Juvenile Salmonid Emigration Monitoring in the Lower Stanislaus River at Caswell Memorial State Park, California

January – June 2021

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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	Cramer Fish Sciences
cfs	cubic feet per second
CI	Confidence Interval
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DO	dissolved oxygen
DSM	Decision Support Modeling
ESA	Endangered Species Act
g	gram
GAM	generalized additive model
L	liter
m/s	meters per second
mg/L	milligrams per liter
mm	millimeter
NMFS	National Marine Fisheries Service
NMFS BiOp	NMFS biological and conference opinion
NOAA	National Oceanic Atmospheric Administration
NTU	Nephelometric Turbidity Units
OID	Oakdale Irrigation District
PSMFC	Pacific States Marine Fisheries Commission
RPA	Reasonable and Prudent Alternatives
RPM	revolutions per minute
RST	rotary screw trap
SEWID	Stockton East Water Irrigation District
SIT	Science Integration Team
SJRRP	San Joaquin River Restoration Program
SNP	single-nucleotide polymorphism
SOG	Stanislaus Operations Group
SSJID	South San Joaquin Irrigation District
Std. Dev.	Standard Deviation
SWT	Stanislaus Watershed Team
USBR	United States Bureau of Reclamation
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Service
VIE	Visual Implant Elastomer

Abstract

Operation of rotary screw traps on the lower Stanislaus River at Caswell Memorial State Park in 2021 is part of the U.S Fish and Wildlife Service's Anadromous Fish Restoration Program and Comprehensive Assessment and Monitoring Program under the Central Valley Project Improvement Act. 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*. 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 at Caswell Memorial State Park on the lower Stanislaus River in California. Sampling occurred on 129 days of the 141 day season (91%) beginning January 14 and concluding on June 3. A total of 199 fall-run juvenile Chinook Salmon were captured. The passage of juvenile fall-run Chinook Salmon peaked the week of April 30, when 22.52% of the total (n = 6,815) was captured. The majority of the juvenile salmon captured were identified as silvery parr followed by smolt, button-up fry, parr and yolk-sac fry life stages. The number of juvenile fall-run Chinook Salmon that were estimated to have emigrated past the Caswell trap site during the 2021 survey season was 30,264 individuals [95% Confidence Interval: 21,830 – 151,300]. Passage estimates for steelhead and non-salmonid fish taxa were not assessed.

This annual report also includes nine 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 Stanislaus River is a tributary to the San Joaquin River, one of two mainstem rivers of California's Central Valley watershed. This watershed once supported large populations of Chinook Salmon *Oncorhynchus tshawytscha* and steelhead *Oncorhynchus mykiss*, the anadromous form of rainbow trout. However, the construction of impassable dams throughout the valley, hydraulic mining, over-harvesting, introduction of predatory species, water diversions and other factors have contributed to the widespread decline of these fish populations (Yoshiyama et al 2000, Lindley et al 2006, NMFS 2019). As a result, spring-run Chinook Salmon and California Central Valley steelhead were listed as threatened under the Endangered Species Act (ESA) by the National Marine Fisheries Service (NMFS) which is a part of the National Oceanic and Atmospheric Administration (NOAA) (NMFS 2016).

Congress passed the Central Valley Improvement Act (CVPIA) in 1992 to mitigate for loss of anadromous fish habitat that resulted from the construction and operation of the Central Valley Project. The Fish Resource Area of the CVPIA includes all provisions under section 3406(b) to improve natural production of anadromous fish in Central Valley rivers and streams. Accordingly, the 2019 CVPIA annual work plan describes specific projects, programs or monitoring activities to be conducted. The rotary screw trap monitoring program on the Stanislaus River is include in this plan (USBR 2019).

There are two sites where rotary screw trap monitoring efforts occur on the lower Stanislaus River; Oakdale (river kilometer (rkm) 64.5) and Caswell (rkm 13.8). These sampling efforts, defined by the CVPIA and NMFS RPA actions, monitor juvenile salmonids to provide current and relevant data to the SIT and have been conducted since 1993 by California Department of Fish and Wildlife (CDFW), U.S. Fish and Wildlife Service (USFWS), Cramer Fish Sciences (CFS), FishBio, or Pacific States Marine Fisheries Commission (PSMFC). This report describes efforts to determine the timing and abundance of emigrating juvenile salmonids using rotary screw traps (RSTs) on the lower Stanislaus River at Caswell Memorial State Park in 2021 as part of a larger effort to determine if habitat restoration activities and flow management regulations are improving Chinook Salmon production. Furthermore, this report presents data that describe the size and abundance of other native and non-native fish species in relation to the time of year, river discharge, and environmental conditions.

The primary objective of the lower Stanislaus River trapping operations is to collect data that can be used to estimate the production of juvenile fall-run Chinook Salmon and observe abundance of steelhead. Secondary objectives of the trapping operations focus on collecting fork length, weight, and fin clips for genetic run assignment of juvenile salmonids, and gathering environmental data that will eventually be used to develop models that correlate environmental parameters with salmonid size, temporal presence, and abundance/production. An ancillary objective of the trapping operations is to collect non-salmonid fish species data that can be used to characterize the fish community in the Stanislaus River in the vicinity of the RSTs.

Study Area

The Stanislaus River headwaters begin on the western slope of Sierra Nevada mountain range and cover an area of about 1,195 square miles (NOAA 2020). The upper Stanislaus River consists of three forks (North, Middle and South) and tributaries which flow southwest into New Melones Reservoir. The lower Stanislaus River, located in Tuolumne, Calaveras and Stanislaus counties, is a major tributary to the San Joaquin River, which is the southern portion of California's Central Valley watershed. The San Joaquin River flows north and joins the Sacramento River in the Sacramento-San Joaquin Delta. The lower Stanislaus River is 96.6 rkms long from the base of Goodwin Dam to the confluence of the San Joaquin River and provides spawning and rearing habitat for fall-run Chinook Salmon and Central Valley steelhead. Suitable spawning habitat exists between Goodwin Dam (rkm 94) and Riverbank (rkm 54.7) (KDH 2008) while downstream areas are predominately sand substrate.

The lower Stanislaus River is regulated by three dams; New Melones Dam, Tulloch Dam and Goodwin Dam (Figure 1). These dams are operated by the USBR and the Tri-Dam Project to provide flood control, irrigation for agricultural use, power generation, temperature regulation, and are also used to meet flow management requirements. Goodwin Dam is equally and jointly owned by the Oakdale (OID) and South San Joaquin (SSJID). The construction of the Melones Dam in 1926 and New Melones Dam in 1966 was believed to have been a factor in the extirpation of the spring-run Chinook Salmon historically supported by the Stanislaus River (Yoshiyama et al 2000).

The trapping site at Caswell Memorial State Park (rkm 13.8) was determined in 1993 to be the furthest location from the spawning area that allowed for trap deployment and access, and maintained flows consistent enough to operate rotary screw traps (CFS 2006). Two 8 foot rotary screw traps were positioned in the thalweg of the channel near the Northeasternmost corner of the State Park. The traps were designated as Trap 1 and Trap 2, with Trap 1 set closer to the southwestern bank of the river and Trap 2 set closer to the northeastern bank of the river (Figure 2). Access to the trapping site was gained through a private road.

Figure 1: Map of the Stanislaus River and rotary screw trap sites at Caswell Memorial State Park and Oakdale. Inset map illustrates the Stanislaus River in the state of California.

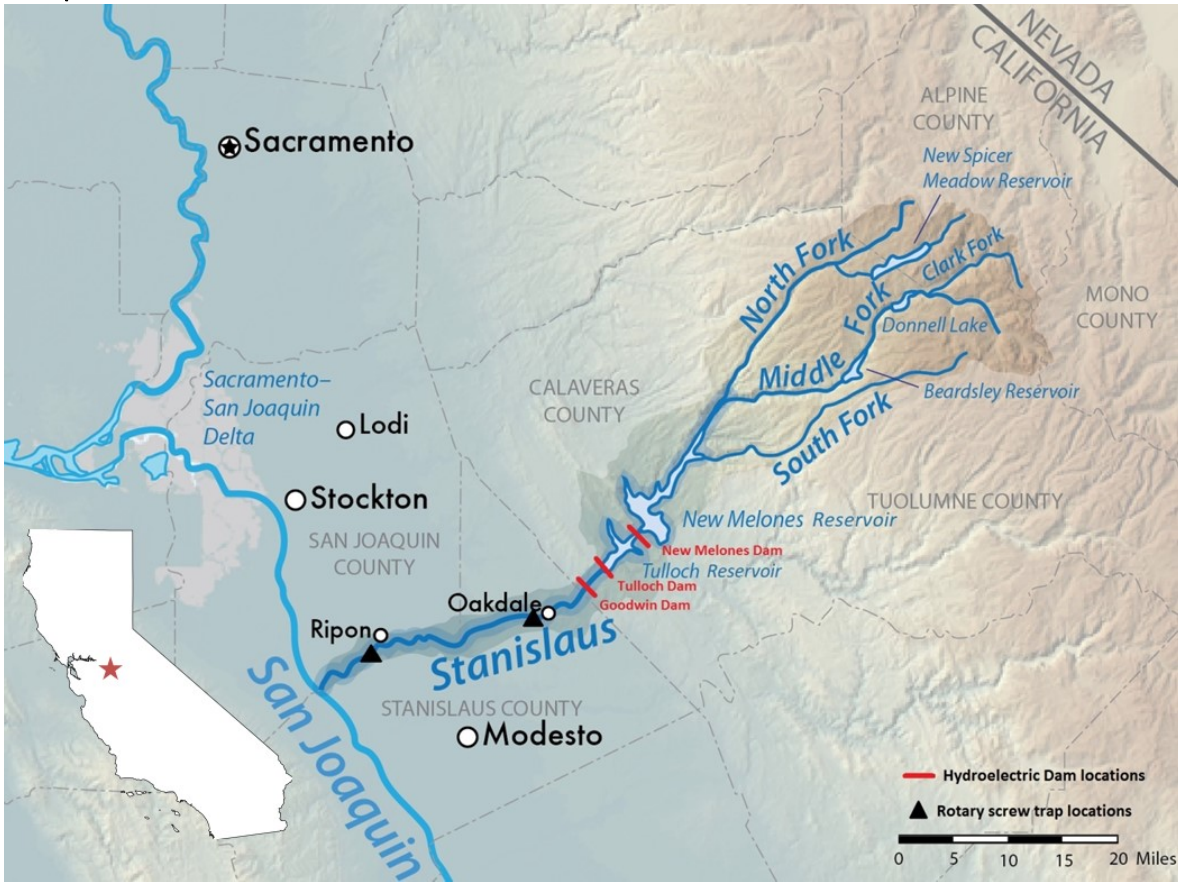


Figure 2: Stanislaus River rotary screw trap site at Caswell Memorial State Park.

Methods

Trapping Operations

Two 2.4 meter (8 feet) diameter RSTs were fished in a side-by side configuration. A 0.95 cm galvanized cable, affixed with orange buoys, was secured to a tree upstream with a cable bridle attached to the outermost pontoon of each trap. An additional anchor rope was attached to the southwestern bank, allowing for in-channel adjustments. In order for the crew to board the traps, this auxiliary anchor rope was also used to pull the traps to shore. Once crew members and field sampling gear were on board, the traps were then released back out into the thalweg to continue trapping while environmental data were collected and live wells were cleared.

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

On daily trap visits, trap function was assessed as “functioning normally”, “functioning, but not normally”, or “stopped functioning”. If the trap was functioning, the revolutions per minute (RPM) was recorded before cleaning the trap. Additionally, intakes were checked and recorded as “clear”, “partially blocked”, “completely blocked”, or “backed up into cone” before live wells were cleared of debris and fish. If the trap was not functioning upon arrival, an attempt was made to return the trap to functioning normally without raising the cones before all fish had been processed. If this could not be done safely, cones remained in the sampling position until all fish were cleared before raising cones to restore normal functionality to the trap. Doing so ensured that all fish were accounted for without the possibility of escape while the cones were raised. Upon clearing the live well of fish, time and total cone rotations were recorded using a mechanical lever actuated counter (Trumeter Company Inc.) attached to the port side pontoon on each trap. This data was used to determine how well traps had functioned between trap visits by comparing RPMs before and after cleaning the cones.

Safety Measures

All crew members were trained in RST and boat operation safety 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.

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 installed on and upstream of the traps. Orange reflective buoys were also placed on the 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 when fish were processed, the following environmental parameters were recorded at least once per visit. Temperature and dissolved oxygen were measured using a YSI meter (YSI EcoSense DO200A), velocity was recorded in front of each cone using a Global Water flow probe (FP111) or Hach flow meter (Hach; Model FH950), and turbidity was measured using a Eutech portable turbidity meter (Eutech; Model TN-100). When water depth was ≤ 300 cm, a depth rod was used to record water depth to the nearest centimeter on the port and starboard sides of the two-trap array, in line with the front of the trap cones. Average daily river discharge and average daily temperature for the Stanislaus River was determined using data from the U.S. Geological Survey's (USGS) Stanislaus River at Ripon monitoring station (USGS station number 11303000).

