Juvenile Salmonid Emigration Monitoring in the Lower American River, California

January – June 2021

By

Logan Day

Cory Starr

Prepared for:

U.S. Fish and Wildlife Service, Comprehensive Assessment and Monitoring Program

and California Department of Fish and Wildlife

by the

Pacific States Marine Fisheries Commission

The suggested citation for this report is:

Day, L. and C. Starr. 2021. Juvenile Salmonid Emigration Monitoring in the Lower American River, California January – June 2021. Unpublished report prepared for the U.S. Fish and Wildlife Service and California Department of Fish and Wildlife, Sacramento, California. 51 pp.

Table of Contents

List of Figures

List of Tables

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
St. 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 2021 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: 1) collecting fork length and weight data for juvenile salmonids, 2) collecting fin clips from juvenile salmonids to determine genetic run assignment, and 3) 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 2021 survey season, two 2.4 meter (8 foot) rotary screw traps (RSTs) were operated downstream of the Watt Avenue Bridge. Sampling occurred on 124 of the 144 day season (86%) beginning January 12 and concluding on June 4. Following genetic analysis, it was determined that a total of 35,433 fall-run, 3 winter-run, and 4 spring-run Chinook Salmon as well as 282 juvenile steelhead were captured. The passage of juvenile fall-run Chinook Salmon peaked the week of 26 February, when 25.16% of the total (n = 125,685) was captured. The majority of the juvenile salmon captured were identified as button-up fry followed by parr, silvery 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 4.29% to 28.81%, with an average efficiency of 10.77%. The number of juvenile fall-run Chinook Salmon that were estimated to have emigrated past the Watt Avenue trap site during the 2021 survey season was 499,502 individuals (95 percent confidence intervals = 395,200 to 648,600). Passage estimates for steelhead, winter-run Chinook Salmon, spring-run Chinook Salmon, and non-salmonid fish taxa were not assessed. During the 2021 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 ten appendices to describe different environmental variables and studies related to the trap site or rotary screw trap operations during the 2021 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. Nimbus Fish Hatchery was constructed in 1958 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. 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 continue 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 rearing *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 2021 as part of a larger effort to determine if habitat restoration activities and flow management practices are resulting in a positive impact for 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 2021 survey season was the continuation of a multi-year juvenile Chinook Salmon emigration survey. In 2021, 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 nine years may help to better understand past, current, and future droughts and whether coinciding drought and flow management strategies impact salmonids on the American River.

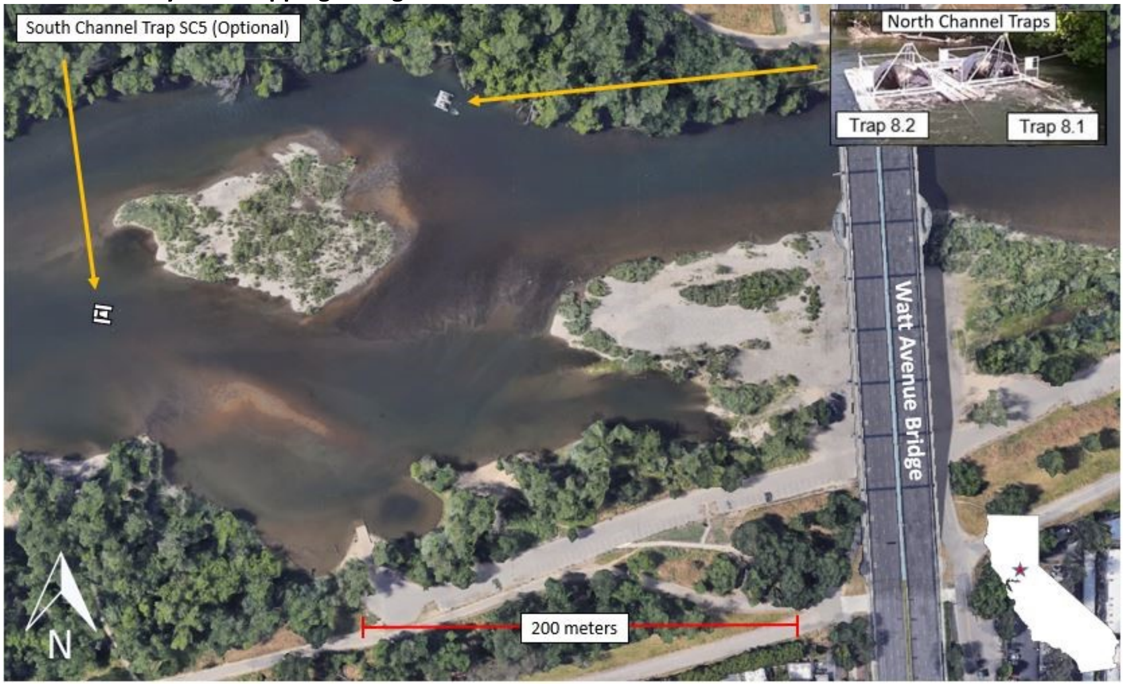
Study Area

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 164,000 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) 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 its normal function without raising the cone 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 effective 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 and required to read PSMFC Safety Manual (PSMFC 2021) and acknowledge the PSMFC Safety Orientation Checklist.

For night operations, crew members were required to attach a strobe light (ACR HemiLight 2) 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.

Public safety measure were also taken. A variety of devices were installed to alert and 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 and yellow buoys were also placed on the chain bridals and anchor lines to help prevent boaters from crossing in front or over the anchor lines. Additionally, weekend sampling was also suspended beginning in May 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, 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 (FP111), 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 processing 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. 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.

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 (dissolved oxygen) and temperature until the fish were ready to be processed.

Chinook Salmon were assigned a run at the time of capture by using a length-at-date (LAD) criteria that was developed for the Sacramento River by Greene (1992). Additionally, Chinook Salmon and steelhead with an intact adipose fin were presumed to be in-river produced and classified as natural origin, whereas when the adipose fin was clipped, they were presumed to be of hatchery origin. 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

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 (3.79 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 and spring-run) as well as natural 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 1 milliliter (ml) stress coat (API Stress Coat Plus) per gallon (gal) 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 5 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.

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 on a weekly basis using disinfected dissection scissors. 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 35 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 passing through the river and collected by the RSTs 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 < 60 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 37 gallon insulated tub and stained using a solution of 0.6 g of BBY for every 20 gallons 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 ≥ 60 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. Tag retention was assessed prior to upstream release. Tagging supplies, mixing procedures and protocols for VIE tags were provided by Northwest Marine Technology, Inc.

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 BBY or VIE 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 model description from a West Inc. document sent to those who implement the model can be found in Appendix 10.

Retention in Analysis

Under ideal circumstances, the rotary screw traps function normally and continuously spin between trap visits to represent an accurate set of data. However, trap stoppages and abnormal trap functionality, can adversely affect catch and misrepresent passage estimates. To account for this, if the trap was stopped upon arrival, determined to have been functioning normally for less than 70% of the sampling period, and the CAMP platform imputes a catch greater than the actual catch during the trap visit, the data is excluded from the analysis and the imputed catch is used to calculate passage estimates. This threshold is calculated by using the trap revolutions per hour after cleaning the trap, the 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.

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 12 and concluded June 4 with 124 days of sampling effort in the 144 day season (86%; Figure 3). Of the 124 days of sampling effort, the traps sampled successfully for approximately 2,852 hours (97.67%), and sampled unsuccessfully for approximately 81 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 1,060 cfs (range: 874 – 3,790 cfs). Sampling of both traps was suspended for a total of 20 days over the course of the season with no outages greater than seven days. Weekend shutdowns began May 8 and continued through the duration of the season accounting for 12 days without sampling. Additionally, trapping was also suspended on three other occasions accounting for the remaining 8 days without sampling: a storm (1), Nimbus Fish Hatchery releases of steelhead smolt (4), and a significant discharge event (3).

Figure 3: Dates sampling occurred during the 2021 Lower American River rotary screw trap survey season.

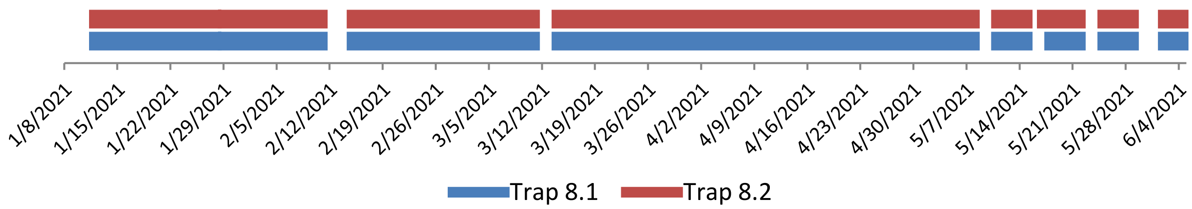
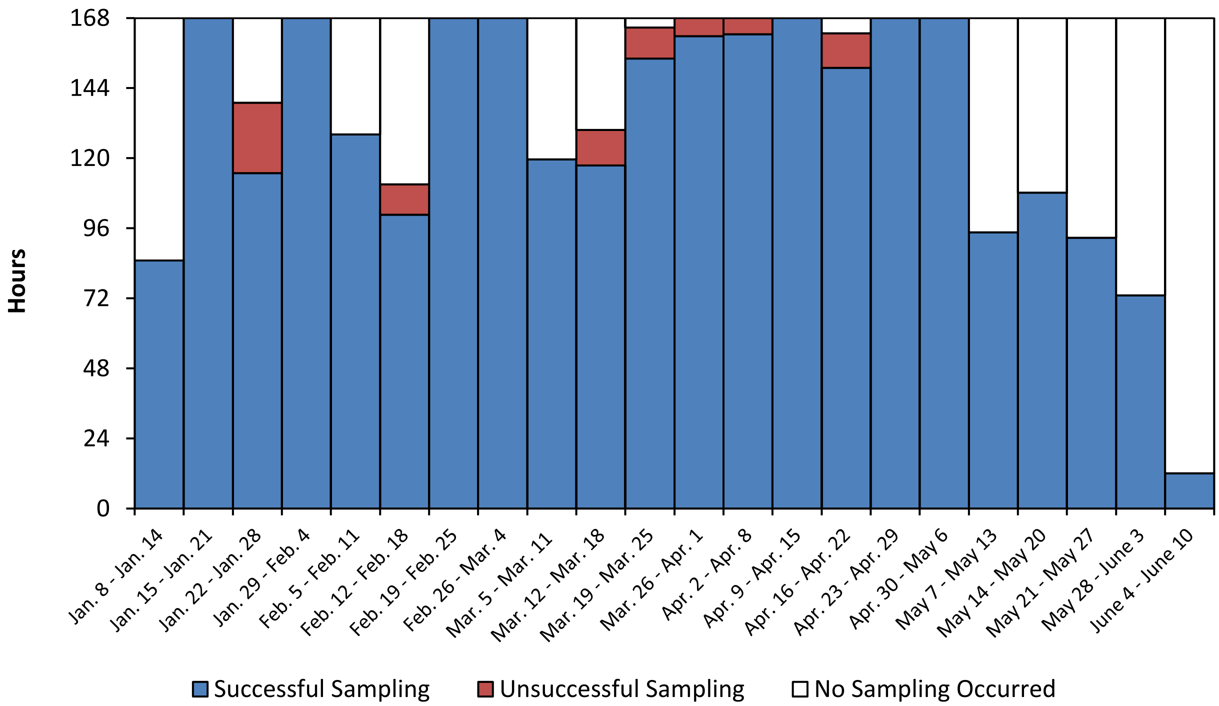


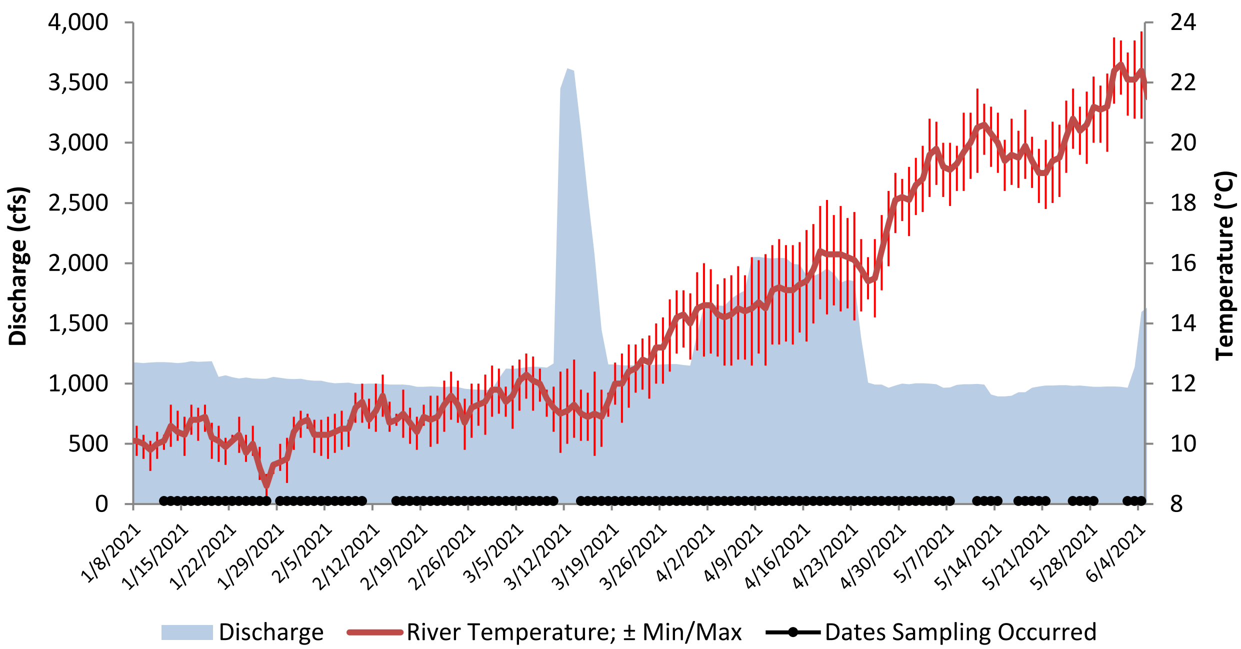
Figure 4: Weighted average hours per Julian week that both traps sampled successfully, sampled unsuccessfully, or did not sample during the 2021 Lower American River rotary screw trap survey season.



