Juvenile Salmonid Emigration Monitoring in the Lower American River, California

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By

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Acronyms and Abbreviations

Acronym	Definition
AFRP	Anadromous Fish Restoration Program
BBY	Bismarck Brown Y
C	Celsius
CAMP	Comprehensive Assessment and Monitoring Program
CDFW	California Department of Fish and Wildlife
cfs	cubic feet per second
CI	confidence interval
cm	centimeter
CVPIA	Central Valley Project Improvement Act
DO	Dissolved oxygen
ft	foot
g	gram
GAM	generalized additive model
km	kilometers
L	liter
LAD	length-at-date
m	meters
m/s	meters per second
mg/L	milligrams per liter
mm	millimeter
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelometric Turbidity Units
rkm	river kilometer
RPM	revolutions per minute
RST	rotary screw trap
SNP	single-nucleotide polymorphism
Std. Dev.	Standard Deviation
USBR	United States Bureau of Reclamation
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VIE	Visual Implant Elastomer

Abstract

Operation of rotary screw traps on the Lower American River in 2020 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 *Oncorhynchus mykiss* as well as winter, spring, and late fall runs of 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 2020 survey season, two 2.4 meter (8 foot) rotary screw traps (RSTs) were operated downstream of the Watt Avenue Bridge. Sampling occurred on 122 of the 157 day season (78%) beginning January 8 and concluding on June 12. A total of 152,378 fall-run, 203 winter-run, and 16 spring-run Chinook Salmon as well as 101 steelhead juveniles were captured. The passage of juvenile fall-run Chinook Salmon peaked the week of 5 March, when 33.48% of the total (n = 51,016) was captured. The majority of the juvenile salmon captured were identified as button-up fry followed by silvery parr, parr, yolk-sac fry and smolt life stages. Six trap efficiency trials were used to estimate the passage of juvenile fall-run Chinook Salmon. Trap efficiencies during these six trials ranged from 1.93% to 15.52%, with an average efficiency of 9.41%. The number of juvenile fall-run Chinook Salmon that were estimated to have emigrated past the Watt Avenue trap site during the 2020 survey season was 1,882,610 individuals (95 percent confidence intervals = 1,635,000 to 2,215,000). Passage estimates for steelhead, winter-run Chinook Salmon, spring-run Chinook Salmon, and non-salmonid fish taxa were not assessed. During the 2020 trapping effort on the American River, minimal substantial logistical and environmental issues interfered with data collection allowing for relatively high confidence in the passage estimates produced.

This annual report also includes nine appendices. Five of those appendices describe different environmental variables and studies related to the trap site or rotary screw trap operations during the 2020 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 salmon, including fall (fall-run), spring (spring-run), and possibly late fall (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 Dam in 1955 made passage impossible for salmonids to migrate to the cool water pools they historically used in the upper portions of the American River watershed. To mitigate the loss of spawning and rearing habitat for Chinook Salmon *Oncorhynchus tshawytscha* and Central Valley steelhead *Oncorhynchus mykiss*, the anadromous form of rainbow trout, Nimbus Fish Hatchery was constructed in 1958. Located 0.80 kilometers (km) downstream of Nimbus Dam, the hatchery continues to produce large numbers of fall-run Chinook Salmon and steelhead. However, hydropower implementation, over-harvest, introduced species, loss of preferential habitat, and other factors continued to contribute to the decline of these salmonid populations (Yoshiyama et al 2001, Lindley et al 2006, NMFS 2019). 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 and steelhead.

In order to help protect, restore, mitigate and improve the natural production of salmonids 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 (USDOI 2008). 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.

Continuous restoration, management, and monitoring activities are needed to preserve healthy populations as well and further aid in the recovery of species listed under the US Endangered Species Act (ESA). These listed species include the *Endangered* Sacramento River winter-run Chinook Salmon (winter-run) as well as the *Threatened* Central Valley Spring-run Chinook Salmon and Central Valley steelhead populations that can be found in the Lower American River. 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 2020 as part of a larger effort to determine if habitat restoration activities and flow management practices are positively impacting the fall-run Chinook Salmon and steelhead production in the American River. Furthermore, this report presents monitoring data assessing the temporal variability in steelhead, winter-run, and spring-run 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, and environmental conditions.

The 2020 survey season was the continuation of a multi-year juvenile Chinook Salmon emigration survey. In 2020, California experienced a below average snowpack and reservoir levels resulting in lower river flows through peak salmon emigration 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 eight years may help to better understand past and future droughts and whether coinciding drought management and flow strategies impact salmonids and other threatened species on the American River.

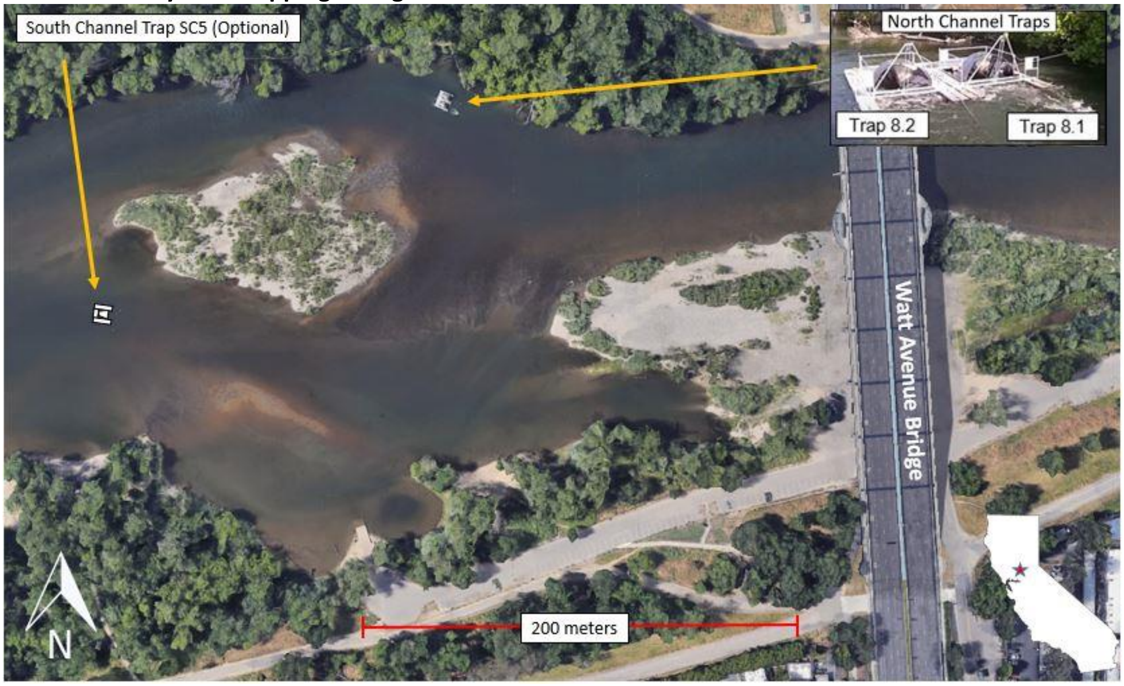
Study Area

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 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, islands, flat water areas, and side-channel habitat characteristics (Merz and Vanicek 1996). However, only a small portion of the Lower American River possesses optimal rearing habitat for juvenile salmonids and substrate that is suitable for anadromous salmonid spawning. 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) (Kelly and Phillips 2020). 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 salmonid spawning activities in the Lower American River, yet far enough upstream to not be significantly 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 9.

Figure 1: Rotary screw trap locations in the north and south channels of the Lower American River. Inset image illustrates the side-by-side trapping configuration in the north channel.



Methods

Trap Operations

Two 2.4 meter (8 foot) diameter RSTs were deployed in the north channel in a side-by-side orientation 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. Traps were anchored to large concrete blocks set into the river channel's cobble substrate 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.

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.

Trap checks were conducted at least once every 24 – 28 hours while traps were actively sampling in a cone-down configuration. During large storm events or measurable discharge events, increases in debris size or quantity could hinder trap functionality and lead to increased fish mortality. Therefore, in cases where a storm, flow increase, or debris loads were deemed severe enough, traps were taken "out of service" (i.e. cones raised, live well screens removed, and traps removed from the thalweg) for an indefinite amount of time until conditions improved.

On daily trap visits, trap function was assessed as "functioning normally", "functioning, but not normally", or "stopped functioning". If the trap was functioning, the revolutions per minute (RPM) was recorded before cleaning the trap. Additionally, intakes were checked and recorded as "clear", "partially blocked", "completely blocked", or "backed up into cone" before live wells were cleared of debris and fish. If the trap was not functioning upon arrival, an attempt was made to return the trap to functioning normally without raising the cones before all fish had been processed. If this could not be done safely, cones remained in the sampling position until all fish were cleared before raising cones to restore normal functionality to the trap. Doing so ensured that all fish were accounted for without the possibility of escape while the cones were raised. Upon clearing the live well of fish, time and total cone rotations were recorded using an electronic hubometer (Veeder-Root TR 1000-000) mounted to the axle inside of the live well. This data was used to determine how well traps had functioned between trap visits by comparing RPMs before and after cleaning the cones.

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. 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 also 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. Signage warning river recreationalists to "Keep Away" in English and Spanish were affixed to the traps as well as to the bank 100 and 150 m directly upstream of the traps. Orange reflective buoys were also placed on the chain bridals and anchor lines to help prevent boaters from crossing in front or over the anchor lines.

Weekend sampling was also suspended beginning in May after daily average temperatures started to rise significantly. Weekend sampling suspensions were primarily conducted to allow recreationalists the safest passage while circumventing the traps during periods of peak river use. These weekend safety shutdowns included raising both trap cones, removing live well screens, and shifting traps out of the thalweg until the following Monday.

Environmental Parameters

During trap visits when fish were processed, the following environmental parameters were recorded at least once per visit. Temperature and dissolved oxygen were measured using a YSI meter (YSI; Model 55), velocity was recorded in front of each cone using a Global Water flow probe or 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, a depth rod was used to record water depth 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 was acquired 21 rkm upstream of the RSTs using data from the U.S. Geological Survey (USGS) American River at Fair Oaks monitoring station (USGS station number 11446500). Average daily temperature was measured 0.16 rkm 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, debris was removed from the live well and placed into 18 gallon (68.14 liter) tubs in order to enumerate the volume of debris collected. Oversized measuring boards and tongs were utilized to carefully sort through debris to ensure all trash was removed and fish were accounted for. After all debris was removed, an assessment of the dominant debris type (aquatic or terrestrial) and total gallons of debris collected was recorded.

If more than 100 natural origin fall-run or steelhead were captured in a single trap, a subsample of 100 fish was netted and placed in their own respective 5 gallon (18.93 liter) buckets. Similarly, if more than 50 fish from a unique combination of run (winter or spring), fish origin (hatchery or natural), or species were captured in a single trap, a subsample of 50 fish was collected and held for processing as outlined in Table 1. In order to help avoid a size bias, fish that were collected while sorting debris were only included in the subsample if not enough fish could be netted directly from the live well for a complete subsample. Fish that were not held for the biological subsample were assessed for marks, enumerated, and designated as either a "live plus-count tally" or "mort plus-count tally", an unassigned life stage category.

Table 1: Subsample size for winter, spring and fall runs of Chinook Salmon, steelhead, and non-salmonid species captured for each trap on the Lower American River.

	Winter Chinook	Spring Chinook	Fall Chinook	Hatchery Chinook	Steelhead	Hatchery Steelhead	Non-Salmonid Species
Enumerate	All	All	All	All	All	All	All
Measure	50	50	100	50	100	50	50
Weigh	25	25	25	0	25	0	0

Maintaining a maximum level of fish health while keeping stress and handling to a minimum was of the highest priority while fish were being processed. Each 5 gallon holding bucket was setup to allow for fast and easy water exchange by perforating the top quarter of each bucket with 3/16" holes. Additionally, dissolved oxygen and temperature was maintained by utilizing 12V aerators, ice packs, and shade umbrellas to keep holding buckets within 2 degrees Celsius (C) of the river's temperature. Depending on environmental conditions and salmon size, overcrowding was also avoided by placing no more than 120 fry, 80 parr, or 50 smolts in a single bucket. Upon reaching a bucket's capacity for fish, a perforated screw top lid was secured so that each holding bucket could be submerged in the river to ensure safe DO and temperature until the fish were ready to be processed.

Fish were processed 0.2 km downstream of the traps on an island with adequate shade and secluded from the general public. Upon arriving to the processing location, fish condition was checked before buckets were secured to the boat and re-submerged in the river. If any fish showed signs of stress or injury, they were enumerated and immediately released at this time. A fish work-up station was then setup with a 1 gallon (3. liter) anesthetic tank, 5 gallon recovery bucket, digital scale (OHAUS Scout Pro), measuring board, and genetic sampling equipment. When the crew was ready to process fish, one perforated 5 gallon bucket would be removed from the river and affixed with a 12v aerator and ice pack if temperatures were high. Species that were identified through a length-at-date criteria as ESA listed (winter-run, spring-run, and steelhead) were always processed and released first followed by fall-run, hatchery steelhead, hatchery salmon, and lastly all other non-salmonid species. Fish were anesthetized to reduce stress during handling using a solution of 0.5 – 2 tabs of Alka Seltzer Gold and 10 milliliter (ml) stress coat (Poly-Aqua) per 1 liter (L) of water depending on fish size, species, DO, and water temperature. The crew diligently monitored operculum activity of fish immersed in the anesthetic solution, with reduced gill activity indicating fish were ready to be processed. After being processed, each fish was released into an aerated recovery bucket containing 40 ml stress coat to help replenish slime coat as they recovered from the anesthetic before being released downstream of the RSTs.

Biological data was collected on all species captured and is detailed by species and run in Table 1. Fork length or total length (species dependent) was recorded to the nearest millimeter (mm) and weight was recorded to the nearest 0.1 gram (g) for salmonids ≥ 40 mm.

Salmonid life stages were assessed by following the criteria in the smolt index rating (Table 2). Lamprey life stages were identified as ammocoete (larval), macrophthalmia (juvenile), or adult. All other non-salmonid species were only identified as either a juvenile or adult life stage. When applicable, the presence of marks from past trap efficiency trials or the absence of an adipose fin on a hatchery fish was noted. Lastly, the mortality status (live or dead) for each fish was also recorded. Whenever possible, live fish were preferentially used for the subsample, since decomposition, which can alter body size, weight, and color, makes accurately measuring and identifying to life stage more difficult. In those cases, mortalities were considered to be a "mort plus-count"; an unassigned life stage category. Additionally, genetic samples were also collected for a subsample of winter-run, spring-run, fall-run, and late fall-run Chinook Salmon.

Table 2: Smolt index rating for assessing life stage of Chinook Salmon and steelhead adapted from CAMP (2008).

Smolt Index	Life Stage	Morphological Criteria
1	Yolk-sac fry	* Newly emerged with visible yolk-sac
2	Button-up Fry	* Recently emerged with yolk sac absorbed * 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 * Minimal 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	* ≥ 300mm

Because multiple entities in the Central Valley have a special interest in juvenile lamprey, an effort was made to distinguish between River Lamprey *Lamperta ayresii* and Pacific Lamprey *Entosphenus tridentatus*. To distinguish between the two species, the number of lateral circumorals in the mouth was observed on individuals identified as juvenile macrophthalmia. River Lamprey have three lateral circumorals, while Pacific lampreys have four (Reid 2012). Because lateral circumorals in ammocoetes are not well developed, they were not identifiable to the species level. In coordination with the UC Davis Genomic Variation Laboratory (GVL), opportunistic fin clips from adult and juvenile lamprey were also collected for genetic analysis to better understand gene flow and population structure. Additional details and protocols for the GVL lamprey project can be found under California SCP #10509.

Chinook Salmon were assigned a salmon run at the time of capture by using a length-at-date (LAD) criteria that was developed for the Sacramento River by Greene (1992). In order to evaluate the accuracy of the LAD criteria, fin clips were collected to more accurately determine origin and run through genetic analysis. Fin clips with a 1 – 2 mm diameter were taken from the upper caudal lobe of healthy, natural origin salmon using disinfected dissection scissors on a weekly basis. Clips were stored in 2 ml vials filled with 95% pure ethanol in a cool location away from direct sunlight. Due to the highly variable annual catch of LAD winter-run, spring-run, and late fall-run Chinook Salmon, up to 30 clips per week from each run were collected upon initial capture. In order to establish a genetic baseline, up to 10 clips per week were also taken from fall-run Chinook Salmon throughout the season. Samples were then sent to the CDFW tissue archive to be split before being shipped to the staff at the U.S. Fish and Wildlife Service's (USFWS) Abernathy Fish Technology Center to have genetic run assignments determined 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 trials, and it was reported that winter-run were correctly assigned to run 100% of the time, fall-run were correctly assigned to run 85 – 95% of the time, and spring-run were correctly assigned to run 78 – 93% 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% 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% 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.

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; this data was then used to estimate the total number of fall-run 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 the average fork length was < 50 mm. When catch allowed, at least 500 salmon were used to conduct efficiency trials with BBY stain. If < 500 fall-run were captured on a given day, they were held overnight and the fall-run captured the following day were added to the previous day's catch to acquire the target number of fish required. If daily catch totals were too low, fall-run Chinook Salmon were provided by the Nimbus Fish Hatchery. Once enough fall-run were acquired to conduct a trap efficiency trial, they were placed in an aerated 18 gallon insulated tub and stained using a solution of 0.6 g of BBY for every 20 L of 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 placed in a 50 gallon live car attached to the rear of the traps and held until twilight before being released.

