0	0	0	0	0
106 - 110	0	0	0	0	0	0
111 - 115	0	0	0	0	0	0

Fulton's Condition Factor

Fulton's condition factor (K) for in-river produced, unmarked fall-run Chinook salmon captured in 2019 is shown in Appendix 5. The overall trend line exhibited a positive slope of 0.0018, indicating a slightly increasing trend in condition throughout the survey season. The trend line slopes were positive for parr (0.0017) and silvery parr (0.0005) life stages; however the button-up fry life stage had a slightly negative slope of -0.0005. Yolk-sac fry captured in 2019 were unable to be accessed for Fulton's condition factor as every fish identified with this life stage was measured below 40 mm and was therefore not weighed. Smolt life stage only included one individual; therefore no trend line could be calculated.

Trap Efficiency

Four mark-recapture trap efficiency trials were conducted throughout the 2019 survey season, two of which were included in analysis and used by the CAMP platform to determine passage estimates, and two of which were excluded from analysis (Table 6). The two trials that were included in analysis used a total of 1,909 fall-run Chinook salmon. Of that total, 599 were in-river produced salmon that were collected with the RSTs and marked with BBY whole body stain, while 1,310 were from Nimbus Fish Hatchery and marked on the snout with a visual implant elastomer. A total of 12 released salmon was recaptured in the included trials. Of the two trials, the average fork length of recaptured fish was approximately the same size as the average fork length of released fish. The average trap efficiency of the two trials kept in analysis and used to determine passage estimates was 0.73 percent.

Table 6: Trap efficiency data for mark and recapture trials during the 2019 lower American River rotary screw trap survey season.

Date	Fish Origin	Mark Color	Release ID Code	Included in Analysis	Date	Time	Average Fl (mm)	Total Released	Trial Day 1	2	3	4	5	6	7	Total Recaptured	Average Fl (mm)	Trap Efficiency	Flow (CFS) Time of Release
BBY Staining					Release				Recaptures for all Traps Combined							Recapture Summary			
3/20/2019	Natural	Brown	314	Yes	3/20/2019	16:51	35	599	4	1	0	1	0	0	0	6	34	1.00%	5070
4/2/2019	Hatchery	Brown	315	No	4/2/2019	18:24	48	1169	0	0	-	-	-	-	-	0	-	0.00%	5090
4/17/2019	Hatchery	Brown	316	Yes	4/17/2019	18:15	52	1310	6	0	0	0	0	0	0	6	52	0.46%	8280
Visual Implant Elastomer					Release				Recaptures for all Traps Combined							Recapture Summary			
4/29/2019	Hatchery	Pink	317	No	4/29/2019	19:39	73	1891	17	-	-	-	-	-	-	17	74	0.90%	7140

Note: Fall-run Chinook salmon were used for all trap efficiency trials.

In-river = Lower American River.

Hatchery = Nimbus Fish Hatchery.

BBY = Bismark brown Y whole body stain.

Visual Implant Elastomer = Elastomer dye, marked on the snout.

Release ID Code: This code is associated with the CAMP RST platform used to store RST data.

Included in Analysis: Indicates if the trial was used by the CAMP RST platform to determine passage estimates.

Flow (CFS) is the discharge from the USGS's American River Fair Oaks monitoring station, 21 rkm upstream of the American River RSTs on the day and time of the trap efficiency release.

Passage Estimate for Fall-Run Chinook salmon

According to the CAMP platform "run_passage" report, a total of 348,100 in-river produced fall-run Chinook salmon was estimated to have emigrated past the Watt Ave rotary screw trap location on the lower American River during the 2019 survey season. The 95 percent confidence interval for this estimate was from 265,900 to 466,700 individuals. The CAMP platform "lifestage_passage" report, which subdivides a passage estimate by life stage, estimated 302,400 fry (including both yolk-sac fry and button-up fry life stages), 40,810 parr (including both parr and silvery parr life stages), and 78 smolts to have emigrated past the trap location. It is important to note that these are only estimates of Chinook salmon emigration during the time the traps were operating: from 10 January to 6 February, from 22 February to 25 February, and from 13 March to 30 April. Potential emigration before the traps started sampling and during the gaps in sampling longer than seven days is not included in these estimates.

A comparison of weekly passage estimates to weekly discharge at the USGS monitoring station at Fair Oaks is displayed in Figure 14 and Table 7.

Figure 14: Daily passage estimate of fall-run Chinook salmon and daily discharge at Fair Oaks during the 2019 lower American River rotary screw trap survey season.

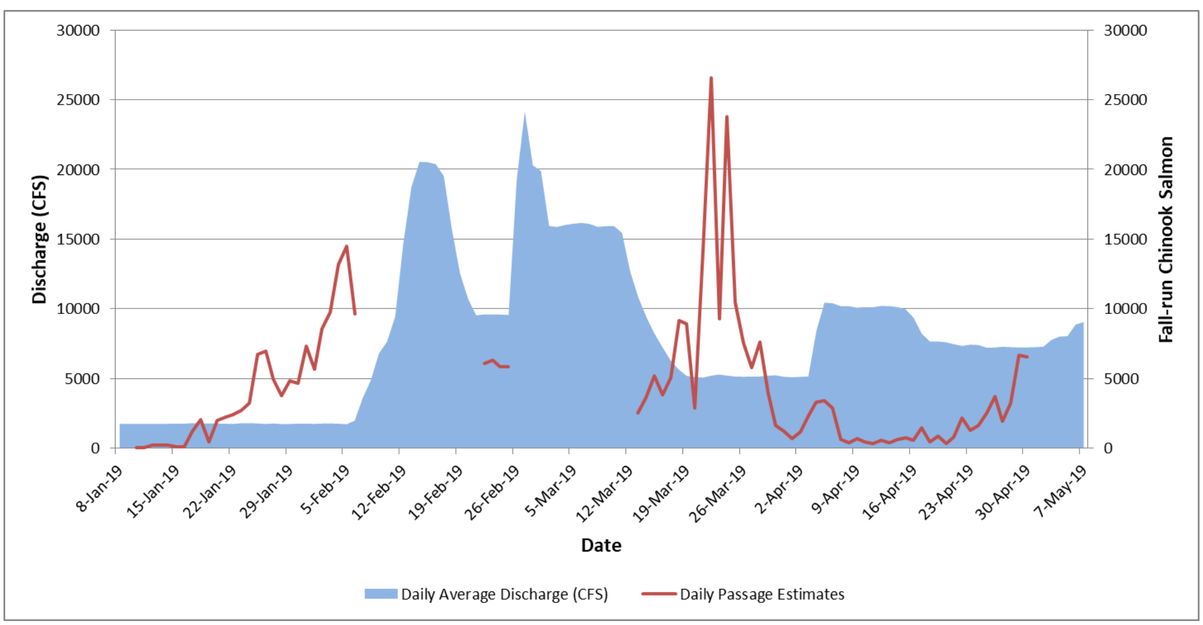


Table 7: Weekly passage estimate of fall-run Chinook salmon and weekly discharge at Fair Oaks during the 2019 lower American River rotary screw trap survey season.

Date	Discharge (CFS)	Passage Estimate
1/8 - 1/14	1,750	688
1/15 - 1/21	1,775	8,094
1/22 - 1/28	1,768	30,849
1/29 - 2/4	1,762	53,911
2/5 - 2/11	5,153	24,139
2/12 - 2/18	18,576	0
2/19 - 2/25	10,162	24,101
2/26 - 3/4	18,769	0
3/5 - 3/11	15,935	0
3/12 - 3/18	8,625	29,507
3/19 - 3/25	5,173	96,080
3/26 - 4/1	5,155	28,419
4/2 - 4/8	8,559	14,202
4/9 - 4/15	10,117	3,784
4/16 - 4/22	7,898	6,712
4/23 - 4/29	7,290	21,066
4/30 - 5/6	7,778	6,574
5/7 - 5/13	9,047	0

Note: See Figure 3 for dates sampling occurred.

Genetic Analysis

During the 2019 survey season, a total of 85 genetic samples taken from juvenile Chinook salmon were analyzed using SNP genetic markers to determine run assignments. The SNP panel's probabilities for each of the 85 samples exceeded a 50 percent threshold; the final salmon run assignments for the corresponding salmon were therefore made based on genetic data. A complete accounting of the salmon run assignments using LAD criteria and genetic markers is provided in Appendix 4. The 85 samples that were processed were taken from salmon that did not have an adipose fin clip, and were therefore presumed to be of in-river production.

A total of 67 in-river produced Chinook salmon captured in 2019 were classified as spring-run Chinook salmon using LAD criteria. Genetic samples taken from 64 of these salmon were analyzed to determine run assignments. The analyses indicated 85.94 percent (n = 55) of these individuals were fall-run Chinook salmon, and 14.06% (n=9) were spring-run Chinook salmon (Table 8). Because the LAD criteria appeared to incorrectly assign salmon runs at a high frequency, the 3 LAD spring-run Chinook salmon that were not analyzed using genetic markers were given a final run assignment of fall-run.

A total of 18 Chinook salmon classified as winter-run Chinook salmon using LAD criteria were captured during the 2019 survey season. Genetic samples were taken from 17 of these fish and were analyzed to determine run assignments. Analyses using SNP genetic markers from those samples indicated that 100.00 percent (n=17) were winter-run Chinook salmon. The remaining individual that was not analyzed using genetic markers was assigned a final run of winter given that 100 percent of the genetically analyzed LAD winter-run fish were determined to be winter-run.