Environmental Summary

Appendix 2 provides a summary of the environmental conditions, averaged by Julian week, starting on January 8 and spanning until the last Julian week of the 2021 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 on March 11 and a minimum on May 15 (range: 874 – 3,790 cfs). Additionally, the daily average discharge reached a high on March 12 and a low on May 15 (range: 895 – 3,619 cfs). Instantaneous river temperature, also recorded in 15 minute intervals by USGS at the Watt Avenue gauge station, recorded a maximum on June 4 and minimum on January 27 (range: 8.2 – 23.7 °C). River discharge and water temperature averaged by day throughout the 2021 survey season are shown in Figure 5.

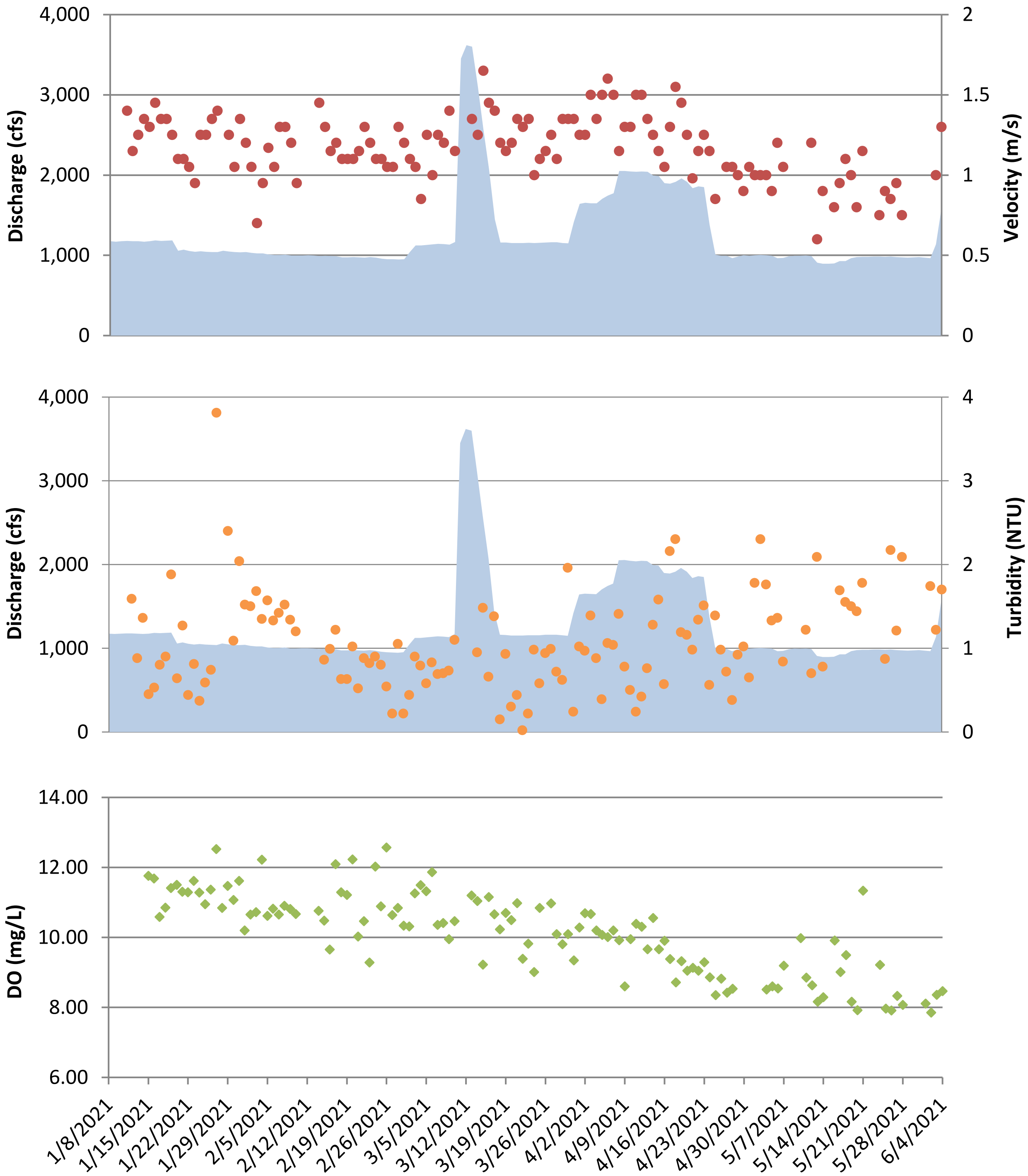
Figure 5: Dates sampling occurred, daily average discharge (cfs) measured at Fair Oaks, and the daily minimum, maximum, and average water temperature (°C) measured at Watt Avenue during the 2021 Lower American River rotary screw trap survey season.



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 June 2 and the maximum on February 26 with a range of 7.85 to 12.57 mg/L. The turbidity, measured in Nephelometric Turbidity Units (NTU), was similar between both traps throughout the season with relatively low NTU. The turbidity for both traps reached a season minimum on March 18 and a maximum on January 27 with a rage of 0.01 – 3.95 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 8.1, slightly higher than Trap 8.2. Water velocity for Trap 8.1 ranged from 0.7 – 1.6 m/s (mean: 1.2 m/s), while Trap 8.2 had a range of 0.5 – 1.7 m/s (mean: 1.1 m/s). Weekly average water velocity, averaged by Julian week, reached a maximum the week of

March 12 and April 2 and a minimum the week of May 14, 21, and 28 with a range of 0.5 – 1.7 m/s. 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), discharge (cfs) measured at Fair Oaks, and dissolved oxygen (DO) (mg/L), averaged between both traps during the 2021 Lower American River rotary screw trap survey season.



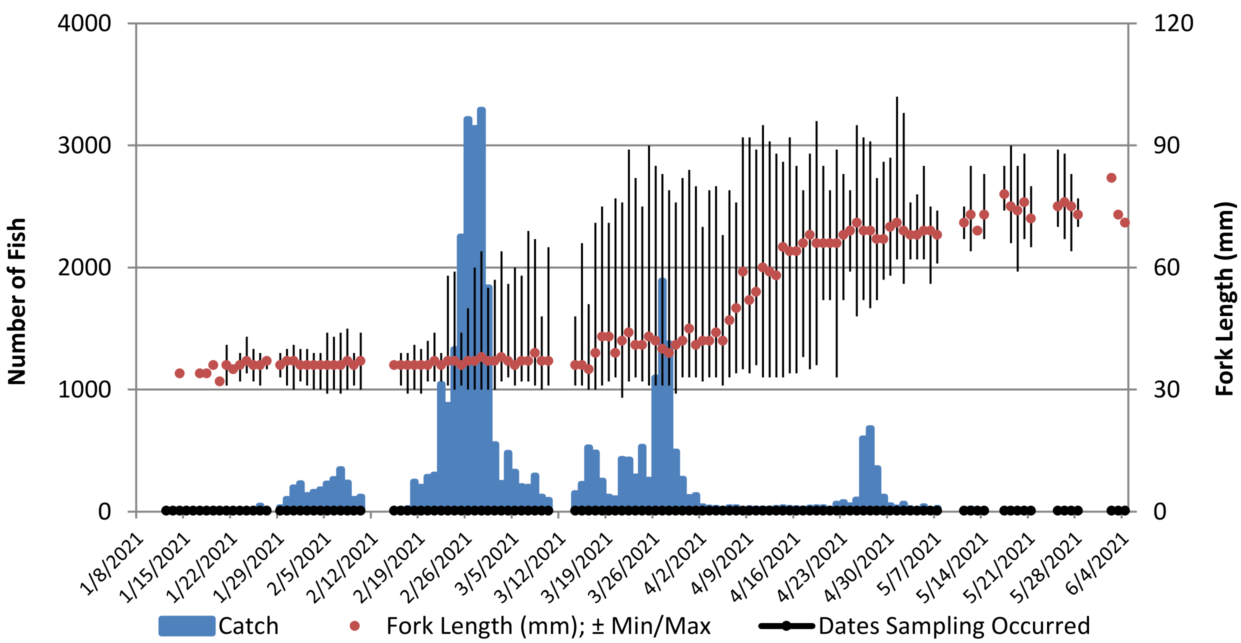
Catch

The two rotary screw traps deployed during the 2021 survey season captured 39,981 fish of natural origin, and 667 hatchery-produced salmonids. The trap furthest from the thalweg, Trap 8.1, captured 62.33% (n = 25,335) of these fish, while Trap 8.2 captured 37.67% (n = 15,313). 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 with 3,695 fish identified 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 2021 survey season with 35,433 (99.98%) 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 peaked on February 28, when 9.29% (n = 3,292) of these fish were captured. The second peak occurred on March 27, when 5.34% (n = 1,892) of the season's total was captured (Figure 7). Of all fall-run captured during the 2021 survey season, 23,935 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 23,935 unmeasured plus count tallies to be classified as fall-run Chinook Salmon.

Figure 7: Daily minimum, maximum, and average fork length (mm) and total catch of natural origin fall-run Chinook Salmon during the 2021 Lower American River rotary screw trap sampling season.



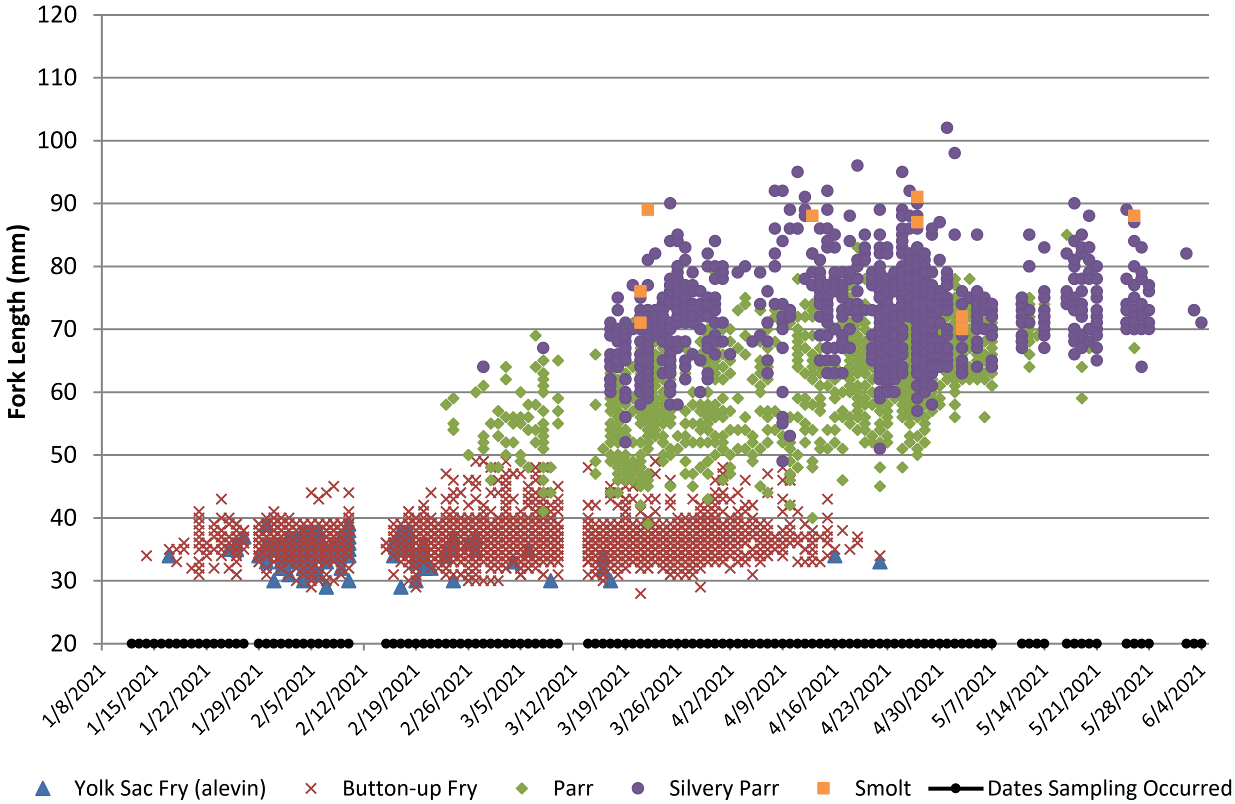
A total of 11,498 natural origin fall-run were measured for fork length. The weekly minimum, maximum, and average fork lengths throughout the 2021 survey season are displayed in Figure 7 and Table 3. The lowest weekly average fork length of 34 mm was seen during the first week of sampling. Fork lengths slowly increased throughout the season with the weekly average reaching a maximum of 75 mm the week of May 14.