The second method was utilized when the majority of the salmon being used for efficiency trials were ≥ 50 mm. A Visual Implant Elastomer (VIE) tag was used for these salmon in lieu of BBY stain. VIE tagging 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 salmon and injecting a small amount of the liquid fluorescent elastomer just under the skin. After the elastomer hardens, tag retention was assessed prior to upstream release. 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 natural origin salmon used during trap efficiency trials was different, 100 fork lengths from the day the natural origin fish were 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 during release, marked salmon were scattered across the width of the river channel using small dip nets. When river flows were relatively low (e.g., < 1,500 cfs), fish were evenly released across the width of the river or until the water depth and velocity became too hazardous to proceed further. When safe river conditions allowed, a boat was used to release the marked fish, keeping the motor upstream of the released fish while a crew member released small groups of fish off the boat's bow. Additionally, every marked salmon release occurred close to dusk to minimize predation.

On trap visits following each trap efficiency release, crew members looked carefully for any marked fish in the RST live wells. 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.

During this period, a subsample of 100 recaptured Chinook Salmon from each trap efficiency trial were measured for fork lengths, assessed for life stage, and evaluated for mortality status. If more than 100 recaptures from a trap efficiency trial 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
Stanislaus	*ST004L1 (1002)*	*–1.846 – 0.0007(flow) – 0.009(depth) + 1.096(velocity)*
	ST004L1B (1003)	*–4.447 + 2.523(moon proportion) – 0.017(depth) + 0.038(turbidity) + 1.294(velocity)*

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

Under ideal circumstances, rotary screw traps are functioning normally for a complete 24-hour period to encompass a complete day of data. However, abnormal trap functionality, can adversely affect daily catch misrepresenting passage estimates. To account for this, it is important to determine which sampling days will be included or excluded in the analysis to most accurately represent the passage estimate. If the trap was presumed to have been functioning normally during the entire sampling period, it was included in the analysis. Contrarily, if the trap had not been functioning normally, it is important to estimate the amount of time the trap had been functioning normally to determine if the period should be included in the analysis. If it was determined that the traps had been functioning normally for at least 70% of the sampling period, the data would be included in the analysis. This threshold was calculated by using trap RPM upon arrival, RPM after trap cleaning, total revolutions of the cone, and the duration of the sampling period. The normal functioning percent (Equation 2) is a proportion of the actual total revolutions to the estimated total revolutions (Equation 1) the trap had been functioning normally during that sampling period. Additionally, when abnormal functionality occurs, the CAMP platform computes the estimated catch by averaging the actual catch before and after the occurrence. Under the assumption that abnormal trap function adversely affects catch, the higher catch was considered to be the most representative of what the trap would have caught while functioning normally and was retained for further analysis.

Equation 1: $$Hours\ Fished * \ Revolutions\ (per\ hour) = Estimated\ Total\ Revolutions$$

Equation 2: $$\frac{Actual\ Total\ Revolutions}{Estimated\ \ Total\ Revolutions} * 100 = Normal\ Functioning\ Percent$$

$$Exclude\ from\ Analysis: Normal\ Functioning\ Percent < 70\%\ \ AND\ \ Imputed\ Catch > Actual\ Catch$$

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 ≥40 mm captured each day were measured for weight and fork lengths. The ratio of the two was used to calculate their condition factor:

$$Fulton's\ Condition\ Factor = \left(\frac{Weight\ (g)}{Fork\ Length\ (mm)^3}\right) 100{,}000$$

Results

Trap Operations

Trap 8.1 and 8.2 began sampling on January 7 and concluded June 12 with 122 days of sampling effort in the 157 day season (78%; Figure 3). Of the 122 days of sampling effort, the traps sampled successfully for approximately 2,773 hours (95.67%), and sampled unsuccessfully for approximately 120 hours (Figure 4). Both traps were deployed into the north channel at the Watt Avenue trapping site (Figure 1). River flows remained relatively stable for the majority of the sampling season with a median discharge of 1,834 cfs (range: 1,160 – 2520 cfs). Sampling of both traps was suspended for a total of 35 days over the course of the season with one prolonged outage being greater than seven days (April 1 – April 8). The one instance of prolonged outage for both traps was a result of necessary trap repairs, response to a hatchery release, and permit modifications. Weekend shutdowns began May 10 and continued through the duration of the season accounting for 13 days without sampling. Trapping was also suspended on four occasions following Nimbus Fish Hatchery releases of salmon and steelhead for a minimum of three days between February and May. Trap 8.1 sampling was also concluded three days early (June 9) due to low catch and overloading of debris within the live well.

Figure 3: Dates sampling occurred during the 2020 Lower American River rotary screw trap survey season.

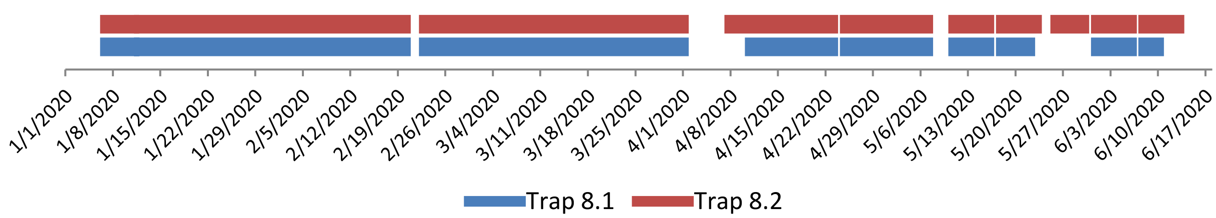
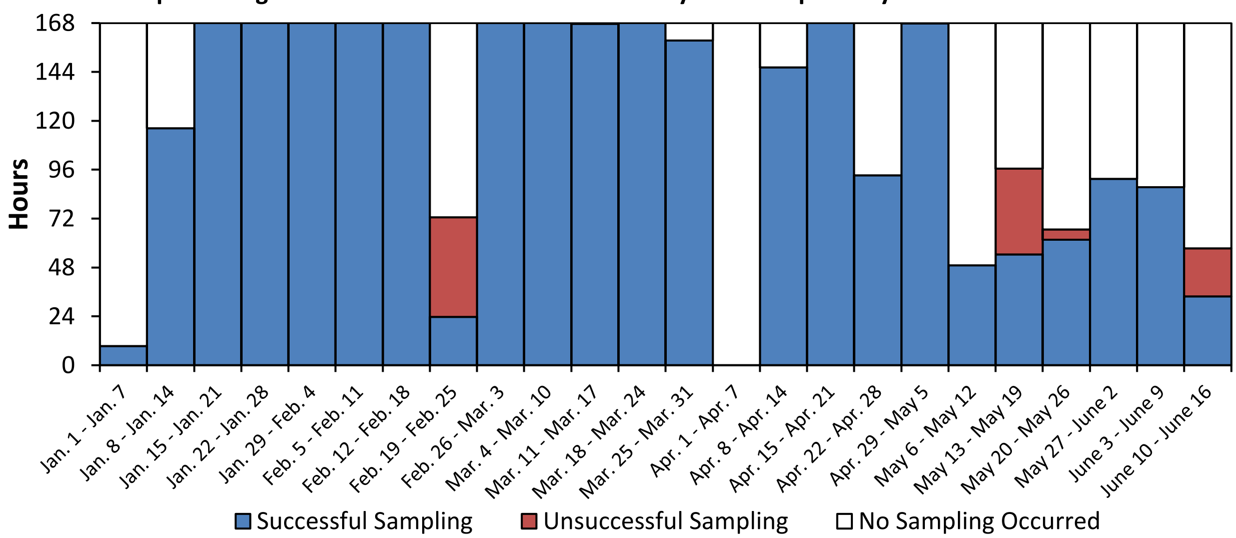


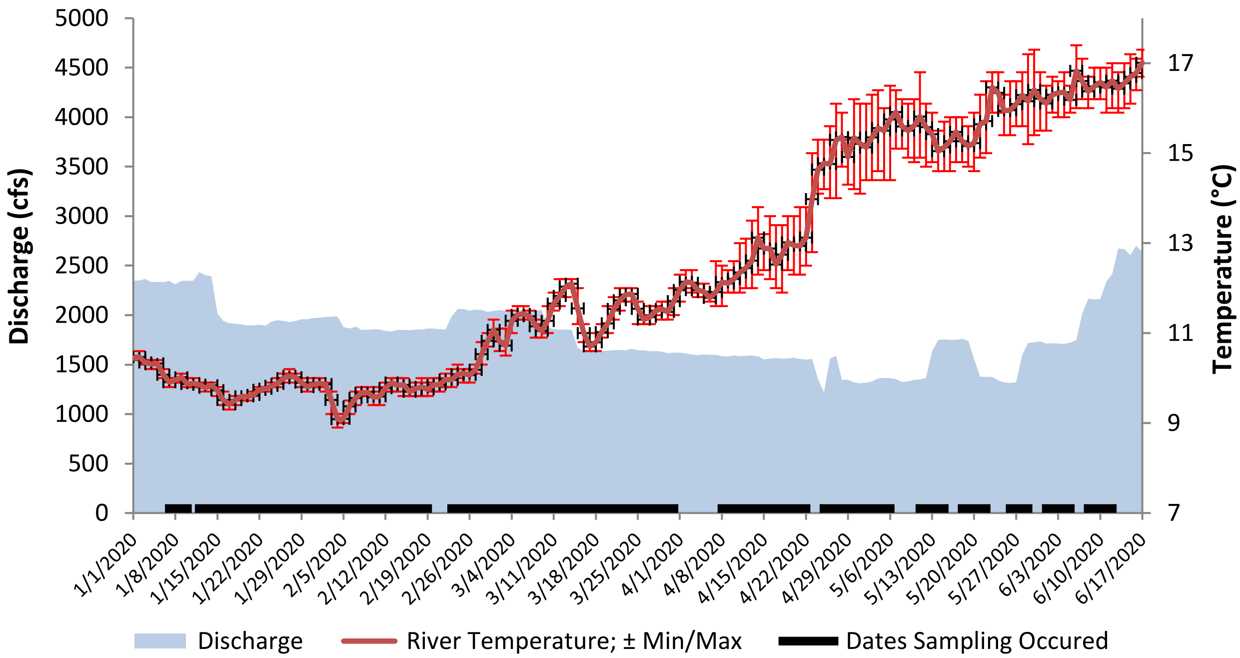
Figure 4: Weighted average hours per Julian week that both traps sampled successfully, sampled unsuccessfully, or did not sample during the 2020 lower American River rotary screw trap survey season.



Environmental Summary

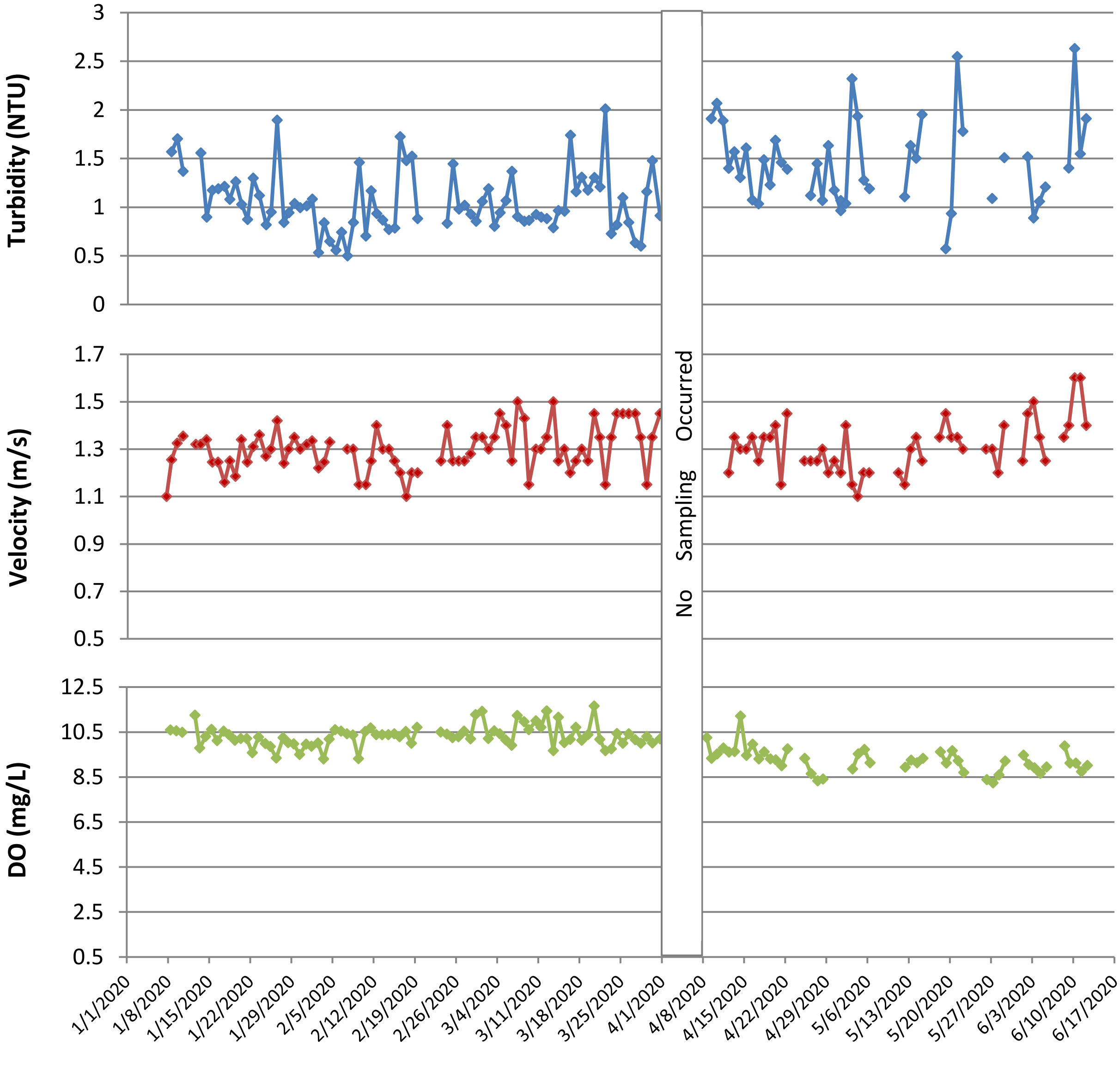
Appendix 2 provides a summary of the environmental conditions, averaged by Julian week, starting on January 1 and spanning until the last Julian week of the 2020 survey season. Measurements taken in the field, such as DO, turbidity, and velocity only reflect days sampling occurred. Instantaneous river discharge, recorded in 15 minute intervals by USGS, reached a maximum during the week of January 8 and a minimum on April 25 (range: 1,160 – 2,520 cfs). Additionally, the daily average discharge reached a high on January 12 and a low on April 25 (range: 1,222 – 2,433 cfs). Instantaneous river temperature, also recorded in 15 minute intervals by USGS at the Watt Avenue gauge station, recorded a maximum on June 6 and minimum on February 4 (range: 8.9 – 17.4 °C). River discharge and water temperature averaged by day throughout the 2020 survey season are shown in Figure 5.

Figure 5: Dates sampling occurred, daily average discharge (cfs) measured at Fair Oaks, and the daily minimum, maximum, and average water temperature (°C) measured at Watt Avenue during the 2020 Lower American River rotary screw trap survey season.



Several environmental parameters including dissolved oxygen, turbidity, and velocity were also measured during trap checks using electronic meters throughout the season (Figure 6). Dissolved oxygen, measured in milligrams per liter (mg/L), was recorded prior to trap checks and monitored as fish were held. Between both traps, the minimum recorded DO occurred on May 27 and the maximum on March 20 with a range of 8.24 to 11.65 mg/L. The turbidity, measured in Nephelometric Turbidity Units (NTU), was consistently similar between both traps throughout the season with relatively low NTU. The turbidity for both traps reached a season minimum on February 7 and a maximum on June 10 with a rage of 0.25 – 2.63 NTU. The velocity, measured in meters per second (m/s), was also similar for both traps throughout the survey season, with velocities for the trap positioned closest to the thalweg, Trap 8.2, slightly higher than Trap 8.1. Water velocity for Trap 8.1 ranged from 1.0 – 1.5 m/s (mean: 1.26 m/s), while Trap 8.2 had a range of 1.1 – 1.6 m/s (mean: 1.35 m/s). Weekly average water velocity, averaged by Julian week, reached a maximum the week of June 11 and a minimum the week of January 1 with a range of 1.1 – 1.5 m/s, although only 1 day of velocity was recorded for the week of January 1. The daily average DO, turbidity, and velocity throughout the season can be seen in Figure 6, and the Julian week minimum, maximum and average values are listed in Appendix 2.

Figure 6: Daily average velocity (m/s), turbidity (NTU), and dissolved oxygen (DO) (mg/L), recorded during the 2020 American River rotary screw trap survey season.