Catch and Fish Data Collection

After environmental data was collected, the process of clearing out each RST's live well and working-up the fish began. First, debris was removed from the live well and placed into 18 gallon (68.14 liter) tubs in order to enumerate the volume of debris collected. Large cutting boards and tongs were utilized to carefully sift 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 high level of fish health while keeping stress and handling to a minimum was of the highest importance while fish were being processed. Each 5 gallon holding bucket was setup to allow for fast and easy water exchange by perforating the top of each bucket with 3/16" holes. Additionally, dissolved oxygen (DO) and temperature were maintained by utilizing 12V aerators, ice packs, and shade umbrellas to keep holding buckets within 2 degrees Celsius

(C) of the river's temperature. Depending on environmental conditions and salmon size, overcrowding was also avoided by placing no more than 120 fry, 80 parr, or 50 smolts in a single bucket. Upon reaching a bucket's capacity for fish, a perforated screw top lid was secured so that each holding bucket could be submerged in the river to ensure safe DO and temperature until the fish were ready to be processed.

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 either salmon run, fish origin (hatchery or natural), and 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 avoid a selective 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 spring and fall runs of Chinook Salmon, steelhead, and non-salmonid species captured for each trap on the Stanislaus River.

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

Fish were processed on the river bank adjacent to the traps in adequate shade. If the days catch resulted in the need for more than two holding buckets, fish condition was checked and any excess holding buckets were re-submerged in the river. Any fish showing signs of stress or injury, were enumerated and immediately released without further holding or handling. 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. Holding buckets were also 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) were always processed and released first followed by: natural steelhead, 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 5-gallon 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.

Length measurements were collected for all species sampled until a daily capture threshold was meet (Table 1); all additional specimen captured beyond that were plus-counted and released. 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. Life stages for salmonid were assessed by following the criteria in the smolt index rating (Table 2). All other non-salmonid species were differentiated by a juvenile or adult life stage, except for lamprey, which were identified by ammocoete (larval), macrophthalmia (juvenile), or the adult life stage. When applicable, the presence of marks from past trap efficiency tests 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 alters 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, a proportionate subsample of genetic samples were collected and analyzed if winter-run, spring-run, fall-run, or 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	Fry	* Recently emerged with yolk sac absorbed (button-up fry) * Seam along mid-ventral line visible * Pigmentation undeveloped
3	Parr	* Seam along mid-ventral line not visible * Scales firmly set * Darkly pigmented with distinct parr marks * No silvery coloration
4	Silvery Parr	* Parr marks visible but faded * Intermediate degree of silvering
5	Smolt	* Parr marks highly faded or absent * Bright silver or nearly white coloration * Scales easily shed (deciduous) * Black trailing edge on caudal fin * Body/head elongating
6	Adult	* ≥ 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 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, fin clips from each LAD assigned 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 perform genetic run assignments using the panel of single-nucleotide polymorphism (SNP) markers described by Clemento et al. (2014). This panel of SNPs was developed by staff from NOAA Fisheries, and is now used for several applications by the USFWS and several partner groups (Christian Smith, USFWS, pers. comm.). Detailed methods for DNA extraction, genotyping, and run assignment are described in Abernathy Fish Technology Center Standard Operating Procedure #034.

Trap Efficiency

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

One method of marking consisted of dyeing the whole body of a fall-run Chinook Salmon with Bismarck Brown Y (BBY) stain when most of the juvenile salmon had a fork length that was < 50 mm. At least 500 salmon were used to conduct trials with BBY stain. If < 500 fall-run were captured on a given day, they were held overnight, and fall-run captured the following day were added to the previous day's catch to acquire the target number of fish required for a trap efficiency test. If daily catch totals were too low, fall-run Chinook Salmon were provided by the Merced River Hatchery. Once enough fall-run were acquired to conduct a trap efficiency trial, they were placed in an aerated 18-gallon tub and stained using a solution of 0.6 g of BBY for every 20 gallons of river water. The actual amount of stain used varied depending on water turbidity and the number of salmon being stained. Salmon were stained for approximately two hours, and their condition was constantly monitored during the staining process. After staining, salmon were placed in a 50-gallon live car attached to the rear of the traps and held until twilight before being released.

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

The trap efficiency release site was approximately 0.5 rkm upstream of the traps with suitable bank access. To avoid schooling when the salmon were released, tagged salmon were scattered by slowly releasing fish with small dip nets along a 5 m section of river bank. When river flows were relatively low (e.g., < 500 cfs), fish were evenly released across the width of the river or until water depth reached the releaser’s chest. When safe river conditions allowed, a boat was used to release the marked fish, keeping the motor upstream of the released fish while a crew member released small groups of fish off the boat’s bow. Additionally, every marked salmon release occurred close to dusk to minimize predation.

On trap visits following each trap efficiency release, crew members looked carefully for any marked fish in the RST live wells. Due to the proximity of the release location to the RSTs, the majority of released fish were found to migrate past the RST location within the first four days following a release. As a result, trial periods were designated as a minimum of four days. During this period, a subsample of 100 recaptured Chinook Salmon from each trap efficiency test were measured for fork lengths, assessed for life stage, and evaluated for mortality status. If more than 100 recaptures from a trap efficiency test were found in a RST live well, the marked salmon in excess of 100 were enumerated and classified as a “live recap plus-count tally” or “mort recap plus-count tally”.

Passage Estimates

Fall-run Chinook Salmon passage estimates were developed using an enhanced efficiency model developed by West Inc. The model description from a West Inc. document sent to those who implement the model can be found in Appendix 9.

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 Intervals

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

Two 8-foot RSTs (Trap 1 and Trap 2) were utilized for the 2021 sampling season. Trap 1 began sampling on January 14 and concluded June 3 with 129 days of sampling effort in the 141 day season (91%; Figure 3). Trap 2 began sampling on January 30 and concluded June 3 with 113 days of sampling effort in the 125 day season (90%; Figure 3).Of the 129 days of sampling effort, the traps fished successfully for approximately 2,610 hours, and fished unsuccessfully for approximately 454 hours (Figure 4). Both traps were positioned in the thalweg of the channel in the northeastern most portion of the state park (Figure 2). River flow fluctuated frequently for the majority of the trapping season with a median discharge of 399 cfs (range: 185 – 1,360 cfs). Sampling of both traps was suspended for a total of 12 days over the course of the season with no outages being greater than seven days. Weekend shutdowns began May 8 and continued through the duration of the season accounting for all of 12 days without sampling.

Figure 3: Dates sampling occurred for each trap during the 2021 Stanislaus rotary screw trap survey season.

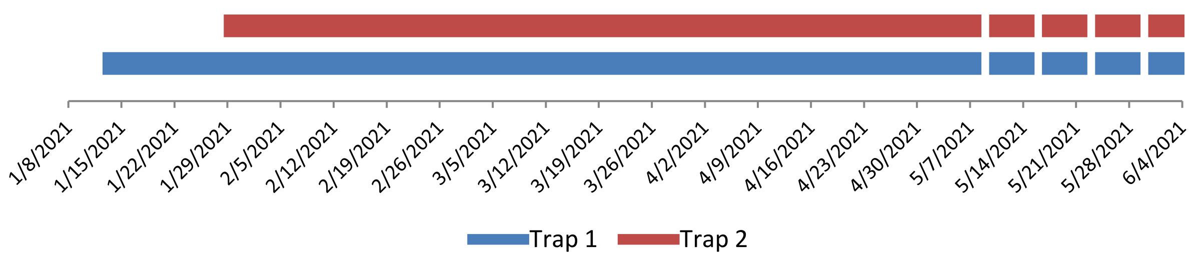
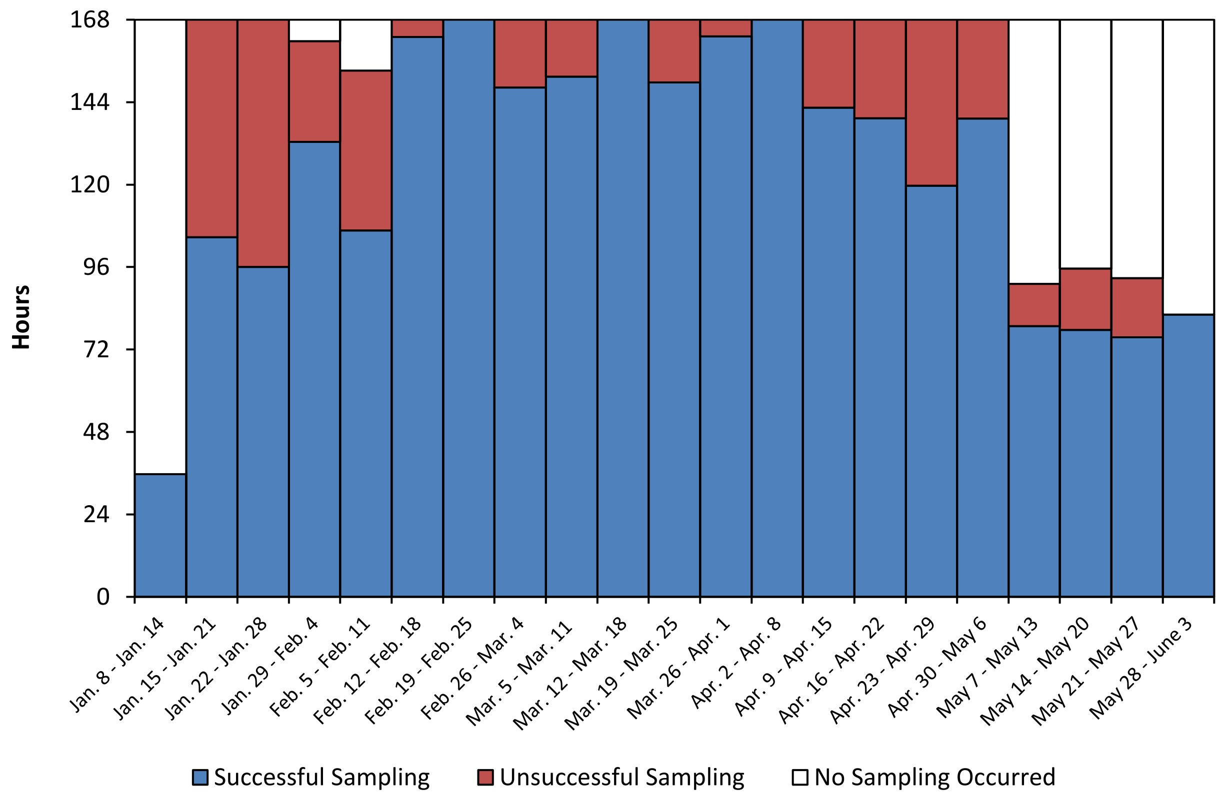


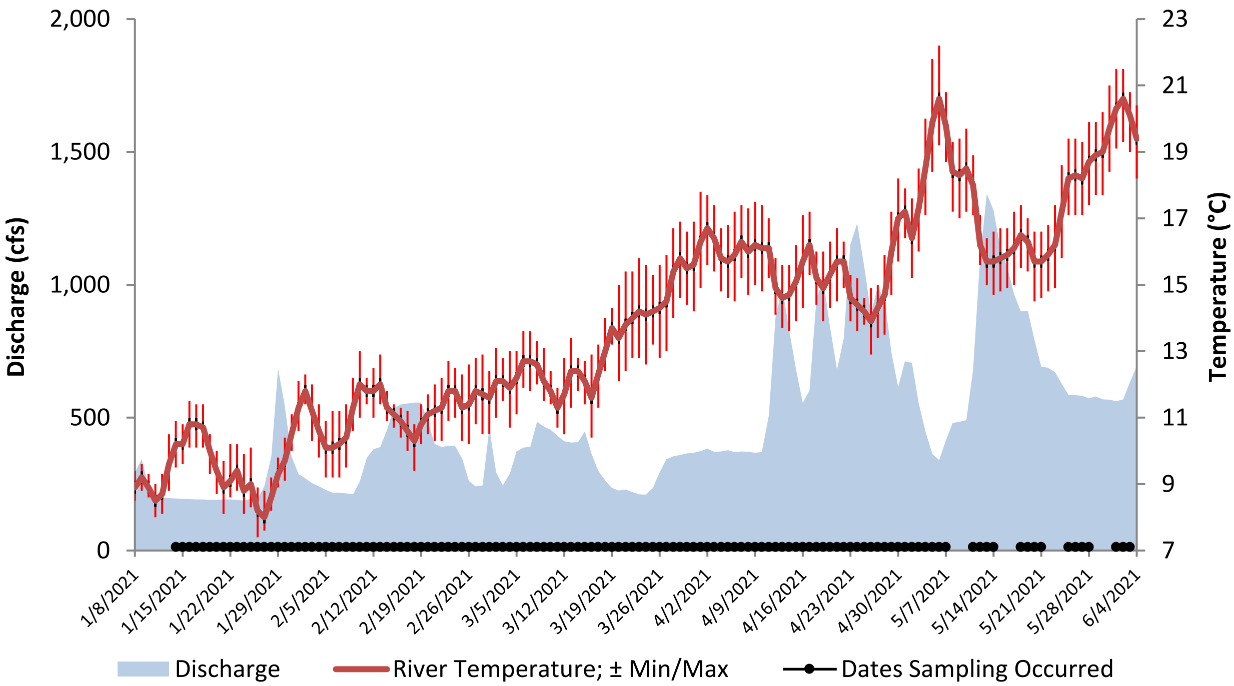
Figure 4: Weighted average hours per Julian week that both traps fished successfully, fished unsuccessfully, or did not fish during the 2021 Stanislaus River rotary screw trap survey season.