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 2021 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	34	34	-	1
1/15 - 1/21	35	31 - 41	2.79	18
1/22 - 1/28	36	31 - 43	1.85	100
1/29 - 2/4	36	30 - 41	1.66	1,050
2/5 - 2/11	36	29 - 45	1.76	1,310
2/12 - 2/18	36	29 - 41	1.69	304
2/19 - 2/25	37	29 - 59	2.14	6,299
2/26 - 3/4	37	30 - 64	3.35	12,759
3/5 - 3/11	37	30 - 69	4.76	1,257
3/12 - 3/18	38	30 - 75	7.61	1,643
3/19 - 3/25	42	28 - 90	12.24	2,171
3/26 - 4/1	41	29 - 85	11.77	5,385
4/2 - 4/8	46	31 - 92	14.32	221
4/9 - 4/15	59	33 - 95	16.39	208
4/16 - 4/22	66	33 - 96	10.09	249
4/23 - 4/29	68	48 - 95	6.86	1,990
4/30 - 5/6	69	56 - 102	5.81	258
5/7 - 5/13	70	61 - 85	4.79	88
5/14 - 5/20	75	59 - 90	6.37	64
5/21 - 5/27	74	64 - 89	5.83	42
5/28 - 6/3	74	70 - 82	3.77	12
6/4 - 6/10	71	71	-	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 77.05% (n = 8,859) of the assessed catch. The remaining life stage catch composition consisted of yolk sac fry (1.77%, n = 204), parr (11.64%, n = 1,338), silvery parr (9.46%, n = 1,088) and smolts (0.08%, n = 9). As shown in Figure 8, fall-run Chinook Salmon identified as yolk sac fry were captured between January 17 and April 22. Button-up fry were identified were captured between January 14 and April 22. The parr life stage was identified between February 23 and May 28, and the silvery parr life stage was captured starting February 28 through June 4. Lastly, the 9 fall-run identified as smolts were captured between March 21 and May 26.

Figure 8: Daily fork length distribution by life stage of natural origin fall-run Chinook Salmon measured during the 2021 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 – 39 mm for yolk-sac fry, 28 – 49 mm for button-up fry, 39 – 85 mm for parr, 49 – 102 mm for silvery parr, and 70 – 91 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 35 mm for yolk-sac fry, 36 mm for button-up fry, 62 mm for parr, 72 mm for silvery parr, and 81 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 2021 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	-	-	-	34	34	1	-	-	-	-	-	-	-	-	-
1/15 - 1/21	34	34	1	36	31 - 41	17	-	-	-	-	-	-	-	-	-
1/22 - 1/28	36	35 - 37	7	36	31 - 43	93	-	-	-	-	-	-	-	-	-
1/29 - 2/4	35	30 - 39	78	36	30 - 41	909	-	-	-	-	-	-	-	-	-
2/5 - 2/11	35	29 - 39	67	36	29 - 45	917	-	-	-	-	-	-	-	-	-
2/12 - 2/18	35	29 - 38	17	36	30 - 41	232	-	-	-	-	-	-	-	-	-
2/19 - 2/25	34	30 - 37	23	37	29 - 47	1,343	57	54 - 59	4	-	-	-	-	-	-
2/26 - 3/4	35	33 - 37	4	37	30 - 49	1,328	54	46 - 64	23	64	64	2	-	-	-
3/5 - 3/11	33	30 - 35	2	37	31 - 48	924	55	41 - 69	43	67	67	1	-	-	-
3/12 - 3/18	32	30 - 34	3	36	30 - 48	796	55	44 - 66	79	66	60 - 75	24	-	-	-
3/19 - 3/25	-	-	-	36	28 - 49	985	56	39 - 72	170	68	52 - 90	147	79	71 - 89	3
3/26 - 4/1	-	-	-	36	29 - 48	1,110	60	43 - 79	112	73	58 - 85	101	-	-	-
4/2 - 4/8	-	-	-	37	31 - 47	145	60	44 - 75	55	75	63 - 92	18	-	-	-
4/9 - 4/15	-	-	-	37	33 - 48	53	61	40 - 78	89	75	49 - 95	62	88	88	1
4/16 - 4/22	34	33 - 34	2	36	34 - 38	6	62	45 - 83	125	72	51 - 96	114	-	-	-
4/23 - 4/29	-	-	-	-	-	-	65	48 - 81	427	72	57 - 95	399	89	87 - 91	2
4/30 - 5/6	-	-	-	-	-	-	67	56 - 78	176	73	63 - 102	76	71	70 - 72	2
5/7 - 5/13	-	-	-	-	-	-	67	61 - 75	26	72	64 - 85	39	-	-	-
5/14 - 5/20	-	-	-	-	-	-	69	59 - 85	7	75	66 - 90	56	-	-	-
5/21 - 5/27	-	-	-	-	-	-	67	67	1	74	64 - 89	40	88	88	1
5/28 - 6/3	-	-	-	-	-	-	71	71	1	74	70 - 82	8	-	-	-
6/4 - 6/10	-	-	-	-	-	-	-	-	-	71	71	1	-	-	-
Entire Season	**35**	**29 - 39**	**204**	**36**	**28 - 49**	**8,859**	**62**	**39 - 85**	**1,338**	**72**	**49 - 102**	**1,088**	**81**	**70 - 91**	**9**

Fulton's Condition Factor

Fulton's condition factor (K) for unmarked fall-run Chinook Salmon captured in 2021 is shown in Appendix 5. The overall trend line exhibited a positive slope of 0.0010, indicating a slightly increasing trend in condition throughout the survey season. The trend line slopes were positive for button-up fry (0.0020), parr (0.0002), silvery parr (0.0006), and smolt (0.0024) life stages. Yolk-sac fry captured in 2021 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

Seven mark-recapture trap efficiency trials were conducted throughout the 2021 survey season. One trial was excluded in analysis and not utilized by the CAMP platform to determine passage estimates (Table 5). The seven trials used a total of 5,589 fall-run Chinook Salmon. Of these fish, 2,153 were natural origin salmon collected from the RSTs and marked with either BBY (n = 1,641) or VIE (n = 512) depending on fork length. The remaining 3,436 were collected from Nimbus Fish Hatchery and marked with either BBY or VIE. The average trap recapture efficiency across the six trials included for analysis was 10.77% with a total of 543 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 2021 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)
2/17/21	Hatchery	BBY	No	2/17/21	18:00	1,000	39	987	10.6%	38
2/27/21	Natural	BBY	Yes	2/27/21	18:00	977	36	1,003	28.8%	37
3/24/21	Natural	BBY	Yes	3/24/21	19:35	1,190	37	638	16.8%	37
4/14/21	Hatchery	BBY	Yes	4/14/21	19:30	1,940	58	1,189	5.8%	59
4/28/21	Natural	VIE	Yes	4/28/21	19:45	968	69	512	4.5%	65
5/10/21	Hatchery	VIE	Yes	5/10/21	18:30	1.010	76	560	4.3%	73
5/24/21	Hatchery	VIE	Yes	5/24/21	18:30	1,000	89	700	4.4%	88

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 = Unmarked (adipose intact) fish caught in the Lower American River RSTs.
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, 499,502 natural origin fall-run Chinook Salmon were estimated to have emigrated past the Watt Ave rotary screw trap location during the 2021 survey season (Figure 9). The 95 percent confidence interval for this estimate was from 395,200 to 648,600 individuals. The highest weekly passage estimate occurred the week of February 26 with approximately 125,685 fall-run being estimated to have emigrated past the rotary screw traps (Table 6).

Figure 9: Daily passage estimate of natural origin fall-run Chinook Salmon and daily average discharge at Fair Oaks during the 2021 lower American River rotary screw trap survey season.

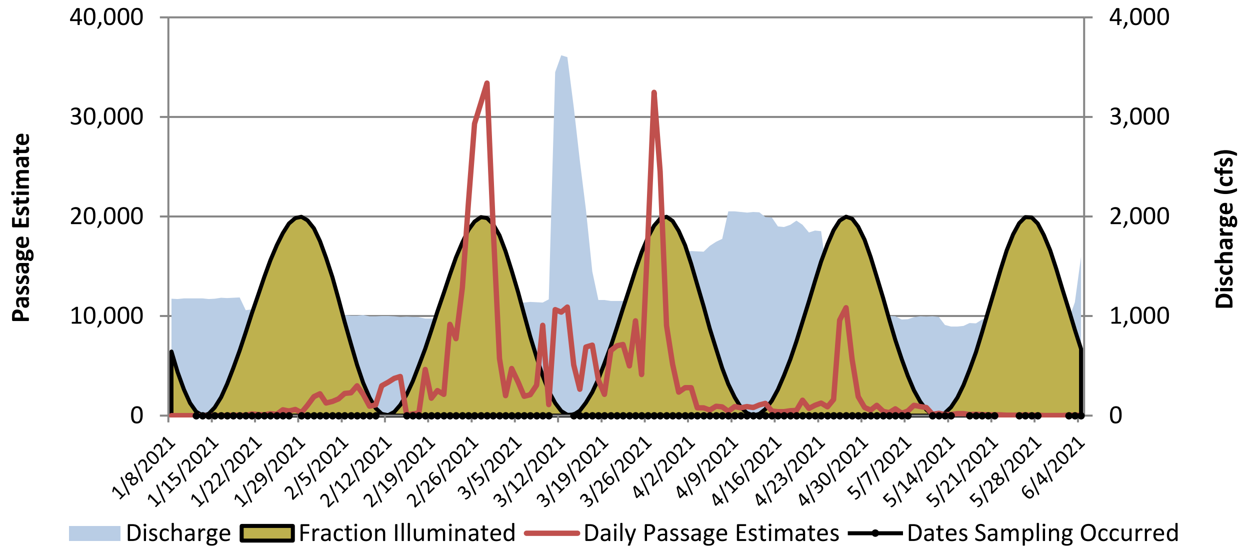


Table 6: Weekly passage estimate of natural origin fall-run Chinook Salmon with 95% confidence intervals (CI) and weekly average discharge at Fair Oaks during the 2021 Lower American River rotary screw trap survey season.

Julian Week	Discharge (cfs)	Passage Estimate	95% CI
1/8 - 1/14	1,175	11	(9 - 14)
1/15 - 1/21	1,148	255	(158 - 417)
1/22 - 1/28	1,047	2,176	(1,332 - 3,189)
1/29 - 2/4	1,035	9,812	(6,886 - 13,621)
2/5 - 2/11	1,003	14,702	(10,601 - 20,459)
2/12 - 2/18	991	16,115	(11,343 - 22,829)
2/19 - 2/25	972	57,531	(45,009 - 74,997)
2/26 - 3/4	1,014	125,685	(98,912 - 161,978)
3/5 - 3/11	1,471	31,314	(23,644 - 40,829)
3/12 - 3/18	2,502	46,559	(35,163 - 62,922)
3/19 - 3/25	1,155	41,495	(31,165 - 61,944)
3/26 - 4/1	1,264	94,425	(72,473 - 138,736)
4/2 - 4/8	1746	7,133	(4,758 - 11,687)
4/9 - 4/15	2,029	6,174	(3,881 - 12,413)
4/16 - 4/22	1,897	5,159	(4,000 - 7,361)
4/23 - 4/29	1,168	31,695	(23,947 - 47,712)
4/30 - 5/6	994	4,049	(3,146 - 5,867)
5/7 - 5/13	978	3,666	(2,691 - 5,416)
5/14 - 5/20	927	929	(646 - 1,638)
5/21 - 5/27	983	426	(346 - 649)
5/28 - 6/3	997	150	(100 - 499)
6/4 - 6/10	1,626	41	(35 - 47)
Total	**1,278**	**499,502**	**(395,200 - 648,600)**

Genetic Analysis

During the 2021 survey season, a total of 197 genetic samples taken from juvenile Chinook Salmon were analyzed using SNP genetic markers to determine run assignments. The SNP panel's probabilities of the 197 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 197 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 76 fall-run throughout the 2021 sampling season. Analyses using SNP genetic markers from these samples indicated that 100% (n = 76) 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 35,069 LAD fall-run that were not genetically sampled.

A total of 25 Chinook Salmon classified as late fall-run using LAD criteria were also captured in 2021. Genetic samples were taken from 8 of these salmon. Analyses using SNP genetic markers from those samples indicated that 100% (n = 8) were fall-run (Table 7). Because the LAD criteria appeared to incorrectly assign this run, all 17 of the LAD late fall-run that were not genetically sampled were given a final run assignment of fall-run.

Genetic samples were taken from all 3 salmon classified as winter-run. Analyses using SNP genetic markers from those samples indicated that 100% (n = 3) were winter-run (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.

A total of 267 natural origin Chinook Salmon captured in 2021 were classified as spring-run using the LAD criteria. Genetic clips were collected and run assignments were identified for 110 samples. The analyses indicated 96.36% (n = 106) of these individuals were fall-run and 3.64% (n = 4) were spring-run (Table 7). Because the LAD criteria appeared to incorrectly assign this run for the majority of these individuals, the remaining 157 of the LAD spring-run that were not genetically sampled were given a final run assignment of fall-run.