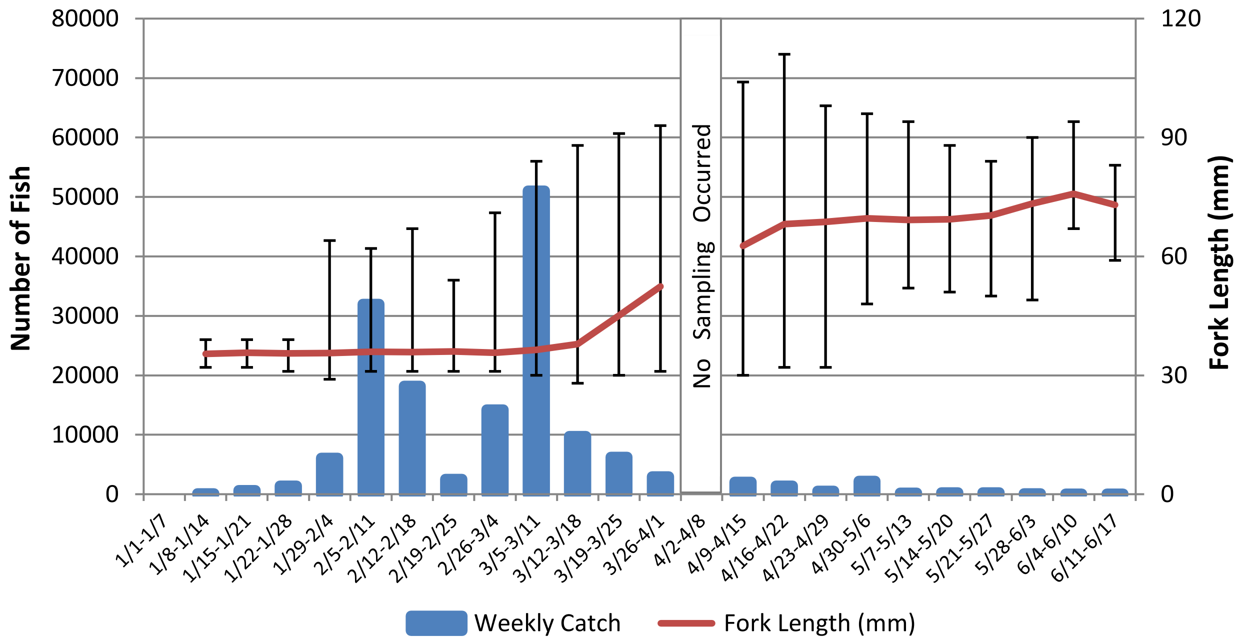
Catch

The two rotary screw traps deployed during the 2020 survey season captured 155,980 fish of natural origin, and 19,225 hatchery-produced salmonids. The trap furthest from the thalweg, Trap 8.1, captured 32.82% (n = 57,496) of these fish, while Trap 8.2 captured 67.18% (n = 117,709). The salmonids captured included fall, spring and winter runs of Chinook Salmon based on the LAD criteria as well as steelhead. Additionally, 23 non-salmonid species were identified along with 2,908 fish that were identifiable to the genus level (Appendix 3).

Fall-run Chinook Salmon

Natural origin fall-run Chinook Salmon encompassed the majority of all natural origin fish captured during the 2020 survey season (97.69%) with 152,378 being determined to be fall-run based on results of the genetic analysis. Because these fish did not have an adipose fin clip, they were presumed to be of natural origin. Catch of fall-run first peaked the week of February 5, when 20.98% (n = 31,964) of these fish were captured. The second, and largest peak occurred the week of March 5, when 33.48% (n = 51,016) of the season's total was captured (Figure 7). Of all fall-run captured during the 2020 survey season, 134,716 were classified as unmeasured plus-count tallies and may have included both LAD fall-run and late fall-run Chinook Salmon. However, based on genetic analysis it was determined that all LAD late fall-run detected in the subsample were fall-run Chinook Salmon. This resulted in all 134,716 unmeasured plus count tallies to be classified as fall-run Chinook Salmon.

Figure 7: Weekly minimum, maximum, and average fork length (mm) and total catch of natural origin fall-run Chinook Salmon during the 2020 Lower American River rotary screw trap sampling season.



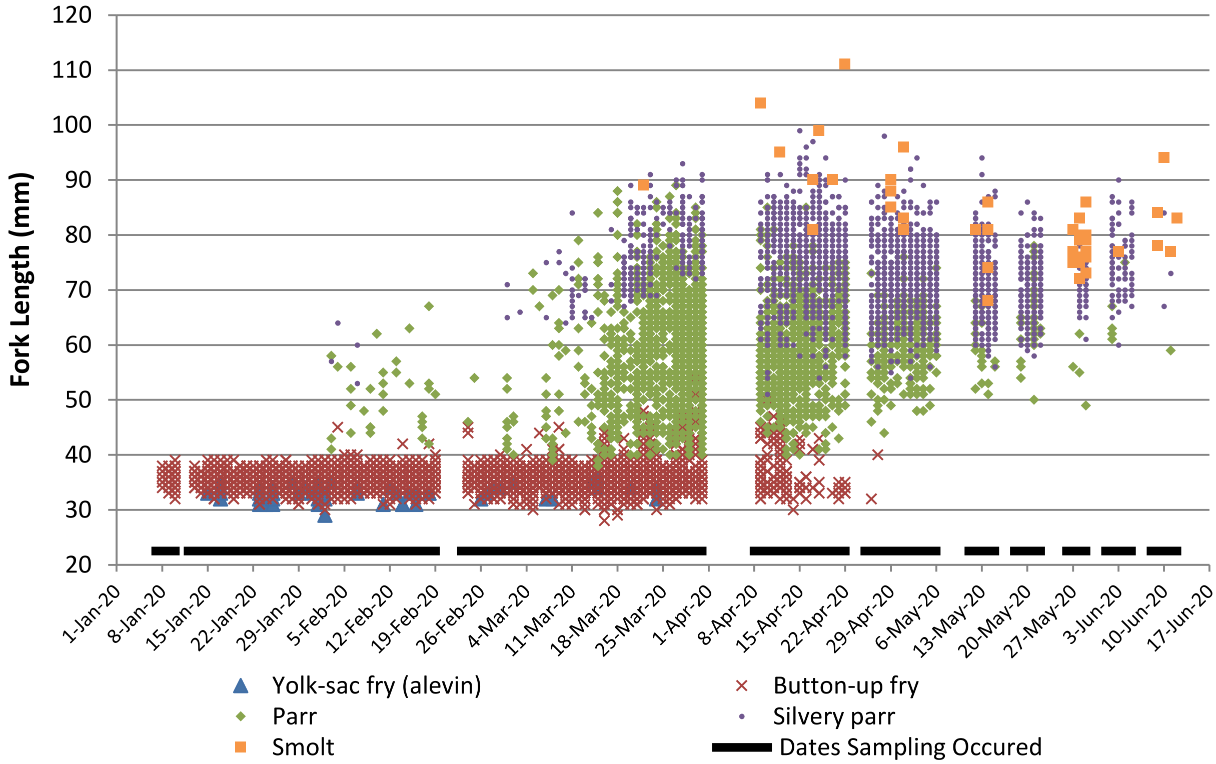
A total of 17,662 natural origin fall-run were measured for fork length. The weekly minimum, maximum, and average fork lengths throughout the 2020 survey season are displayed in Figure 7 and Table 3. The lowest weekly average fork length of 35 mm was seen during the first week of sampling. Fork lengths slowly increased throughout the season with the weekly average reaching a maximum of 76 mm the week of June 4.

Table 3: Weekly average (Avg), minimum and maximum (range), and the standard deviation (St. Dev.) of fork lengths (mm) and total weekly catch (n) for natural origin fall-run Chinook Salmon captured during the 2020 Lower American River rotary screw trap sampling season.

Julian Week	Natural Origin Fall-Run Chinook Salmon			
	Avg	Range	St. Dev.	n
1/8 - 1/14	35	32-39	1.32	127
1/15 - 1/21	36	32-39	1.37	656
1/22 - 1/28	36	31-39	1.33	1,394
1/29 - 2/4	36	29-64	1.93	6,069
2/5 - 2/11	36	31-62	2.23	31,964
2/12 - 2/18	36	31-67	2.07	18,196
2/19 - 2/25	36	31-54	1.96	2,562
2/26 - 3/4	36	31-71	2.10	14,191
3/5 - 3/11	36	30-84	4.86	51,016
3/12 - 3/18	38	28-88	8.17	9,749
3/19 - 3/25	45	30-91	15.17	6,270
3/26 - 4/1	52	31-93	16.39	2,955
4/2 - 4/8	No Sampling			
4/9 - 4/15	63	30-104	14.44	2,070
4/16 - 4/22	68	32-111	10.73	1,423
4/23 - 4/29	69	32-98	8.45	550
4/30 - 5/6	70	48-96	7.14	2,233
5/7 - 5/13	69	52-94	6.48	228
5/14 - 5/20	69	51-88	6.14	298
5/21 - 5/27	70	50-84	5.12	265
5/28 - 6/3	73	49-90	6.50	120
6/4 - 6/10	76	67-94	6.07	38
6/11 - 6/17	73	59-83	10.20	4

The subsample of fall-run that were measured for fork length, were also assessed for life stage (Figure 8; Table 4). The majority of these fish were identified as button-up fry and accounted for 67.78% (n = 11,971) of the assessed catch. The remaining life stage catch composition consisted of yolk sac fry (0.37%, n = 65), parr (14.08%, n = 2,486), silvery parr (17.54%, n = 3,098) and smolts (0.24%, n = 42). As shown in Figure 8, fall-run Chinook Salmon identified as yolk sac fry were captured between January 15 and March 24. Button-up fry were identified starting on the first day of the 2020 season, January 8, and were captured consistently until April 27. The parr life stage was identified between February 3 and June 11, and the silvery parr life stage was captured starting February 3 through June 11. Lastly, the 42 fall-run identified as smolts were captured between March 22 and the final day of the season, June 12.

Figure 8: Daily fork length distribution by life stage of natural origin fall-run Chinook Salmon measured during the 2020 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). Fork lengths ranged from 29 – 36 mm for yolk-sac fry, 28 – 54 mm for button-up fry, 39 – 89 mm for parr, 51 – 99 mm for silvery parr, and 68 – 111 mm for smolt life stages.

Average weekly fork lengths generally increased with life stage progression with yolk-sac fry having the lowest average weekly fork length, and smolts having the largest average weekly fork lengths. Fork lengths for the fall-run with life stages identified averaged 33 mm for yolk-sac fry, 36 mm for button-up fry, 58 mm for parr, 71 mm for silvery parr, and 85 mm for smolts (Table 4).

Table 4: Weekly average fork length in millimeters (Avg), minimum and maximum fork lengths (Range), and sample size (n) for each identified life stage of natural origin fall-run Chinook Salmon captured during the 2020 Lower American River rotary screw trap survey season.

Julian Week	Yolk Sac Fry			Button-up Fry			Parr			Silvery Parr			Smolt		
	Avg	Range	n	Avg	Range	n	Avg	Range	n	Avg	Range	n	Avg	Range	n
1/8 - 1/14	-	-	-	35	32-39	127	-	-	-	-	-	-	-	-	-
1/15 - 1/21	34	32-35	8	36	32-39	605	-	-	-	-	-	-	-	-	-
1/22 - 1/28	33	31-35	16	36	31-39	939	-	-	-	-	-	-	-	-	-
1/29 - 2/4	33	29-35	13	36	30-45	1351	51	41-58	5	61	57-64	2	-	-	-
2/5 - 2/11	33	31-34	3	36	31-40	1388	51	44-62	15	57	53-60	2	-	-	-
2/12 - 2/18	33	31-34	10	36	31-42	1382	52	42-67	12	-	-	-	-	-	-
2/19 - 2/25	-	-	-	36	31-45	339	50	46-54	3	-	-	-	-	-	-
2/26 - 3/4	34	32-35	6	36	31-41	1507	46	40-54	10	67	65-71	3	-	-	-
3/5 - 3/11	32	32-32	2	36	30-45	1375	52	39-73	30	71	64-84	16	-	-	-
3/12 - 3/18	35	34-36	4	35	28-44	1243	55	38-88	148	69	65-81	18	-	-	-
3/19 - 3/25	33	32-34	3	35	30-48	1075	60	40-86	405	75	67-91	148	89	89-89	1
3/26 - 4/1	-	-	-	36	31-54	497	60	40-89	681	80	72-93	116	-	-	-
4/2 - 4/8	No Sampling			No Sampling			No Sampling			No Sampling			No Sampling		
4/9 - 4/15	-	-	-	37	30-50	120	59	40-85	501	76	51-99	386	100	95-104	2
4/16 - 4/22	-	-	-	35	32-43	21	61	41-85	367	74	54-97	548	94	81-111	5
4/23 - 4/29	-	-	-	36	32-40	2	58	44-73	69	71	55-98	366	88	85-90	3
4/30 - 5/6	-	-	-	-	-	-	61	48-76	172	72	54-94	698	87	81-96	3
5/7 - 5/13	-	-	-	-	-	-	60	52-68	15	70	60-94	194	81	81-81	1
5/14 - 5/20	-	-	-	-	-	-	58	51-65	11	70	56-88	261	77	68-86	4
5/21 - 5/27	-	-	-	-	-	-	66	50-78	33	71	58-84	208	78	75-81	3
5/28 - 6/3	-	-	-	-	-	-	60	49-67	7	74	60-90	98	78	72-86	15
6/4 - 6/10	-	-	-	-	-	-	75	75-75	1	75	67-86	33	85	78-94	3
6/11 - 6/17	-	-	-	-	-	-	59	59-59	1	73	73-73	1	80	77-83	2
Entire Season	**33**	**29-36**	**65**	**36**	**28-54**	**11971**	**59**	**39-89**	**2486**	**73**	**51-99**	**3098**	**83**	**68-111**	**42**

In addition to the natural origin fall-run Chinook Salmon catch, 18,702 adipose clipped salmon were also captured. All adipose clipped salmon were assumed to have originated from the Nimbus Fish Hatchery releases of fall-run Chinook Salmon and thus the LAD criteria was not utilized to determine runs. These salmon were caught between March 31 and May 2, with an average fork length of 76 mm and range of 53 – 96 mm. A subsample of these adipose clipped salmon were also assessed for life stage with parr encompassing the majority (75.91%, n = 104) of the catch followed by silvery parr (21.90%, n = 30) and smolts (2.19%, n = 3). The vast majority of these fish (99.77%, n = 18,659) were captured on March 31 following the first Nimbus Fish Hatchery release of 200,000 salmon on March 30. After this event, maximum daily catch ranged between 1 and 12 adipose clipped salmon for the remainder of the season.

Fulton's Condition Factor

Fulton's condition factor (K) for natural origin, unmarked fall-run Chinook Salmon captured in 2020 is shown in Appendix 5. The overall trend line exhibited a positive slope of 0.0040, indicating a slightly increasing trend in condition throughout the survey season. The trend line slopes were positive for button-up fry (0.0029), parr (0.0040), silvery parr (0.0042), and smolt (0.0005) life stages. Yolk-sac fry captured in 2020 were unable to be accessed for Fulton's condition factor as every fish identified with this life stage measured < 40 mm and was therefore not weighed.

Trap Efficiency

Six mark-recapture trap efficiency trials were conducted throughout the 2020 survey season, all of which were included in analysis and used by the CAMP platform to determine passage estimates (Table 5). The six trials used a total of 7,137 fall-run Chinook Salmon. Of these fish, 5,776 were natural origin salmon collected from the RSTs and marked with either BBY (n = 5,506) or VIE (n = 270) depending on fork length. The remaining 1,361 were collected from Nimbus Fish Hatchery and marked with VIE. The average trap recapture efficiency across all six trials was 9.41% with a total of 872 marked salmon being recaptured within seven days of each release. Additionally, the average fork length of the recaptured fish was approximately the same size as the average fork length of the released fish.

Table 5: Trap efficiency mark, release, and recapture data acquired during the 2020 Lower American River rotary screw trap survey season.

				Release Data					Recapture Data	
Date Marked	Fish Origin	Mark Type	Included	Date	Release Time	Flow (cfs)	Avg FL (mm)	n	Capture Efficiency	Avg FL (mm)
2/4/20	Natural	BBY	Yes	2/4/20	18:12	1879	36	1716	13.6%	35
2/13/20	Natural	BBY	Yes	2/13/20	18:03	1853	35	2204	15.5%	36
3/19/20	Natural	BBY	Yes	3/19/20	19:00	1646	36	1586	15.2%	36
4/15/20	Natural	VIE	Yes	4/15/20	19:24	1560	65	270	6.7%	71
4/30/20	Hatchery	VIE	Yes	4/30/20	15:05	1338	77	674	1.9%	80
5/11/20	Hatchery	VIE	Yes	5/11/20	19:00	1570	86	687	3.5%	84

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

Included: Indicates if the trial was utilized in determining passage estimates.
Flow (cfs) = discharge from the USGS gauge 11446500 at time of release.
Avg FL (mm) = Average fork length in millimeters for released or recaptured salmon.
n = Total number of marked salmon released for the efficiency trial.
Natural = Assumed natural production from the Lower American River.
Hatchery = Nimbus Fish Hatchery.
BBY = Bismark brown Y whole body stain.
VIE = Visual Implant Elastomer dye, marked on the snout.