A total of 84 Chinook salmon classified as late fall-run Chinook salmon using LAD criteria were also captured in 2019. Genetic samples were taken from 3 of these and were analyzed to determine run assignments. Analyses using SNP genetic markers from those samples indicated that 100.00 percent (n=3) were fall-run Chinook salmon (Table 8). Because the LAD criteria appeared to incorrectly assign this salmon run, all 81 of the LAD late fall-run Chinook salmon that were not analyzed using genetic markers were given a final run assignment of fall-run.

A genetic sample from one salmon classified as fall-run Chinook salmon using LAD criteria was also analyzed. Analyses using SNP genetic markers from this sample indicated that this individual was a fall-run Chinook salmon (Table 8).

Table 8: Comparison of Chinook salmon run assignments using length-at-date (LAD) criteria and SNP genetic markers.

	Genetic Run Assignment			
Length-at-Date Run Assignment	**Fall**	**Late Fall**	**Spring**	**Winter**
Fall	1	0	0	0
Late Fall	3	0	0	0
Spring	55	0	9	0
Winter	0	0	0	17

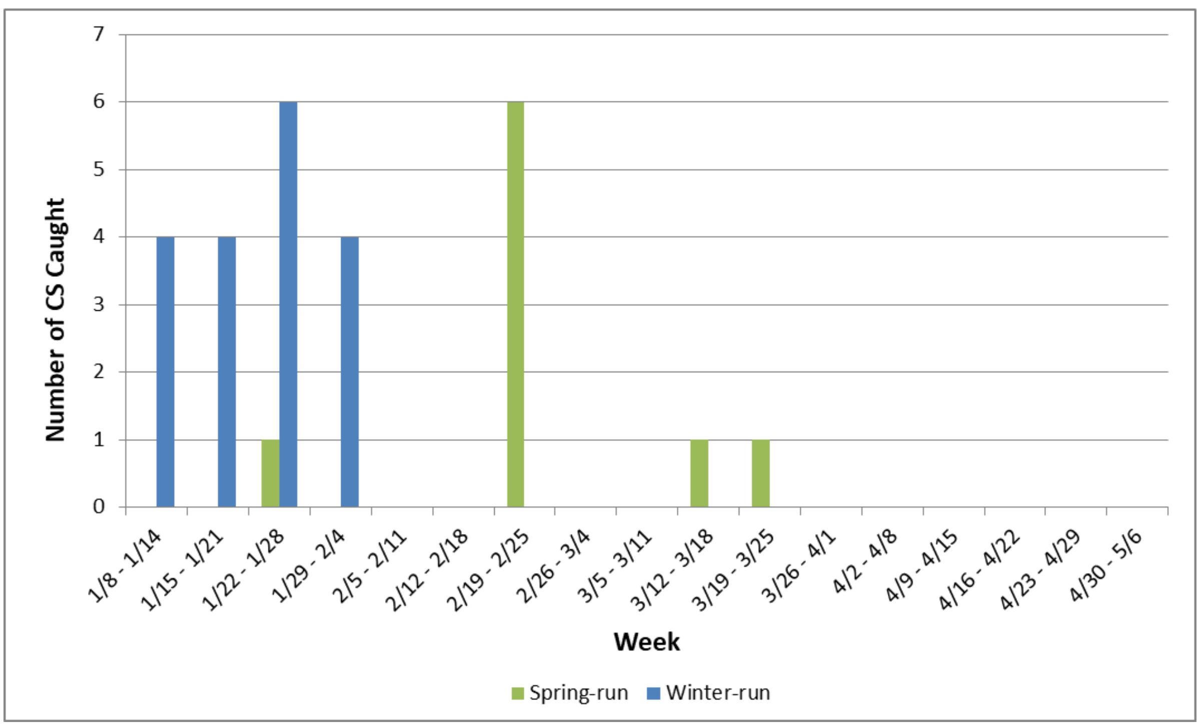
Note: Genetic salmon run assignment was based on a >50 percent genetic probability threshold. The table only includes Chinook salmon presumed to be of in-river production: i.e., it does not include salmon with an adipose fin clip, which are known to be hatchery produced.

Spring-run and Winter-run Chinook salmon

Genetic analyses suggest that 9 in-river produced spring-run Chinook salmon were captured during the 2019 survey season. Six of the nine caught were captured the week of 19 February. The remaining three were captured on 28 January, 17 March and 25 March (Figure 15). Six of these fish were identified to be parr life stage and three were identified as silvery parr life stage. Fork lengths ranged from 52 mm to 74 mm with the average fork length being 63 mm.

The genetic analyses suggest that 18 in-river produced winter-run Chinook salmon were captured during the 2019 survey season. All 18 winter-run Chinook salmon were captured during the first four weeks of trapping with the first captured on 14 January and the last captured on 1 February (Figure 15). Seventeen of these fish were identified to be silvery parr life stage and one was identified as parr life stage. Fork lengths ranged from 67 mm to 87 mm with the average fork length being 78 mm.

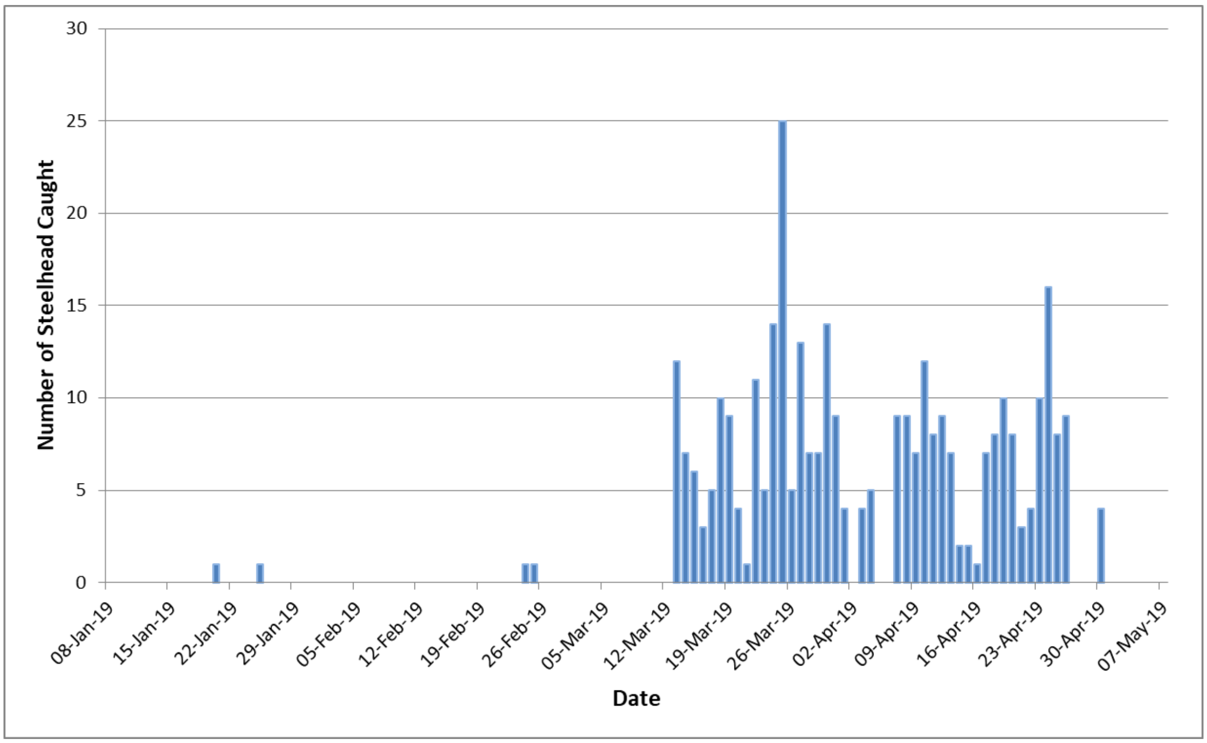
Figure 15: Weekly catch totals for in-river produced spring-run and winter-run Chinook salmon during the 2019 lower American River rotary screw trap survey season.



Steelhead/Rainbow Trout

During the 2019 survey season, a total of 337 in-river produced steelhead was captured. The day with the highest catch of steelhead was 25 March, when 7.42 percent (n = 25) of the season's total was captured (Figure 16). Weekly steelhead catch peaked the week of 19 March, comprising 20.47 percent (n = 69) of the total steelhead captured (Table 9).

Figure 16: Daily catch totals for in-river produced steelhead during the 2019 lower American River rotary screw trap survey season.



Note: See Figure 3 for dates sampling occurred.