Environmental Summary

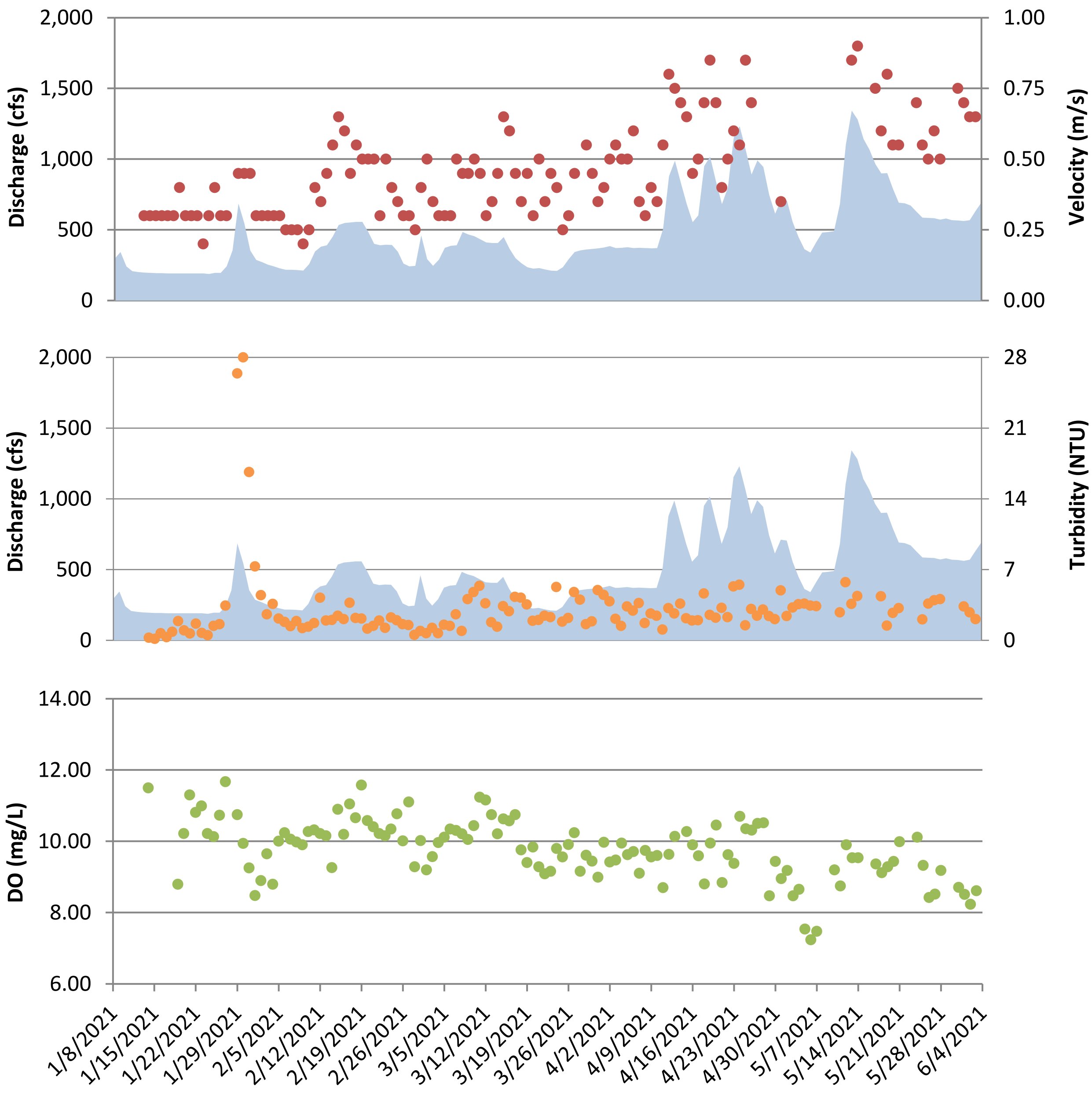
Appendix 2 provides a summary of the environmental conditions, averaged by Julian week, starting on January 8 and concluding June 4. Measurements taken in the field, such as DO, turbidity, and velocity only reflect days sampling occurred. Instantaneous river discharge, recorded in 15-minute intervals by USGS, reached a maximum on May 13 and a minimum on January 24 (range: 185 – 1,360 cfs). Additionally, the daily average discharge reached a high on May 13 and a low on January 24 (range: 187 – 1,343 cfs). Instantaneous river temperature, also recorded in 15-minute intervals by USGS at the Ripon gauge station, recorded a maximum temperature on May 6 and minimum on January 26 (range: 7.4 – 22.2 °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, and the daily minimum, maximum, and average water temperature (°C) measured at Ripon during the 2021 Stanislaus 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. Dissolved oxygen, measured in milligrams per liter (mg/L), was recorded prior to trap checks and monitored while fish were held. Between both traps, the minimum recorded DO occurred on May 6 and the maximum on January 27 with a range of 7.24 – 11.67 mg/L. The turbidity, measured in Nephelometric Turbidity Units (NTU), was consistently similar between both traps throughout the season with relatively low NTU. The turbidity for both traps reached a season minimum on January 15 and a maximum on January 30 with a range of 0.15 – 28.10 NTU. The velocity, measured in meters per second (m/s), was similar for both traps throughout the survey season, with velocities for Trap 2 slightly higher than Trap 1. During trap visits, water velocity for both Traps ranged between 0.2 and 0.9 m/s over the course of the season. Weekly average water velocity, averaged by Julian week, reached a maximum of 0.9 m/s the week of May 5. The weekly minimum average of 0.2 m/s was reached during four separate weeks as base flows were released as required from Goodwin Dam in January and February. The daily average DO, turbidity, and velocity throughout the season can be seen in Figure 6, and the average Julian week minimum, maximum and mean values are listed in Appendix 2.

Figure 6: Daily average velocity (m/s), turbidity (NTU), discharge (cfs) measured at Ripon, and dissolved oxygen (DO) (mg/L) averaged between both traps during the 2021 Stanislaus River rotary screw trap survey season.



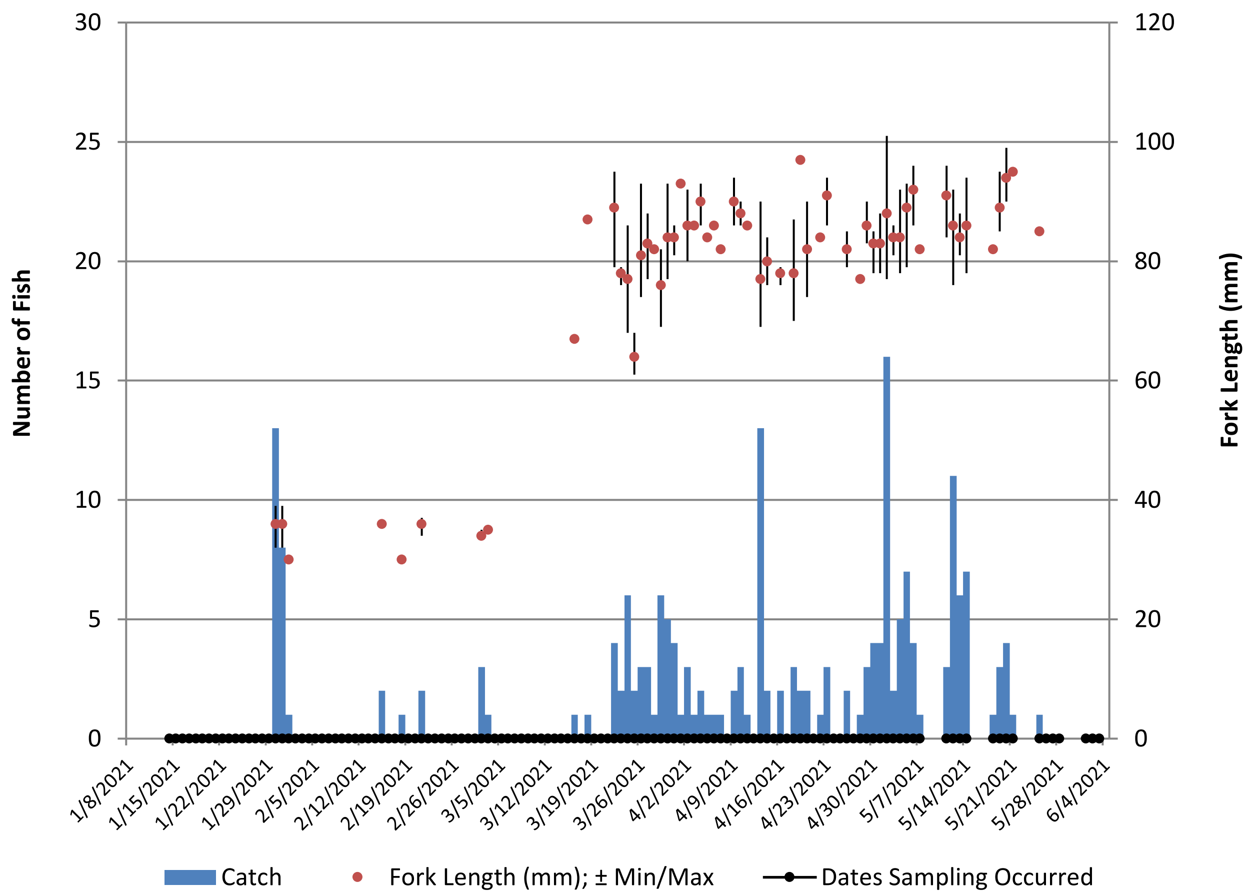
Catch

The two rotary screw traps deployed during the 2021 survey season captured a total of 4,486 fish. Trap 1 (south western side) captured 27.28% (n = 1,224) of these fish, and Trap 2 (north eastern side) captured 72.72% (n = 3,262). Of these fish, 18 non-salmonid species were identified as well as 32 non-salmonid individuals that were unable to be identified to the species level (Appendix 3).

Fall-run Chinook Salmon

A total of 199 natural origin fall-run Chinook Salmon were captured during the 2021 survey season. Because these fish did not have an adipose fin clip, they were presumed to be of natural origin. Catch of fall-run first peaked on May 2, when 8.04% (n = 16) of these fish were captured (Figure 7). Of all fall-run captured during the 2021 survey season, 3 were classified as unmeasured plus-count tallies. This resulted in 3 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 Stanislaus rotary screw trap sampling season.