Passage Estimate for Fall-Run Chinook Salmon

According to the CAMP platform "run_passage" report, 1,882,610 natural origin fall-run Chinook Salmon were estimated to have emigrated past the Watt Ave rotary screw trap location during the 2020 survey season (Figure 9). The 95 percent confidence interval for this estimate was from 1,635,000 to 2,215,000 individuals. The highest weekly passage estimate occurred the week of March 5 with approximately 622,000 fall-run being estimated to have emigrated past the rotary screw traps (Table 6). The CAMP platform "lifestage_passage" report, which subdivides a passage estimate by life stage, estimated 1,649,000 fry (including both yolk-sac fry and button-up fry), 216,900 parr, and 67,510 smolts (including both smolt and silvery parr) 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. Traps were not operating for 7 or more days on two occasions: between April, 1 and April, 8 when neither trap was operating, and between May, 22 and June, 1 when only one trap was operating. Potential emigration before the traps started sampling and during the gaps in sampling that are seven or more days in duration for both traps are not included in these estimates.

Figure 9: Daily passage estimate of natural origin fall-run Chinook Salmon and daily average discharge at Fair Oaks during the 2020 lower American River rotary screw trap survey season.

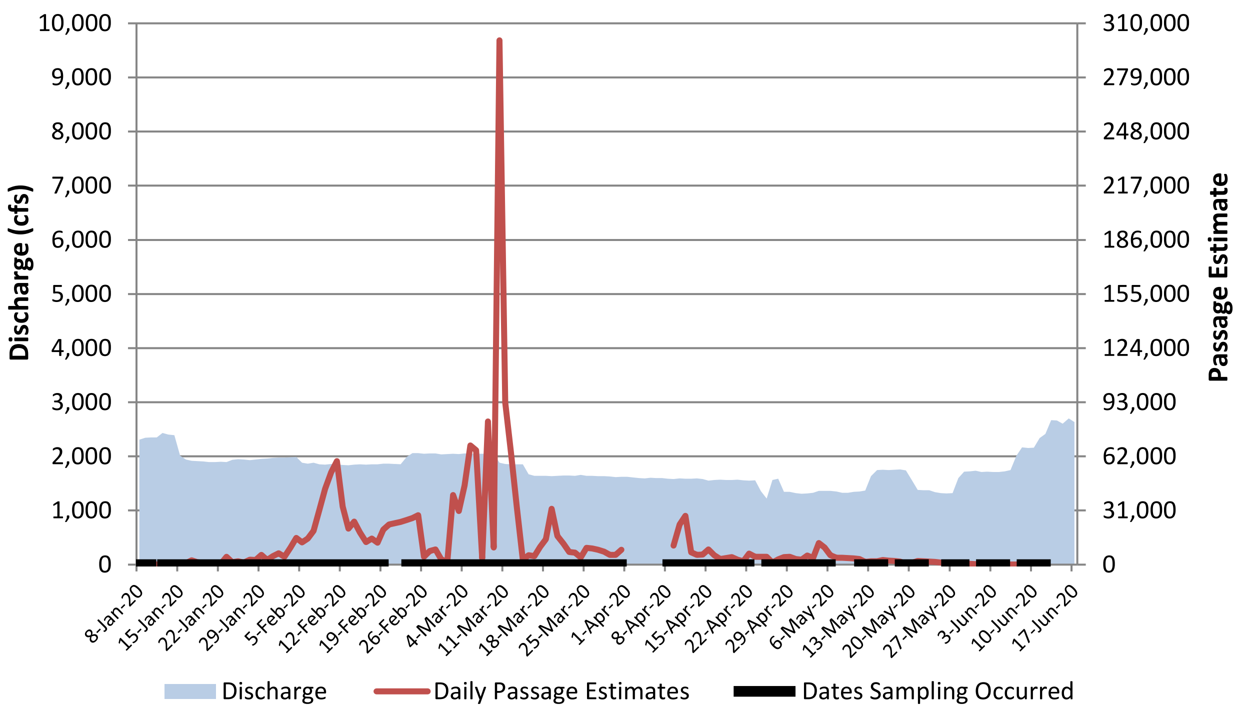


Table 6: Weekly passage estimate of natural origin fall-run Chinook Salmon and weekly average discharge at Fair Oaks during the 2019 Lower American River rotary screw trap survey season.

Julian Week	Discharge (cfs)	Passage Estimate
1/8 - 1/14	2,369	1,786
1/15 - 1/21	1,927	8,870
1/22 - 1/28	1,928	14,785
1/29 - 2/4	1,973	49,264
2/5 - 2/11	1,863	233,722
2/12 - 2/18	1,848	137,335
2/19 - 2/25	1,936	171,866
2/26 - 3/4	2,047	141,737
3/5 - 3/11	1,998	622,207
3/12 - 3/18	1,735	135,117
3/19 - 3/25	1,646	88,239
3/26 - 4/1	1,629	45,062
4/2 - 4/8	No Sampling	
4/9 - 4/15	1,583	88,832
4/16 - 4/22	1,561	27,893
4/23 - 4/29	1,425	26,400
4/30 - 5/6	1,338	42,517
5/7 - 5/13	1,386	21,680
5/14 - 5/20	1,723	12,096
5/21 - 5/27	1,347	9,461
5/28 - 6/3	1,703	3,035
6/4 - 6/10	1,953	643
6/11 - 6/17	2,377	63
Entire Season	**1,762**	**1,882,610**

Genetic Analysis

During the 2020 survey season, a total of 246 genetic samples taken from juvenile Chinook Salmon were analyzed using SNP genetic markers to determine run assignments. Twenty-four of these samples were considered to be “no-calls” and were not able to be identified to a specific run. These 24 samples were excluded in any further analysis when assigning runs. The SNP panel’s probabilities for the remaining 222 samples exceeded the 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 222 samples that were assigned were taken from salmon that did not have an adipose fin clip, and were therefore presumed to be of natural origin.

Genetic samples were collected from 50 fall-run throughout the 2020 sampling season with 7 unidentifiable no-calls. Analyses using SNP genetic markers from these samples indicated that 100% (n = 43) were correctly identified as fall-run Chinook Salmon (Table 7). Because the LAD criteria continued to be highly accurate when assigning this run, a final run assessment of fall was applied to the remaining 151,456 LAD fall-run that were not genetically sampled.

A total of 64 Chinook Salmon classified as late fall-run using LAD criteria were also captured in 2020. Genetic samples were taken from 7 of these salmon with 1 unidentifiable no-call. Analyses using SNP genetic markers from those samples indicated that 100% (n = 6) were fall-run (Table 7). Because the LAD criteria appeared to incorrectly assign this run, all 58 of the LAD late fall-run that were unidentifiable or not genetically sampled were given a final run assignment of fall-run.

Genetic samples were taken from 90 of the 204 salmon classified as winter-run with 5 returning as unidentifiable no-calls. Analyses using SNP genetic markers from those samples indicated that 98.82% (n = 84) were winter-run and 1.18% (n = 1) was identified as a spring-run Chinook Salmon (Table 7). Because the LAD criteria appeared to be highly accurate when assigning this run, a final run assessment of winter was applied to all LAD winter-run that were not genetically sampled.

A total of 830 natural origin Chinook Salmon captured in 2020 were classified as spring-run using the LAD criteria. Genetic clips were collected and run assignments were identified for 88 samples with 11 returning as unidentifiable no-calls. The analyses indicated 88.64% (n = 78) of these individuals were fall-run and 11.36% (n = 10) were spring-run (Table 7). As seen in the genetic results of the 2013 – 2019 PSMFC sampling efforts, the LAD criteria for spring-run captured on the American River is highly inaccurate. However, a potential trend has been observed where the accuracy of the LAD criteria to correctly assign spring-run diminishes as the season progresses. In order to help mitigate for a potential bias in abundance on years when not all LAD spring-run are sampled, it was determined that splitting the genetic samples into high and low accuracy sub-groups would yield the most accurate passage estimates when expanding run assignments to the unsampled population (Silva and Bouton 2015).

Of the 830 LAD spring-run Chinook Salmon captured, 94.58% (n = 785) were captured after March 9. Run assignments were identified for 58 of these salmon with 1.72% (n = 1) being determined to be spring-run. The remaining 45 LAD spring-run were captured on or before March 9 with 30.00% (n = 9) of the 30 identified samples being determined to be spring-run. Because the LAD criteria appeared to incorrectly assign runs at a considerably higher rate after March 9, proportional run expansions were only applied to the LAD spring-run captured on or before March 9 in order to avoid overestimating spring-run abundance. Of the 15 LAD spring-run that were not genetically sampled on or before March 9, 33.33% (n = 5) retained a final run assignment of spring while 66.67% (n = 10) were changed to a final run assignment of fall. This proportional expansion best represented the 30.00% run assignment accuracy of the LAD criteria during this period of time. The remaining 784 unsampled LAD spring-run Chinook Salmon captured after March 9 were assigned a final run of fall due to the inaccuracy of the LAD criteria during this period of time.

Table 7: Comparison of Chinook Salmon run assignments using length-at-date criteria and SNP genetic markers.

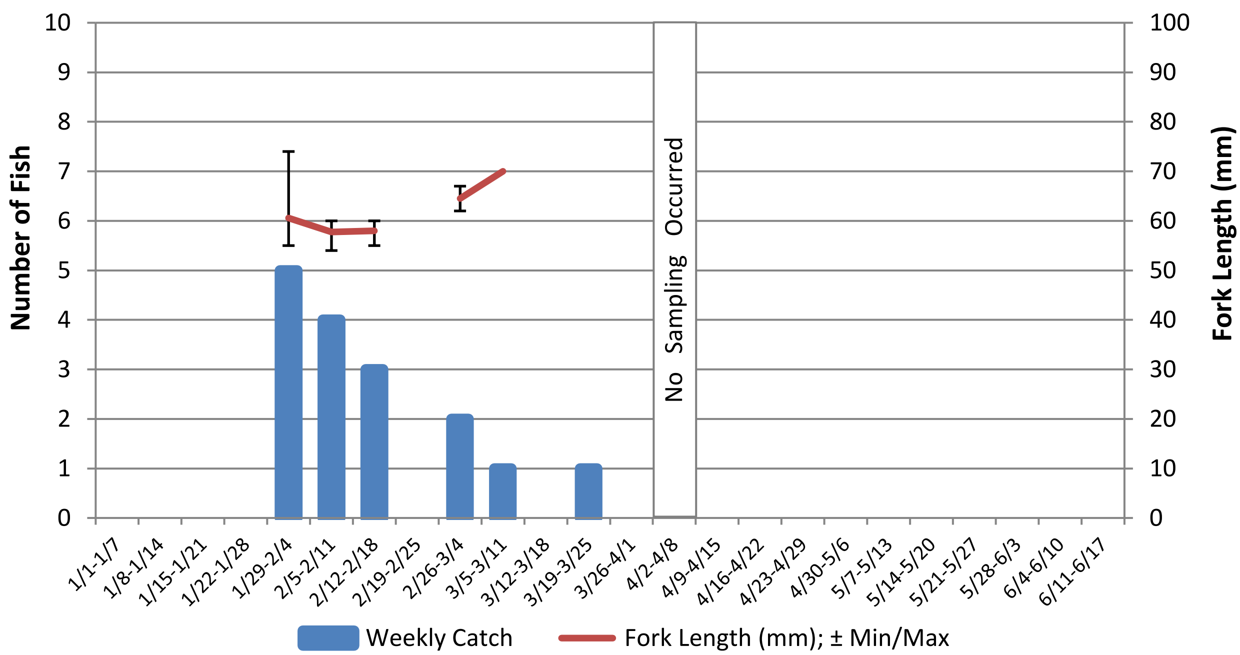
Length-at-Date Run Assignment	Genetic Run Assignment				
	Fall	Late Fall	Spring	Winter	No Call
Fall	43	0	0	0	7
Late Fall	6	0	0	0	1
Spring (January 8 – March 9)	21	0	9	0	4
Spring (March 9 – June 12)	57	0	1	0	7
Winter	0	0	1	84	5

Note: Genetic salmon run assignment was based on a >50 percent genetic probability threshold. The table only includes Chinook Salmon presumed to be of natural origin (i.e. presence of an adipose fin).

Spring-run and Winter-run Chinook Salmon

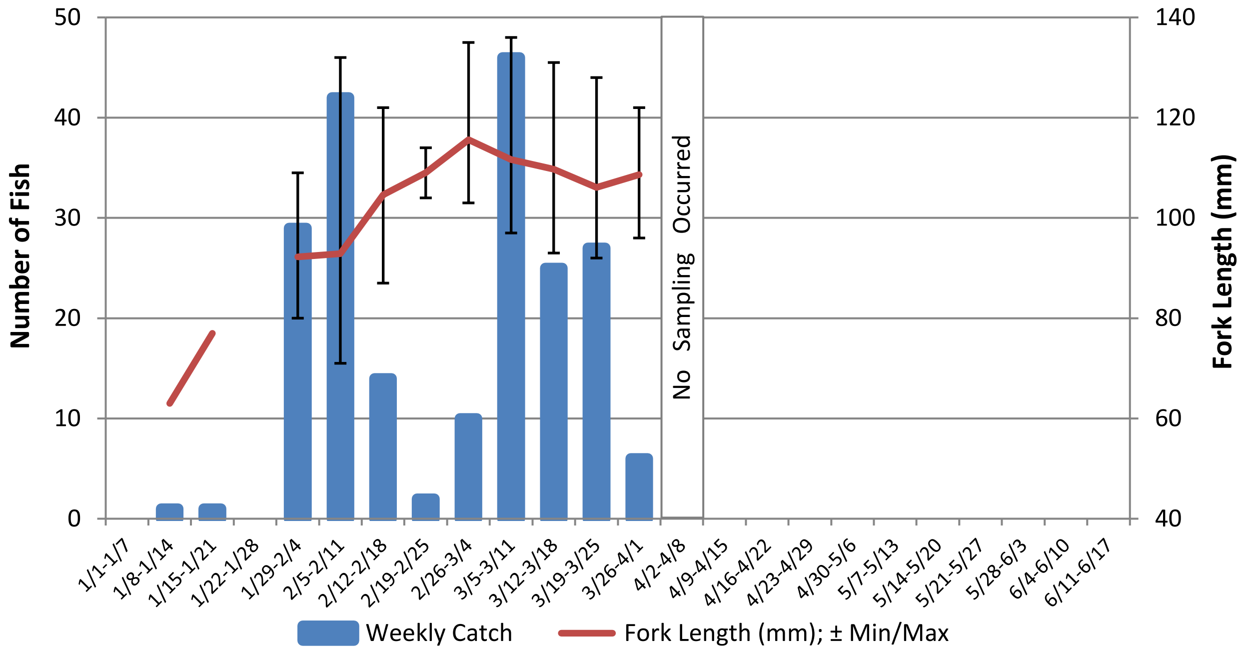
Genetic analyses suggest that 16 natural origin spring-run Chinook Salmon were captured during the 2020 survey season. The first week that spring-run were captured, January 29, coincided with the season's peak catch of five. Catch generally decreased proceeding this week with the final spring-run being captured the week of March 19 (Figure 10). Ten of these fish were identified as parr and six were identified as silvery parr. The average fork length was 61 mm with a range of 54 – 74 mm (Figure 10).

Figure 10: Weekly minimum, maximum, and average fork length (mm) and catch distribution of natural origin spring-run Chinook Salmon captured during the 2020 Lower American River rotary screw trap survey season.



The genetic analyses results also suggest that 203 natural origin winter-run Chinook Salmon were captured during the 2020 survey season. These salmon were captured between the weeks of January 8 and March 26 with two weeks of peak capture. The first occurred the week of February 5 when 20.69% (n = 42) of the seasons total was captured and the second occurred the week of March 5 when 22.66% (n = 46) were captured (Figure 11). Of these fish, two were identified as parr, 138 were identified as silvery parr, and 55 were identified as smolts. Fork lengths ranged from 63 – 136 mm over the course of the season with an average fork length of 103 mm (Figure 11).

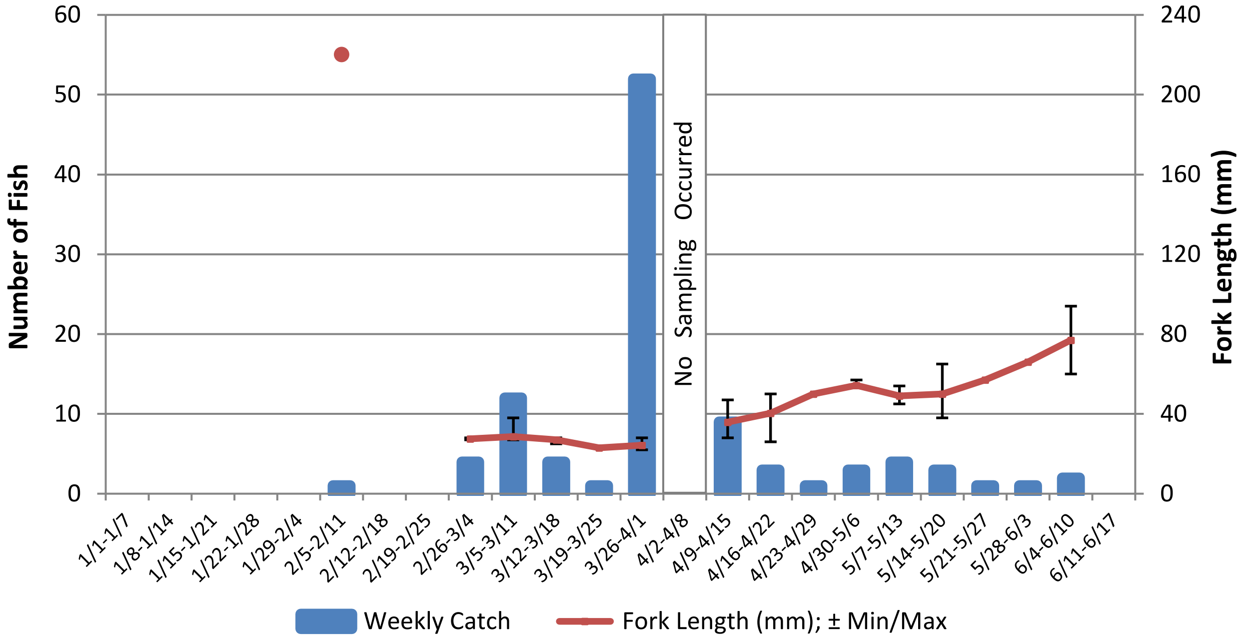
Figure 11: Weekly minimum, maximum, and average fork length (mm) and catch distribution of natural origin winter-run Chinook Salmon captured during the 2020 Lower American River rotary screw trap survey season.