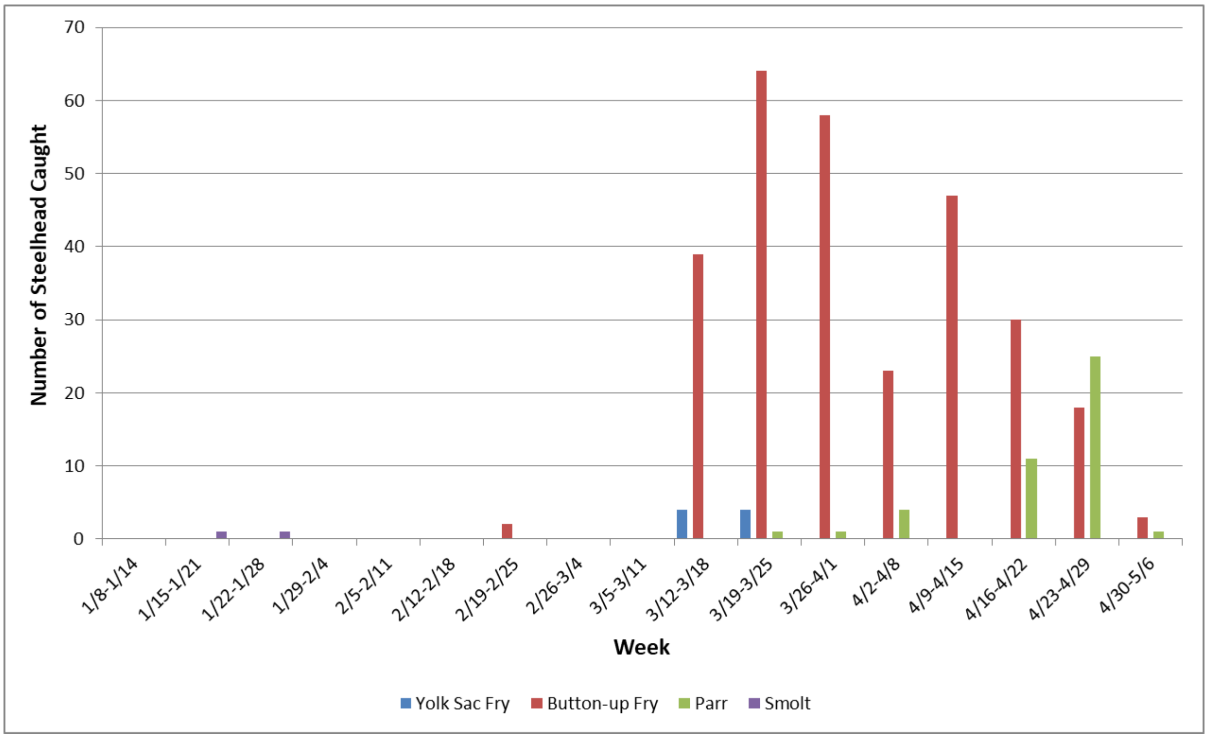
Table 9: Weekly catch totals by life stage for in-river produced steelhead during the 2019 lower American River rotary screw trap survey season.

Julian Week	Yolk Sac Fry	Button-up Fry	Parr	Silvery Parr	Smolt	Adult	Total
1/8-1/14	0	0	0	0	0	0	0
1/15-1/21	0	0	0	0	1	0	1
1/22-1/28	0	0	0	0	1	0	1
1/29-2/4	0	0	0	0	0	0	0
2/5-2/11	0	0	0	0	0	0	0
2/12-2/18	0	0	0	0	0	0	0
2/19-2/25	0	2	0	0	0	0	2
2/26-3/4	0	0	0	0	0	0	0
3/5-3/11	0	0	0	0	0	0	0
3/12-3/18	4	39	0	0	0	0	43
3/19-3/25	4	64	1	0	0	0	69
3/26-4/1	0	58	1	0	0	0	59
4/2-4/8	0	23	4	0	0	0	27
4/9-4/15	0	47	0	0	0	0	47
4/16-4/22	0	30	11	0	0	0	41
4/23-4/29	0	18	25	0	0	0	43
4/30-5/6	0	3	1	0	0	0	4
Total	8	284	43	0	2	0	337

Note: See Figure 3 for dates sampling occurred.

All steelhead captured in 2019 were assessed for a life stage. The life stage composition of these steelhead consisted of 8 yolk sac fry (2.37 percent), 284 button-up fry (84.27 percent), 43 parr (12.76 percent), and 2 smolts (0.59 percent) (Figure 17). No in-river produced steelhead were identified as silvery parr life stage.

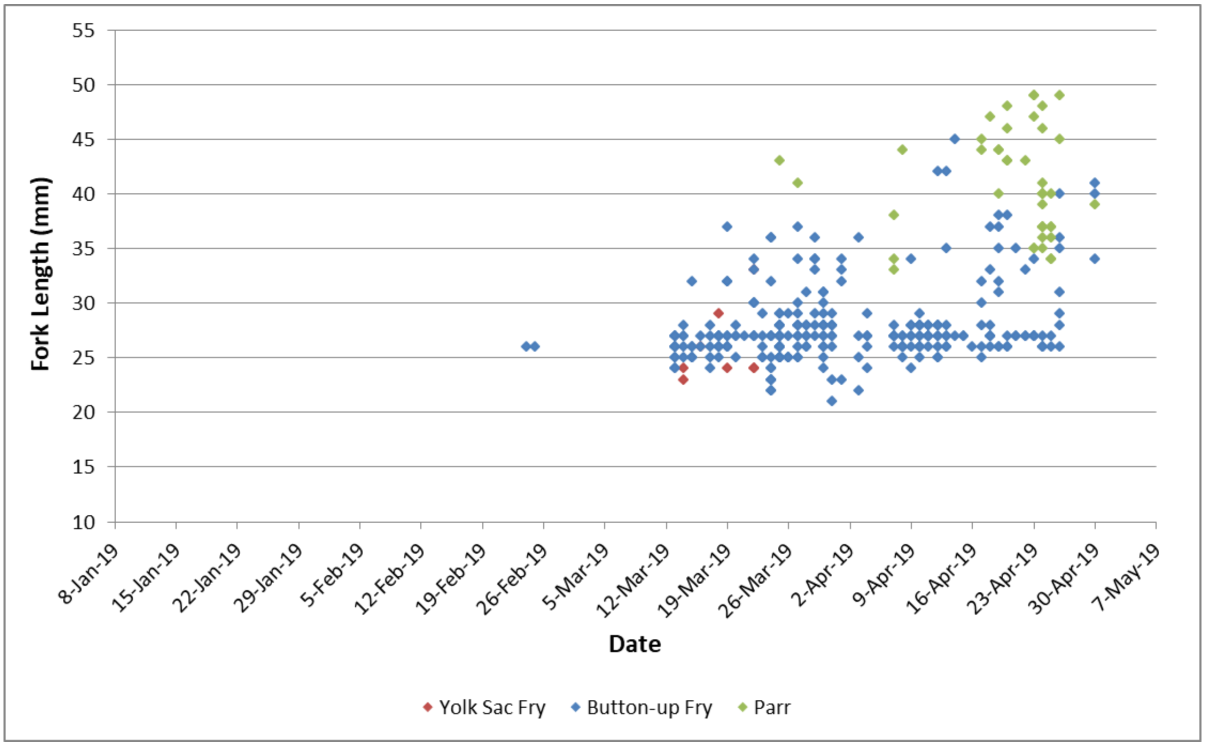
Figure 17: Weekly catch totals by life stage for in-river produced steelhead during the 2019 lower American River rotary screw trap survey season.



Note: See Figure 3 for dates sampling occurred.

The steelhead identified as yolk sac fry life stage were captured between 14 March and 22 March, with fork lengths ranging between 23 mm and 33 mm. Steelhead identified as button-up fry life stage were captured between 24 February and 30 April. Fork lengths for button-up fry ranged from 21 mm to 45 mm. Steelhead identified as parr were captured between 25 March and 30 April and ranged in fork length from 33 mm to 49 mm (Figure 18). Two steelhead identified as smolt life stage were captured on 20 January and 25 January and fork lengths measured 298 mm and 260 mm respectively.

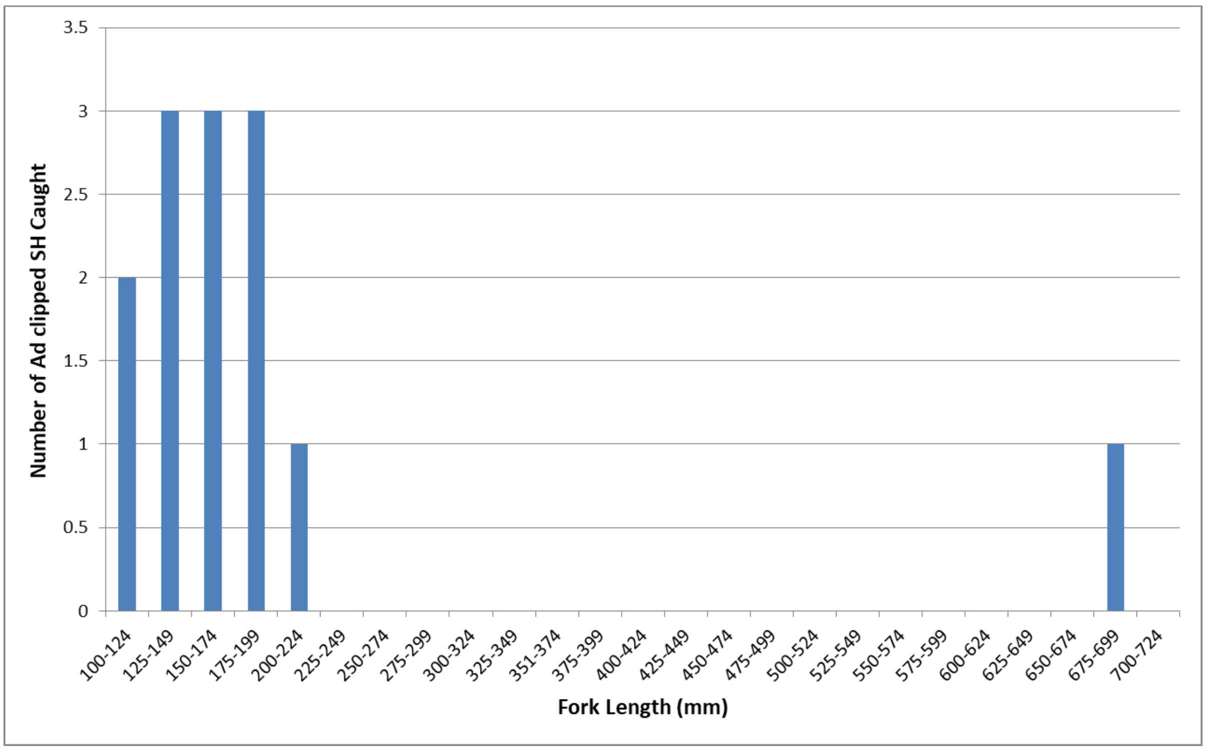
Figure 18: Individual fork lengths by date for in-river produced steelhead captured during the 2019 lower American River rotary screw trap survey season.