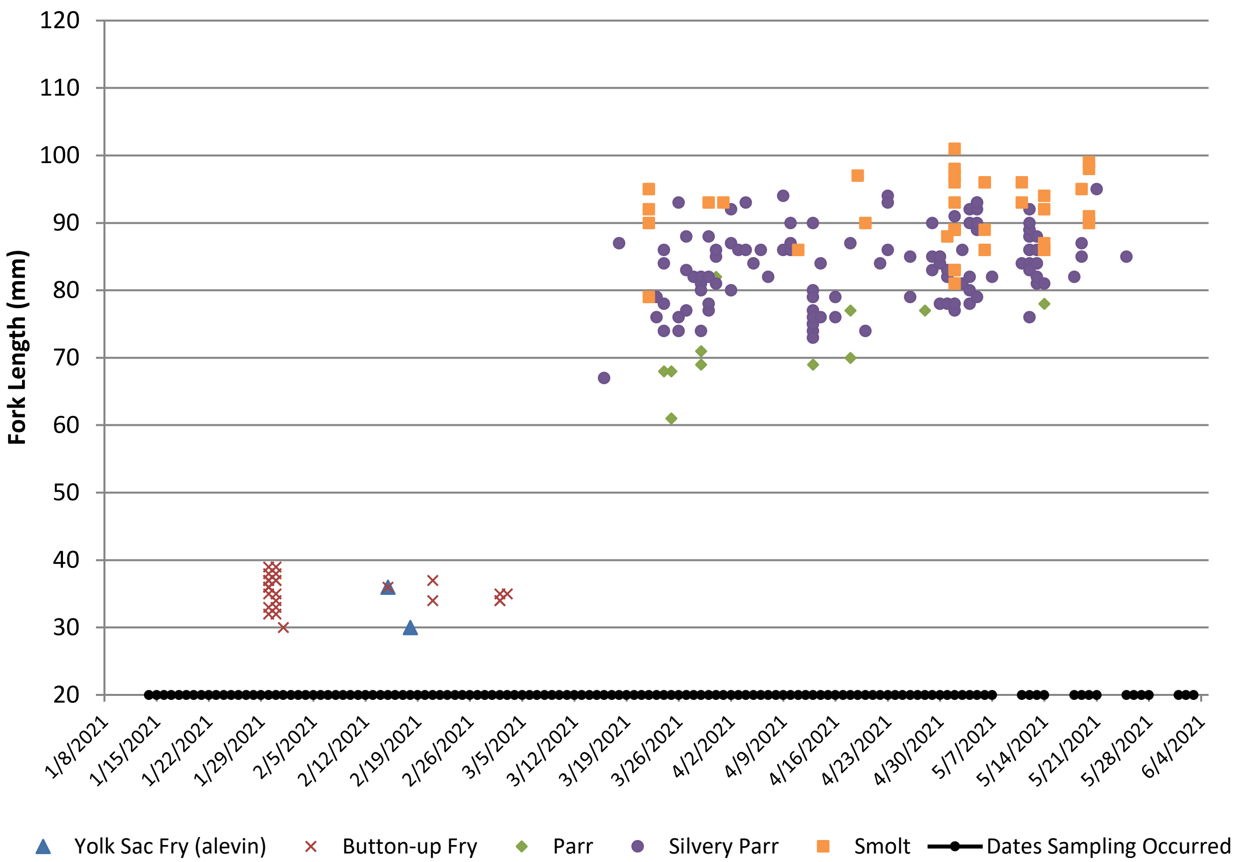
A total of 196 natural origin fall-run were measured for fork length. The weekly minimum, maximum, and average fork lengths throughout the 2021 survey season are displayed in Table 3. The lowest weekly average fork length of 34 mm was observed during the week of February 12. Fork lengths increased throughout the season with the weekly average reaching a maximum of 90 mm the week of May 21.

Table 3: Weekly average (Avg), minimum and maximum (range), and standard deviation (St. Dev.) of fork lengths (mm) and total weekly catch (n) for natural origin fall-run Chinook Salmon captured during the 2021 Stanislaus River rotary screw trap sampling season.

Julian Week	Natural Origin Fall-Run Chinook Salmon			
	Avg	Range	St. Dev.	n
1/8 - 1/14	-	-	-	-
1/15 - 1/21	-	-	-	-
1/22 - 1/28	-	-	-	-
1/29 - 2/4	36	30 - 39	2.40	22
2/5 - 2/11	-	-	-	-
2/12 - 2/18	34	30 - 36	3.46	3
2/19 - 2/25	36	34 - 37	2.12	2
2/26 - 3/4	35	34 - 35	0.58	4
3/5 - 3/11	-	-	-	-
3/12 - 3/18	77	67 - 87	14.14	2
3/19 - 3/25	79	61 - 95	9.79	14
3/26 - 4/1	82	69 - 93	6.68	23
4/2 - 4/8	86	80 - 93	4.21	9
4/9 - 4/15	81	69 - 94	7.06	21
4/16 - 4/22	82	70 - 97	8.62	10
4/23 - 4/29	86	77 - 94	5.80	9
4/30 - 5/6	87	77 - 101	6.33	42
5/7 - 5/13	86	76 - 96	4.54	21
5/14 - 5/20	89	78 - 99	6.16	15
5/21 - 5/27	90	85 - 95	7.07	2
5/28 - 6/3	-	-	-	-

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 silvery parr and accounted for 58.67% (n = 115) of the assessed catch. The remaining life stage catch composition consisted of yolk sac fry (1.02%, n = 2), button-up fry (14.80%, n = 29), parr (6.63%, n = 13) and smolts (18.88%, n = 37). As shown in Figure 8, fall-run Chinook Salmon identified as yolk sac fry were captured on February 15 and February 18. Button-up fry were identified starting on January 30 and were captured until March 3. The parr life stage was identified between March 24 and May 14, and the silvery parr life stage was captured starting March 16 through May 25. Lastly, those identified as the smolt life stage were captured between March 22 and May 20.

Figure 8: Daily fork length distribution by life stage of natural origin fall-run Chinook Salmon measured during the 2021 Stanislaus 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 30 – 36 mm for yolk sac fry, 30 – 39 mm for button-up fry, 61 – 78 mm for parr, 67 – 95 mm for silvery parr, and 79 – 101 mm for smolt life stages.

Average weekly fork lengths generally increased with life stage progression with yolk-sac fry life stage having the lowest average weekly fork lengths, and smolts having the largest average weekly fork lengths. The fall-run fork lengths averaged 33 mm for yolk-sac fry, 36 mm for button-up fry, 72 mm for parr, 84 mm for silvery parr, and 91 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 Stanislaus 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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1/15 - 1/21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1/22 - 1/28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1/29 - 2/4	-	-	-	36	30 - 39	22	-	-	-	-	-	-	-	-	-
2/5 - 2/11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2/12 - 2/18	33	30 - 36	2	36	36	1	-	-	-	-	-	-	-	-	-
2/19 - 2/25	-	-	-	36	34 - 37	2	-	-	-	-	-	-	-	-	-
2/26 - 3/4	-	-	-	35	34 - 35	4	-	-	-	-	-	-	-	-	-
3/5 - 3/11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3/12 - 3/18	-	-	-	-	-	-	-	-	-	77	67 - 87	2	-	-	-
3/19 - 3/25	-	-	-	-	-	-	68	61 - 74	4	80	74 - 86	6	89	79 - 95	4
3/26 - 4/1	-	-	-	-	-	-	74	69 - 82	3	82	74 - 93	18	93	93	2
4/2 - 4/8	-	-	-	-	-	-	-	-	-	86	80 - 93	9	-	-	-
4/9 - 4/15	-	-	-	-	-	-	72	69 - 74	2	81	73 - 94	16	86	86	1
4/16 - 4/22	-	-	-	-	-	-	74	70 - 77	2	80	74 - 87	5	94	90 - 97	2
4/23 - 4/29	-	-	-	-	-	-	77	77	1	87	79 - 94	8	-	-	-
4/30 - 5/6	-	-	-	-	-	-	-	-	-	85	77 - 93	26	91	81 - 101	16
5/7 - 5/13	-	-	-	-	-	-	-	-	-	85	76 - 92	19	95	93 - 96	2
5/14 - 5/20	-	-	-	-	-	-	78	78	1	84	81 - 87	4	92	86 - 99	10
5/21 - 5/27	-	-	-	-	-	-	-	-	-	90	85 - 95	2	-	-	-
5/28 – 6/3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Entire Season	**33**	**30-36**	**2**	**35**	**30-39**	**29**	**72**	**61-82**	**13**	**84**	**67-95**	**115**	**91**	**79-101**	**37**

Fulton's Condition Factor

Fulton's condition factor (K) for in-river produced, unmarked fall-run Chinook Salmon captured in 2021 displayed a slightly positive trend in condition throughout the survey season (Appendix 5). The overall trend line exhibited a positive slope of 0.0009. The trend line slopes were positive for parr (0.0066) and silvery parr (0.0011) and negative for smolt (-0.0010) life stages. Yolk-sac fry and button-up fry captured in 2021 were unable to be accessed for Fulton's condition factor as every fish identified with this life stage was measured below 40 mm and was therefore not weighed.

Trap Efficiency

One mark-recapture trap efficiency trial was conducted during the 2021 survey season, which was included in analysis and used by the CAMP platform to determine passage estimates (Table 5). The trial used a total of 540 fall-run Chinook Salmon. All salmon were of natural origin and marked with BBY stain. The trap recapture efficiency was 9.44% with a total of 51 marked salmon being recaptured within seven days of the 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 Stanislaus 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)
3/2/21	Natural	BBY	Yes	3/2/21	18:15	366	36	540	9.44%	36

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 11303000 at time of release.
Avg FL (mm) = Average fork length in millimeters for released or recaptured salmon.
n = Total number of marked salmon released for the efficiency trial.
Natural = Assumed natural production of the Stanislaus River.
BBY = Bismark brown Y whole body stain.

Passage Estimate for Fall-run Chinook Salmon

According to the CAMP platform “run_passage” report, 30,264 natural origin fall-run Chinook Salmon were estimated to have emigrated past the Caswell rotary screw trap location during the 2021 survey season (Figure 9). The 95 percent confidence interval for this estimate was from 21,830 to 151,300 individuals. The highest weekly passage estimate occurred the week of April 30 with approximately 6,815 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 Ripon during the 2021 Stanislaus River rotary screw trap survey season.

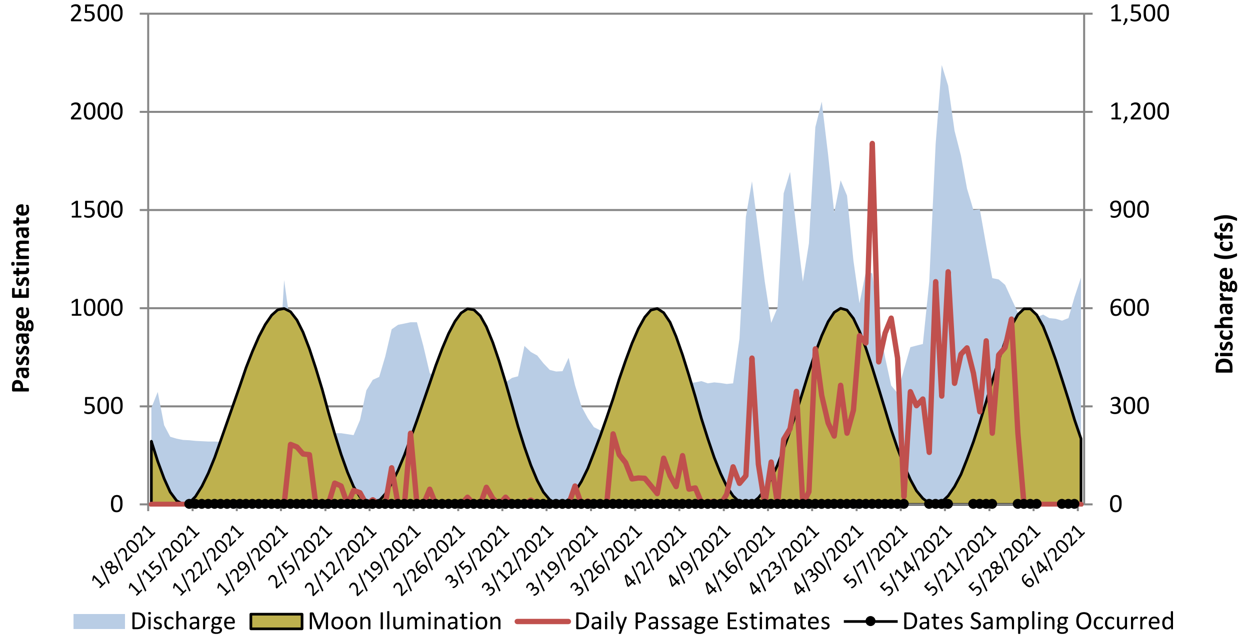


Table 6: Weekly passage estimate of natural origin fall-run Chinook Salmon with 95% confidence intervals (CI) and weekly average discharge at Ripon during the 2021 Stanislaus River rotary screw trap survey season.

Julian Week	Discharge	Passage Estimate	CI 95%
1/8 - 1/14	240	0	-
1/15 - 1/21	192	0	-
1/22 - 1/28	222	0	-
1/29 - 2/4	377	1,106	(393 - 3,667)
2/5 - 2/11	242	332	(74 - 1,886)
2/12 - 2/18	488	573	(176 - 1,806)
2/19 - 2/25	424	77	(53 - 125)
2/26 - 3/4	291	154	(98 - 312)
3/5 - 3/11	427	59	(10 - 302)
3/12 - 3/18	371	110	(45 - 274)
3/19 - 3/25	224	955	(353 - 2,918)
3/26 - 4/1	351	886	(437 - 2,309)
4/2 - 4/8	374	446	(180 - 1,083)
4/9 - 4/15	658	1,444	(629 - 3,248)
4/16 - 4/22	778	1,574	(671 - 4,155)
4/23 - 4/29	1,003	3,561	(1,539 - 12,587)
4/30 - 5/6	534	6,815	(3,608 - 48,709)
5/7 - 5/13	714	3,600	(1,696 - 8,934)
5/14 - 5/20	1,006	5,340	(2,785 - 23,729)
5/21 - 5/27	633	3,232	(1,510 - 35,589)
5/28 - 6/3	579	0	-
Total	**482**	**30,264**	**(21,830 - 151,300)**

Genetic Analysis

During the 2021 survey season, a total of 103 genetic samples taken from juvenile Chinook Salmon were analyzed using SNP genetic markers to determine run assignments. The SNP panel's probabilities for the 103 samples exceeded the 50 percent threshold; the final salmon run assignments for the corresponding salmon were therefore made based on genetic data. A complete account of the salmon run assignments using LAD criteria and genetic markers is provided in Appendix 4. The 103 samples that were assigned were taken from salmon that did not have an adipose fin clip and were therefore presumed to be of in-river production.