Steelhead

During the 2020 survey season, a total of 101 natural origin steelhead were captured. Catch peaked the week of March 26, comprising 51.49% (n = 52) of the total steelhead captured. Weekly catch generally decreased and remained low (range: 1 – 9) proceeding this week with the final two steelhead being captured the week of June 4 (Figure 12). All captured steelhead were also assessed for a life stage. The life stage composition consisted of 2 yolk sac fry, 80 button-up fry, 18 parr, and 1 smolt. Fork lengths ranged from 23 – 28 mm for yolk sac fry, 22 – 41 mm for button-up fry, 38 – 94 mm for parr, and the one natural origin steelhead smolt identified had a fork length of 220 mm (Figure 12).

Figure 12: Weekly minimum, maximum, and average fork length (mm) and catch distribution of natural origin steelhead captured during the 2020 Lower American River rotary screw trap survey season.

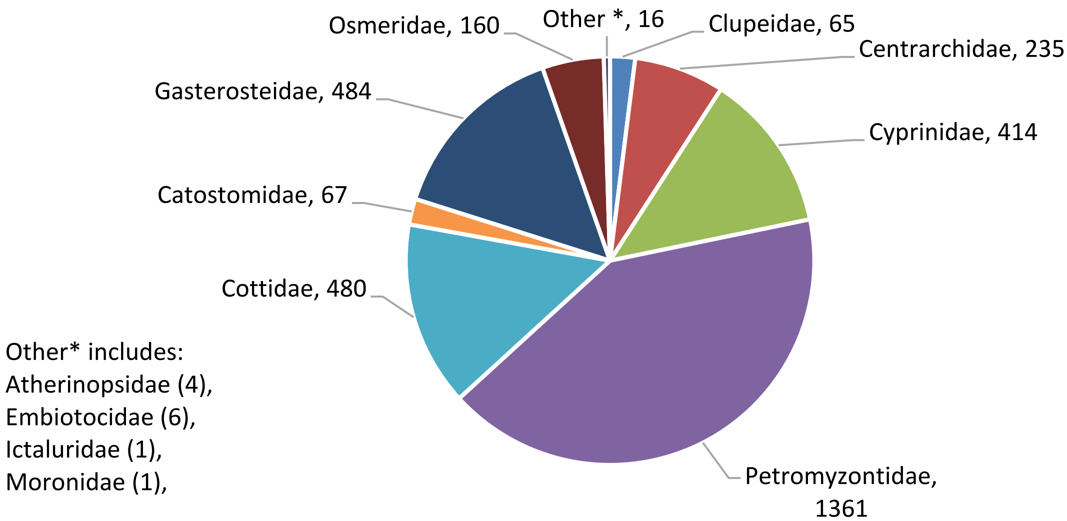


In addition to the natural origin steelhead catch, 523 adipose clipped, hatchery steelhead were also captured. These fish were caught between February 24 and May 3, with an average fork length of 214 mm and range of 93 – 323 mm. The hatchery produced steelhead were also assessed for life stage with smolts comprising 98.47% (n = 515) of the catch. Daily catch peaked on February 26 (n = 103) and weekly catch remained consistent until sampling was suspended on March 31 in response to the hatchery salmon release.

Non-salmonid Species

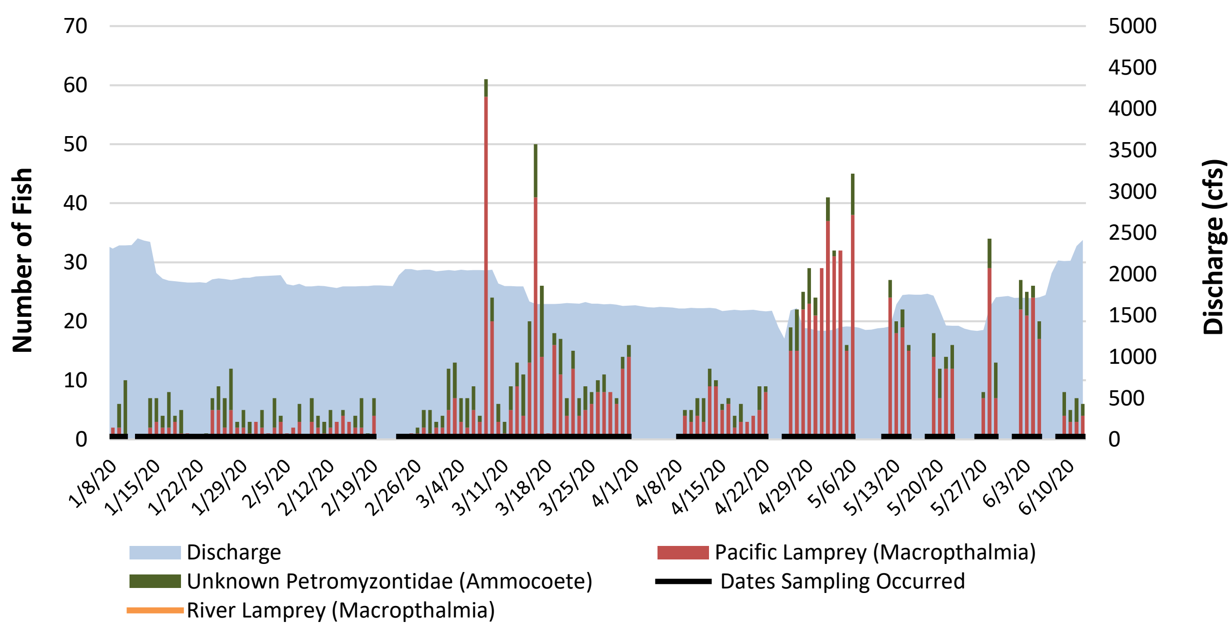
A total of 3,282 non-salmonid fish were also captured during the 2020 survey season. The majority (n = 2,908, 88.6%) of these fish belonged to 23 identified species in the following families: Atherinopsidae (silversides), Catostomidae (suckers), Centrarchidae (sunfish), Clupeidae (shad), Cottidae (sculpins), Cyprinidae (minnows), Embiotocidae (Tule Perch), Gasterosteidae (sticklebacks), Ictaluridae (catfish), Moronidae (Striped Bass), Osmeridae (smelts), Petromyzontidae (northern lampreys), and Poeciliidae (mosquitofish) (Figure 13). The remaining 11.4% (n = 374) were not able to be identified to species level, but belonged to the following families: Centrarchidae (n = 1), Cottidae (n = 5), Cyprinidae (n = 16), and Petromyzontidae (n = 346). The majority of non-salmonid fish captured were native to the Central Valley watershed (n = 2,785, 84.86%) with the remaining individuals (n = 497, 15.14%) being non-native species. Appendix 3 contains a complete list of species captured in the 2020 survey season.

Figure 13: Non-salmonid catch totals for each family of species collected during the 2020 Lower American River rotary screw trap survey season.



Of the 3,282 non-salmonid fish captured, 1,361 (41.47%) were identified as Petromyzontidae spp. (northern lampreys); 1,008 (74.06%) of which were identified as Pacific Lamprey, consisting of 3 adults and 1,005 juveniles. Seven (0.51%) of these fish were identified as juvenile River Lamprey and were captured between February 18 and May 13. The remaining 346 (25.4%) lamprey captured were identified as juvenile ammocoetes of Petromyzontidae and were not identified to a species level. Catch of Pacific Lamprey peaked on March 8 when 58 (5.75%) of the season's Pacific Lamprey total was captured. Catch of ammoceotes peaked on March 17 when 12 (3.47%) of the season's total was captured. Lastly, catch of River Lamprey peaked the week of April 16 when two (28.6%) were captured (Figure 14).

Figure 14: Weekly lamprey catch during the 2020 Lower American River rotary screw trap survey season.



Discussion

Project Scope

The continued operation of the Lower American River rotary screw traps during the 2020 survey season provided valuable biological monitoring data for emigrating Chinook Salmon and steelhead. Primary objectives of the study were met by developing fall-run Chinook Salmon passage estimates and accurately quantifying the catch of steelhead, winter-run, and spring-run Chinook Salmon. Additionally, secondary objectives were met by collecting biological data from captured salmonids that can be used to determine how populations respond to various environmental parameters. This data will continue to strengthen our understanding of Lower American River salmonids by expanding on previous findings from the CDFW emigration surveys (1992-2012) and PSMFC rotary screw trap emigration surveys (2013-2019).

Passage Estimate and Catch

A total of 152,378 natural origin fall-run Chinook Salmon were captured during the 2020 survey season. This marks the highest catch of natural origin fall-run since 2015 and a substantial increase from the 2019 survey season when 15,056 of these salmon were captured. The natural origin fall-run passage estimate of 1,882,610 [95% CI: 1,635,000 – 2,215,000] also represents a significant increase from the 2019 estimate of 348,100 [95% CI: 348,100 – 466,700] (Appendix 6). These changes represent a 912% increase in actual catch and a 441% increase in the passage estimate from 2019 to 2020. Additionally, the ratio between interval width and the passage estimate decreased from 58% in 2019 to 31% in 2020 posing relatively higher precision in the estimate.

Steelhead, winter-run, and spring-run Chinook Salmon were also captured and processed in order to accurately enumerate and collect biological data for these fish during the 2020 survey season. The total catch of natural origin steelhead decreased from 337 in 2019 to 101 in 2020. Contrarily, the total catch of winter-run increased from 18 in 2019 to 203 in 2020. Additionally, the 2020 season represents the largest annual catch of winter-run since PSMFC took over trap operations in 2013. Between 2013 and 2019, only 125 winter-run had been captured (annual range: 0 – 43) relative to the 203 that were captured in 2020. While less significant, catch of spring-run Chinook Salmon increased from nine in 2019 to 16 in 2020. Lastly, hatchery origin, adipose clipped salmonids were also captured and accounted for 18,702 Chinook Salmon and 523 steelhead. A summary table for the total annual catch of natural origin salmonids captured between 2013 and 2020 can be found in Appendix 6.

Several factors must be considered when interpreting the passage estimates of fall-run Chinook Salmon and the quantified catch of steelhead, winter-run, and spring-run Chinook

Salmon. Trap operation is consistently one of the most important factors when developing meaningful annual passage estimates. Because data cannot be collected when traps are not sampling, the CAMP platform is used to estimate daily passage during prolonged periods of abnormal trap function or for gaps in sampling that are seven or less days in duration. However, any gaps in sampling greater than seven days in duration could not have passage estimates assigned, biasing the passage estimate low. In 2019, sampling could only be conducted for 60% (67 days) of the season and contained two 14 day gaps where production estimates could not be generated. In contrast, sampling was conducted for 76% (120 days) of the 157 day season in 2020 with only one eight day gap in sampling that could not have a production estimate generated. Operational differences of this nature can add a significant bias that needs to be considered when comparing annual passage estimates.

Another significant factor to consider while interpreting the results is whether the survey season encompassed the entire juvenile salmonid emigration period. During the first seven days of sampling during the 2020 survey season, a total of 275 fall-run were captured, accounting for 0.18% of the total season catch and 0.10% (n = 1,786) of the total passage estimate. Furthermore, during the last seven days of sampling, a total of 61 fall-run were captured accounting for 0.04% of the total season catch. The last seven days of the survey season also comprised 0.04% (n = 706) of the total passage estimate, which includes two days of imputed catch when trapping did not occur. Because of this, it is likely that the 2020 survey season encompassed the vast majority of the fall-run Chinook Salmon emigration. In contrast, the 2019 season likely did not encompass the full emigration period due to a season ending trap failure, further diminishing the ability to make a meaningful annual comparison.

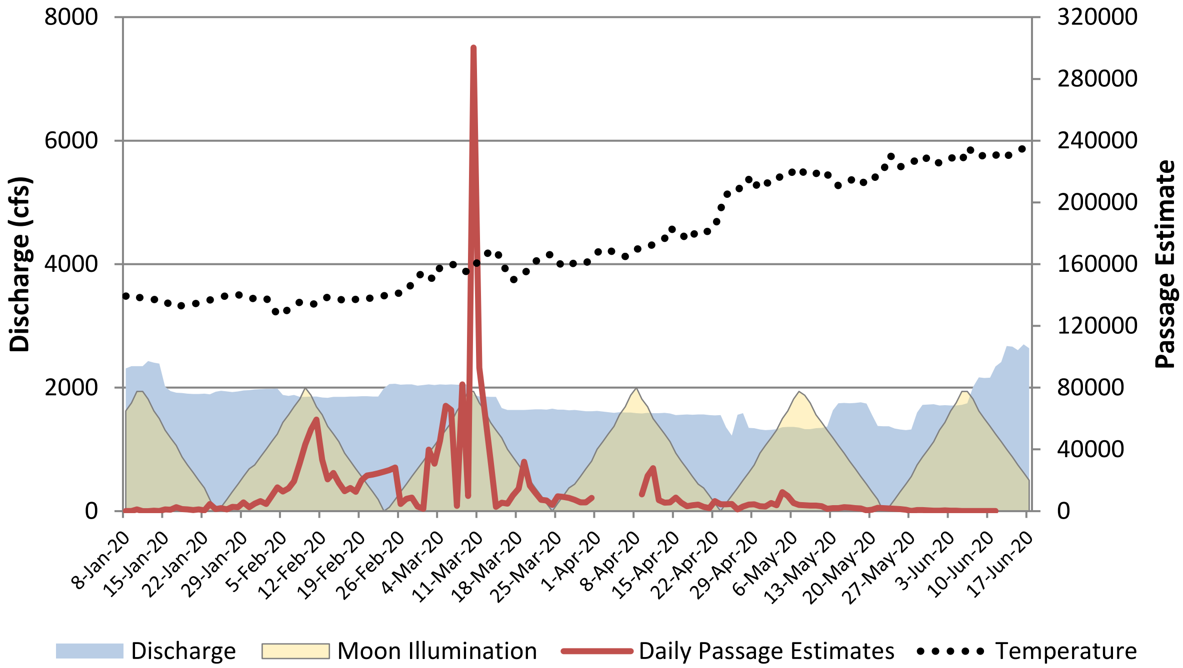
The accuracy of the fall-run passage estimates also comes from the quantity, quality, and recapture efficiencies obtained during trap efficiency trials. An attempt is made each screw trapping season to complete at least ten efficiency trials to produce estimates of the highest confidence. However, insufficient catch of natural origin fall-run and a temporary inability to receive hatchery fish due to the mounting concerns from the COVID-19 pandemic lead to the completion of six efficiency trials in 2020. Capture efficiencies during the first three trials in February and March averaged 14.8% (range: 13.6 – 15.5%), while the last three trials in April and May averaged 4.0% (range: 1.9 – 6.7%). This decrease in capture efficiency could be explained by trap avoidance of larger fish (Johnson et al. 2007) the possibility of an insufficient sample size, or from in-season adjustments to trap position. A difference in average sample size and fork length was observed between the February – March trials (n = 1,835, 36 mm) and April – May trials (n = 544, 76 mm) and could have resulted in increased trap avoidance and/or resulted in more volatile efficiencies by using smaller release groups. Furthermore, this decrease could also be a result of the two necessary alterations to trap position in April and May that allowed river recreationalists more room to safely circumvent the traps.

Additional insight to the decrease in capture efficiencies also came unexpectedly from the raw catch of hatchery origin fall-run Chinook Salmon. Of the 18,702 captured in 2020, 99.8% (n = 18,659) were captured on March 31 during the temporary termination of efficiency trials. The average fork length of 75 mm for these fish was 39 mm larger than the natural origin fish that were utilized during previous efficiency trial on March 19 (Table 5). Despite their larger size, 9.3% of the 200,000 hatchery fish released ten miles upriver were captured within one day of their release. Although this capture efficiency is purely anecdotal, it does allow for additional speculation when determining which factor may have had the greatest influence on capture efficiency during the final three trials. Because this relatively high capture efficiency occurred prior to the alterations in trap location, the repositioning of traps further from the thalweg may have been a larger factor than size based trap avoidance.