Note: The two captured steelhead identified as smolt life stage were not included in this graph due to their significantly larger fork length (260 mm captured on 25 January and 298 mm captured on 20 January).

In addition to the in-river produced steelhead catch, 13 adipose clipped, hatchery produced steelhead were also captured. These fish were caught from 26 January through 23 March. The minimum fork length recorded was 102 mm, the maximum was 695 mm and the average was 196 mm (Figure 19). The hatchery produced steelhead were assessed for life stage with smolts comprising 92.31 percent (n=12) of the catch. One adult was caught (7.69 percent).

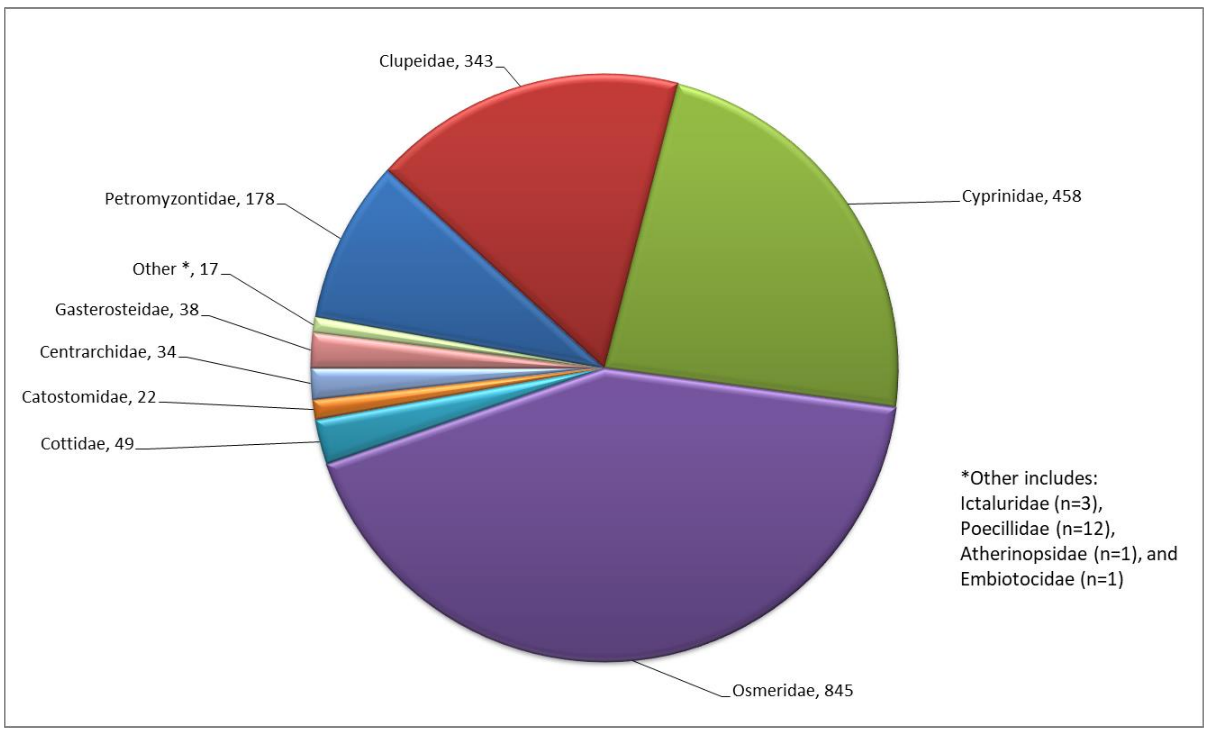
Figure 19: Fork length distribution of adipose fin clipped steelhead during the 2019 lower American River rotary screw trap survey season.



Non-salmonid Species

In addition to the salmonids, a total of 1,984 non-salmonid fish was captured during the 2019 survey season. The majority (n = 1,872 or 94.35 percent) of these fish belonged to 22 identified species in the following families: *Atherinopsidae* (silverside), *Catostomidae* (sucker), *Centrarchidae* (sunfish/black bass), *Clupeidae* (shad), *Cottidae* (sculpin), *Cyprinidae* (minnow), *Embiotocidae* (Tule perch), *Gasterosteidae* (stickleback), *Ictaluridae* (bullhead/catfish), *Osmeridae* (smelt), *Petromyzontidae* (lamprey), and *Poeciliidae* (mosquitofish) (Figure 20). The remaining 5.65 percent (n =112) were not able to be identified to species level, but belonged to the following families: *Centrarchidae*, *Cottidae, Cyprinidae*, and *Petromyzontidae*. A total of 623 (33.28 percent) of the non-salmonid fish captured in 2019 were of species native to Central Valley watersheds, a total of 1249 (66.72 percent) were of non-native species. A complete list of non-salmonid species captured in the 2019 survey season is presented in Appendix 3.

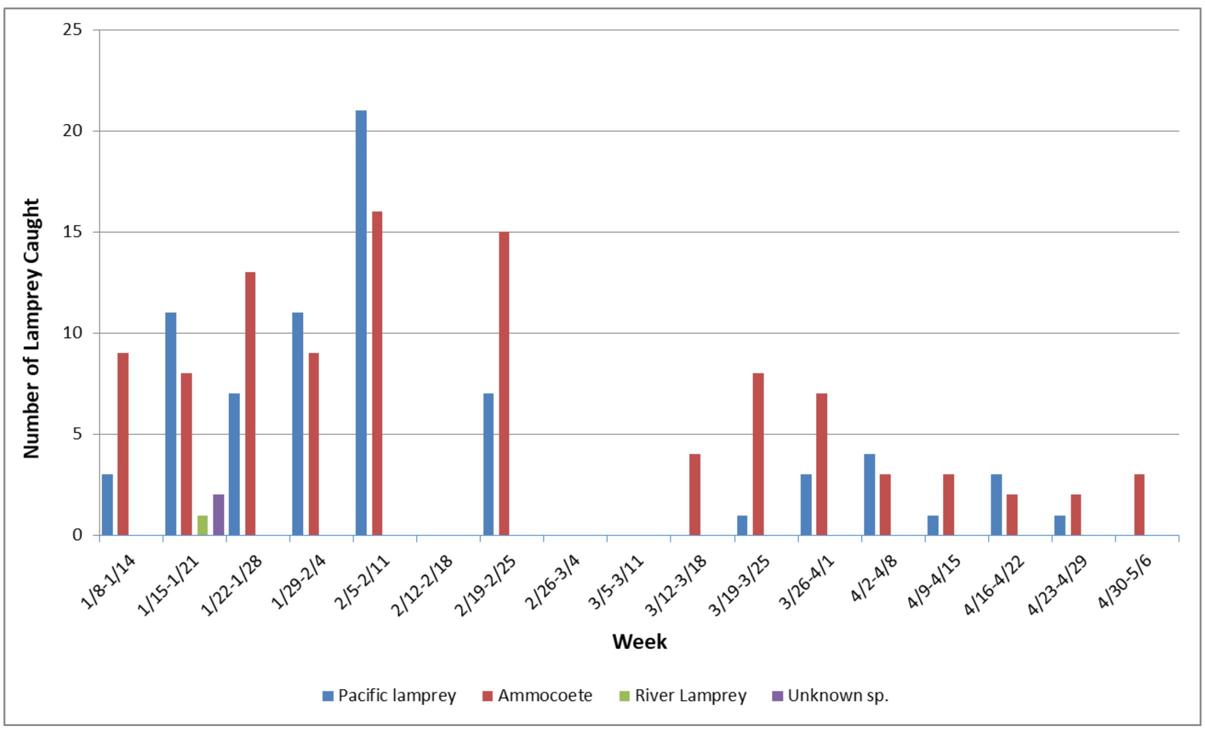
Figure 20: Non-salmonid catch totals for families of fish species collected during the 2019 lower American River rotary screw trap survey season.