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
Fall	76	0	0	0
Late Fall	8	0	0	0
Spring	106	0	4	0
Winter	0	0	0	3

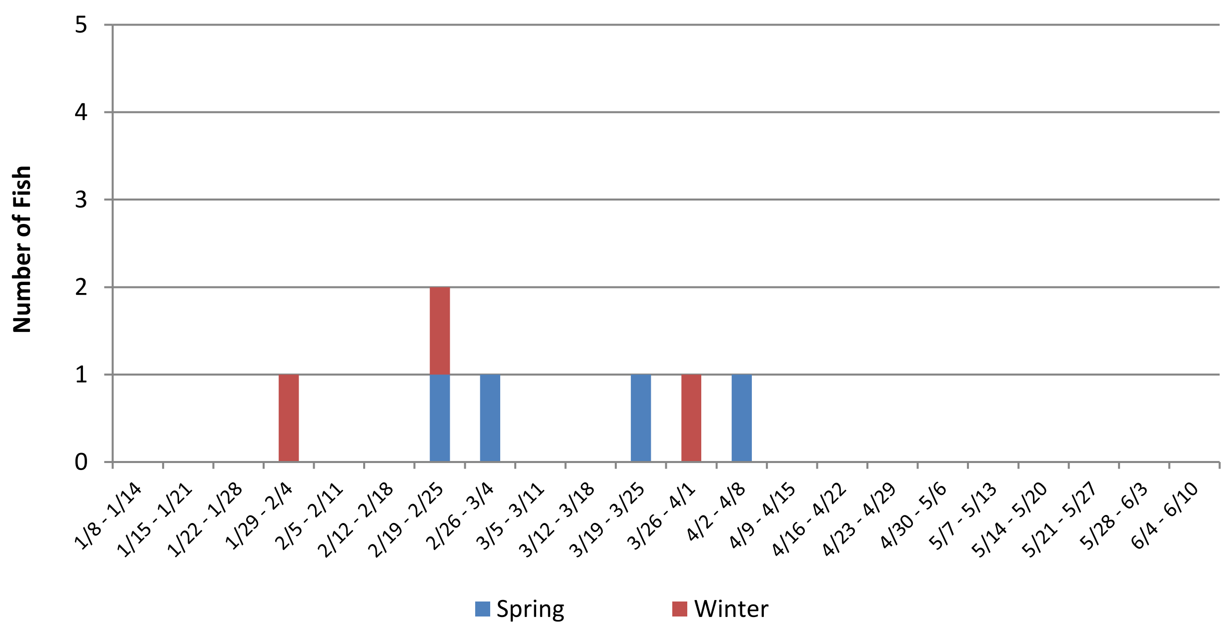
Note: Genetic salmon run assignment was based on a >50 percent genetic probability threshold. The table only includes Chinook Salmon presumed to be of natural origin (i.e. presence of an adipose fin).

Spring-run and Winter-run Chinook Salmon

Genetic analyses suggest that 4 natural origin spring-run Chinook Salmon were captured during the 2021 survey season. The first week that a spring-run was captured was on February 19. The final spring-run was captured the week of April 2 (Figure 10). Two of these fish were identified as parr and two were identified as silvery parr. The average fork length was 70 mm with a range of 63 – 80 mm (Appendix 4).

The genetic analyses results also suggest that three natural origin winter-run Chinook Salmon were captured during the 2021 survey season. The first was captured the week of January 29. The last was captured the week of March 26 (Figure 10). Of these three fish, two were identified as silvery parr, and one identified as a smolt. Fork lengths ranged from 77 – 102 mm over the course of the season with an average fork length of 91 mm (Appendix 4).

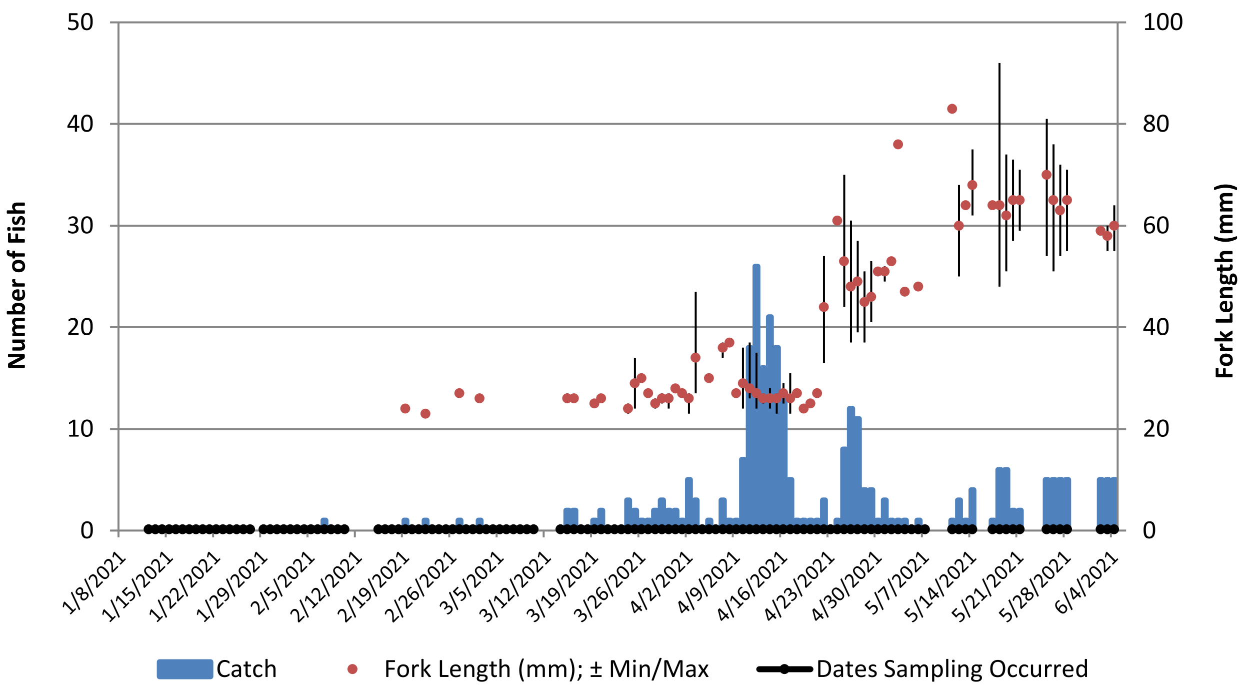
Figure 10: Weekly catch distribution of natural origin spring-run and winter-run Chinook Salmon captured during the 2021 Lower American River rotary screw trap survey season.



Steelhead

During the 2021 survey season, a total of 283 natural origin steelhead were captured. Catch peaked on April 12, comprising 9.19% (n = 26) of the total steelhead captured (Figure 11). All captured steelhead were assessed for a life stage. The life stage composition consisted of 5 yolk sac fry, 171 button-up fry, 92 parr, 3 silvery parr, 1 adult, and 11 not assigned a life stage. Fork lengths ranged from 23 – 30 mm for yolk sac fry, 23 – 46 mm for button-up fry, 37 – 92 mm for parr, and 65 – 76 mm for silvery parr.

Figure 11: Daily minimum, maximum, and average fork length (mm) and catch distribution of natural origin steelhead captured during the 2021 Lower American River rotary screw trap survey season.

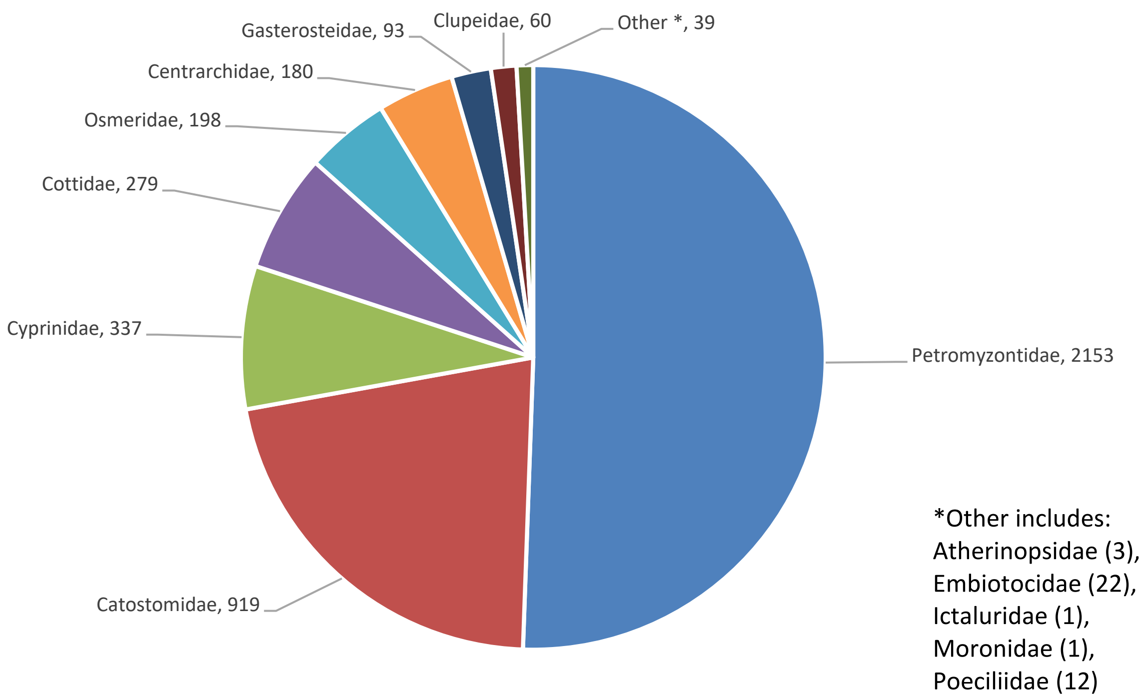


In addition to the natural origin steelhead catch, 667 adipose clipped, hatchery steelhead were also captured. These fish were caught between February 15 and April 25, with an average fork length of 204 mm and range of 142 – 711 mm. Daily catch peaked on February 16 (n = 182) and weekly catch remained consistent until March 9.

Non-salmonid Species

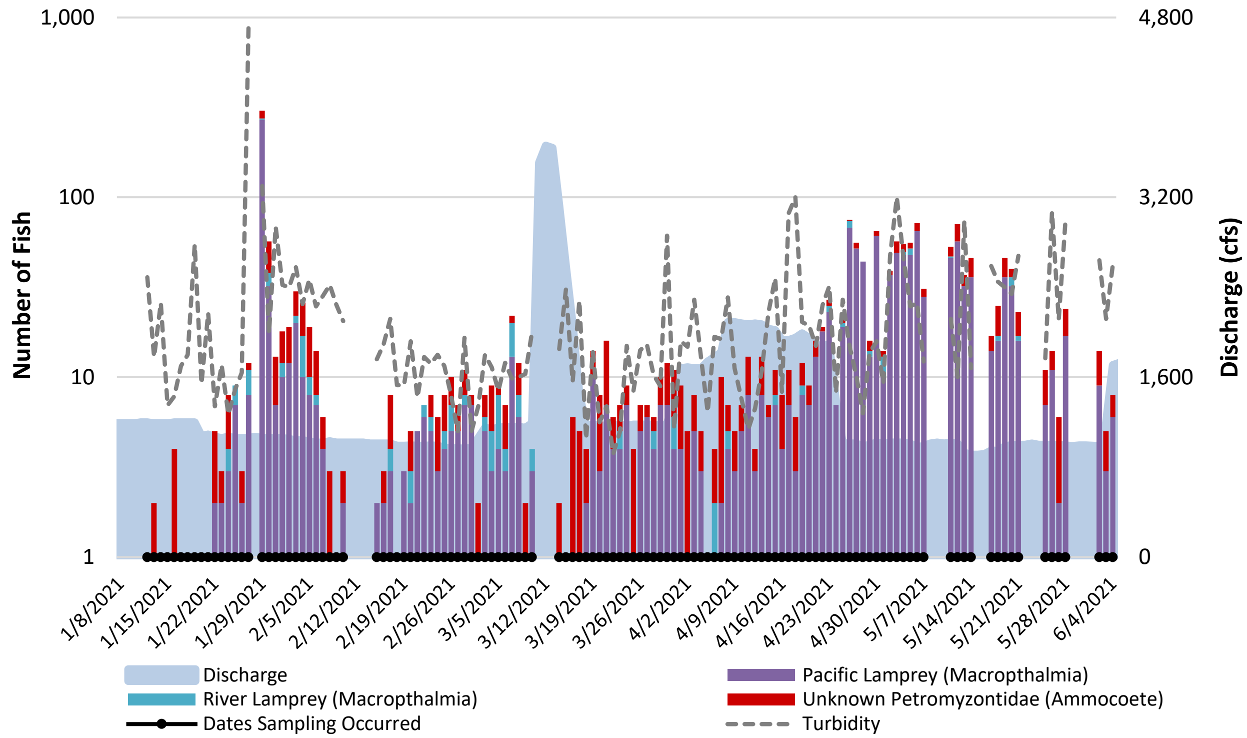
A total of 4,258 non-salmonid fish were also captured during the 2021 survey season. The majority (n = 3,695, 86.78%) of these fish belonged to 23 identified species in the following families: Atherinopsidae (silversides), Catostomidae (suckers), Centrarchidae (sunfish), Clupeidae (shad), Cottidae (sculpins), Cyprinidae (minnows), Embiotocidae (Tule Perch), Gasterosteidae (sticklebacks), Ictaluridae (catfish), Moronidae (Striped Bass), Osmeridae (smelts), Petromyzontidae (northern lampreys), and Poeciliidae (mosquitofish) (Figure 12). The remaining 13.22% (n = 563) were not able to be identified to species level, but belonged to the following families: Centrarchidae (n = 105), Cottidae (n = 10), Cyprinidae (n = 4), and Petromyzontidae (n = 444). The majority of non-salmonid fish captured were native to the Central Valley watershed (n = 3,789, 88.99%) with the remaining individuals (n = 469, 11.01%) being non-native species. Appendix 3 contains a complete list of species captured in the 2021 survey season.