Genetic samples were collected from 34 LAD fall-run throughout the 2021 sampling season. Analyses using SNP genetic markers from these samples indicated that 100% (n = 34) were correctly identified as fall-run Chinook Salmon (Table 7). Because the LAD criteria continued to accurately assign this run, a final run assessment of fall was applied to the remaining 91 LAD fall-run that were not genetically sampled.

A total of 68 Chinook Salmon classified as spring-run using LAD criteria were also captured in 2021. Analyses using SNP genetic markers from those samples indicated that all 68 were fall-run Chinook Salmon (Table 7). Because the LAD criteria appeared to incorrectly assign this run, the remaining 5 LAD spring-run that were not genetically sampled were given a final run assignment of fall-run.

One Chinook Salmon classified as a winter-run using LAD criteria was captured in 2021. Analysis using SNP genetic markers of the sample indicated that it was a fall-run Chinook Salmon (Table 7). The LAD winter-run was assigned 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-Run	Spring-Run	Winter-Run
Fall	34	0	0
Spring	68	0	0
Winter	1	0	0

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).

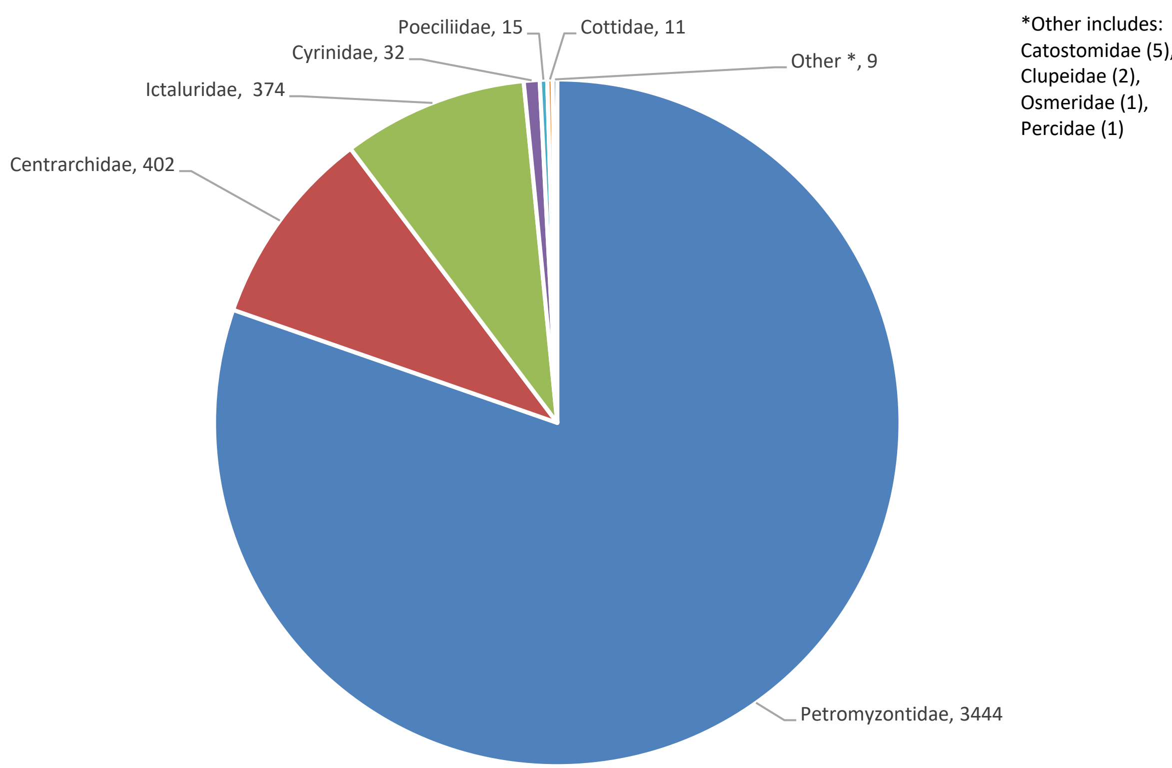
Spring, Winter, and Late Fall runs of Chinook Salmon

The results of the genetic analyses suggest that no in-river produced spring-run, winter-run, or late fall-run Chinook Salmon were detected in the subsample during the 2021 survey season.

Non-salmonid Species

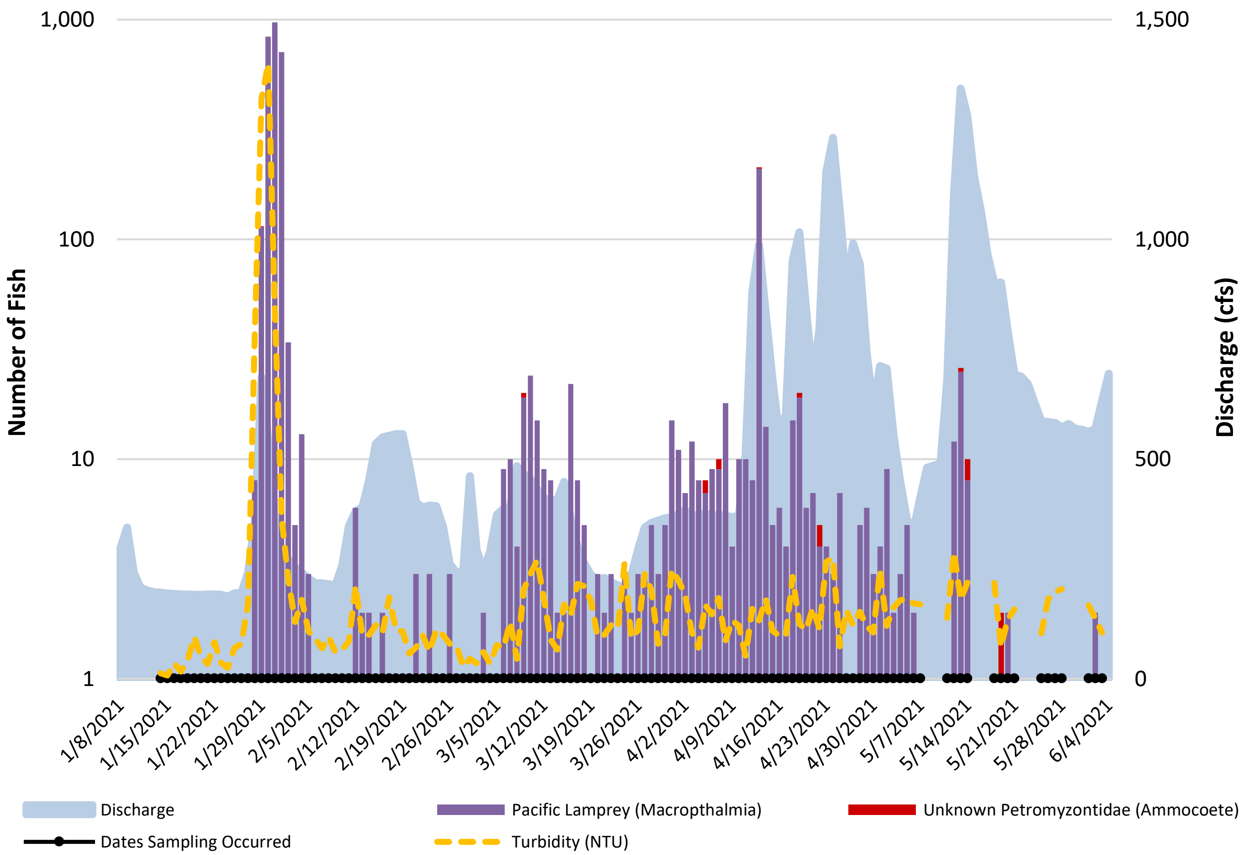
In addition to the salmonids, 4,287 non-salmonid fish were captured during the 2021 survey season. The majority (n = 4,255, 99.25%) of these fish belonged to 18 identified species in the following families: Catostomidae (sucker), Centrarchidae (sunfish/black bass), Clupeidae (shad), Cottidae (sculpin), Cyprinidae (minnow), Ictaluridae (bullhead/catfish), Osmeridae (smelt), Percidae (perch), Petromyzontidae (lamprey), and Poeciliidae (mosquitofish) (Figure 10). The remaining 0.75% (n = 32) were not able to be identified to species level, but belonged to the following families: Centrarchidae (n = 13), Cottidae (n = 1), Cyprinidae (n = 3), and Petromyzontidae (n = 15). The majority of non-salmonid fish captured were native to the Central Valley watershed (n = 3,477, 81.11%) with the remaining individuals (n = 810, 18.89%) being non-native species. Appendix 3 contains a complete list of non-salmonid species captured in the 2021 survey season.

Figure 10: Non-salmonid catch totals for each family of species collected during the 2021 Stanislaus River rotary screw trap survey season.



Of the 4,287 non-salmonid fish captured, 3,444 (80.34%) were identified as Petromyzontidae spp. (northern lampreys); 3,429 (99.56%) of which were identified as Pacific Lamprey, all classified as juveniles. The catch of lamprey during the 2021 survey season marks a substantial increase in catch from the previous four sampling seasons (Appendix 6). Despite the increased catch, no lamprey that were identified to the species level, i.e., macrophthalmia, were identified as River Lamprey. The remaining 15 (0.44%) lamprey captured were identified as juvenile ammocoetes of Petromyzontidae and could not be identified to a species level. Additionally, catch of Pacific Lamprey peaked on January 31 during a discharge and turbidity event (Figure 6) when 973 (28.38%) of the season's Pacific Lamprey total was captured. Catch of ammocoetes peaked on April 13 when 3 (20.00%) of the season's total was captured (Figure 11).

Figure 11: Daily lamprey catch and daily discharge at Ripon during the 2021 Stanislaus River rotary screw trap survey season.



Discussion

Objective

The continued operation of the Stanislaus River rotary screw traps during the 2021 survey season provided valuable biological monitoring data for emigrating salmonids. Primary objectives of the study were met by developing fall-run Chinook Salmon passage estimates and accurately quantifying the catch of all salmonids. 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 Stanislaus River salmonids by expanding on previous rotary screw trap emigration survey data from Cramer Fish Sciences (CFS 2016) and Pacific States Marine Fisheries Commission (PSMFC 2017 – 2020).

Passage Estimate and Catch

A total of 199 natural origin fall-run Chinook Salmon were captured during the 2021 survey season. This marks the lowest catch of natural origin fall-run captured at the Caswell RST sampling site and a substantial decrease from the 2020 survey season when 912 salmon were captured. The natural origin fall-run passage estimate of 30,264 [95% CI: 21,830 – 151,300] also depicts a decrease from the 2020 estimate of 166,720 [95% CI: 70,570 – 632,500] (Appendix 6). These changes represent a 78% decrease in actual catch and an 82% decrease in the passage estimate from 2020 to 2021. Additionally, the ratio between interval width and the passage estimate increased from 337% in 2020 to 428% in 2021 posing relatively lower precision in the estimate.

Based on the results of the genetic analysis, no listed Chinook Salmon were detected in the subsample during the 2021 sampling season. Thus, the 2018 survey seasons remain the only seasons with catch of genetically confirmed, spring-run Chinook Salmon (Appendix 6). Furthermore, no natural origin steelhead smolts were captured during the 2021 survey season. Annual catch of natural origin steelhead has not exceeded five steelhead since the 2007 sampling season (CFS 2016, PSMFC 2017 – 2020).

Several factors must be considered when interpreting the passage estimates of fall-run Chinook and the quantity of salmonids captured. Trap operation is consistently one of the most important factors when developing meaningful annual passage estimates. During the 2021 survey season, highly variable discharge and large debris events affected successful operation of the rotary screw traps. Sampling occurred for 91% (129 days) of the 141-day season with an 85% successful sample rate. No gaps in sampling greater than seven days occurred, allowing for a complete season production estimate to be generated. Comparatively, sampling in 2020 was subject to similar operational conditions with sampling occurring for 90% (123 days) of the 137-day season with an 85% successful sample rate and no gaps in sampling greater than seven days. The similar operational conditions observed in 2020 and 2021 allow more room to make meaningful annual comparisons.