Of the 1,984 non-salmonid fish captured, 178 (8.97 percent) were identified as *Petromyzontidae* spp. (northern lampreys); seventy-three (41.01 percent) of which were identified as *Entosphenus tridentatus* (Pacific lamprey), and consisted of 4 adults and 69 juveniles. One (0.56 percent) *Lamperta ayresii* (river lamprey) was captured and was identified as juvenile life stage. Two (1.12 percent) juvenile lamprey were captured that could not be identified to species level. The remaining 102 (57.30 percent) lamprey captured were identified as juvenile ammocoetes and were not identified to a species level.

Both Pacific lamprey and ammocoetes were captured throughout the season. Catch of Pacific lamprey peaked between 5 February and 11 February. At this time, 21 (28.77 percent) of the season's Pacific lamprey total was captured. Catch of ammoceotes also peaked between 5 February and 11 February, when 16 (15.68 percent) of the season's ammocoete total was captured. The river lamprey was captured on 19 January.

Figure 21: Total weekly lamprey catch during the 2019 lower American River rotary screw trap survey season.



Note: See Figure 3 for dates sampling occurred.

Discussion

When interpreting the data collected during the 2019 survey season on the Lower American River and the juvenile Chinook salmon passage estimate produced from that data, several influential factors must be considered. One of the most significant of these may have been environmental factors, especially fluctuating river flows. During the 2019 survey season high flows were experienced on multiple occasions which hindered the ability to collect consistent, high quality data. This restricted the number of days that the traps could be safely operated and limited the number of trap efficiency trials that could be conducted. Backflow events occurred where the increased height stage on the Sacramento River filled into the American River reducing the flows at the trapping site and hindering the RSTs ability to function properly.

Increased flows, like those seen during the 2019 survey season, increase the amount of debris in the water column, which can affect the successful operation of the rotary screw traps by stopping the rotation of the cone or can increase the potential for damage to traps and sampling equipment. Increased debris associated with high flows can also cause fish mortality by crushing fish within the debris or by causing fish trapped within a stopped cone to become pummeled by incoming water. In cases where debris was too high to manage with multiple checks per day cones were raised and sampling was temporarily suspended. This occurred four times during the 2019 survey season, where two of those periods of suspended sampling exceeded seven days. Since these gaps in sampling exceeded the seven day maximum threshold for the CAMP Platform to accurately estimate catch, the passage estimate produced for the 2019 survey season also excludes those periods of time likely biasing the passage estimate low. Additionally, because these gaps occurred during periods of historical peak emigration, the passage estimate is likely biased significantly lower than it would have been had trapping been possible on these dates.

Another factor to consider while interpreting the data is whether the survey season encompassed the entire fall-run Chinook salmon emigration period. During the first seven days of the 2019 survey season, a total of 25 juvenile fall-run Chinook salmon was captured, accounting for 0.17percent of the total season catch and comprising of 0.25 percent (n=872) of the total passage estimate. The relatively low catch the first week of trapping reflects that the 2019 survey season did encompass the beginning of the fall-run Chinook salmon emigration period. Alternatively, during the last seven days of the survey season, including days where traps were not sampling, a total of 249 juvenile fall-run Chinook salmon was captured accounting for 1.65 percent of the total season catch. The last seven days of the survey season comprised 7.57 percent (n=26,344) of the total passage estimate, which includes three days of imputed catch when trapping did not occur. The difference in actual catch percentage versus passage percentage suggests the 2019 survey season likely did not encompass the end of the emigration period. Typically, trapping would continue into late May or early June, however an anchor line failure required the trapping season to conclude on 30 April.

The total number of in-river produced fall-run Chinook salmon estimated to have emigrated past the rotary screw trap location on the American River during the 2019 survey season was 348,100 individuals, with 95 percent confidence intervals ranging from 256,900 to 466,700 individuals.

In considering the accuracy of the 2019 passage estimate, trap efficiencies must also be considered. For highest accuracy, as many trap efficiency trials as possible should be conducted throughout a survey season. However, since trap efficiencies are inversely affected by river discharge, trap efficiency trials rely heavily on consistent river discharge throughout the entire trial period to accurately determine efficiencies. In 2019, an attempt was made to conduct trap efficiency trials when river flows stabilized, but with multiple flow increases and rather low numbers of Chinook salmon captured, only four trap efficiency trials were able to be conducted. One of these trials was discarded because traps were raised after only two days due to a river flow increase. Another trial was discarded because it was taking place at the time of the anchor line failure and the survey season was forced to conclude. These trials were excluded from analysis and were not used to determine the passage estimate.

Passage estimates were not produced for spring-run or winter-run Chinook salmon, since low numbers of these runs were captured. Of the 67 Chinook salmon identified as LAD spring-run, genetic analysis was conducted on 64 and determined 55 (85.94 percent) were fall-run. The remaining nine (14.06 percent) were determined to be spring-run Chinook salmon. As in previous years, LAD spring-run criteria proved to be inaccurate in determining the actual run of these Chinook salmon and therefore the three LAD spring-run fish that were not analyzed genetically were given a final fall-run determination. Seventeen of the 18 Chinook salmon measured as LAD winter-run were genetically analyzed and all 17 were determined to be winter-run. The LAD criteria appears to be much more accurate in the determination of winter-run and therefore the one LAD winter-run that was not analyzed genetically, was given final winter-run determination. As seen in previous years as well as in isotopic studies, these winter-run are thought to be using the American River as non-natal rearing habitat (Phillis 2017).

A total of 337 in-river produced steelhead was captured. This is a relatively high number compared to recent survey seasons, which is possibly due to close proximity of steelhead redds to the RST location, however a survey conducted by Cramer Fish Sciences only observed one redd (Figure 22) in proximity to the trapping site (Cramer 2019). Another potential explanation is that there was a significant decrease in flow on the Lower American River that coincided with the emergence of steelhead fry starting around the week of 12 March. The flow reduced from 15,900 cfs on 10 March to 5,200 cfs on 18 March. As seen in appendix 8, the width of the river is reduced considerably in a drop in flow of that magnitude. It could have created conditions that necessitated the emigration of juvenile steelhead beyond the traps.

Figure 22: Steelhead redd locations on the lower American River, depicted by the markers, during the 2019 survey conducted by Cramer Fish Sciences.

Management Implications

In order to determine if efforts made by AFRP and others to increase abundance of Chinook salmon and steelhead on the lower American River have been successful, additional monitoring of juvenile salmonid emigration is required. Continued management of water temperature and flow to provide ideal river conditions and habitat for anadromous fishes is also of importance. The 2019 data will be coupled with prior and future data to provide crucial information to better understand and improve conditions for Chinook salmon and steelhead on the lower American River. The comparison of this year's data to previous years can be used to influence water management modifications for the American River to make the river environment more favorable to anadromous fishes in future drought conditions. Management options such as modifications to discharge volume and timing could be adjusted to reduce pre-spawn mortality and minimize redd dewatering and superimposition which have likely had a negative influence on spawning in previous drought years, however it did not likely influence spawning in 2019 due to the higher volumes of water.

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Appendix 1: Points of interest on the lower American River.

Point of Interest	Significance	Operator	River Miles (rkm)
Folsom Dam	Constructed 1956; Power Generation, flood control, water supply, recreation.	U.S. Bureau of Reclamation	29.4 (47.3)
Nimbus Dam	Constructed 1955; Power Generation, flood control, water supply, recreation.	U.S. Bureau of Reclamation	22.3 (35.8)
Nimbus Fish Hatchery	Chinook salmon and Steelhead Hatchery; Fish ladder, weir.	California Department of Fish and Wildlife	22.2 (35.7)
American River at Fair Oaks	River discharge gauging station	U.S. Geological Survey	22.1 (35.6)
Sailor Bar	Habitat improvement; Gravel augmentation		~22 (35.4)
Lower Sunrise	Habitat improvement; Gravel augmentation		~19 (30.6)
Sacramento Bar	Habitat improvement; Gravel augmentation		~18 (29)
La Riviera storm water outflow	Release site for trap efficiency mark-recapture trials (Chinook and Steelhead Trial)		9.7 (15.6)
Above Watt Avenue Bridge	Release site for trap efficiency mark-recapture trials (Steelhead Trial Only)		9.4 (15.1)
Watt Avenue bridge	River temperature monitoring station	U.S. Geological Survey	9.2 (14.8)
North channel RST below Watt Avenue	RST site for monitoring juvenile salmonid abundance and outmigration		9 (14.5)
South channel RST below Watt Avenue	RST site for monitoring juvenile salmonid abundance and outmigration (Site not used in low water years)		8.8 (14.2)
Howe Avenue boat launch	Nimbus Fish Hatchery release site for Chinook salmon and steelhead		7.8 (12.6)
Jabboom St. bridge	Nimbus Fish Hatchery release site for Chinook salmon and steelhead		0.2 (0.3)
Mouth of American River	American-Sacramento River Confluence		0

Appendix 2: **Weekly environmental conditions on the lower American River during the 2019 survey season.**