Figure 12: Non-salmonid catch totals for each family of species collected during the 2021 Lower American River rotary screw trap survey season.



Of the 4,258 non-salmonid fish captured, 2,153 (50.56%) were identified as Petromyzontidae spp. (northern lampreys); 1,613 (37.88%) of which were identified as Pacific Lamprey, consisting of 3 adults and 1,610 juveniles. 96 (2.25%) of these fish were identified as juvenile River Lamprey. The remaining 444 (10.43%) lamprey captured were identified as juvenile ammocoetes of Petromyzontidae and were not identified to a species level. Catch of Pacific Lamprey macropthalmia peaked on January 29 when 270 (16.74%) of the season's Pacific Lamprey total was captured. Catch of ammocoetes peaked on January 29 when 28 (6.31%) of the season's total was captured. Lastly, catch of River Lamprey peaked on February 4 when seven (7.29%) were captured (Figure 13).

Figure 13: Daily lamprey catch and daily discharge at Fair Oaks during the 2021 Lower American River rotary screw trap survey season.



Discussion

Project Scope

The continued operation of the Lower American River rotary screw traps during the 2021 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 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 (2013-2020).

Passage Estimate and Catch

A total of 35,433 natural origin fall-run Chinook Salmon were captured during the 2021 survey season. This marks the third lowest catch of natural origin fall-run and a substantial decrease from the 2020 survey season when 152,378 of these salmon were captured. The natural origin fall-run passage estimate of 499,502 [95% CI: 395,200 – 648,600] also represents a significant decrease from the 2020 estimate of 1,883,000 [95% CI: 1,635,000 – 2,215,000] (Appendix 6). These changes represent a 77% decrease in actual catch and a 73% decrease in the passage estimate from 2020 to 2021. Additionally, the ratio between interval width and the passage estimate increased from 31% in 2020 to 51% in 2021 posing relatively lower precision in the estimate.

Steelhead, winter-run, and spring-run Chinook Salmon were also captured and processed to accurately enumerate and collect biological data during the 2021 survey season. The total catch of natural origin steelhead increased from 101 to 283 (180%) from 2020 to 2021. Contrarily, the total catch of winter-run decreased from 203 to three (-99%) and spring-run decreased from 16 to four (-75%) from 2020 to 2021. A summary table for the total annual catch of natural origin salmonids captured between 2013 and 2021 can be found in Appendix 6.

Several factors must be considered when interpreting the passage estimates of fall-run Chinook Salmon and the quantity of steelhead, winter-run, and spring-run Chinook Salmon captured. Trap operation is consistently one of the most important factors when developing meaningful annual comparisons between raw catch or passage estimates. Notably, when the traps are not sampling, data is not being recorded. Consequently, the CAMP platform imputes an estimate for fall-run catch to estimate daily passage for gaps in sampling that are seven or less days in duration. Any gaps in sampling greater than seven days in duration do not have passage estimates assigned, biasing the passage estimate low. Additionally, raw catch diminishes with abnormal trap functioning, and trap visits with significant abnormal functioning were removed from data analysis with imputed catch utilized for passage estimates. In 2020, successful sampling was conducted for 120 days (76%) of the 158 day season containing one eight day gap in sampling where production estimates could not be generated. In contrast, successful sampling was conducted for 116 days (81%) of the 144 day season in 2021 with no gaps in sampling of more than seven days. Therefore, the passage estimates generated for the 2021 season represented the entirety of the 144 day sampling season, contrary to the 2020 season, with imputed catch utilized for 28 days (19%).

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 2021 survey season, a total of five fall-run were captured, accounting for 0.01% of the total season catch and 0.01% (n = 65) of the total passage estimate. Furthermore, during the last seven days of sampling, a total of 47 fall-run were captured accounting for 0.13% of the total season catch. The last seven days of the survey season also comprised 0.03% (n = 162) of the total passage estimate, which includes four days of imputed catch when trapping did not occur. Because of this, it is likely that the 2021 survey season encompassed the vast majority of the fall-run Chinook Salmon emigration, similar to the 2020 survey season.

The accuracy of the fall-run passage estimates also comes from the quantity, quality, and recapture efficiencies obtained during trap efficiency trials. Of the seven efficiency trials conducted during the 2021 season, only one efficiency trial was excluded from data analysis. Of the six efficiency trials that were included, capture efficiencies during the first two trials in February and March averaged 22.8% (range: 16.8 – 28.8%), while the last four trials in April and May averaged 4.8% (range: 4.3 – 5.8%). This decrease in capture efficiency could be explained by trap avoidance of larger fish (Johnson et al. 2007) or the possibility of an insufficient sample size. A difference in average sample size and fork length was observed between the February – March trials (n = 821, 37 mm) and April – May trials (n = 740, 69 mm) and could have resulted in increased trap avoidance and/or resulted in more volatile efficiencies by using smaller release groups.

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 as age 0 fry from the American River (PSMFC 2013 – 2020, 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 2021 with 91% (n = 32,297) of the season's fall-run catch being captured before the week of April 2. During this period, fork lengths averaged 38 mm (Std Dev = 7.44) with 93% of the subsampled fish being identified as alevin or button up fry. After April 2, 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 9). This emigration trend was observed over the course of the season with 84% (n = 29,872) of the fall-run being captured while fraction of the moon illuminated was ≥ 50%, and 59% (n = 20,737) being captured while fraction of the moon illuminated 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). Because discharge, a primary environmental cue for emigration, remained relatively constant in 2021 (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 the significance of this trend.

California Central Valley steelhead were also assessed for life stage, fork length, and weighed if ≥ 40 mm. Between 2013 and 2020, 3,769 steelhead have been captured (annual mean: 471) with 2,206 of these fish being captured in 2013. During the 2021 season, 283 steelhead were captured consisting of 282 age 0 juveniles, and one spawned-out carcass (kelt). 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 – 2020). The 2021 American River steelhead redd surveys conducted by Cramer Fish Sciences (CFS, 2021) helped explain the low catch of juvenile steelhead as only 56 redds were identified in 2021. 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 2021 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 2021 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 2022. In order to obtain the highest accuracy for passage estimates and maintain the highest level of safety, adjustments are recommended for future seasons. Firstly, timely coordination with the Bureau of Reclamation during large discharge events will allow ample time to effectively and safely schedule personnel to maintain continuous sampling and accurately enumerate raw catch to estimate fall-run passage. Secondly, should COVID-19 protocols allow, multiple daily trap visits and nightly trap operations should be considered during large discharge and debris events to maintain continuous and consistent sampling. 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 2021 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.

Acknowledgements

The funding for this project was provided by the USFWS's Comprehensive Assessment and Monitoring Program (CAMP). The Lower American River RST Project would like to thank Matt Dekar, Paul Cadrett, and staff at USFWS CAMP for their technical support. Thank you also to the Pacific States Marine Fisheries Commission staff, Stan Allen, for management support and Amy Roberts and Kathy Ameral for administrative support and purchasing. In addition, recognition goes to the American River RST Project crew members Jordan Butler, Austin Galinat, Hunter Morris, Elizabeth Ruszczyk, Allison Scott, and Garrett Smith for their hard work and assistance in collecting the data for this report. Special thanks goes to the staff at the CDFW's Tissue Archive Lab especially Rob Titus, Lea Koerber and the scientific aides for their collaborative effort and guidance in processing the fin-clip samples for further genetic analyses. The project thanks the staff at the Abernathy Fish Technology Center, especially Christian Smith and Jennifer Von Bargen, for the genetic analyses of the fin-clips. Additional gratitude goes to the Nimbus Fish Hatchery staff, and manager Gary Novak, for setting aside approximately 3,500 fall-run Chinook Salmon for use in the efficiency trials. Additionally, the project thanks Amanda Cranford and Shivonne Nesbit from the National Marine Fisheries Service for the ongoing assistance with the Federal take permit.

References

Clemento A.J., E.D. Crandall, J.C. Garza, E.C. Anderson. 2014. Evaluation of a SNP baseline for genetic stock identification of Chinook Salmon (Oncorhynchus tshawytscha) in the California Current large marine ecosystem. Fishery Bulletin 112:112-130.

Cramer Fish Sciences (CFS). 2021. Lower American River Monitoring: 2021 Steelhead (Oncorhyncus *mykiss*) Spawning and Stranding Surveys. Prepared for: U.S. Bureau of Reclamation. July 2021. 48p + appendix

Fisher, F.W. 1994. Past and present status of Central Valley Chinook Salmon. Conservation Biology 8:870-873.

Greene, S. 1992. Estimated winter-run Chinook Salmon salvage at the State Water Project and Central Valley Project Delta Pumping Facilities. 8 May 1992. California Department of Water Resources. Memorandum to Randall Brown, California Department of Water Resources. 3 pp. plus 15 pp. tables.

Harvey, B.N., P. David, J.A. Banks and M.A. Banks. 2014. Quantifying the Uncertainty of a Juvenile Chinook Salmon Race Identification Method for a Mixed-Race Stock. North American Journal of Fisheries Management 34:6, 1177-1186.

James, L.A. 1997. Channel incision on the lower American River, California, from stream flow gage records. Water Resources Research 33:485-490.

Johnson, D.H., B.M. Shrier, J.S. O'Neal, J.A. Knutzen, X. Augerot, T.A. O'Neal, T.N. Pearsons. 2007. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Grimes, T., A. Galinat. 2021. Lower American River fall-run Chinook Salmon escapement survey October 2020 – January 2021. California Department of Fish and Wildlife. 25 pp.

Kjelson, M.A., and P.F. Raquel. 1981. Influences of Freshwater Inflow on Chinook Salmon In the Sacramento – San Joaquin Estuary. California Fish and Game.

Lindley et al 2006. Historical Population Structure of Central Valley Steelhead and its Alteration by Dams. San Francisco Estuary and Watershed Science. Vol 4, Iss.1 [February 2006], Art. 3

Maslin, P.E., W.R. McKinnev, and T.L. Moore. 1998. Intermittent streams as rearing habitat for Sacramento River Chinook Salmon. Unpublished report prepared for the U. S. Fish and Wildlife Service under the authority of the Federal Grant and Cooperative Agreement Act of 1977 and the Central Valley Improvement Act.

McCullough, D. A. 1999. A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, With Special Reference to Chinook Salmon. Report No. EPA 910-R-99-010. Seattle, WA: EPA, Region 10.

McDonald, T., and M. Banach. 2010. Feasibility of unified analysis methods for rotary screw trap data in the California Central Valley. U.S. Fish and Wildlife Service's Comprehensive Assessment and Monitoring Program, Cooperative Agreement No. 81420-8-J163. 18 pp.

Merz, J.E., and D.C. Vanicek. 1996. Comparative feeding habits of juvenile Chinook Salmon, steelhead, and Sacramento squawfish in the Lower American River, California. California Fish and Game 82(4):149-159.

National Marine Fisheries Service (NMFS). 2019. Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project. NMFS, Southwest Region. 900 pp.

National Marine Fisheries Service (NMFS). 2014. Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead. California Central Valley Area Office. July 2014.

National Marine Fisheries Service (NMFS). 2016. 2016 5-Year Review: Summary and Evaluation of California Coastal Chinook Salmon and Northern California Steelhead. NMFS, West Coast Region. April 2016. 54 pp.

Pacific States Marine Fisheries Commission et al. (PSMFC). 2013-2020. Juvenile salmonid emigration monitoring in the Lower American River, California. Unpublished annual report prepared for the U.S. Fish and Wildlife Service and California Department of Fish and Wildlife, Sacramento, California.

Pacific States Marine Fisheries Commission (PSMFC). 2021. Field Safety Manual. Pacific States Marine Fisheries Commission. 55 pp.

Phillis, C.C., A.M. Sturrock, R.C. Johnson, P.K. Weber. 2017. Endangered winter-run Chinook salmon rely on diverse rearing habitats in a highly altered landscape. Biological Conservation. 358-362.

Reid, S. 2012. Lampreys of Central California field ID key (a living document). U.S. Fish & Wildlife Pacific Lamprey Conservation Initiative.

Rich, A.A. 1987. Report on studies conducted by Sacramento County to determine the temperatures which optimized growth and survival in juvenile Chinook Salmon (*Oncorhynchus tshawytscha*). Prepared for the County of Sacramento.

Roper B.B., and D.L. Scarnecchia. 1999. Emigration of age-0 chinook salmon (Oncorhynchus tshawytscha) smolts from the upper South Umpqua River basin, Oregon, U.S.A. The Canadian Journal of Fisheries and Aquatic Sciences. 56:939-946.

Schroeder R.K., K.R. Kenaston, and L.K. McLaughlin. 2007. Spring Chinook Salmon in the Willamette and Sandy Rivers. October 2005- September 2007. Prepared for: U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers. 1-62.