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, 0 juvenile fall-run Chinook Salmon were captured. However, since Trap 2 had not been operating yet, it is possible that migrating Chinook Salmon may not have been captured. Furthermore, during the last seven days of sampling, a total of one juvenile fall-run was captured accounting for 0.50% of the total season catch. The last seven days of the sampling season also comprised 1.20% (n = 363) of the total passage estimate. Because of this, it is likely that the 2021 survey season encompassed the majority of the fall-run Chinook Salmon emigration, further allowing for meaningful annual comparisons 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. An attempt is made each screw trapping season to complete at least ten efficiency trials to produce estimates of the highest confidence. However, insufficient catch of natural origin fall-run Chinook Salmon and an inability to receive hatchery fish led to the completion of only one efficiency trial in 2021. The trial, conducted on March 2 utilized 540 natural origin salmon with a mean fork length of 36 mm and resulted in a 9.44% capture efficiency.

Effective efficiency trials are also dependent upon adequate, stable flow and successful trap operation during the entirety of the efficiency trial period (USFWS 2008). However, several environmental factors had detrimental effects on the quality of the efficiency trial including insufficient velocity, flow alterations, and periods of unsuccessful sampling during each trial. Insufficient velocity can be one of the most challenging factors to control without making significant alterations to the RSTs or sampling site. The ideal velocity of 1.5 m/s for 8-foot RSTs is rarely seen on the Stanislaus River at Caswell and was again not observed in 2021 with velocity averaging 0.5 m/s and a range of 0.2 – 0.9 m/s (USFWS 2008). However, it should be noted that the velocity meter experienced intermittent sensor connectivity failures that limited the number of days that velocity could be recorded (Figure 6). Additionally, the efficiency trial experienced a moderate increase in discharge ensuing a Vernalis flow requirement in early March. Unsuccessful sampling also occurred for Trap 1 on March 5 and March 9 as the discharge increased from 237 - 548 cfs during the seven-day trial period. Despite these factors, traps sampled successfully during the first 48 hours of the trial with 96% of the test fish recaptured within 24 hours. However, it is likely that the efficiency percentage biased low due to the short periods of unsuccessful sampling during the trial period.

Biological Observations

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 to evaluate potential changes in health, growth, and life history strategies. As seen in previous years of biological sampling on the Stanislaus River, most of the fall-run Chinook Salmon population emigrate at age 0 from the Stanislaus River (PSMFC 2017 – 2020, CFS 1996 – 2016). In the Central Valley, this emigration timing is most representative of an ocean-type life history where recently emerged fry and parr emigrate from their natal stream prior to the summer season before entering the ocean (Kjelson and Raquel 1981). The fall-run emigration also experienced one unique capture period the week of April 30 when 23% (n = 6,815) of the fall-run were estimated to have emigrated past the trap. This emigration timing coincided with a season high discharge in April because of a pulse flow intended to cue the outmigration of juvenile salmonids (Figure 5). An increase in passage during discharge events was observed throughout the season as the majority (81%, n = 24,582) of the fall-run passage estimate emigrated when daily average discharge was > 400 cfs, the sampling season's median discharge. Evidently, discharge was likely the most influential environmental factor in determining emigration timing of fall-run Chinook Salmon during the 2021 survey season. Similar observations were made by Zeug et al (2014) in which historically higher cumulative discharge resulted in higher catch and survival of emigrating Chinook Salmon. This relationship can be further observed with Figure 9 and Table 6 which details weekly passage estimates and the average weekly discharge.

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 1996 and 2016. During this period, differences in sampling methodology (including the number of RSTs used), 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 Stanislaus River at Caswell in 2022. To obtain the highest accuracy for passage estimates and maintain the highest level of safety, the following adjustments are recommended for future seasons. To achieve an increased level of accuracy in the passage estimates, additional focus should be applied to the quantity of efficiency trials completed throughout the season. Expansions to the dates that fish can be acquired from Merced River Hatchery have been pre-approved by CDFW, which would allow for hatchery origin mark recapture trials between January and May if sufficient natural origin fish are not available. Additionally, if Merced River Hatchery is unable to provide hatchery fish, coordinating and collaborating with the Oakdale RST project for test fish should be considered. To increase capture efficiency and decrease trap avoidance, hydraulic modifications (e.g., sandbags, wings, or screen panels) to guide more water into the cone and increase velocity and trap RPM during moderate and low flows should be considered in future sampling seasons. These changes could result in increased capture efficiency, increased probability of capturing smolting salmonids, decrease the number of in-season trap adjustments, and provide a greater confidence in the passage estimates produced. We believe these efforts will strengthen the future of the Stanislaus River Caswell RST project by continuing to improve our understanding of juvenile salmonids while maintaining focus on safe and effective sampling practices.

Management Implications

To determine if efforts made by AFRP and others to increase the abundance of Chinook Salmon and steelhead on the lower Stanislaus River have been successful, additional monitoring of juvenile salmonid emigration is required. The continued management of river discharge and water temperature to maintain favorable river conditions for the anadromous fish populations in the Stanislaus River should also continue. The 2021 data is of particular interest as it can be used to further understand the impact of drought and low water years on anadromous species. Additionally, it is a required monitoring program as stated in the NMFS BiOp and can be used to help determine the success of habitat rehabilitation and species reintroduction. This data can then also be used to guide water management modifications including timing of pulse flows which may influence juvenile Chinook Salmon emigration.

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Appendix 1: **Points of interest on the Stanislaus River.**

Point of Interest	Significance	Operator	River Mile (rkm)
New Melones Dam	Constructed 1978; Flood control, power generation, water supply, recreation.	U.S. Bureau of Reclamation	60 (96.6)
Tulloch Dam	Constructed 1957; Flood control, power generation, water supply, recreation.	Tri-Dam Project	55 (88.5)
Goodwin Dam	Constructed 1913; Flood control, water supply.	U.S. Bureau of Reclamation	58.4 (94)
Lover's Leap	Habitat improvement; Gravel augmentation		53.4-51.8 (85.9-83.4)
Lancaster Road	Habitat improvement; side channel restoration project		~41 (65.9)
Oakdale	RST site for monitoring juvenile salmonid abundance and outmigration	FishBio Consulting	40.1(64.5)
Stanislaus River at Ripon (Hwy 99 Bridge)	River discharge and temperature monitoring station	U.S. Geological Survey	15.8 (25.4)
Upper Irrigation Pump at Caswell	Release site for trap efficiency mark-recapture trials		8.9 (14.3)
Caswell Memorial State Park	RST site for monitoring juvenile salmonid abundance and outmigration		8.6 (13.8)
Mouth of Stanislaus River	Stanislaus-San Joaquin Confluence		0

Appendix 2: **Weekly environmental conditions on the Stanislaus 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	9.2	8.0	10.9	240	193	372	11.50	11.50	11.50	0.26	0.26	0.26	0.3	0.3	0.3
1/15 - 1/21	10.1	8.1	11.5	192	189	196	10.10	8.79	11.30	0.80	0.15	1.90	0.3	0.3	0.4
1/22 - 1/28	8.7	7.4	10.2	222	185	492	10.76	10.13	11.67	1.55	0.50	3.43	0.3	0.2	0.4
1/29 - 2/4	10.6	8.9	12.3	377	234	772	9.39	8.48	11.71	11.66	2.54	28.10	0.4	0.3	0.5
2/5 - 2/11	10.9	9.2	13.0	242	211	372	10.15	9.90	10.64	1.71	1.20	2.21	0.3	0.2	0.5
2/12 - 2/18	11.1	9.4	12.9	488	368	562	10.35	9.26	11.05	2.66	1.76	4.59	0.5	0.3	0.7
2/19 - 2/25	11.3	10.2	12.7	424	284	560	10.58	10.15	11.58	1.74	0.97	2.48	0.4	0.2	0.5
2/26 - 3/4	11.8	10.2	13.1	291	231	521	9.88	9.20	11.10	1.02	0.27	1.63	0.3	0.2	0.5
3/5 - 3/11	12.2	10.7	13.6	427	356	548	10.38	10.05	11.24	2.95	0.91	5.83	0.4	0.3	0.5
3/12 - 3/18	12.2	10.4	14.0	371	246	477	10.55	9.76	11.20	3.08	1.23	4.43	0.5	0.3	0.7
3/19 - 3/25	13.9	12.1	15.8	224	208	268	9.45	9.09	9.84	2.76	1.66	5.47	0.4	0.2	0.5
3/26 - 4/1	15.3	12.8	17.8	351	267	401	9.62	8.99	10.24	3.42	1.17	5.39	0.4	0.3	0.6
4/2 - 4/8	16.1	14.5	17.7	374	365	397	9.57	9.10	9.95	2.72	1.24	4.15	0.5	0.3	0.6
4/9 - 4/15	15.4	13.6	17.5	658	365	1050	9.65	8.70	10.27	2.54	0.87	5.00	0.6	0.3	0.8
4/16 - 4/22	15.5	13.9	17.2	778	480	1080	9.59	8.80	10.45	2.69	1.43	5.61	0.6	0.3	0.9
4/23 - 4/29	14.6	12.9	17.2	1003	688	1310	10.03	8.47	10.70	3.33	1.23	6.52	0.7	0.5	0.9
4/30 - 5/6	18.1	15.2	22.2	534	319	806	8.49	7.24	9.43	3.33	1.47	4.94	0.4	0.3	0.4
5/7 - 5/13	17.9	15.0	20.8	714	353	1360	8.97	7.47	9.90	3.88	2.23	6.69	0.9	0.8	0.9
5/14 - 5/20	16.0	14.5	17.4	1006	714	1350	9.35	9.12	9.54	3.22	1.34	4.47	0.7	0.5	0.9
5/21 - 5/27	17.1	14.6	19.4	633	574	711	9.27	8.42	10.11	3.20	1.56	4.32	0.6	0.5	0.8
5/28 - 6/3	19.6	17.4	21.5	579	554	693	8.65	8.23	9.18	3.07	2.03	5.08	0.7	0.5	0.8

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

Appendix 3: List of fish species caught during the 2021 Stanislaus River rotary screw trap survey season.

Common Name	Family Name	Species Name	Total
Chinook salmon	Salmonidae	Oncorhynchus tshawytscha	199
Bigscale logperch	Percidae	Percina macrolepida	1
Black crappie	Centrarchidae	Pomoxis nigromaculatus	1
Bluegill	Centrarchidae	Lepomis macrochirus	110
Golden shiner	Cyprinidae	Notemigonus crysoleucas	12
Hardhead	Cyprinidae	Mylopharodon conocephalus	4
Largemouth bass	Centrarchidae	Micropterus salmoides	2
Pacific lamprey	Petromyzontidae	Lampetra entosphenus	3,429
Prickly sculpin	Cottidae	Cottus asper	6
Riffle sculpin	Cottidae	Cottus gulosus	4
Sacramento pikeminnow	Cyprinidae	Ptychocheilus grandis	13
Sacramento sucker	Catostomidae	Catostomus occidentalis	5
Smallmouth bass	Centrarchidae	Micropterus dolomieu	17
Spotted bass	Centrarchidae	Micropterus punctulatus	258
Threadfin shad	Clupeidae	Dorosoma petenense	2
Unknown bass (Micropterus)	Centrarchidae	Micropterus sp.	10
Unknown lamprey (Entosphenus or Lampetra)	Petromyzontidae		15
Unknown minnow	Cyprinidae		3
Unknown sculpin (Cottus)	Cottidae	Cottus sp.	1
Unknown sunfish (Lepomis)	Centrarchidae	Lepomis sp.	3
Wakasagi / Japanese smelt	Osmeridae	Hypomesus nipponensis	1
Warmouth	Centrarchidae	Lepomis gulosus	1
Western mosquitofish	Poeciliidae	Gambusia affinis	15
White catfish	Ictaluridae	Ameiurus catus	374

Appendix 4: Genetic results for fin-clip samples from Chinook Salmon caught in the Stanislaus River during the 2021 survey season.