Julian Week	Water Temperature (C°)			Discharge			Dissolved Oxygen (mg/L)			Turbidity (NTU)			Velocity (m/s)		
	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max
1/8-1/14	10.17	9.0	11.0	1750	1630	1920	9.02	8.60	9.73	2.10	1.80	2.81	1.35	1.16	1.47
1/15-1/21	10.33	9.3	11.6	1775	1650	1930	8.63	9.16	9.16	4.36	1.57	8.91	0.89	0.08	1.45
1/22-1/28	9.88	8.8	10.8	1768	1640	2010	8.84	7.98	9.32	3.49	2.91	3.93	1.01	0.39	1.39
1/29-2/4	10.32	9.4	11.2	1762	1690	1820	8.52	7.50	9.39	3.13	2.52	3.91	1.45	1.36	1.58
2/5-2/11	8.99	8.1	10.2	5153	1700	12700	9.04	8.96	9.11	4.84	4.46	5.23	1.19	0.96	1.42
2/12-2/18	8.61	8.0	9.1	18576	12700	20800									
2/19-2/25	8.30	7.8	9.0	10162	9470	13100	9.71	8.89	10.13	5.63	3.18	5.87	1.00	0.74	1.22
2/26-3/4	8.38	7.9	9.0	18769	9620	25700									
3/5-3/11	8.89	8.3	10.0	15935	12900	16300									
3/12-3/18	9.62	8.6	11.3	8625	5200	13000	9.28	8.57	10.34	3.85	3.12	4.39	0.64	0.53	0.79
3/19-3/25	9.80	8.7	11.2	5173	5050	5330	9.26	8.07	11.46	3.76	3.18	5.83	0.73	0.53	0.85
3/26-4/1	10.41	9.1	12.5	5155	5000	5290	8.52	7.18	9.05	2.51	1.70	3.15	0.62	0.47	0.88
4/2-4/8	10.74	10.0	12.0	8559	5070	10600	8.84	8.12	9.44	2.01	1.50	3.32	0.62	0.52	0.79
4/9-4/15	11.41	10.2	12.7	10117	9350	10500	8.61	8.28	8.92	2.11	1.18	2.83	0.80	0.71	0.92
4/16-4/22	11.95	10.4	13.8	7898	7270	9450	8.38	7.92	8.80	1.78	1.54	2.24	0.80	0.70	0.97
4/23-4/29	12.76	11.8	14.2	7290	7100	7550	8.53	7.94	9.29	1.27	1.18	1.37	1.09	1.02	1.20
4/30-5/6	12.49	11.4	13.8	7778	7230	9540	8.31	8.31	8.31	1.33	1.33	1.33	1.21	1.21	1.21

Note: The USGS website provides the discharge and temperature data by day in 15 minute intervals. To calculate the averages by week, the 15 minute intervals were first averaged by day, and then the days were averaged by the seven day Julian week indicated by the "Week" column in the table above. The min and max values for the discharge and temperature data are the highest and lowest values recorded for the week. Dissolved oxygen was calculated by weekly averages from daily values gathered by crew members in the field. Dissolved oxygen min and max values are reflective of the minimum and maximum daily value gathered during the Julian week defined by the "Julian Week" column in the table above. Turbidity and velocity reflect a weekly average of values, gathered per trap by crew members in the field and averaged into a single daily value. Turbidity and velocity min and max values are reflective of the minimum and maximum daily value gathered for each trap during the Julian week defined by the "Julian Week" column in the table above.

Appendix 3: List of fish species caught during the 2019 season using rotary screw traps on the lower American River.

Common Name	Family Name	Species Name	Total Number Caught
Chinook salmon	Salmonidae	*Oncorhynchus tshawytscha*	15,274
Steelhead / rainbow trout	Salmonidae	*Oncorhynchus mykiss*	350
American shad	Clupeidae	*Alosa Sapidissima*	3
Bluegill	Centrarchidae	*Lepomis macrochirus*	20
Channel catfish	Ictaluridae	*Ictalurus punctatus*	1
Common carp	Cyprinidae	*Cyprinus carpio*	1
Golden shiner	Cyprinidae	*Notemigonus crysoleucas*	14
Green sunfish	Centrarchidae	*Lepomis cyanellus*	1
Hardhead	Cyprinidae	*Mylopharodon conocephalus*	79
Inland silverside	Atherinopsidae	*Menidia beryllina*	1
Pacific lamprey	Petromyzontidae	*Entosphenus tridentatus*	73
Prickly sculpin	Cottidae	*Cottus asper*	17
Riffle sculpin	Cottidae	*Cottus gulosus*	30
River lamprey	Petromyzontidae	*Lampetra ayresii*	1
Sacramento pikeminnow	Cyprinidae	*Ptychocheilus grandis*	362
Sacramento sucker	Catostomidae	*Catostomus occidentalis*	22
Spotted bass	Centrarchidae	*Micropterus punctulatus*	9
Threadfin shad	Clupeidae	*Dorosoma petenense*	337
Threespine stickleback	Gasterosteidae	*Gasterosteus aculeatus*	38
Tule perch	Embiotocidae	*Hysterocarpus traskii*	1
Wakasagi / Japanese smelt	Osmeridae	*Hypomesus nipponensis*	845
Western mosquitofish	Poeciliidae	*Gambusia affinis*	12
White catfish	Ictaluridae	*Ameiurus catus*	1
White crappie	Centrarchidae	*Pomoxis annularis*	1
Unknown bony fish			3
Unknown catfish or bullhead	Ictaluridae		1
Unknown lamprey	Petromyzontidae		104
Unknown minnow	Cyprinidae		2
Unknown sculpin (Cottus)	Cottidae	*Cottus sp.*	2
Unknown sunfish (Lepomis)	Centrarchidae	*Lepomis sp.*	3
		Total	**17,608**

Appendix 4: **Genetic results for fin-clip samples from Chinook salmon caught in the lower American River during the 2018 survey season.**

Sample #: refer to a unique number assigned by field staff, and that allowed the tracking of individual fish samples.

LAD run assignment: Chinook salmon run assignment based on the length-at-date run assignment methodology developed by Greene (1992).

SNP Run Assignment: Chinook salmon run assignment using "Genetic Call to three lineages" single-nucleotide polymorphism (SNP) markers.

SNP Probability: Probability of the correct SNP Chinook salmon run assignment.

Final run assignment: Run assignment using a 50 percent threshold based on the SNP probability.

FL: Fork length in millimeters.

W: Weight in grams.

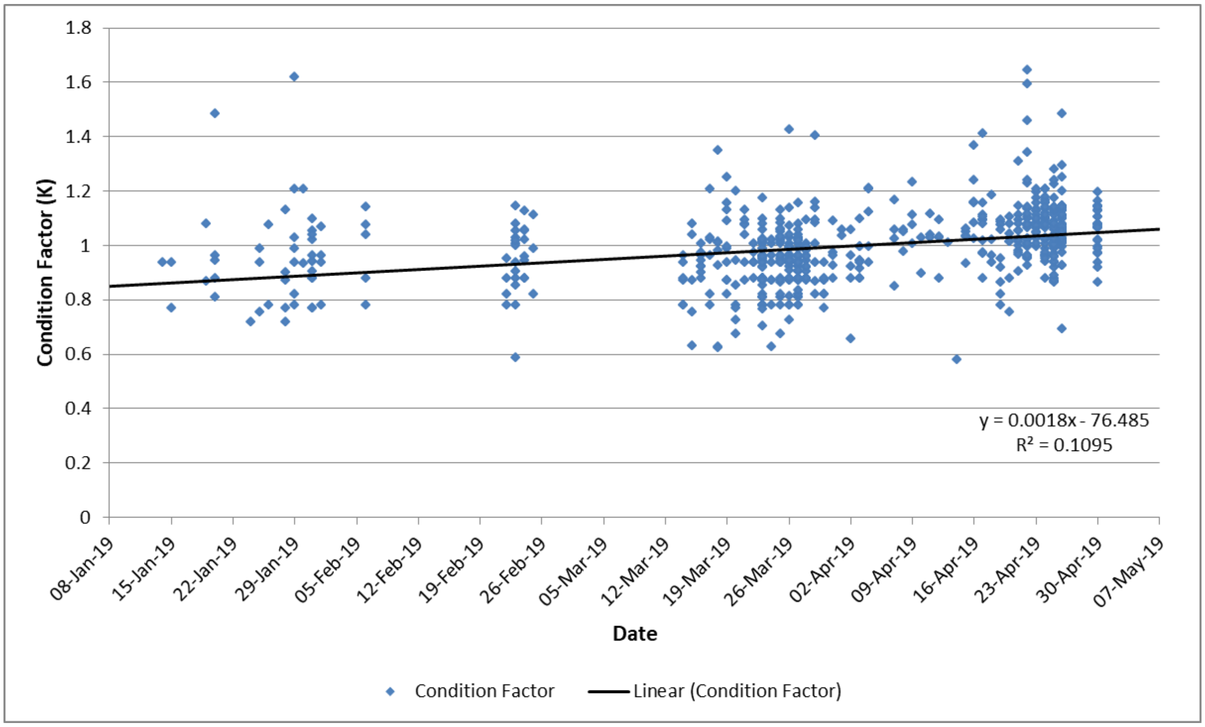
Date	Sample #	LAD Run Assign ment	SNP Run Assignment	SNP Probablity	Final Run Assignment	FL (mm)	W (g)
14-Jan	3527-001	Winter	Winter	1.000	Winter	80	4.9
14-Jan	3527-002	Winter	Winter	1.000	Winter	72	4
14-Jan	3527-003	Winter	Winter	1.000	Winter	74	4.1
14-Jan	3527-004	Winter	Winter	1.000	Winter	68	3.1
15-Jan	3527-005	Winter	Winter	1.000	Winter	77	4
15-Jan	3527-006	Winter	Winter	1.000	Winter	74	3.8
16-Jan	3527-007	Winter	Winter	1.000	Winter	67	3
19-Jan	3527-008	Spring	Fall	0.946	Fall	47	0.9
19-Jan	3527-009	Winter	Winter	1.000	Winter	85	5.9
20-Jan	3527-010	Spring	Fall	0.948	Fall	47	1
25-Jan	3527-011	Winter	Winter	1.000	Winter	69	3.1
25-Jan	3527-012	Winter	Winter	1.000	Winter	85	6.8
25-Jan	3527-013	Winter	Winter	1.000	Winter	79	4.8
26-Jan	3527-014	Winter	Winter	1.000	Winter	78	4.6
26-Jan	3527-015	Winter	Winter	1.000	Winter	85	6.9
26-Jan	3527-016	Winter	Winter	1.000	Winter	78	5.7