Silva, J., and K. Bouton. 2015. Juvenile Salmonid Emigration Monitoring in the Lower American River, California January – May 2015. Unpublished report prepared for the U.S. Fish and Wildlife Service and California Department of Fish and Wildlife, Sacramento, California.

Snider, B., and R. G. Titus. 2001. Timing, composition, and abundance of juvenile anadromous salmonid emigration in the Sacramento River near Knights Landing October 1997 – September 1998. Conducted by the Department of Fish and Game. Funded partially by the California Department of Water Resources through the Interagency Ecological Program. Stream Evaluation Program Technical Report No. 00-5. July 2001.

U.S. Army Corps of Engineers (USACE). 1991. American River watershed investigation, California Lower American River area. United States Department of Interior, Fish and Wildlife Service. Appendix S Part 2, Vol 7:1-460.

U.S. Geological Survey (USGS). 2016. National Water Information System data available on the World Wide Web (USGS Water Data for the Nation). Accessed August 1, 2020, at URL http://waterdata.usgs.gov/ca/nwis/uv.

United States Department of the Interior (USDOI). 2008. Lower American River salmonid spawning gravel augmentation and side-channel habitat establishment program. Bureau of Reclamation, Mid-Pacific Region Rpt. 27 pp.

West Inc. 2018. Enhanced Rotary-Screw-Trap Efficiency Models. Not published. Contact: Trent McDonald tmcdonald@west-inc.com

Williams, J.G. 2006. . A Perspective on Chinook and Steelhead in the Central Valley of California. San Francisco Estuary & Watershed Science. 4(3 Suppl): 1 – 398.

Yoshiyama, R.M., E.R. Gerstung, F.W. Fisher, and P.B. Moyle. 2001. Historical and present distribution of Chinook Salmon in the Central Valley drainage of California. Contributions to the Biology of Central Valley Salmonids, Vol 1. Fish Bulletin 179:71-176.

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 2021 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	10.1	9.1	11.3	1,175	1,140	1,200	--	--	--	1.28	0.70	1.79	1.3	1.1	1.5
1/15 - 1/21	10.5	9.3	11.3	1,148	994	1,230	11.30	10.58	11.76	0.92	0.35	1.98	1.3	1.0	1.5
1/22 - 1/28	9.6	8.2	10.9	1,047	994	1,090	11.41	10.84	12.52	1.13	0.26	3.95	1.2	0.9	1.5
1/29 - 2/4	10.2	8.7	11.1	1,035	985	1,080	11.13	10.20	12.22	1.66	0.87	2.52	1.1	0.7	1.4
2/5 - 2/11	10.7	9.5	12.0	1,003	959	1,040	10.73	10.61	10.90	1.40	1.02	1.80	1.2	0.9	1.3
2/12 - 2/18	10.9	9.8	12.3	991	933	1,030	10.85	9.65	12.09	0.92	0.57	1.43	1.2	1.0	1.6
2/19 - 2/25	11.1	9.8	12.4	972	916	1,010	10.87	9.28	12.23	0.80	0.47	1.14	1.2	1.0	1.3
2/26 - 3/4	11.5	10.2	12.6	1,014	916	1,160	11.06	10.31	12.57	0.59	0.14	1.24	1.1	0.8	1.3
3/5 - 3/11	11.7	9.7	13.0	1,471	1,100	3,740	10.73	9.95	11.86	0.78	0.42	1.39	1.2	0.9	1.4
3/12 - 3/18	11.1	9.6	12.8	2,502	1,120	3,700	10.58	9.22	11.20	0.92	0.01	1.76	1.4	1.1	1.7
3/19 - 3/25	12.5	10.7	14.0	1,155	1,090	1,210	10.24	9.01	11.14	0.50	0.02	1.36	1.2	0.9	1.6
3/26 - 4/1	14.1	12.0	16.0	1,264	1,110	1,680	10.10	9.34	10.97	0.93	0.24	2.94	1.3	1.1	1.4
4/2 - 4/8	14.4	12.6	16.2	1,746	1,590	2,120	10.25	9.92	10.69	1.02	0.13	1.91	1.4	1.0	1.6
4/9 - 4/15	15.0	12.6	16.8	2,029	1,860	2,120	9.87	8.60	10.55	0.80	0.16	1.88	1.3	1.1	1.6
4/16 - 4/22	16.1	13.4	18.1	1,897	1,760	2,100	9.21	8.71	9.90	1.39	0.56	2.58	1.2	0.7	1.7
4/23 - 4/29	16.4	14.1	19.0	1,168	942	1,940	8.71	8.35	9.29	0.92	0.10	1.57	1.1	0.7	1.4
4/30 - 5/6	18.9	16.9	20.8	994	924	1,030	8.55	8.51	8.60	1.46	0.63	2.31	1.0	0.9	1.2
5/7 - 5/13	19.9	17.9	21.8	978	890	1,040	8.96	8.16	9.98	1.22	0.63	2.44	1.0	0.5	1.3
5/14 - 5/20	19.6	18.0	21.1	927	857	1,060	8.70	7.92	9.91	1.36	0.75	2.01	0.9	0.8	1.3
5/21 - 5/27	20.0	17.8	21.8	983	950	1,010	8.95	7.91	11.33	1.51	0.71	2.52	0.9	0.7	1.2
5/28 - 6/3	21.8	19.7	23.5	997	916	1,180	8.10	7.85	8.36	1.68	1.08	2.20	0.9	0.7	1.0
6/4 - 6/10	20.8	17.6	23.7	1,626	1,110	1,780	8.46	8.46	8.46	1.70	1.57	1.82	1.3	1.2	1.4

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 2021 season using rotary screw traps on the Lower American River.

Common Name	Family Name	Species Name	Total
Chinook salmon	Salmonidae	Oncorhynchus tshawytscha	35,440
Steelhead / rainbow trout	Salmonidae	Oncorhynchus mykiss	283
American shad	Clupeidae	Alosa sapidissima	39
Bluegill	Centrarchidae	Lepomis macrochirus	42
Golden shiner	Cyprinidae	Notemigonus crysoleucas	10
Hardhead	Cyprinidae	Mylopharodon conocephalus	198
Hitch	Cyprinidae	Lavinia exilicauda	4
Inland silverside	Atherinopsidae	Menidia beryllina	3
Largemouth bass	Centrarchidae	Micropterus salmoides	3
Pacific lamprey	Petromyzontidae	Lampetra entosphenus	1,613
Prickly sculpin	Cottidae	Cottus asper	27
Redear sunfish	Centrarchidae	Lepomis microlophus	28
Riffle sculpin	Cottidae	Cottus gulosus	242
River lamprey	Petromyzontidae	Lampetra ayresii	96
Sacramento pikeminnow	Cyprinidae	Ptychocheilus grandis	121
Sacramento sucker	Catostomidae	Catostomus occidentalis	919
Spotted bass	Centrarchidae	Micropterus punctulatus	1
Striped bass	Moronidae	Morone saxatilis	1
Threadfin shad	Clupeidae	Dorosoma petenense	21
Threespine stickleback	Gasterosteidae	Gasterosteus aculeatus	93
Tule perch	Embiotocidae	Hysterocarpus traskii	22
Unknown bass (Micropterus)	Centrarchidae	Micropterus sp.	104
Unknown Centrarchid	Centrarchidae		1
Unknown lamprey (Entosphenus or Lampetra)	Petromyzontidae		444
Unknown minnow	Cyprinidae		4
Unknown sculpin (Cottus)	Cottidae	Cottus sp.	10
Wakasagi / Japanese smelt	Osmeridae	Hypomesus nipponensis	198
Warmouth	Centrarchidae	Lepomis gulosus	1
Western mosquitofish	Poeciliidae	Gambusia affinis	12
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 2021 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)
1/24/2021	3732-001	Fall	Fall	1.00	Fall	43	1.1
1/31/2021	3732-003	Fall	Fall	1.00	Fall	38	-
1/31/2021	3732-005	Fall	Fall	1.00	Fall	39	-
2/4/2021	3732-007	Winter	Winter	1.00	Winter	93	11.8
2/6/2021	3732-008	Fall	Fall	1.00	Fall	43	0.7
2/9/2021	3732-009	Fall	Fall	1.00	Fall	34	-
2/9/2021	3732-010	Fall	Fall	1.00	Fall	36	-
2/9/2021	3732-011	Fall	Fall	1.00	Fall	37	-
2/9/2021	3732-012	Fall	Fall	1.00	Fall	37	-
2/9/2021	3732-013	Fall	Fall	1.00	Fall	39	-
2/16/2021	3732-014	Fall	Fall	1.00	Fall	39	-
2/16/2021	3732-015	Fall	Fall	1.00	Fall	36	-
2/16/2021	3732-016	Fall	Fall	1.00	Fall	36	-
2/16/2021	3732-018	Fall	Fall	1.00	Fall	36	-
2/19/2021	3732-019	Winter	Winter	1.00	Winter	77	4.5
2/21/2021	3732-020	Spring	Spring	0.87	Spring	63	3.1
2/23/2021	3732-021	Spring	Fall	1.00	Fall	58	1.5
2/24/2021	3732-022	Spring	Fall	1.00	Fall	59	1.8
2/25/2021	3732-028	Fall	Fall	1.00	Fall	36	-
2/25/2021	3732-029	Fall	Fall	1.00	Fall	36	-
2/25/2021	3732-030	Fall	Fall	1.00	Fall	37	-
2/25/2021	3732-031	Fall	Fall	1.00	Fall	37	-
2/25/2021	3732-025	Fall	Fall	1.00	Fall	36	-
2/28/2021	3732-033	Spring	Fall	1.00	Fall	61	2.3
2/28/2021	3732-034	Spring	Fall	1.00	Fall	64	2.8
3/3/2021	3732-035	Fall	Fall	1.00	Fall	36	-
3/3/2021	3732-036	Fall	Fall	1.00	Fall	38	-
3/3/2021	3732-037	Fall	Fall	1.00	Fall	36	-

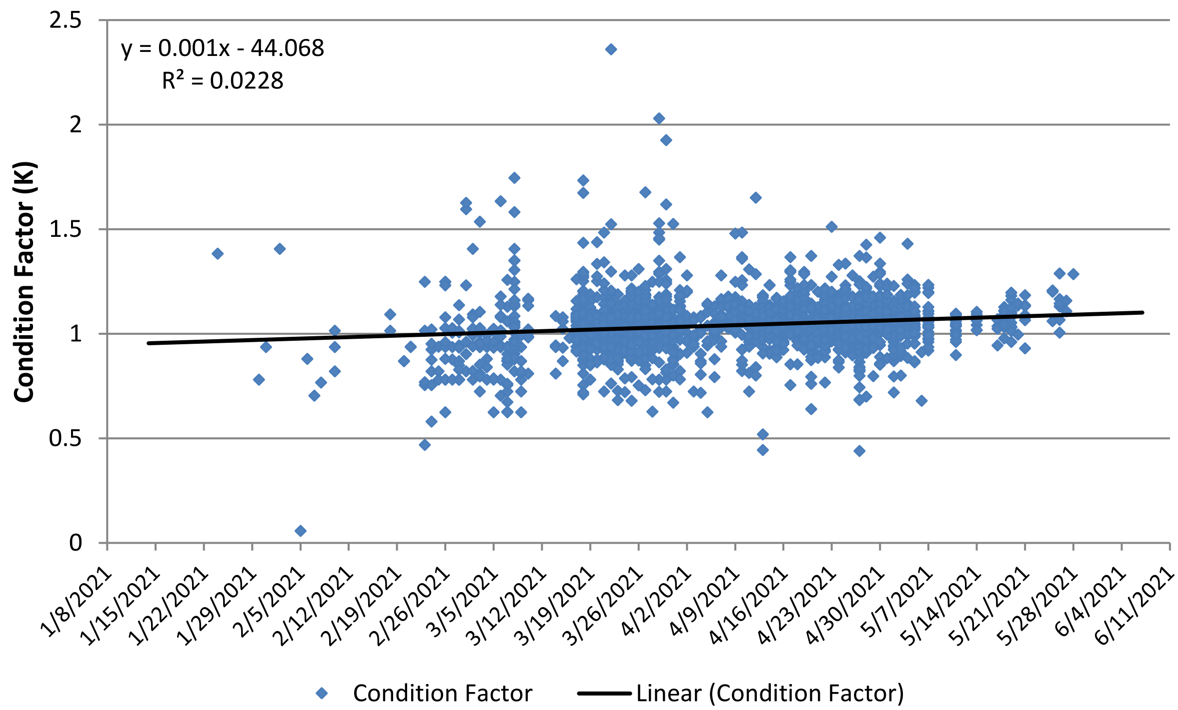
3/3/2021	3732-038	Fall	Fall	1.00	Fall	34	-
3/3/2021	3732-039	Fall	Fall	1.00	Fall	37	-
3/3/2021	3732-040	Fall	Fall	0.99	Fall	37	-
3/3/2021	3732-041	Fall	Fall	1.00	Fall	35	-
3/3/2021	3732-042	Fall	Fall	1.00	Fall	39	-
3/3/2021	3732-043	Fall	Fall	1.00	Fall	38	-
3/3/2021	3732-045	Fall	Fall	1.00	Fall	36	-
3/3/2021	3732-046	Spring	Spring	1.00	Spring	64	2.7
3/3/2021	3732-047	Spring	Fall	1.00	Fall	64	2.5
3/3/2021	3732-048	Spring	Fall	1.00	Fall	62	1.9
3/7/2021	3732-044	Spring	Fall	1.00	Fall	64	3.3
3/7/2021	3732-049	Spring	Fall	1.00	Fall	69	2.9
3/8/2021	3732-050	Fall	Fall	1.00	Fall	60	2.1
3/8/2021	3732-051	Fall	Fall	1.00	Fall	36	-
3/8/2021	3732-052	Fall	Fall	1.00	Fall	40	0.6
3/8/2021	3732-053	Fall	Fall	1.00	Fall	37	-
3/8/2021	3732-054	Fall	Fall	1.00	Fall	39	-
3/8/2021	3732-055	Spring	Fall	1.00	Fall	63	2.2
3/8/2021	3732-056	Spring	Fall	1.00	Fall	65	2.6
3/8/2021	3732-057	Spring	Fall	1.00	Fall	65	2.6
3/8/2021	3732-058	Spring	Fall	1.00	Fall	63	2.3
3/8/2021	3732-059	Spring	Fall	1.00	Fall	63	2.6
3/8/2021	3732-060	Spring	Fall	1.00	Fall	67	3.1
3/10/2021	3732-061	Spring	Fall	1.00	Fall	65	2.7
3/17/2021	3732-064	Spring	Fall	1.00	Fall	69	3.2
3/17/2021	3732-062	Spring	Fall	1.00	Fall	69	3.5
3/17/2021	3732-063	Spring	Fall	1.00	Fall	70	3.7
3/17/2021	3732-065	Spring	Fall	1.00	Fall	71	-
3/18/2021	3732-066	Spring	Fall	1.00	Fall	75	4
3/18/2021	3732-067	Spring	Fall	1.00	Fall	70	3.2
3/18/2021	3732-068	Spring	Fall	1.00	Fall	70	3.5
3/18/2021	3732-069	Fall	Fall	1.00	Fall	59	2.3
3/18/2021	3732-070	Fall	Fall	1.00	Fall	36	-
3/18/2021	3732-071	Fall	Fall	1.00	Fall	36	-
3/18/2021	3732-072	Fall	Fall	1.00	Fall	35	-
3/18/2021	3732-073	Fall	Fall	1.00	Fall	37	-
3/18/2021	3732-074	Spring	Fall	1.00	Fall	69	3.6
3/18/2021	3732-075	Spring	Fall	1.00	Fall	68	3.3
3/18/2021	3732-076	Spring	Fall	1.00	Fall	73	3.5
3/19/2021	3732-081	Spring	Fall	1.00	Fall	70	3.4
3/19/2021	3732-082	Spring	Fall	1.00	Fall	68	3.3
3/19/2021	3732-083	Spring	Fall	1.00	Fall	71	3.6
3/19/2021	3732-077	Spring	Fall	1.00	Fall	69	3.7