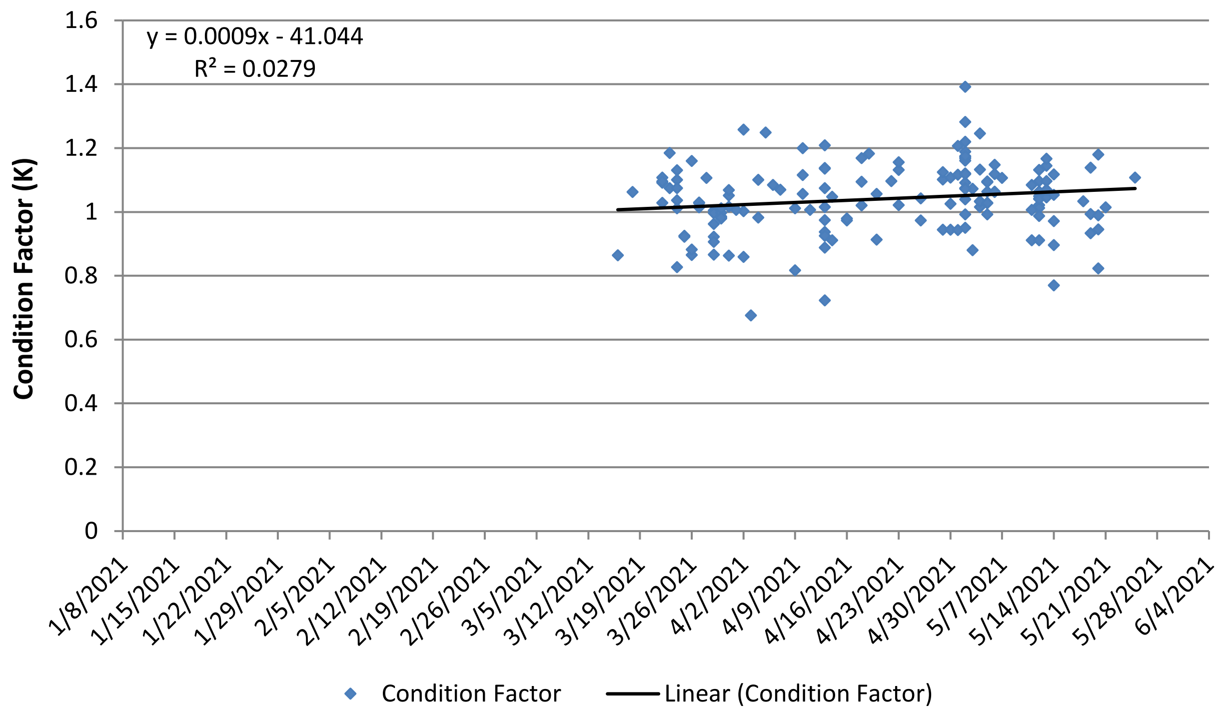
Sample #: refer to a unique number assigned by field staff, and that allowed the tracking of individual fish samples.
LAD run assignment: Chinook Salmon run assignment based on the length-at-date run assignment methodology developed by Greene (1992).
SNP Run Assignment: Chinook Salmon run assignment using “Genetic Call to four 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.

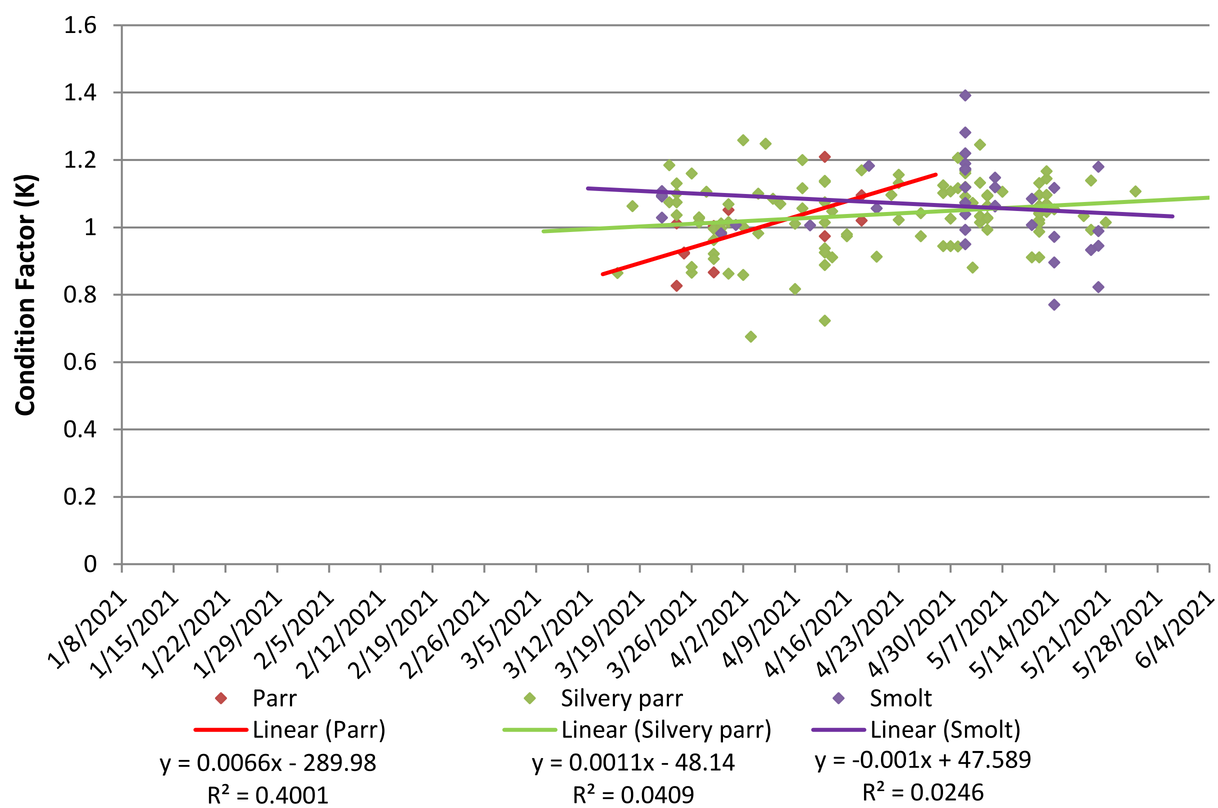
Date	Sample #	LAD Run Assignment	SNP Run Assignment	SNP Probability	Final Run Assignment	FL (mm)	W (g)
1/31/2021	3731-001	Fall	Fall	1.00	Fall	34	-
1/31/2021	3731-002	Fall	Fall	1.00	Fall	33	-
1/31/2021	3731-005	Fall	Fall	1.00	Fall	32	-
2/21/2021	3731-006	Fall	Fall	1.00	Fall	34	-
2/21/2021	3731-008	Fall	Fall	1.00	Fall	37	-
3/2/2021	3731-007	Fall	Fall	1.00	Fall	35	-
3/16/2021	3731-009	Spring	Fall	1.00	Fall	67	2.6
3/18/2021	3731-010	Spring	Fall	1.00	Fall	87	7.0
3/22/2021	3731-012	Spring	Fall	1.00	Fall	92	8.5
3/22/2021	3731-013	Spring	Fall	1.00	Fall	90	7.5
3/22/2021	3731-014	Winter	Fall	1.00	Fall	95	9.5
3/22/2021	3731-011	Spring	Fall	1.00	Fall	79	5.4
3/23/2021	3731-015	Spring	Fall	1.00	Fall	76	5.2
3/23/2021	3731-016	Spring	Fall	1.00	Fall	79	5.3
3/24/2021	3731-017	Spring	Fall	1.00	Fall	86	7.0
3/24/2021	3731-018	Spring	Fall	1.00	Fall	78	5.1
3/24/2021	3731-019	Spring	Fall	0.99	Fall	84	6.7
3/24/2021	3731-020	Spring	Fall	1.00	Fall	74	4.1
3/24/2021	3731-021	Spring	Fall	1.00	Fall	74	4.2
3/25/2021	3731-022	Fall	Fall	1.00	Fall	61	2.1
3/25/2021	3731-023	Fall	Fall	1.00	Fall	68	2.9
3/26/2021	3731-024	Spring	Fall	1.00	Fall	76	3.8
3/26/2021	3731-025	Spring	Fall	1.00	Fall	74	4.7
3/26/2021	3731-027	Spring	Fall	1.00	Fall	93	7.1
3/27/2021	3731-029	Spring	Fall	1.00	Fall	77	4.7
3/27/2021	3731-030	Spring	Fall	1.00	Fall	83	5.8
3/27/2021	3731-031	Spring	Fall	1.00	Fall	88	7.0
3/28/2021	3731-026	Spring	Fall	1.00	Fall	82	6.1
3/29/2021	3731-028	Spring	Fall	1.00	Fall	81	4.9

3/29/2021	3731-032	Spring	Fall	1.00	Fall	82	5.0
3/29/2021	3731-033	Spring	Fall	1.00	Fall	80	5.1
3/29/2021	3731-034	Spring	Fall	1.00	Fall	74	3.9
3/30/2021	3731-035	Spring	Fall	1.00	Fall	93	7.9
3/30/2021	3731-036	Spring	Fall	1.00	Fall	82	5.4
3/30/2021	3731-037	Spring	Fall	1.00	Fall	78	4.8
3/30/2021	3731-038	Spring	Fall	1.00	Fall	77	4.5
3/30/2021	3731-039	Spring	Fall	1.00	Fall	88	6.8
3/31/2021	3731-040	Spring	Fall	1.00	Fall	82	5.8
3/31/2021	3731-041	Spring	Fall	1.00	Fall	86	6.8
3/31/2021	3731-042	Spring	Fall	1.00	Fall	81	5.4
4/1/2021	3731-044	Spring	Fall	1.00	Fall	93	8.1
4/2/2021	3731-045	Spring	Fall	1.00	Fall	92	9.8
4/2/2021	3731-046	Spring	Fall	1.00	Fall	87	6.6
4/2/2021	3731-047	Spring	Fall	1.00	Fall	80	4.4
4/3/2021	3731-048	Spring	Fall	1.00	Fall	86	4.3
4/4/2021	3731-050	Spring	Fall	1.00	Fall	93	7.9
4/4/2021	3731-049	Spring	Fall	1.00	Fall	86	7.0
4/5/2021	3731-051	Spring	Fall	1.00	Fall	84	7.4
4/6/2021	3731-052	Spring	Fall	1.00	Fall	86	6.9
4/7/2021	3731-053	Spring	Fall	0.99	Fall	82	5.9
4/9/2021	3731-054	Spring	Fall	1.00	Fall	86	5.2
4/9/2021	3731-055	Spring	Fall	1.00	Fall	94	8.4
4/10/2021	3731-057	Spring	Fall	1.00	Fall	87	7.9
4/10/2021	3731-058	Spring	Fall	1.00	Fall	90	7.7
4/11/2021	3731-059	Spring	Fall	1.00	Fall	86	6.4
4/13/2021	3731-060	Spring	Fall	1.00	Fall	90	7.4
4/13/2021	3731-061	Spring	Fall	0.99	Fall	80	5.5
4/13/2021	3731-062	Spring	Fall	1.00	Fall	79	5.6
4/14/2021	3731-063	Spring	Fall	1.00	Fall	84	5.4
4/14/2021	3731-064	Fall	Fall	1.00	Fall	76	4.6
4/16/2021	3731-066	Fall	Fall	1.00	Fall	76	4.3
4/16/2021	3731-065	Fall	Fall	1.00	Fall	79	4.8
4/18/2021	3731-067	Fall	Fall	1.00	Fall	70	3.5
4/18/2021	3731-068	Spring	Fall	1.00	Fall	87	7.7
4/18/2021	3731-069	Fall	Fall	1.00	Fall	77	5.0
4/19/2021	3731-070	Spring	Fall	1.00	Fall	97	10.8
4/20/2021	3731-073	Fall	Fall	1.00	Fall	74	3.7
4/20/2021	3731-074	Spring	Fall	1.00	Fall	90	7.7
4/23/2021	3731-072	Spring	Fall	1.00	Fall	94	9.4
4/23/2021	3731-075	Spring	Fall	0.99	Fall	86	6.5
4/23/2021	3731-076	Spring	Fall	1.00	Fall	93	9.3
4/26/2021	3731-077	Fall	Fall	1.00	Fall	79	4.8

4/26/2021	3731-078	Fall	Fall	1.00	Fall	85	6.4
4/29/2021	3731-079	Spring	Fall	1.00	Fall	90	8.2
4/29/2021	3731-080	Fall	Fall	1.00	Fall	83	6.3
4/29/2021	3731-081	Fall	Fall	1.00	Fall	85	5.8
4/30/2021	3731-082	Fall	Fall	1.00	Fall	84	5.6
4/30/2021	3731-083	Fall	Fall	1.00	Fall	85	6.8
5/1/2021	3731-084	Fall	Fall	1.00	Fall	82	5.2
5/1/2021	3731-085	Fall	Fall	1.00	Fall	83	6.9
5/2/2021	3731-086	Spring	Fall	1.00	Fall	101	12.1
5/2/2021	3731-087	Spring	Fall	1.00	Fall	93	9.0
5/2/2021	3731-088	Spring	Fall	1.00	Fall	98	13.1
5/2/2021	3731-089	Spring	Fall	1.00	Fall	97	11.7
5/2/2021	3731-090	Fall	Fall	1.00	Fall	89	8.6
5/2/2021	3731-091	Fall	Fall	1.00	Fall	83	6.7
5/2/2021	3731-092	Fall	Fall	1.00	Fall	89	7.0
5/2/2021	3731-093	Spring	Fall	1.00	Fall	96	9.2
5/2/2021	3731-094	Spring	Fall	1.00	Fall	91	8.8
5/2/2021	3731-095	Fall	Fall	1.00	Fall	78	5.1
5/4/2021	3806-050	Spring	Fall	1.00	Fall	92	9.7
5/5/2021	3731-098	Spring	Fall	1.00	Fall	93	8.8
5/5/2021	3731-099	Spring	Fall	1.00	Fall	92	8.0
5/5/2021	3731-096	Fall	Fall	1.00	Fall	89	7.0
5/5/2021	3731-097	Fall	Fall	1.00	Fall	89	7.5
5/6/2021	3806-051	Fall	Fall	1.00	Fall	86	7.3
5/6/2021	3806-052	Spring	Fall	1.00	Fall	96	9.4
5/11/2021	3731-100	Fall	Fall	1.00	Fall	93	8.1
5/11/2021	3806-054	Spring	Fall	1.00	Fall	96	9.6
5/13/2021	3806-055	Fall	Fall	1.00	Fall	86	-
5/13/2021	3806-056	Fall	Fall	1.00	Fall	88	7.8
5/13/2021	3806-057	Fall	Fall	1.00	Fall	84	6.5
5/18/2021	3806-058	Fall	Fall	1.00	Fall	82	5.7