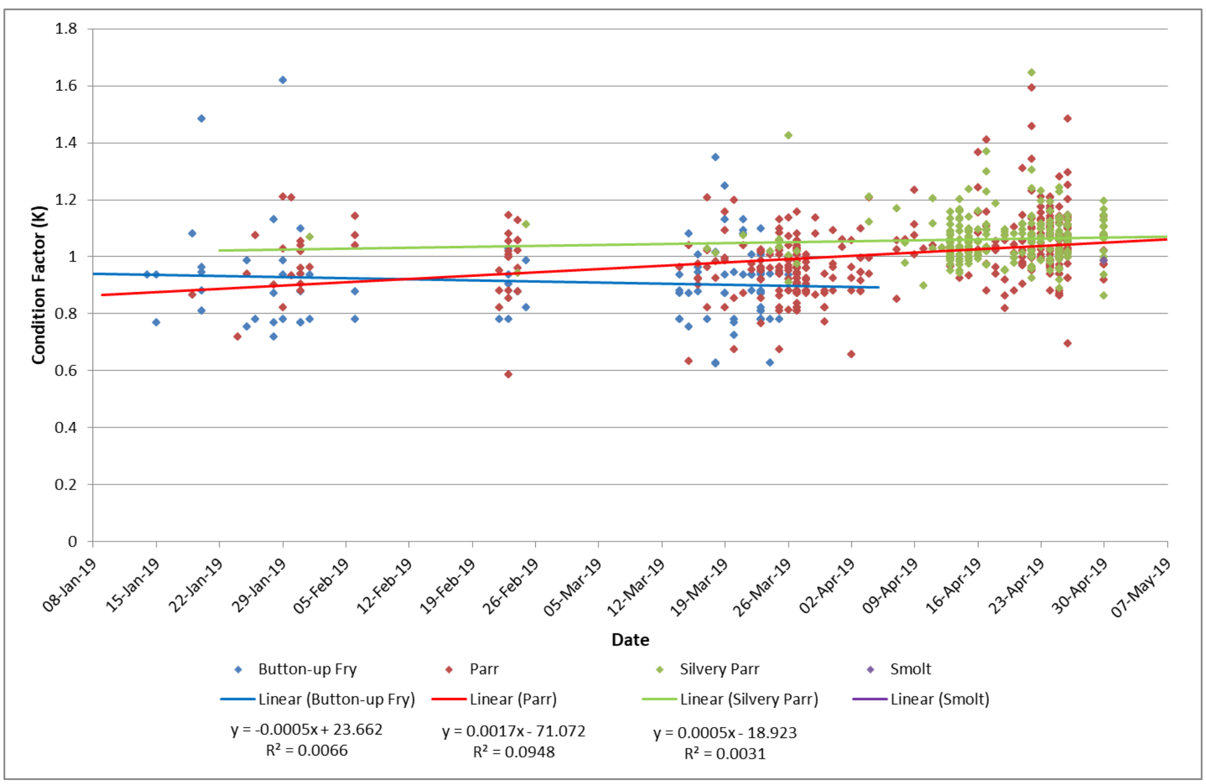
26-Jan	3527-017	Spring	Fall	0.922	Fall	53	1.6
28-Jan	3527-018	Spring	Fall	1.000	Fall	59	
28-Jan	3527-019	Spring	Fall	0.999	Fall	55	1.5
28-Jan	3527-020	Spring	Spring	0.984	Spring	52	0.3
29-Jan	3527-021	Spring	Fall	1.000	Fall	53	1.8
30-Jan	3527-022	Spring	Fall	0.999	Fall	49	1.1
31-Jan	3527-023	Winter	Winter	1.000	Winter	82	5.5
31-Jan	3527-024	Winter	Winter	1.000	Winter	87	7.2
31-Jan	3527-025	Spring	Fall	1.000	Fall	53	1.4
31-Jan	3527-026	Spring	Fall	0.967	Fall	62	2.1
31-Jan	3527-027	Spring	Fall	1.000	Fall	51	1.4
31-Jan	3527-028	Spring	Fall	0.999	Fall	51	1.2
31-Jan	3527-029	Spring	Fall	1.000	Fall	55	1.6
31-Jan	3527-030	Winter	Winter	1.000	Winter	78	4.9
31-Jan	3527-031	Spring	Fall	0.996	Fall	50	1.3
1-Feb	3527-032	Spring	Fall	0.859	Fall	64	2.8
5-Feb	3527-033	Spring	Fall	0.999	Fall	54	7.8
6-Feb	3527-034	Spring	Fall	1.000	Fall	53	1.6
6-Feb	3527-035	Spring	Fall	0.999	Fall	55	1.9
22-Feb	3527-036	Spring	Spring	0.982	Spring	59	1.9
22-Feb	3527-037	Spring	Spring	0.999	Spring	61	2.2
22-Feb	3527-038	Spring	Spring	0.981	Spring	57	1.8
23-Feb	3527-039	Spring	Fall	1.000	Fall	63	2.5
23-Feb	3527-040	Spring	Fall	0.815	Fall	65	2.8
23-Feb	3527-041	Fall	Fall	0.998	Fall	57	2
23-Feb	3527-042	Spring	Fall	0.844	Fall	61	2.6
24-Feb	3527-043	Spring	Fall	0.791	Fall	69	3.1
24-Feb	3527-044	Spring	Fall	0.691	Fall	59	2.1
24-Feb	3527-045	Spring	Spring	0.689	Spring	69	3.3
24-Feb	3527-046	Spring	Fall	0.996	Fall	65	3.1
24-Feb	3527-047	Spring	Spring	0.921	Spring	60	2.1
24-Feb	3527-048	Spring	Fall	0.998	Fall	65	2.9

24-Feb	3527-049	Spring	Fall	1.000	Fall	61	2.4
25-Feb	3527-050	Spring	Fall	0.987	Fall	75	4.7
25-Feb	3527-051	Spring	Spring	0.524	Spring	59	2.9
17-Mar	3527-052	Spring	Spring	0.796	Spring	74	4.3
17-Mar	3527-053	Spring	Fall	0.999	Fall	70	3.3
17-Mar	3527-054	Spring	Fall	1.000	Fall	88	7
18-Mar	3527-055	Spring	Fall	0.547	Fall	74	4.1
19-Mar	3527-056	Spring	Fall	0.999	Fall	73	4.5
19-Mar	3527-057	Spring	Fall	0.954	Fall	68	
21-Mar	3527-058	Spring	Fall	0.994	Fall	79	5.3
22-Mar	3527-059	Spring	Fall	0.999	Fall	79	4.8
24-Mar	3527-060	Spring	Fall	0.871	Fall	70	3.5
25-Mar	3527-061	Spring	Spring	0.999	Spring	73	4.1
25-Mar	3527-062	Spring	Fall	0.999	Fall	79	5.1
25-Mar	3527-063	Spring	Fall	1.000	Fall	82	5.8
25-Mar	3527-064	Spring	Fall	0.999	Fall	71	3.7
25-Mar	3527-065	Spring	Fall	0.999	Fall	71	3.8
26-Mar	3527-066	Spring	Fall	0.983	Fall	80	7.3
27-Mar	3527-067	Spring	Fall	0.997	Fall	72	3.8
31-Mar	3527-068	Spring	Fall	1.000	Fall	74	3.9
4-Apr	3527-069	Spring	Fall	0.949	Fall	80	6.2
4-Apr	3527-070	Spring	Fall	1.000	Fall	85	6.9
9-Apr	3527-071	Spring	Fall	0.998	Fall	78	5.1
9-Apr	3527-072	Spring	Fall	0.954	Fall	88	8.4
9-Apr	3527-073	Spring	Fall	0.999	Fall	77	4.6
11-Apr	3527-074	Spring	Fall	1.000	Fall	79	5.5
11-Apr	3527-075	Spring	Fall	1.000	Fall	92	8
12-Apr	3527-076	Spring	Fall	0.975	Fall	83	5.9
15-Apr	3527-077	Spring	Fall	0.997	Fall	84	6.3
15-Apr	3527-078	Spring	Fall	0.750	Fall	83	5.9
16-Apr	3527-079	Spring	Fall	0.997	Fall	88	7.9
24-Apr	3527-080	Late fall	Fall	0.999	Fall	32	