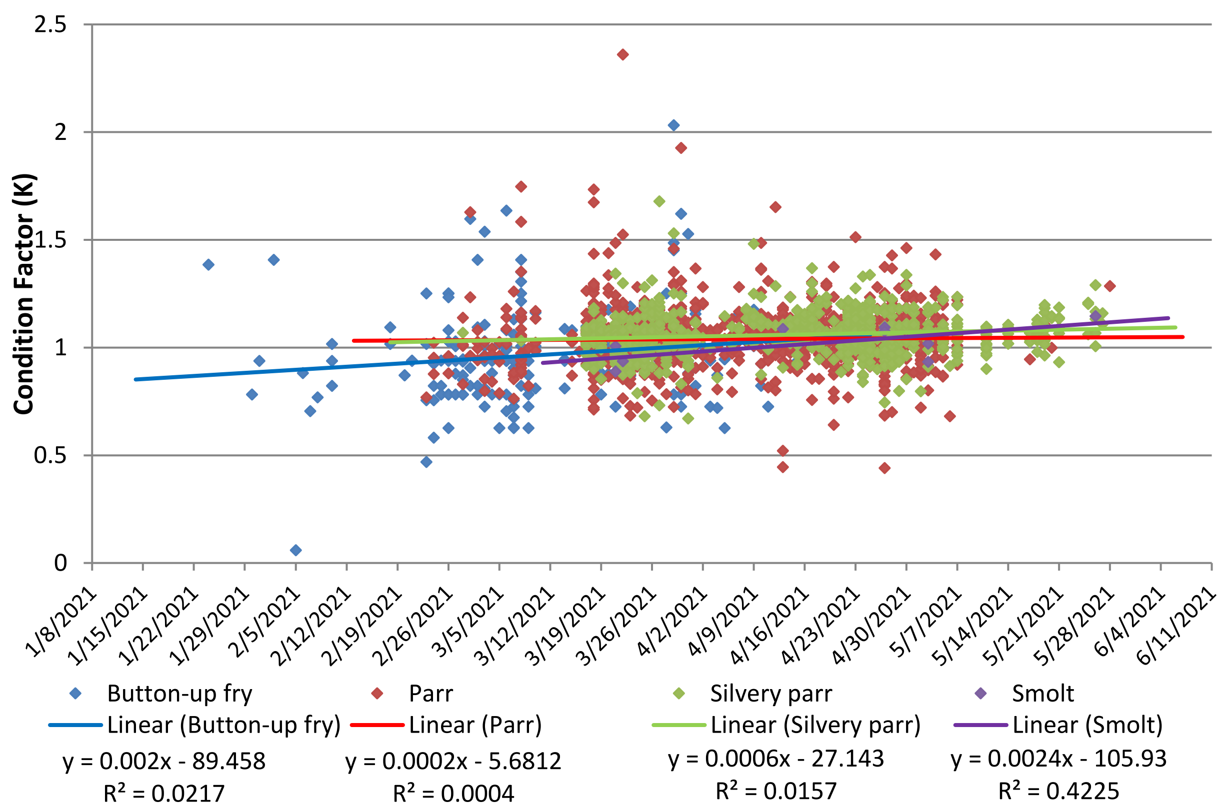
3/19/2021	3732-078	Spring	Fall	1.00	Fall	69	3.6
3/19/2021	3732-079	Spring	Fall	1.00	Fall	67	3
3/19/2021	3732-080	Spring	Fall	1.00	Fall	70	3.7
3/20/2021	3732-084	Spring	Fall	1.00	Fall	70	3.7
3/20/2021	3732-085	Spring	Fall	1.00	Fall	71	3.9
3/20/2021	3732-086	Spring	Fall	1.00	Fall	77	4.8
3/21/2021	3732-087	Spring	Fall	1.00	Fall	76	4.1
3/21/2021	3732-088	Spring	Fall	1.00	Fall	72	3.6
3/21/2021	3732-089	Spring	Fall	1.00	Fall	76	4.4
3/21/2021	3732-090	Spring	Fall	1.00	Fall	71	3.6
3/21/2021	3732-091	Spring	Fall	1.00	Fall	76	3.9
3/21/2021	3732-092	Spring	Fall	1.00	Fall	72	3.8
3/21/2021	3732-093	Spring	Fall	1.00	Fall	73	3.9
3/21/2021	3732-094	Spring	Fall	1.00	Fall	75	4.1
3/21/2021	3732-095	Spring	Fall	1.00	Fall	68	3.2
3/21/2021	3732-096	Spring	Fall	1.00	Fall	68	3.3
3/21/2021	3732-097	Spring	Fall	1.00	Fall	72	3.7
3/21/2021	3732-098	Spring	Fall	1.00	Fall	76	4.7
3/21/2021	3732-099	Spring	Spring	0.99	Spring	74	4.2
3/21/2021	3732-100	Spring	Fall	1.00	Fall	70	3.6
3/23/2021	3733-011	Spring	Fall	1.00	Fall	71	3.2
3/23/2021	3733-012	Spring	Fall	1.00	Fall	72	3.1
3/23/2021	3733-013	Spring	Fall	1.00	Fall	72	3.8
3/23/2021	3733-014	Spring	Fall	1.00	Fall	72	3.8
3/23/2021	3733-001	Spring	Fall	1.00	Fall	72	4.2
3/23/2021	3733-002	Spring	Fall	1.00	Fall	69	3.3
3/23/2021	3733-003	Spring	Fall	1.00	Fall	82	5
3/23/2021	3733-004	Spring	Fall	1.00	Fall	73	3.5
3/23/2021	3733-005	Spring	Fall	1.00	Fall	71	3.9
3/23/2021	3733-006	Spring	Fall	1.00	Fall	72	4.1
3/23/2021	3733-008	Spring	Fall	1.00	Fall	71	3.3
3/23/2021	3733-009	Spring	Fall	1.00	Fall	71	3.9
3/23/2021	3733-010	Spring	Fall	1.00	Fall	69	2.9
3/24/2021	3733-022	Spring	Fall	1.00	Fall	72	3.9
3/24/2021	3733-015	Spring	Fall	1.00	Fall	74	4.1
3/24/2021	3733-016	Spring	Fall	1.00	Fall	74	4.2
3/24/2021	3733-017	Spring	Fall	1.00	Fall	75	4.8
3/24/2021	3733-018	Spring	Fall	1.00	Fall	75	4
3/24/2021	3733-019	Spring	Fall	1.00	Fall	70	2.7
3/24/2021	3733-020	Spring	Fall	1.00	Fall	71	3.8
3/24/2021	3733-021	Spring	Fall	1.00	Fall	70	3.3
3/26/2021	3733-007	Winter	Winter	1.00	Winter	102	11.4
3/26/2021	3733-023	Fall	Fall	1.00	Fall	38	-

3/26/2021	3733-024	Fall	Fall	1.00	Fall	35	-
3/26/2021	3733-026	Fall	Fall	1.00	Fall	35	-
3/26/2021	3733-027	Fall	Fall	1.00	Fall	36	-
3/28/2021	3733-028	Spring	Fall	1.00	Fall	79	4.9
3/28/2021	3733-029	Spring	Fall	1.00	Fall	77	4.2
3/28/2021	3733-030	Spring	Fall	1.00	Fall	74	4.2
3/29/2021	3733-031	Spring	Fall	1.00	Fall	76	4.8
3/29/2021	3733-032	Spring	Fall	1.00	Fall	73	4.3
3/29/2021	3733-033	Spring	Fall	1.00	Fall	76	4.9
3/30/2021	3733-034	Spring	Fall	1.00	Fall	75	-
4/1/2021	3733-037	Spring	Fall	1.00	Fall	79	5
4/1/2021	3733-035	Spring	Fall	1.00	Fall	78	5.3
4/1/2021	3733-038	Fall	Fall	1.00	Fall	66	3.4
4/1/2021	3733-039	Fall	Fall	1.00	Fall	37	-
4/1/2021	3733-040	Fall	Fall	1.00	Fall	53	1.8
4/1/2021	3733-041	Fall	Fall	1.00	Fall	51	1.2
4/1/2021	3733-042	Fall	Fall	1.00	Fall	48	1
4/5/2021	3733-045	Spring	Spring	0.81	Spring	80	5.2
4/5/2021	3733-044	Late fall	Fall	1.00	Fall	31	-
4/6/2021	3733-047	Spring	Fall	1.00	Fall	79	5
4/6/2021	3733-046	Late fall	Fall	1.00	Fall	33	-
4/7/2021	3733-048	Spring	Fall	1.00	Fall	76	-
4/8/2021	3733-051	Spring	Fall	1.00	Fall	92	8.1
4/8/2021	3733-052	Spring	Fall	1.00	Fall	80	5.8
4/8/2021	3733-053	Spring	Fall	1.00	Fall	82	5.7
4/8/2021	3733-049	Spring	Fall	1.00	Fall	86	7.5
4/8/2021	3733-050	Spring	Fall	1.00	Fall	80	6
4/10/2021	3733-054	Fall	Fall	1.00	Fall	42	1.1
4/10/2021	3733-055	Fall	Fall	1.00	Fall	36	-
4/10/2021	3733-056	Fall	Fall	1.00	Fall	71	4.5
4/10/2021	3733-057	Fall	Fall	1.00	Fall	72	4.1
4/11/2021	3733-058	Spring	Fall	1.00	Fall	78	5.1
4/11/2021	3733-059	Spring	Fall	1.00	Fall	86	6.3
4/11/2021	3733-060	Spring	Fall	1.00	Fall	95	9.5
4/11/2021	3733-062	Late fall	Fall	1.00	Fall	33	-
4/12/2021	3733-063	Spring	Fall	1.00	Fall	88	7
4/12/2021	3733-064	Spring	Fall	1.00	Fall	91	8.3
4/12/2021	3733-065	Spring	Fall	1.00	Fall	89	-
4/13/2021	3733-066	Late fall	Fall	1.00	Fall	34	-
4/13/2021	3733-067	Late fall	Fall	1.00	Fall	33	-
4/13/2021	3733-068	Fall	Fall	1.00	Fall	36	-
4/14/2021	3733-076	Spring	Fall	1.00	Fall	86	7
4/14/2021	3733-069	Fall	Fall	1.00	Fall	57	2