Biological Observations

In order to develop models that correlate environmental parameters with temporal presence and abundance for salmonids, biological data was collected throughout the season. This data was collected for a subsample of all salmonids in order to evaluate potential changes in health, growth, and life history strategies. As seen in previous years of biological sampling on the Lower American River, the majority of the fall-run Chinook Salmon population emigrate before spring as age 0 fry from the American River (PSMFC 2013 – 2019, Snider and Titus 2001). In the Central Valley, this emigration timing is most representative of an ocean-type life history where recently emerged fry emigrate from their natal stream prior to the summer season before entering the ocean (Kjelson and Raquel 1981). The ocean-type life history strategy remained the primary life history strategy utilized in 2020 with 89% (n = 135,924) of the season's fall-run catch being captured before the week of March 19. During this period, fork lengths averaged 36 mm (Std Dev = 3.87) with 98% of the subsampled fish being identified as alevin or button up fry. After March 19, a steady increase in temperature, average fish length, and the ratio of parr, silvery parr, and smolt life stages were observed. The fall-run emigration also experienced two unique peak capture periods in February and March that portrayed a bimodal distribution. Interestingly, the two major peaks in emigration coincided with the full moon in February and March (Figure 15). This emigration trend was observed over the course of the season with 82% (n = 124,899) of the fall-run being captured while moon illumination was ≥ 50%, and 51% (n = 77,521) being captured while moon illumination was ≥ 90%. While correlations between moon illumination and Chinook Salmon emigration have been previously documented, a negative correlation is most frequently observed (Roper and Scarnecchia 1999, Schroeder et. al 2008, Williams 2006). This is contrary to what was observed during the 2020 RST survey season. Because discharge, a primary environmental cue for emigration, remained relatively constant in 2020 (Appendix 8), lunar cycles could be a significant factor in determining the emigration timing of fall-run Chinook Salmon from the Lower American River. However, because lunar cycles cannot be isolated form other key environmental cues (e.g., temperature, turbidity, discharge), further research is needed to determine if past or future emigration trends exist.

Figure 15: Daily average moon illumination, discharge (cfs) at Fair Oaks, temperature, and passage estimate for fall-run Chinook Salmon during the 2020 Lower American River survey season.



Note: Peak of Moon Illumination = 100% illumination (full moon)

Moon Illumination: Data acquired from https://www.meteomatics.com/en/api/available-parameters/moon.
Daily Passage Estimates: Does not provide an estimate for gaps > seven days (ie: April 1 – April 8).
Temperature: USGS Watt Ave, Station #11446980. See daily values in Figure 5 or Appendix 2.

Biological data was also collected for winter-run Chinook Salmon and included the collection of genetic samples, recording fork length, assigning a life stage, and collecting individual weights. It has been previously hypothesized that these fish specifically utilize the Lower American River during Sacramento River discharge events that cause the river to backflow (Maslin et al. 1998, Phillis et al. 2017). The American River showed no signs of backflow at the rotary screw traps in 2020, but a positive relationship could still exist between catch on the American River and a late January discharge event on the Sacramento River (USGS station number 11425500). Despite this, catch of winter-run still followed the same bimodal emigration trend as the recently emerged fall-run fry. The two weeks of peak capture of 42 and 46 fish also occurred during the weeks of February 5 and March 5 during the full moon and peak emigration of fall-run. However, other environmental factors such as an increase in flow on the Sacramento River and subsequent backflow into the American River, may have had an influenced on the first capture event based on a late January discharge event. Although discharge did not appear to be a factor during the second and largest emigration period for these salmon, some temperature fluctuations were observed (Figure 5) and could also explain the emigration timing (Williams 2006). Additionally, because these peak capture events occurred simultaneously with the peak capture of fall-run Chinook Salmon, the increased catch of winter-run could have also been a result of schooling behavior as thousands of fry emigrated from the American River.

Of the 195 winter-run Chinook Salmon that were assessed for a life stage in 2020, 1% were identified as parr (n = 2) while the remaining 193 fish were identified as silvery parr or smolts. In contrast, 13% (n = 17) of the winter-run captured in the previous seven seasons were identified as parr with the remaining 108 fish being identified as silvery parr and smolts. Additionally, the average fork length of 103 mm (Std Dev = 12.94) was the largest annual average for years when more than 1 fish was captured since sampling began in 2013. This increase in size provides one likely explanation for the proportional decrease of parr identified.

Spring-run Chinook Salmon have also been captured in six of the seven previous years with an average annual catch of seven fish (range: 0 – 19). During the 2020 season, 830 salmon met the LAD criteria of spring-run but only 16 of these fish retained this run designation based the genetic results. This inaccuracy of the LAD criteria for spring-run has been well documented and is consistent throughout the Central Valley (Harvey et al. 2014). Because the LAD criteria has appeared to more accurately identify spring-run captured early in the sampling season (PSMFC 2013 – 2019), the same expansion methodology previously used by PSMFC was again utilized in 2020 (Silva and Bouton 2015). This expansion method allowed for a proportional expansion of spring-run to be applied while the LAD criteria was more accurate opposed to changing all LAD spring-run that were not genetically sampled to fall-run. However, it should be noted that this expansion method only accounted for 5 of the 16 spring-run identified due to lower early season catch of LAD spring-run and the higher proportion of genetic clips collected. It should also be noted that two salmon recorded as LAD spring-run were identified as winter-run from the genetic results but were determined to be inaccurate and not utilized for the expansion analysis. The first of these salmon, captured the week of January 29, had a fork length of 58 mm while the average length of winter-run captured during this period was 91mm (n = 21, range: 84 – 105 mm). The second salmon was captured the week of March 5 and had a fork length of 74 mm while the average winter-run length was 112 mm (n = 17, range: 100 – 136 mm) during the same week. Due to the known accuracy of the winter-run LAD criteria and the highly irregular lengths for both of these fish it was determined that a recording error had likely occurred at the time of capture so both samples were treated as no calls.

All 16 of the final spring-run Chinook Salmon were measured, weighed, and a life stage was assigned. The average fork length of 61 mm was the smallest annual average that had been observed between 2013 and 2019 (mean range: 63 – 88 mm). This is likely a result from the majority of these salmon (n = 15) being captured during the winter season, when salmon size is typically smaller due to lower water temperature, food availability, and fish age (McCullough 1999, Rich 1987). Additionally, the range of lengths observed in 2020 remains within the minimum and maximum lengths observed during the previous seven sampling seasons. The smaller lengths observed in 2020 also coincides with parr being the most abundant life stage identified (63%, n = 10) as opposed to silvery parr (66%, n = 51) during the 2013 – 2019 survey seasons.

California Central Valley steelhead were also assessed for life stage, fork length, and weighed if ≥ 40 mm. Between 2013 and 2019, 3,668 steelhead have been captured (annual mean: 524) with 2,206 of these fish being captured in 2013. During the 2020 season, 101 steelhead were captured consisting of 100 age 0 juveniles, and one yearling smolt. This marks the third lowest annual capture of steelhead over the past eight seasons since 11 were captured in 2015 followed by 28 in 2017. As seen in previous years, the number of redds observed within a close upstream proximity of the trap as well as the total number of steelhead redds observed on the Lower American River has an influence on the quantity of juveniles captured (PSMFC 2013 – 2019). The 2020 American River steelhead redd surveys conducted by Cramer Fish Sciences (CFS, 2020) helped explain the low catch of juvenile steelhead as only 53 redds were identified in 2020. Additionally, the most redds observed between 2013 and 2020 occurred in 2013 when 316 redds were identified coinciding with the highest catch of juvenile steelhead in the RSTs. The life stage composition observed in 2020 also coincides with what has been previously observed on the American River with the majority of fish captured being recently emerged, age 0 juveniles.

Limitations and Recommendations

The 2020 rotary screw trap sampling effort to quantify catch and estimate passage of emigrating juvenile salmonids met all study objectives. However, we acknowledge several limitations and challenges when interpreting the data collected. One such challenge arises when attempting to make meaningful annual comparisons to production estimates and biological data that was obtained between 1992 and 2012. During this time period, changes in sampling methodology, how life stages were classified, and how annual production estimates were developed occurred. This was in part due to the development, establishment, and standardization of the CAMP platform across the Central Valley. Additionally, and as previously noted, gaps in sampling of varying frequency and magnitude will continue to present additional challenge for managers when correlating environmental parameters with biological changes or fall-run passage estimates.

Juvenile salmonid emigration monitoring will continue on the Lower American River in 2021. In order to obtain the highest accuracy to the passage estimates and maintain the highest level of safety, adjustments are recommended for future seasons. In order to achieve an increased level of accuracy for passage estimates, additional focus should be applied to the quantity of efficiency trials completed throughout the season. Expansions to the dates that fish can be acquired from Nimbus Fish Hatchery have been pre-approved by CDFW which would allow for hatchery origin mark recapture trials between January and May if sufficient natural origin fish are not available. Additionally, due to the increasing density of river recreationalists observed in 2020, a 20 ft anchor line extension should be added at the start of the 2021 season to allow additional navigational clearance between the RST and the higher gradient riffle upstream of the traps. In addition to an anchor line extension, a debris boom affixed to the river-left anchor line to help deflect debris and river recreationalists away from the traps should be considered. These changes should decrease the frequency of adjustments to trap location, decrease fish mortality as a result from less debris, have a more even distribution of catch between each trap, and reduce the probability of river recreationalists coming in contact with the traps. We believe these efforts will strengthen the future of the Lower American River RST project by continuing to improve our understanding of juvenile salmonids while maintaining focus on safe sampling practices for our staff and public.

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, continued monitoring of juvenile salmonid emigration is required. Hydrologic monitoring and adaptive management to maintain ideal water temperature and flow for anadromous salmonids continues to be of high importance. The 2020 data will be further 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. Additionally, 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 increase habitat availability, reduce pre-spawn mortality and minimize redd dewatering and superimposition which have likely had a negative influence on spawning in previous drought years.

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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 1955; 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 Salmon 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 2020 survey season.**

Julian Week	Water Temperature (°C)			Discharge (cfs)			Dissolved Oxygen (mg/L)			Turbidity (NTU)			Velocity (m/s)		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
1/8 - 1/14	9.9	9.8	10.0	2369	2309	2433	10.49	9.78	11.24	1.42	0.71	1.80	1.32	1.01	1.55
1/15 - 1/21	9.6	9.4	9.7	1927	1896	2016	10.31	10.11	10.61	1.12	0.85	1.61	1.24	1.13	1.36
1/22 - 1/28	9.9	9.7	10.0	1928	1894	1949	9.90	9.34	10.27	1.13	0.68	2.26	1.31	1.13	1.52
1/29 - 2/4	9.7	9.1	9.9	1973	1956	1987	9.83	9.30	10.18	0.88	0.47	1.16	1.30	1.06	1.42
2/5 - 2/11	9.5	9.1	9.7	1863	1850	1884	10.34	9.31	10.68	0.86	0.25	1.70	1.23	1.00	1.40
2/12 - 2/18	9.8	9.7	9.9	1848	1834	1856	10.33	10.00	10.52	1.16	0.66	2.10	1.26	1.10	1.40
2/19 - 2/25	9.9	9.7	10.1	1936	1855	2062	10.46	10.24	10.70	1.06	0.79	1.51	1.28	1.10	1.50
2/26 - 3/4	10.7	10.1	11.3	2047	2034	2054	10.61	10.19	11.42	0.97	0.56	1.48	1.32	1.10	1.50
3/5 - 3/11	11.3	11.1	11.7	1998	1856	2052	10.65	9.90	11.23	0.98	0.62	1.60	1.33	1.10	1.60
3/12 - 3/18	11.4	10.7	12.1	1735	1638	1855	10.59	9.66	11.43	1.12	0.62	1.83	1.31	1.10	1.60
3/19 - 3/25	11.5	11.0	11.9	1646	1637	1661	10.29	9.67	11.65	1.20	0.56	2.42	1.35	1.10	1.50
3/26 - 4/1	11.5	11.3	12.0	1629	1616	1643	10.18	10.00	10.42	0.94	0.52	1.61	1.37	1.00	1.50
4/2 - 4/8	No Sampling			No Sampling			No Sampling			No Sampling			No Sampling		
4/9 - 4/15	12.5	12.1	13.1	1583	1555	1593	9.85	9.33	11.21	1.60	1.02	2.07	1.29	1.20	1.50
4/16 - 4/22	12.9	12.5	13.1	1561	1551	1568	9.45	9.00	9.95	1.34	0.83	1.71	1.33	1.10	1.50
4/23 - 4/29	14.8	14.0	15.4	1425	1222	1588	8.67	8.32	9.32	1.35	1.00	1.88	1.24	1.10	1.30
4/30 - 5/6	15.4	15.1	15.8	1338	1312	1365	9.31	8.85	9.72	1.39	0.86	2.35	1.22	1.00	1.40
5/7 - 5/13	15.6	15.4	15.9	1386	1325	1633	9.09	8.93	9.25	1.37	0.92	1.91	1.22	1.10	1.30
5/14 - 5/20	15.2	15.0	15.5	1723	1560	1762	9.37	9.11	9.66	1.24	0.52	2.61	1.35	1.20	1.50
5/21 - 5/27	16.0	15.6	16.5	1347	1313	1378	8.75	8.24	9.22	1.99	1.09	2.58	1.32	1.30	1.40
5/28 - 6/3	16.3	16.1	16.4	1703	1598	1733	9.08	8.59	9.47	1.27	0.55	1.63	1.38	1.20	1.60
6/4 - 6/10	16.5	16.2	16.8	1953	1709	2164	9.14	8.65	9.87	1.43	0.67	2.63	1.37	1.20	1.60
6/11 - 6/17	16.5	16.5	16.6	2377	2341	2413	8.87	8.73	9.01	1.73	1.55	1.91	1.50	1.40	1.60

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 natural origin fish species caught during the 2020 season using rotary screw traps on the Lower American River.

Common Name	Family Name	Species Name	Total
Chinook Salmon	Salmonidae	*Oncorhynchus tshawytscha*	152,597
Steelhead / Rainbow trout	Salmonidae	*Oncorhynchus mykiss*	101
American shad	Clupeidae	*Alosa sapidissima*	35
Bluegill	Centrarchidae	*Lepomis macrochirus*	20
Fathead minnow	Cyprinidae	*Pimephales promelas*	2
Golden shiner	Cyprinidae	*Notemigonus crysoleucas*	9
Hardhead	Cyprinidae	*Mylopharodon conocephalus*	279
Hitch	Cyprinidae	*Lavinia exilicauda*	2
Inland silverside	Atherinopsidae	*Menidia beryllina*	4
Largemouth bass	Centrarchidae	*Micropterus salmoides*	187
Pacific lamprey	Petromyzontidae	*Lampetra entosphenus*	1,008
Prickly sculpin	Cottidae	*Cottus asper*	13
Redear sunfish	Centrarchidae	*Lepomis microlophus*	19
Riffle sculpin	Cottidae	*Cottus gulosus*	462
River lamprey	Petromyzontidae	*Lampetra ayresii*	7
Sacramento pikeminnow	Cyprinidae	*Ptychocheilus grandis*	106
Sacramento sucker	Catostomidae	*Catostomus occidentalis*	67
Spotted bass	Centrarchidae	*Micropterus punctulatus*	2
Striped bass	Moronidae	*Morone saxatilis*	1
Threadfin shad	Clupeidae	*Dorosoma petenense*	30
Threespine stickleback	Gasterosteidae	*Gasterosteus aculeatus*	484
Tule perch	Embiotocidae	*Hysterocarpus traskii*	6
Unknown Centrarchid	Centrarchidae		1
Unknown lamprey (Entosphenus or Lampetra)	Petromyzontidae		346
Unknown minnow	Cyprinidae		16
Unknown sculpin (Cottus)	Cottidae	*Cottus* sp.	5
Unknown sunfish (Lepomis)	Centrarchidae	*Lepomis* sp.	6
Wakasagi / Japanese smelt	Osmeridae	*Hypomesus nipponensis*	160
Western mosquitofish	Poeciliidae	*Gambusia affinis*	4
White catfish	Ictaluridae	*Ameiurus catus*	1

Appendix 4: **Genetic results for fin-clip samples from Chinook Salmon caught in the Lower American River during the 2020 survey season.**