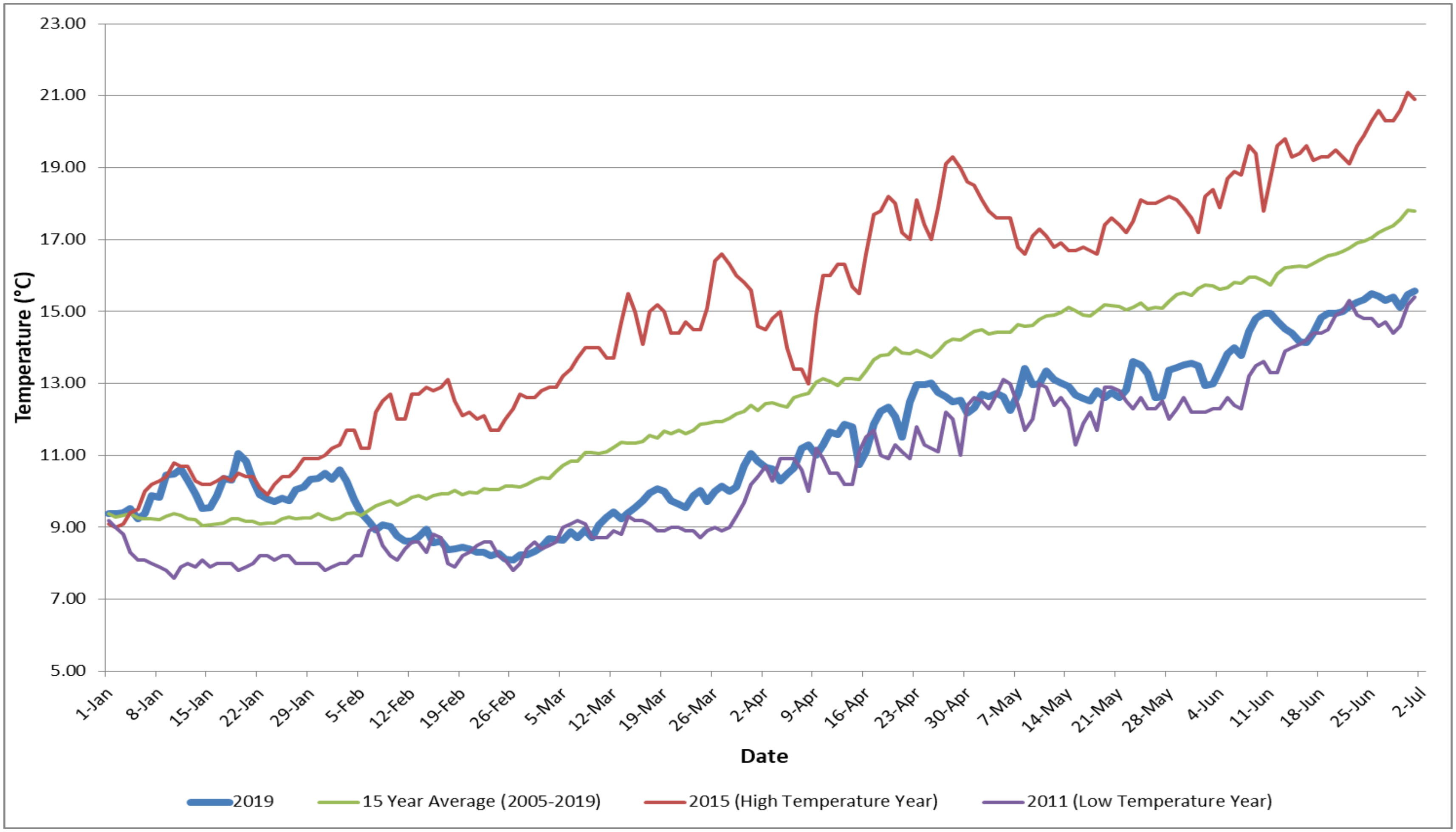
25-Apr	3527-081	Late fall	Fall	0.999	Fall	37	
25-Apr	3527-082	Late fall	Fall	0.986	Fall	33	
26-Apr	3527-083	Spring	Fall	1.000	Fall	89	7.4
26-Apr	3527-084	Spring	Fall	0.985	Fall	87	7.3
30-Apr	3527-085	Spring	Fall	0.926	Fall	94	8.2

Appendix 5: Fulton's condition factor (K), overall, and by life stage, of fall-run Chinook salmon during the 2019 lower American River rotary screw trap survey season.

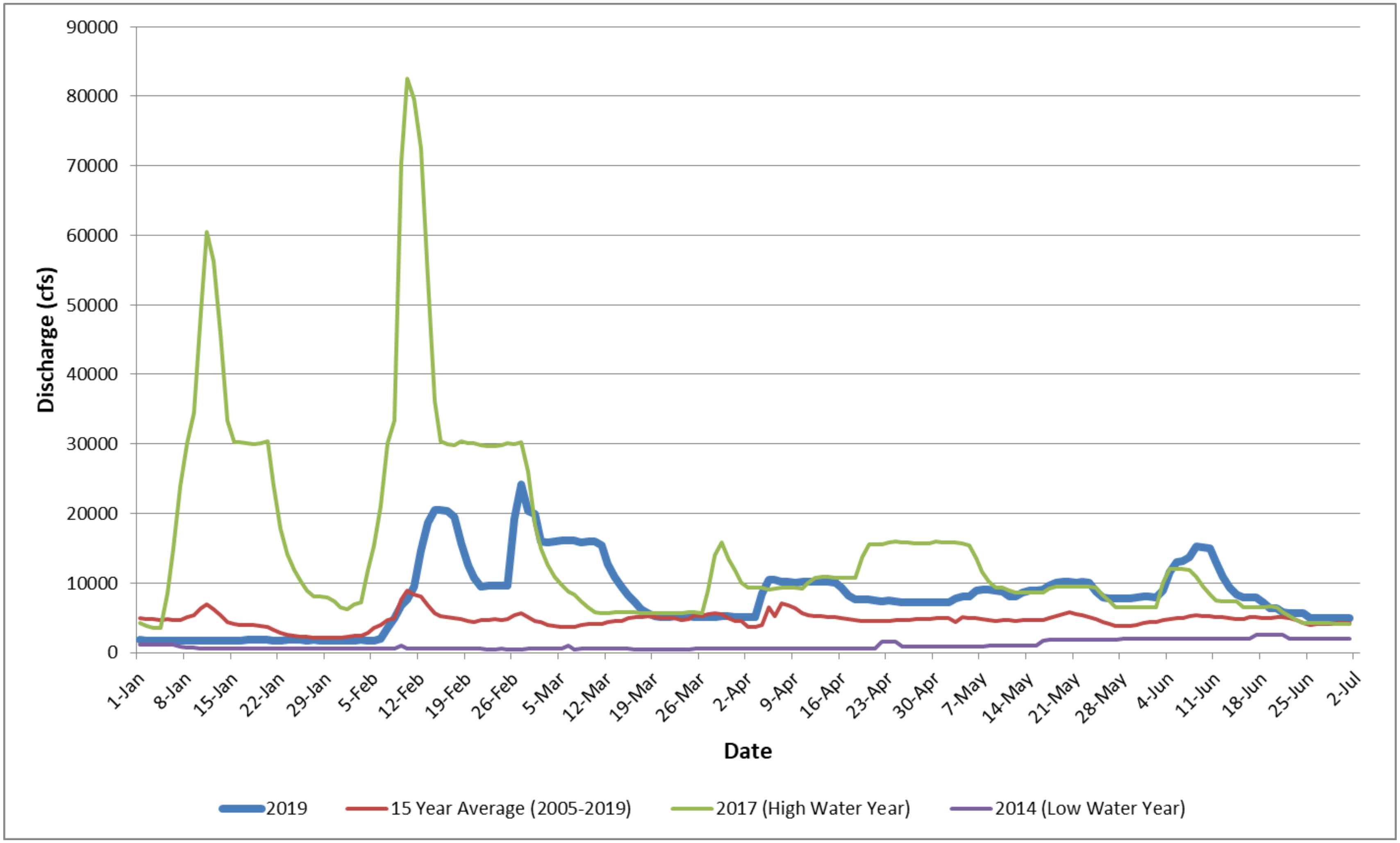




Appendix 6: Daily average water temperature (°C) in the lower American River at Watt Avenue for the 15 year period 2005-2019, the highest temperature year, the lowest temperature year, the 15 year average and the current year (2019). Data obtained from USGS station number 11446980.



Appendix 7: Daily average discharge (CFS) on the lower American River at Fair Oaks for the 15-year period 2004 – 2018, the highest water year, the lowest water year, 15 year average and the current year (2018). Data obtained from USGS station number 11446500.



Appendix 8: A view of the American River at Watt Ave under different flow conditions.

500 CFS 3/20/2014

1,500 CFS 4/24/2014

7,000 CFS 2/23/2016

20,000 CFS 3/14/2016

35,000 CFS 12/16/2016

60,000 CFS 1/11/2017

Note: These photos were taken from the Watt Ave Bridge outlook, at UTM Northing NAD83 4269922, and UTM Easting NAD83 640864