4/14/2021	3733-070	Fall	Fall	1.00	Fall	64	2.6
4/14/2021	3733-071	Fall	Fall	1.00	Fall	67	3.2
4/14/2021	3733-072	Fall	Fall	1.00	Fall	65	2.9
4/14/2021	3733-073	Fall	Fall	1.00	Fall	61	2.8
4/14/2021	3733-074	Spring	Fall	1.00	Fall	81	5.7
4/14/2021	3733-075	Late fall	Fall	1.00	Fall	33	-
4/16/2021	3733-077	Late fall	Fall	1.00	Fall	34	-
4/18/2021	3733-078	Spring	Fall	1.00	Fall	84	5.6
4/18/2021	3733-080	Spring	Fall	1.00	Fall	88	8.3
4/19/2021	3733-081	Spring	Fall	1.00	Fall	83	6.7
4/19/2021	3733-082	Spring	Fall	1.00	Fall	96	9.2
4/19/2021	3733-083	Late fall	Fall	1.00	Fall	36	-
4/20/2021	3733-084	Spring	Fall	1.00	Fall	85	6.9
4/20/2021	3733-085	Spring	Fall	1.00	Fall	83	6
4/22/2021	3733-086	Fall	Fall	1.00	Fall	62	2.9
4/22/2021	3733-087	Fall	Fall	1.00	Fall	69	3.1
4/22/2021	3733-089	Fall	Fall	1.00	Fall	63	-
4/22/2021	3733-090	Fall	Fall	1.00	Fall	66	3.1
4/25/2021	3733-091	Spring	Fall	1.00	Fall	95	9.6
4/25/2021	3733-092	Spring	Fall	1.00	Fall	86	6.6
4/25/2021	3733-093	Spring	Fall	1.00	Fall	88	7.5
4/25/2021	3733-094	Spring	Fall	1.00	Fall	89	7.9
4/25/2021	3733-095	Spring	Fall	1.00	Fall	88	7
4/30/2021	3733-096	Fall	Fall	1.00	Fall	71	3.7
4/30/2021	3733-097	Fall	Fall	1.00	Fall	65	2.8
4/30/2021	3733-099	Fall	Fall	1.00	Fall	67	3.4
4/30/2021	3733-100	Fall	Fall	1.00	Fall	74	3.9
5/1/2021	3806-000	Spring	Fall	1.00	Fall	102	12.6
5/2/2021	3806-001	Spring	Fall	1.00	Fall	98	7.5
5/14/2021	3806-002	Fall	Fall	1.00	Fall	75	4.4
5/14/2021	3806-003	Fall	Fall	1.00	Fall	67	3.2
5/14/2021	3806-004	Fall	Fall	1.00	Fall	74	-
5/14/2021	3806-005	Fall	Fall	1.00	Fall	72	3.8
5/14/2021	3806-006	Fall	Fall	1.00	Fall	73	4.3
5/17/2021	3806-007	Fall	Fall	1.00	Fall	82	5.9
5/17/2021	3806-008	Fall	Fall	1.00	Fall	74	4.2
5/17/2021	3806-009	Fall	Fall	1.00	Fall	75	4.5
5/17/2021	3806-010	Fall	Fall	1.00	Fall	85	5.8
5/26/2021	3806-012	Fall	Fall	1.00	Fall	80	6.6
5/26/2021	3806-013	Fall	Fall	1.00	Fall	73	4.4

Appendix 5: **Fulton's condition factor (K), overall, and by life stage, of fall-run Chinook Salmon during the 2021 Lower American River rotary screw trap survey season.**



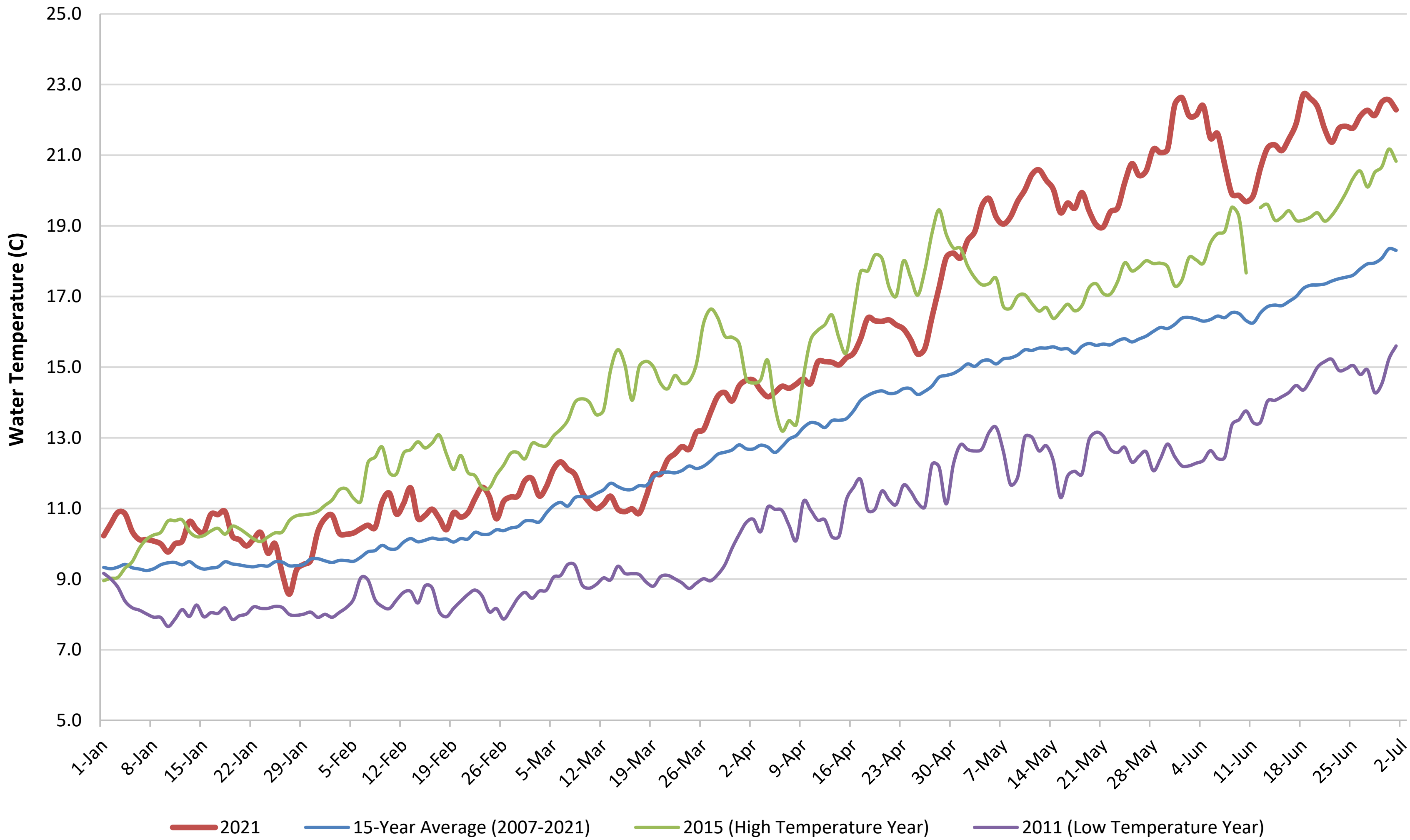


Appendix 6: **Median seasonal discharge (cfs), total catch of fall-run Chinook Salmon, winter-run Chinook Salmon, spring-run Chinook Salmon, steelhead, and lamprey, and the associated passage estimate with 95% confidence intervals (CI) for fall-run Chinook Salmon from the 2013 – 2021 Lower American River rotary screw trap sampling seasons.**

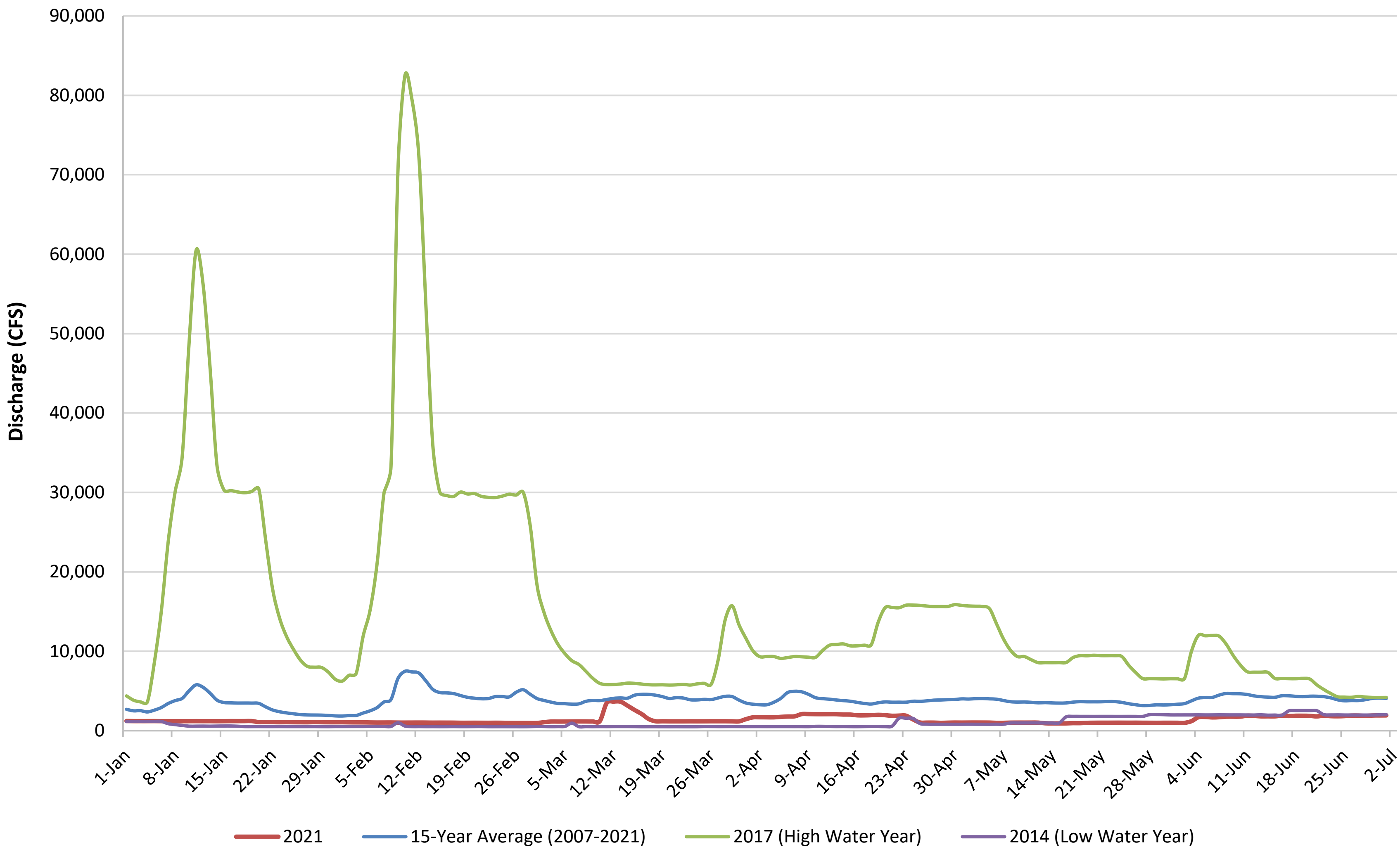
Year	Discharge (cfs)	Total Catch					Passage Estimate	
		Fall-run	Winter-run	Spring-run	Steelhead	Lamprey	Fall-run	95% CI
2013	1,897	262,589	39	14	2,206	1,917	5,692,376	(4,843,254 - 6,032,358)
2014	560	379,542	13	5	592	1,525	1,726,298	(1,681,326 - 2,171,375)
2015	881	283,153	28	19	11	953	1,459,122	(1,417,136 - 1,620,575)
2016	3,776	80,626	1	2	332	1,217	2,394,719	(1,803,134 - 2,907,545)
2017	9,459	9,567	0	1	28	269	788,409	(763,355 - 796,848)
2018	2,857	90,104	11	0	162	1,093	1,287,000	(1,245,000 - 1,426,000)
2019	7,726	15,056	18	9	337	176	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)
2021	1,172	35,433	3	4	283	2,153	499,502	(395,200 – 648,600)

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: **Daily average water temperatures (°C) in the Lower American River at Watt Avenue for the 15 year period 2007-2021, the highest temperature year, lowest temperature year, the 15 year average and the current year (2021). Data from USGS station number 11446980.**



Appendix 8: **Daily average discharge (cfs) on the Lower America River at Fair Oaks for the 15-year period 2007 – 2021, the highest water year, the lowest water year, 15 year average and the current year (2021). Data from USGS station number 11446500.**



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

Appendix 10: **Enhanced efficiency model description by West Inc.**

The CAMP Rotary Screw Trap platform utilizes a trap efficiency model to adjust upward the number of captured fish for those that were not captured. Prior to implementation of enhanced efficiency models, the Platform estimated daily passage by dividing daily catch by a daily estimate of efficiency derived from efficiency trials conducted during the season. To estimate efficiency every day of the season, the Platform utilized a b-spline smoothing method to model daily efficiency.

Recently, the Platform added an option to use an enhanced model of trap efficiency in passage estimation. The enhanced efficiency models utilized efficiency trials conducted during multiple seasons and covariates such as stream flow and temperature to estimate efficiency.

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

Methods

Catch Estimation

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

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

Simple Efficiency Estimation

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

Enhanced Efficiency Estimation

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

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

Efficiency-trial Covariates

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

Environmental Covariates

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

CAMP Covariates

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

Percent-Q Covariates

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

Application of Enhanced Efficiency Models

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

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

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

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