Note:
Sample #: refers 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 Assignment	SNP Run Assignment	SNP Probability	Final Run Assignment	FL (mm)	W (g)
1/10/2020	3620-001	Winter	Winter	1.00	Winter	63	2.7
1/16/2020	3620-002	Winter	Winter	1.00	Winter	77	6
1/28/2020	3620-003	Fall	No Call	-	Fall	37	-
1/28/2020	3620-004	Fall	Fall	0.98	Fall	35	-
1/28/2020	3620-005	Fall	No Call	-	Fall	35	-
1/28/2020	3620-006	Fall	Fall	0.85	Fall	35	-
1/28/2020	3620-007	Fall	Fall	1.00	Fall	34	-
1/30/2020	3620-010	Winter	Winter	1.00	Winter	91	-
1/30/2020	3620-011	Winter	Winter	1.00	Winter	86	-
1/31/2020	3620-008	Winter	Winter	1.00	Winter	96	-
1/31/2020	3620-012	Winter	Winter	1.00	Winter	89	-
1/31/2020	3620-013	Winter	Winter	1.00	Winter	92	-
1/31/2020	3620-014	Winter	Winter	1.00	Winter	101	-
1/31/2020	3620-015	Winter	Winter	1.00	Winter	87	-
1/31/2020	3620-016	Winter	Winter	1.00	Winter	80	-
2/1/2020	3620-018	Winter	Winter	1.00	Winter	84	6.4
2/1/2020	3620-019	Winter	Winter	1.00	Winter	103	12.7
2/3/2020	3620-020	Spring	Winter	1.00	Fall	58	3.1
2/3/2020	3620-026	Spring	Fall	1.00	Fall	57	2
2/3/2020	3620-028	Winter	Winter	1.00	Winter	81	5.8
2/3/2020	3620-029	Winter	Winter	1.00	Winter	81	6.8
2/3/2020	3620-030	Winter	Winter	1.00	Winter	93	8.5
2/3/2020	3620-031	Spring	No Call	-	Fall	58	1.8
2/3/2020	3620-032	Spring	Spring	0.78	Spring	55	1.5
2/4/2020	3620-034	Winter	Winter	1.00	Winter	96	13.5
2/4/2020	3620-035	Winter	Winter	1.00	Winter	105	12.4
2/4/2020	3620-036	Winter	Winter	1.00	Winter	105	15
2/4/2020	3620-038	Winter	Winter	1.00	Winter	85	6.6
2/4/2020	3620-039	Winter	Winter	1.00	Winter	88	9
2/4/2020	3620-040	Winter	Winter	1.00	Winter	95	8.5
2/4/2020	3620-041	Spring	Spring	0.98	Spring	55	5.7
2/4/2020	3620-042	Spring	Fall	1.00	Fall	56	1.2
2/4/2020	3620-043	Winter	Winter	1.00	Winter	96	8.1
2/4/2020	3620-044	Winter	Winter	1.00	Winter	90	7.1
2/4/2020	3620-045	Winter	Spring	0.92	Spring	74	3.5

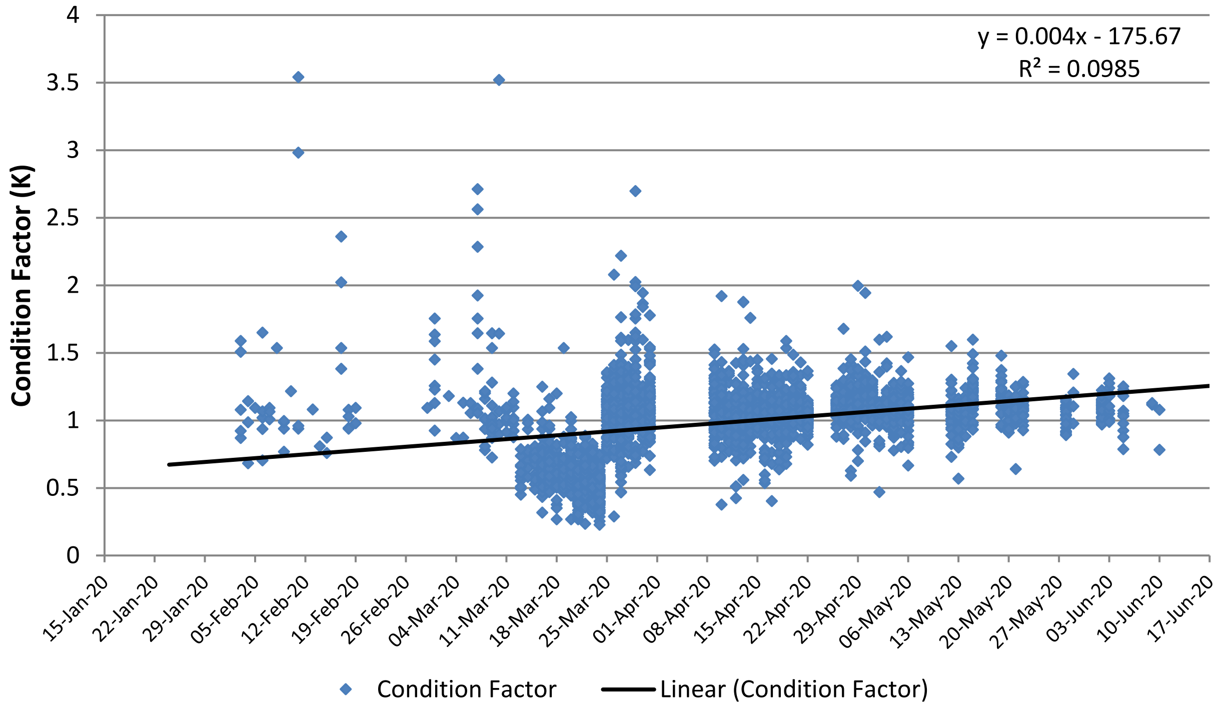
2/4/2020	3620-046	Spring	Spring	1.00	Spring	56	1.5
2/4/2020	3620-047	Spring	No Call	-	Fall	64	3
2/5/2020	3620-049	Winter	Winter	1.00	Winter	86	7.2
2/5/2020	3620-052	Winter	No Call	-	Winter	90	9.7
2/5/2020	3620-053	Winter	Winter	1.00	Winter	82	5.7
2/5/2020	3620-054	Winter	Winter	1.00	Winter	93	8.7
2/5/2020	3620-055	Winter	Winter	1.00	Winter	71	4
2/5/2020	3620-056	Spring	Spring	0.89	Spring	59	2.4
2/5/2020	3620-057	Winter	Winter	1.00	Winter	97	10.1
2/5/2020	3620-058	Winter	Winter	1.00	Winter	91	8.3
2/5/2020	3620-059	Winter	Winter	1.00	Winter	101	10.2
2/6/2020	3620-061	Winter	Winter	1.00	Winter	99	10.7
2/6/2020	3620-062	Winter	Winter	1.00	Winter	99	10.7
2/6/2020	3620-063	Winter	Winter	1.00	Winter	72	5
2/6/2020	3620-064	Spring	Spring	1.00	Spring	60	2.9
2/6/2020	3620-065	Winter	Winter	1.00	Winter	100	10.4
2/6/2020	3620-066	Winter	Winter	1.00	Winter	95	9.2
2/6/2020	3620-067	Winter	Winter	0.98	Winter	86	6.8
2/6/2020	3620-068	Spring	Fall	0.99	Fall	52	1.5
2/6/2020	3620-069	Winter	Winter	1.00	Winter	94	9.1
2/6/2020	3620-070	Spring	Fall	1.00	Fall	56	2.9
2/6/2020	3620-081	Winter	Winter	1.00	Winter	100	11
2/7/2020	3620-017	Winter	Winter	1.00	Winter	85	6.4
2/7/2020	3620-027	Winter	No Call	-	Winter	104	12.1
2/7/2020	3620-082	Winter	Winter	1.00	Winter	105	12.1
2/7/2020	3620-083	Winter	Winter	1.00	Winter	110	14.7
2/7/2020	3620-084	Winter	Winter	1.00	Winter	99	9.7
2/7/2020	3620-086	Winter	Winter	1.00	Winter	89	8.3
2/7/2020	3620-087	Winter	Winter	1.00	Winter	87	7.1
2/7/2020	3620-088	Spring	Fall	1.00	Fall	53	1.5
2/8/2020	3621-001	Winter	Winter	1.00	Winter	90	7.8
2/8/2020	3621-002	Winter	Winter	1.00	Winter	89	8.1
2/8/2020	3621-003	Winter	Winter	1.00	Winter	95	8
2/8/2020	3621-004	Spring	Spring	0.99	Spring	54	2.1
2/10/2020	3621-014	Spring	Fall	0.95	Fall	62	-
2/11/2020	3621-005	Winter	Winter	1.00	Winter	97	8.6
2/11/2020	3621-007	Winter	Winter	1.00	Winter	101	12.8
2/11/2020	3621-008	Spring	Fall	1.00	Fall	55	1.6
2/11/2020	3621-009	Spring	Fall	1.00	Fall	53	1.4
2/13/2020	3621-011	Spring	No Call	-	Fall	57	-
2/13/2020	3621-012	Spring	Spring	0.85	Spring	60	3.3
2/13/2020	3621-013	Spring	Fall	0.81	Fall	55	1.8
2/14/2020	3621-015	Winter	Winter	1.00	Winter	104	11.4
2/17/2020	3621-018	Winter	Winter	1.00	Winter	122	21.7
2/19/2020	3621-019	Fall	Fall	1.00	Fall	37	-
2/19/2020	3621-020	Fall	Fall	1.00	Fall	38	-
2/19/2020	3621-021	Fall	Fall	1.00	Fall	37	-
2/19/2020	3621-022	Fall	Fall	1.00	Fall	37	-
2/19/2020	3621-023	Fall	Fall	1.00	Fall	37	-
2/25/2020	3621-024	Winter	Winter	1.00	Winter	114	13.4
2/25/2020	3621-026	Winter	No Call	-	Winter	104	11.9
2/27/2020	3621-027	Winter	Winter	1.00	Winter	125	22.5
2/28/2020	3621-028	Winter	Winter	1.00	Winter	108	21.3

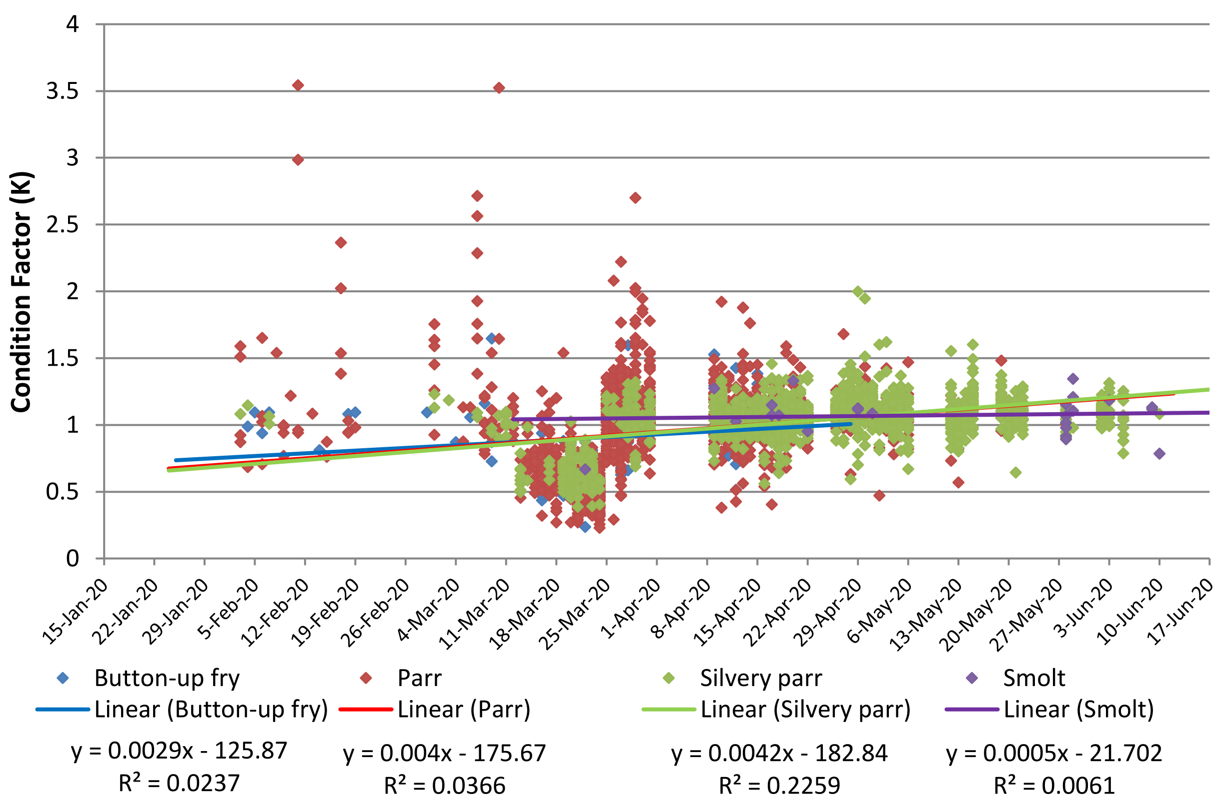
2/28/2020	3621-029	Winter	Winter	1.00	Winter	135	25.9
2/28/2020	3621-031	Winter	Winter	1.00	Winter	103	13.5
3/1/2020	3621-032	Spring	Fall	1.00	Fall	71	4.4
3/1/2020	3621-033	Spring	Fall	0.99	Fall	65	3.1
3/1/2020	3621-035	Spring	Spring	1.00	Spring	67	3.3
3/5/2020	3621-040	Winter	Winter	1.00	Winter	105	11.1
3/5/2020	3621-049	Spring	Fall	0.98	Fall	73	4.4
3/5/2020	3621-056	Spring	Fall	1.00	Fall	70	3
3/6/2020	3621-053	Winter	Winter	1.00	Winter	109	13.1
3/6/2020	3621-054	Winter	Winter	1.00	Winter	125	22.6
3/6/2020	3621-060	Spring	Fall	1.00	Fall	67	3.4
3/7/2020	3620-094	Spring	Fall	0.96	Fall	65	2.9
3/7/2020	3620-098	Winter	Winter	1.00	Winter	109	13.7
3/7/2020	3620-099	Spring	Fall	1.00	Fall	75	4.6
3/9/2020	3621-039	Spring	Fall	1.00	Fall	63	2.5
3/9/2020	3621-041	Spring	Fall	1.00	Fall	77	4.3
3/9/2020	3621-042	Spring	Fall	1.00	Fall	75	4.1
3/9/2020	3621-047	Spring	Spring	0.69	Spring	70	3.4
3/9/2020	3621-052	Winter	Winter	0.77	Winter	97	4
3/9/2020	3621-055	Spring	Fall	1.00	Fall	70	3.5
3/9/2020	3621-059	Winter	Winter	1.00	Winter	118	17.8
3/9/2020	3622-036	Spring	Fall	1.00	Fall	64	-
3/10/2020	3620-091	Winter	No Call	-	Winter	110	15.1
3/10/2020	3620-093	Winter	Winter	1.00	Winter	110	14.7
3/10/2020	3620-095	Winter	Winter	1.00	Winter	108	13.5
3/10/2020	3620-096	Winter	No Call	-	Winter	116	12.7
3/10/2020	3620-097	Winter	Winter	1.00	Winter	113	15.3
3/10/2020	3620-100	Spring	Fall	0.99	Fall	64	2.8
3/10/2020	3622-085	Winter	Winter	1.00	Winter	105	11.8
3/10/2020	3622-086	Winter	Winter	1.00	Winter	100	9.3
3/10/2020	3622-087	Spring	Fall	1.00	Fall	73	3.5
3/10/2020	3622-088	Winter	Winter	1.00	Winter	111	13.6
3/11/2020	3620-090	Winter	Winter	1.00	Winter	109	14.2
3/11/2020	3621-037	Winter	Winter	1.00	Winter	113	16
3/11/2020	3621-038	Spring	Fall	0.99	Fall	66	3.1
3/11/2020	3621-043	Spring	No Call	-	Fall	70	3.4
3/11/2020	3621-048	Spring	Fall	1.00	Fall	69	3.3
3/11/2020	3621-051	Spring	Fall	1.00	Fall	68	3.4
3/11/2020	3621-057	Spring	Fall	1.00	Fall	70	3.5
3/11/2020	3621-058	Spring	Fall	0.93	Fall	65	3
3/11/2020	3622-084	Winter	Winter	1.00	Winter	114	16.1
3/11/2020	3622-089	Winter	Winter	1.00	Winter	110	14.2
3/11/2020	3622-090	Winter	Winter	1.00	Winter	136	29.8
3/11/2020	3622-091	Winter	Winter	1.00	Winter	104	12.2
3/11/2020	3622-092	Spring	Winter	1.00	Fall	74	3.7
3/12/2020	3621-065	Winter	Winter	1.00	Winter	106	12
3/12/2020	3621-066	Spring	Fall	1.00	Fall	72	3.8
3/12/2020	3621-068	Spring	Fall	1.00	Fall	69	3.3
3/12/2020	3621-073	Winter	Winter	1.00	Winter	116	16.5
3/12/2020	3621-075	Spring	Fall	1.00	Fall	71	3.3
3/12/2020	3621-079	Winter	Winter	1.00	Winter	101	11.5
3/12/2020	3621-081	Winter	Winter	1.00	Winter	107	13.6
3/12/2020	3621-083	Spring	Fall	1.00	Fall	75	3.7