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





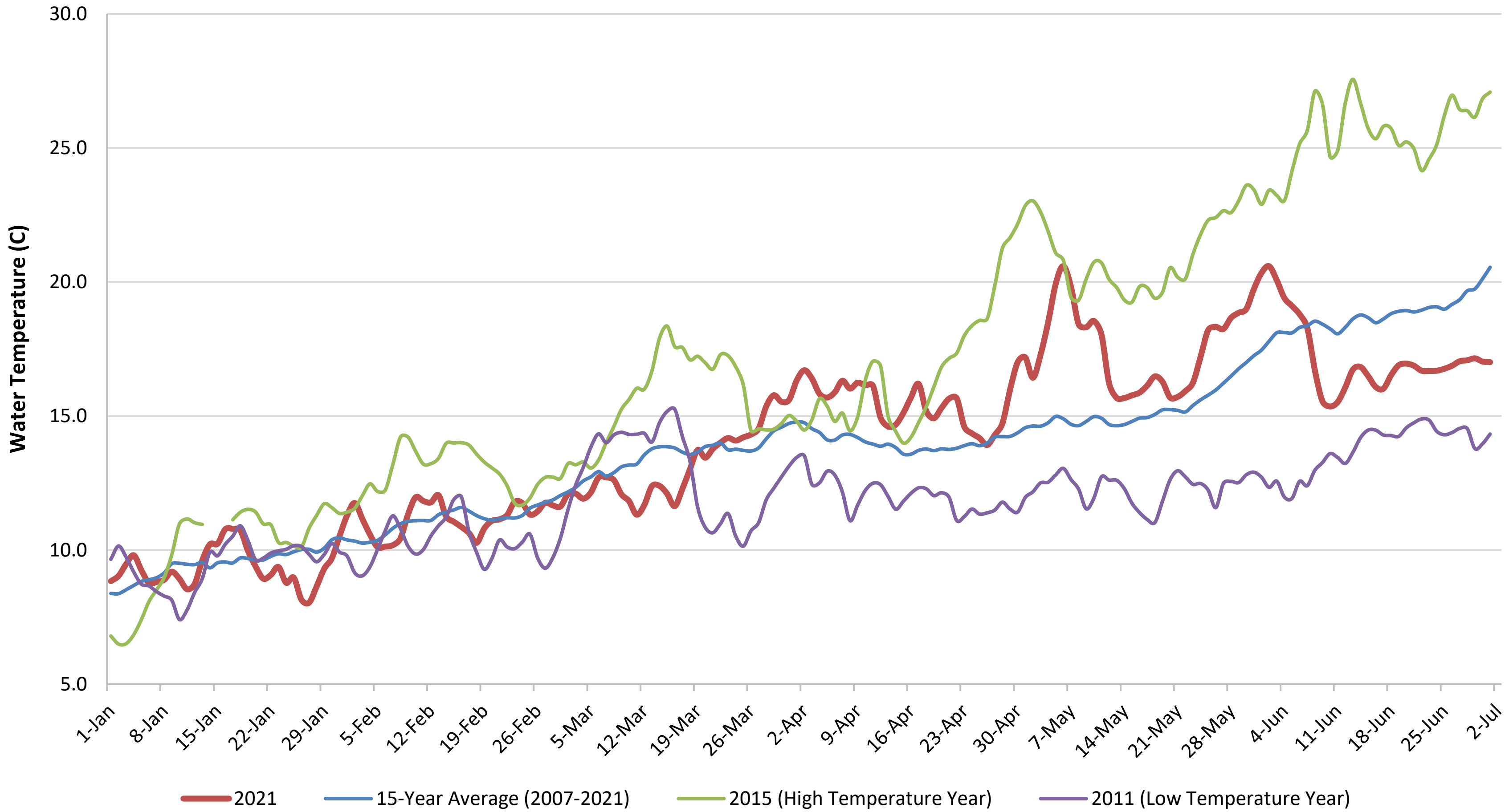
Appendix 6: Median seasonal discharge (cfs), total catch of fall-run, late fall-run, winter-run, and spring-run Chinook Salmon, steelhead, and lamprey and the associated passage estimate with 95% confidence intervals (CI) for fall-run Chinook Salmon from the 1996 – 2021 Stanislaus River rotary screw trap sampling seasons.

		Total Catch						Passage Estimate	
Year	Discharge	Fall-run	Late Fall-run	Winter-run	Spring-run	Steelhead	Lamprey	Fall-run	95% CI
1996	1,561	2,468	0	0	0	4	857	54,218	[35,733–60,137]
1997	1,701	2,357	0	0	0	11	57	57,586	[44,828–75,666]
1998	2,047	19,525	0	0	0	4	445	1,557,561	[899,587–3,474,805]
1999	1,536	41,234	0	0	0	12	969	1,568,699	[1,334,966–2,413,635]
2000	1,366	73,715	0	0	0	15	4,356	2,338,070	[1,461,824–2,623,188]
2001	532	9,907	0	0	0	34	9,762	93,747	[88,356–N/A]
2002	541	3,835	0	0	0	10	210	45,982	[33,720–50,275]
2003	606	14,059	0	0	0	13	476	136,397	[127,369–179,869]
2004	440	40,087	0	0	0	19	3,589	490,554	[287,261–549,557]
2005	384	25,287	0	0	0	11	5,551	236,279	[187,019–299,694]
2006	3,250	1,589	0	0	0	2	9	375,327	[199,617-836,170]
2007	1,055	2,909	0	0	0	23	502	134,561	[48,417–741,089]
2008	508	230	0	0	0	1	1,010	32,063	[5,535–54,020]
2009	403	767	0	0	0	5	1,074	5,349	[3,156–5,743]
2010	455	1,102	0	0	0	1	5,011	16,994	[8,181–25,129]
2011	1,416	605	0	0	0	2	545	N/A	N/A
2012	637	1,199	0	0	0	3	265	34,235	[20,298–54,952]
2013	498	19,072	0	0	0	4	276	381,702	[161,693–550,092]
2014	353	2,083	0	0	0	3	1,304	23,582	[14,222–46,110]
2015	258	905	0	0	0	2	1,162	10,750	[8,814–N/A]
2016	332	2,207	0	0	0	2	11,839	28,492	[24,662–47,726]
2017	1,940	8,246	0	0	0	0	5	613,144	[217,351–831,859]
2018	1,249	3,515	0	0	1	0	272	222,000	[162,000–293,500]
2019	2,130	6,498	0	0	0	0	686	979,000	[529,400–2,824,000]
2020	872	912	0	0	0	2	1,624	166,720	[70,570–632,500]
2021	450	199	0	0	0	0	3,444	30,264	[21,830 – 151,300]

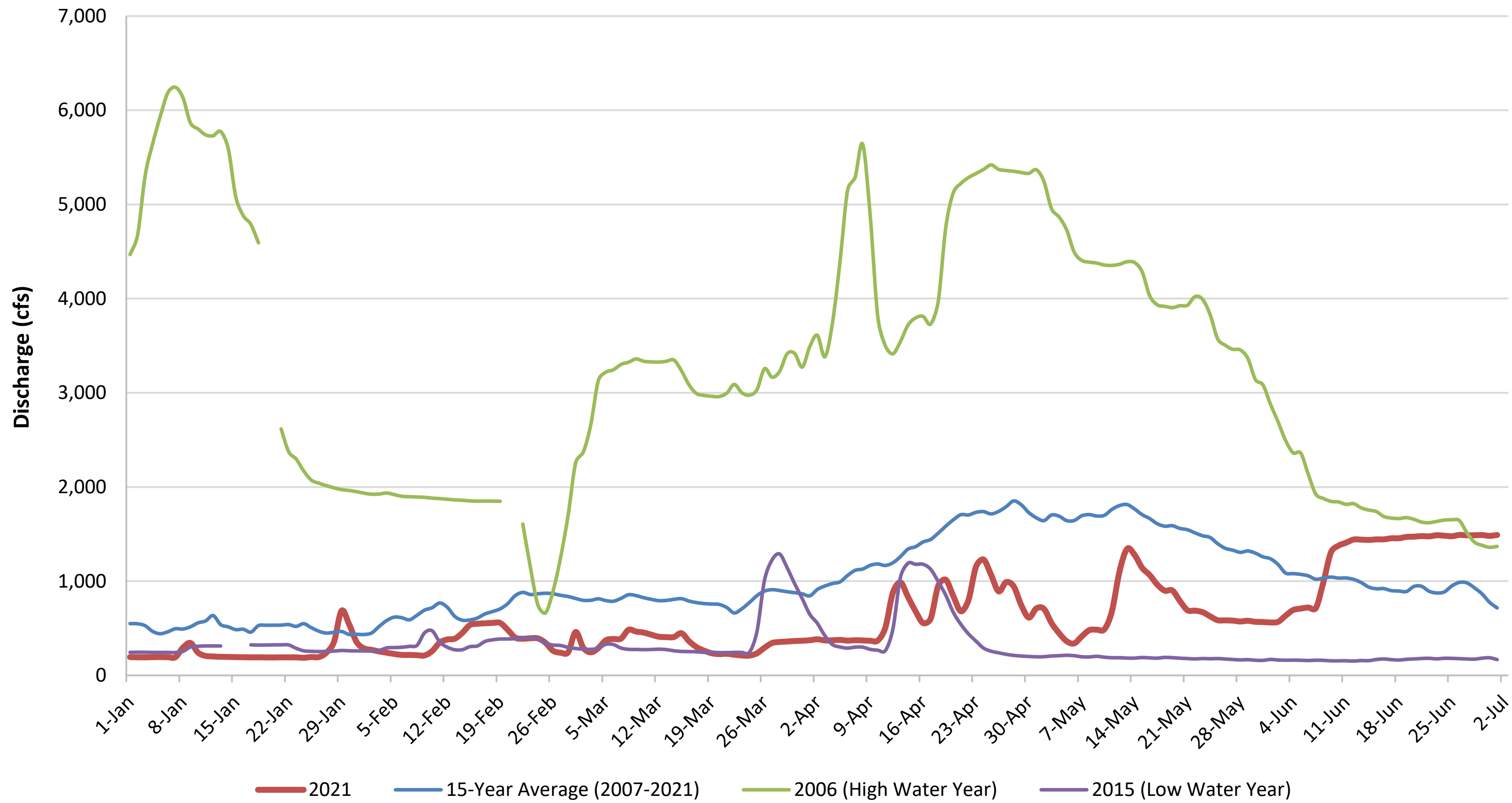
Note: Historical catch is only intended to be used as a baseline reference due to changes in sampling methodology (e.g., number of traps used, length of sampling season, and variability in sampling location) and how production estimates were calculated (CFS 2016, PSMFC 2017 – 2021).

Discharge: Is based on the annual median discharge between January 1 and June 30 from USGS at Ripon, Station #11303000.
Lamprey: Includes adult and all juvenile life stages of Petromyzontidae.
Passage Estimate and CI: Adopted from table 6 of CFS 2016 annual report and from PSMFC 2017 – 2020 annual reports.

Appendix 7: **Daily average water temperature (°C) in the Stanislaus River at Ripon for the 15 year period 2007-2021, the highest temperature year, the lowest temperature year, the 15 year average and the current year (2021). Data from USGS station number 11303000.**



Appendix 8: **Daily average discharge (cfs) on the Stanislaus River at Ripon 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 11303000.**



Appendix 9: 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
Stanislaus	*ST004L1 (1002)*	*–1.846 – 0.0007(flow) – 0.009(depth) + 1.096(velocity)*
	ST004L1B (1003)	*–4.447 + 2.523(moon proportion) – 0.017(depth) + 0.038(turbidity) + 1.294(velocity)*

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