3/12/2020	3621-086	Spring	Fall	1.00	Fall	79	5.4
3/13/2020	3621-062	Winter	Winter	1.00	Winter	107	8.8
3/13/2020	3621-063	Winter	Winter	1.00	Winter	131	-
3/13/2020	3621-064	Spring	Fall	1.00	Fall	70	2
3/13/2020	3621-067	Spring	Fall	1.00	Fall	70	1.7
3/13/2020	3621-070	Spring	Fall	1.00	Fall	71	2.1
3/13/2020	3621-071	Spring	Fall	1.00	Fall	72	2.3
3/13/2020	3621-072	Spring	Fall	1.00	Fall	70	2.3
3/13/2020	3621-076	Winter	Winter	1.00	Winter	111	-
3/13/2020	3621-077	Spring	Fall	1.00	Fall	66	1.6
3/17/2020	3621-093	Spring	Fall	1.00	Fall	71	2.1
3/17/2020	3621-095	Spring	Fall	0.99	Fall	81	3.7
3/17/2020	3621-097	Spring	Fall	1.00	Fall	68	2.2
3/17/2020	3622-097	Spring	Fall	0.93	Fall	68	2.3
3/18/2020	3621-088	Winter	Winter	1.00	Winter	111	11.4
3/18/2020	3621-089	Spring	Fall	1.00	Fall	71	2.3
3/18/2020	3621-098	Spring	Fall	1.00	Fall	67	2.1
3/18/2020	3621-100	Winter	Winter	1.00	Winter	119	11.8
3/18/2020	3622-095	Spring	Fall	0.94	Fall	70	2.6
3/18/2020	3622-096	Spring	Fall	1.00	Fall	69	1.7
3/19/2020	3621-090	Spring	Fall	1.00	Fall	74	2.6
3/19/2020	3621-091	Spring	Fall	1.00	Fall	75	2.8
3/19/2020	3621-094	Winter	Winter	1.00	Winter	102	7.5
3/19/2020	3621-096	Spring	Fall	1.00	Fall	70	2.4
3/19/2020	3621-099	Spring	Spring	0.73	Spring	68	2
3/19/2020	3622-093	Spring	Fall	1.00	Fall	70	1.8
3/19/2020	3622-098	Spring	Fall	1.00	Fall	69	2
3/19/2020	3622-099	Spring	Fall	1.00	Fall	67	1.8
3/24/2020	3622-012	Fall	Fall	1.00	Fall	51	0.6
3/24/2020	3622-013	Fall	Fall	1.00	Fall	65	1.6
3/24/2020	3622-018	Fall	Fall	0.95	Fall	55	0.8
3/24/2020	3622-019	Spring	Fall	1.00	Fall	79	2.9
3/24/2020	3622-020	Fall	No Call	-	Fall	47	0.4
3/24/2020	3622-021	Fall	Fall	1.00	Fall	47	0.3
3/24/2020	3622-023	Fall	Fall	1.00	Fall	50	0.5
3/24/2020	3622-024	Spring	Fall	1.00	Fall	74	2
3/24/2020	3622-025	Fall	Fall	1.00	Fall	52	0.6
3/24/2020	3622-026	Spring	Fall	1.00	Fall	79	1.6
3/24/2020	3622-027	Fall	Fall	1.00	Fall	68	0.8
3/24/2020	3622-028	Fall	No Call	-	Fall	65	1.2
3/24/2020	3622-029	Spring	Fall	0.95	Fall	85	3.8
3/24/2020	3622-030	Fall	Fall	1.00	Fall	61	1.1
3/31/2020	3622-045	Spring	Fall	1.00	Fall	74	-
3/31/2020	3622-046	Spring	Fall	1.00	Fall	80	-
3/31/2020	3622-047	Spring	Fall	1.00	Fall	84	-
4/10/2020	3622-031	Spring	Fall	1.00	Fall	87	8.8
4/10/2020	3622-032	Spring	Fall	1.00	Fall	81	6.3
4/10/2020	3622-033	Spring	Fall	0.99	Fall	82	6.5
4/10/2020	3622-034	Spring	Fall	1.00	Fall	79	6.3
4/10/2020	3622-035	Spring	Fall	1.00	Fall	83	6.8
4/10/2020	3622-063	Fall	Fall	0.96	Fall	76	5.2
4/10/2020	3622-064	Fall	Fall	1.00	Fall	49	1.5
4/10/2020	3622-066	Fall	Fall	1.00	Fall	60	-

4/10/2020	3622-067	Fall	Fall	1.00	Fall	49	-
4/11/2020	3622-062	Late fall	Fall	1.00	Fall	34	-
4/12/2020	3622-060	Late fall	Fall	0.95	Fall	32	-
4/12/2020	3622-061	Late fall	Fall	1.00	Fall	35	-
4/15/2020	3646-083	Spring	No Call	-	Fall	83	-
4/15/2020	3646-084	Spring	Fall	1.00	Fall	92	8.4
4/15/2020	3646-085	Spring	No Call	-	Fall	99	10.4
4/15/2020	3646-086	Spring	No Call	-	Fall	88	7.3
4/15/2020	3646-087	Fall	Fall	1.00	Fall	73	4.3
4/15/2020	3646-090	Fall	No Call	-	Fall	64	2.8
4/15/2020	3646-091	Fall	Fall	1.00	Fall	58	2.1
4/15/2020	3646-092	Fall	Fall	0.90	Fall	76	4.8
4/15/2020	3646-093	Fall	No Call	-	Fall	72	3.8
4/17/2020	3646-095	Late fall	Fall	0.98	Fall	34	-
4/19/2020	3646-071	Spring	Fall	1.00	Fall	89	7.9
4/19/2020	3646-076	Spring	Fall	1.00	Fall	83	7
4/19/2020	3646-096	Spring	Fall	1.00	Fall	90	7.4
4/19/2020	3646-099	Spring	Fall	1.00	Fall	86	6.3
4/19/2020	3646-100	Spring	Fall	1.00	Fall	84	-
4/20/2020	3646-041	Spring	Fall	1.00	Fall	90	9.7
4/20/2020	3646-061	Spring	Fall	1.00	Fall	87	7.2
4/20/2020	3646-072	Spring	No Call	-	Fall	84	6.2
4/20/2020	3646-073	Late fall	Fall	1.00	Fall	33	-
4/21/2020	3646-074	Late fall	No Call	-	Fall	33	-
4/21/2020	3646-075	Late fall	Fall	1.00	Fall	34	-
4/22/2020	3646-001	Fall	Fall	1.00	Fall	76	4.9
4/22/2020	3646-031	Fall	Fall	1.00	Fall	80	5.1
4/22/2020	3646-077	Fall	Fall	1.00	Fall	71	3.8
4/22/2020	3646-079	Fall	Fall	1.00	Fall	63	2.2
4/22/2020	3646-080	Fall	No Call	-	Fall	53	1.6
4/28/2020	3646-078	Spring	Fall	0.61	Fall	88	7.3
4/28/2020	3646-089	Spring	Fall	1.00	Fall	98	10.2
5/1/2020	3622-043	Spring	Fall	0.97	Fall	96	9.6
5/2/2020	3646-011	Spring	Fall	0.98	Fall	92	-
5/2/2020	3646-088	Spring	Fall	1.00	Fall	90	6.2
5/2/2020	3646-097	Spring	No Call	-	Fall	92	8.4
5/6/2020	3646-020	Fall	Fall	1.00	Fall	75	-
5/6/2020	3646-030	Fall	Fall	1.00	Fall	67	-
5/6/2020	3646-040	Fall	Fall	1.00	Fall	71	4.2
5/6/2020	3646-070	Fall	Fall	1.00	Fall	73	3.1
5/12/2020	3622-059	Fall	Fall	1.00	Fall	68	-
5/12/2020	3646-050	Fall	Fall	1.00	Fall	75	-
5/12/2020	3646-060	Fall	Fall	1.00	Fall	72	-
5/20/2020	3622-054	Fall	Fall	1.00	Fall	70	3.2
5/20/2020	3622-055	Fall	Fall	1.00	Fall	69	3.9
5/20/2020	3622-056	Fall	Fall	1.00	Fall	73	3.9
5/20/2020	3622-057	Fall	Fall	1.00	Fall	63	2.4
5/28/2020	3622-048	Fall	Fall	1.00	Fall	83	5.1
5/28/2020	3622-049	Fall	Fall	1.00	Fall	71	3.3
5/28/2020	3622-050	Fall	Fall	1.00	Fall	65	2.6
5/28/2020	3622-052	Fall	Fall	1.00	Fall	74	4.4
5/28/2020	3622-053	Fall	Fall	1.00	Fall	72	3.9

Appendix 5: **Fulton's condition factor (K), overall, and by life stage, of fall-run Chinook Salmon during the 2020 Lower American River rotary screw trap survey season.**



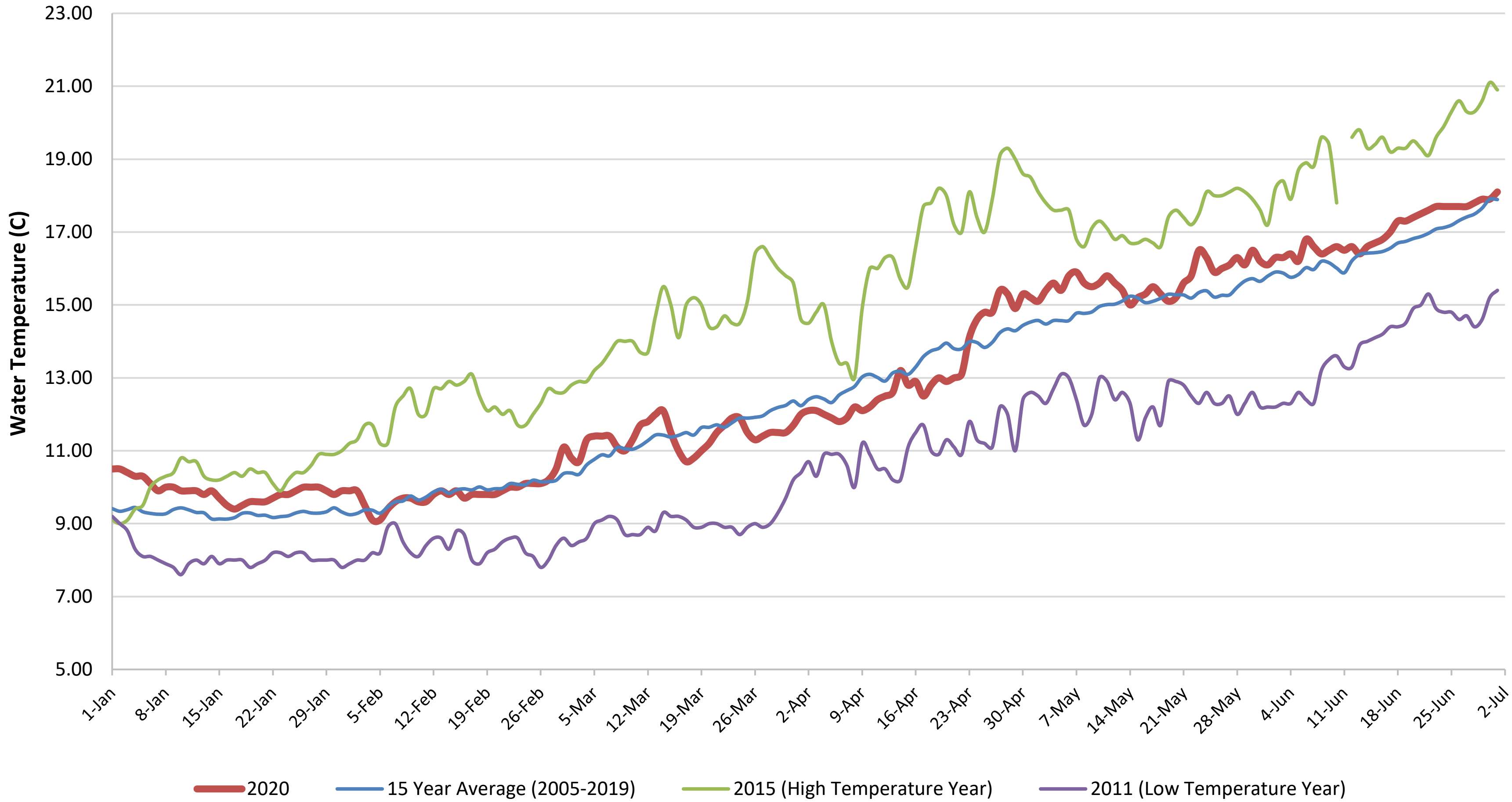


Appendix 6: **Median seasonal discharge (cfs), total catch of fall-run Chinook Salmon, winter-run Chinook Salmon, spring-run Chinook Salmon, and steelhead, and the associated passage estimate with 95% confidence intervals (CI) for fall-run Chinook Salmon from the 2013 – 2020 Lower American River rotary screw trap sampling seasons.**

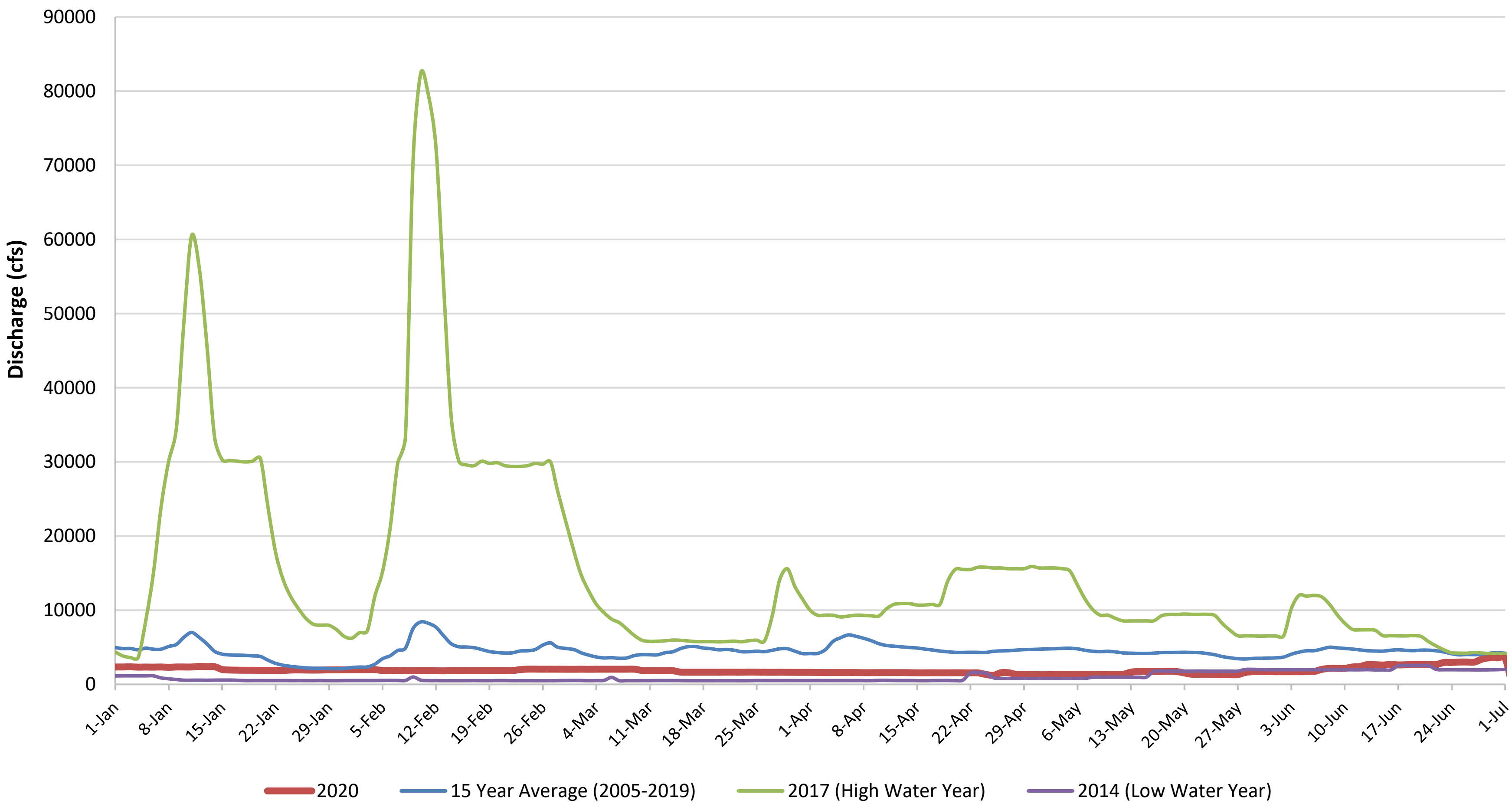
Year	Discharge (cfs)	Total Catch					Passage Estimate	
		Fall-run	Winter-run	Spring-run	Steelhead	Lamprey	Fall-run	95% CI
2013	1,897	262,589	39	14	2,206	1,917	5,692,376	(4,843,254 - 6,032,358)
2014	560	379,542	13	5	592	1,525	1,726,298	(1,681,326 - 2,171,375)
2015	881	283,155	43	19	11	957	1,459,122	(1,417,136 - 1,620,575)
2016	3,776	80,593	1	2	332	1,218	2,394,719	(1,803,134 - 2,907,545)
2017	9,459	9,569	0	1	28	272	788,409	(763,355 - 796,848)
2018	2,857	90,119	11	0	162	1,093	1,287,000	(1,245,000 - 1,426,000)
2019	7,726	15,056	18	9	337	178	348,100	(256,900 - 466,700)
2020	1,853	152,378	203	16	101	1,361	1,883,000	(1,635,000 - 2,215,000)

Note: Discharge is based on the annual median discharge between January 1 and June 30 from USGS at Fair Oaks, Station #11446500.
Lamprey: Includes adult and all juvenile life stages of Petromyzontidae.

Appendix 7: **Annual comparison of daily average water temperatures at Watt Avenue between 2006 and 2020. Daily average water temperature (°C), highest temperature year, lowest temperature year, 15 year average, and the current year (2020).**



Appendix 8: **Annual comparison of daily average discharge at Fair Oaks on the American River between 2006 and 2020. Daily average discharge (cfs), highest water year, lowest water year, 15 year average, and the current year (2020).**



Appendix 9: **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