Juvenile Spring-Run Chinook Salmon Production, Survival, and Emigration in the San Joaquin River Restoration Area

2020–21 Monitoring and Analysis Report

SAN JOAQUIN RIVER
RESTORATION PROGRAM

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Self-Certification of Peer Review

This report has been peer reviewed by the following two individuals, at least one of whom is from outside my work group:

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I certify that, to my best knowledge, these individuals are qualified to review this work, and that they have peer reviewed this report.

Zachary Sutphin

PI Signature

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1.0 Introduction

In 1988, a coalition of environmental groups, led by the Natural Resources Defense Council (NRDC), filed a lawsuit challenging the renewal of long-term water service contracts between the United States and the Central Valley Project Friant Division Long-Term Contractors. After more than 18 years of litigation of this lawsuit, known as NRDC et al. vs. Rodgers et al., 2006, a stipulation of the settlement (Settlement) was reached. The Settlement establishes two primary goals: (1) Restoration—to restore and maintain fish populations in "good condition" in the mainstem San Joaquin River (SJR) below Friant Dam to the confluence of the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish and (2) Water Management—to reduce or avoid adverse water supply impacts on all of the Friant Division long-term contractors that may result from the Interim and Restoration Flows provided for in the Settlement.

The Settlement, though, does not define the process for restoring and maintaining fish populations. Resultantly, the Fisheries Framework was developed to provide "a realistic schedule for implementation of the fisheries management actions," while defining goals and objectives towards reestablishing Chinook Salmon (*Oncorhynchus tshawytscha*) in the Restoration Area (SJRRP 2018). Within the Framework, stressors are identified (e.g., predation, water quality, entrainment), and a plan is provided for reducing these stressors. Furthermore, it provides measurable metrics to evaluate progress towards producing self-sustaining populations of fall-run and spring-run Chinook Salmon. The use of rotary screw trap (RST) monitoring allows evaluation of these objectives; specifically, RST monitoring may help estimate juvenile passage rate, fry-to-smolt survival, and juvenile production. Evaluation of these objectives using RSTs may also help identify areas within the monitoring locations that may be adversely impacting juvenile salmon survival and emigration success.

Juvenile migration success has been posited as one limited factor for sustaining spring-run and fall-run Chinook Salmon in the Restoration Area (SJRRP 2018). Since salmon have been extirpated from the area following the construction of Friant Dam in the 1940s, limited data are available regarding juvenile Chinook Salmon emigration, timing, and survival prior to recent reintroduction efforts (e.g., adult trap and haul, juvenile releases, broodstock releases). The 2020–21 season marks the fourth consecutive year of rotary screw trap monitoring for spring-run Chinook Salmon. Prior to that, juvenile tracking and monitoring efforts were limited to fall-run Chinook Salmon (Hueth et al. 2017; Sutphin et al. 2018). While volitional adult salmon passage to spawning grounds in the RA was not possible in spring 2020, 285 (136 females, 148 males, and 1 unknown) spring-run adult broodstock were released into Reach 1 following rearing efforts at California Department of Fish and Wildlife's Interim Salmon Conservation and Research Facility (hereafter, referred to as SCARF) located in Friant, California (Demarest et al. 2022). An additional 48 adult salmon (16 females, 16 males, and 16 unknowns) were also released into Reach 1 after capture and transport from Reaches 4–5 as a result of the SJRRP adult spring-run Chinook Salmon Trap and Haul project (Sutphin and Root 2021). Offspring from these spawning adults comprised the juvenile spring-run salmon described herein. Data collected through these activities will continue to provide information regarding juvenile spring-run

Chinook Salmon production, emigration timing, survival, and growth, and will assist management understanding current population conditions as well as progress towards meeting those criteria in the Fisheries Framework. In turn, this will help to determine whether future restoration efforts are appropriate or need to be re-evaluated to meet the conditions of the Settlement.

1.1 Objectives

Data collected during RST monitoring provide an estimate of juvenile spring-run Chinook Salmon production, survival, growth and emigration timing from the spawning grounds, and how environmental conditions impact these metrics. Previous years' data can be combined with those proposed for collection in this study to evaluate annual trends and fluctuations for juvenile spring-run Chinook Salmon. The following are the target objectives of this study, and will assist San Joaquin River Restoration Program (SJRRP) management with decisions regarding continued restoration activities and establish a long-term plan for juvenile monitoring:

1) Estimate natural production of juvenile spring-run Chinook Salmon from the spawning grounds in Reach 1.

2) Estimate survival rates of juvenile spring-run Chinook Salmon through the Restoration Area where rotary screw traps are installed and identify sections where higher rates of loss may occur.

3) Evaluate migration timing of juvenile spring-run Chinook Salmon from spawning areas in Reach 1 to downstream areas where rotary screw traps are installed.

4) Identify factors that may influence natural production, survival rates, and migration timing (e.g., flow, temperature, fish size).

5) Genetically determine total spawners contributing to progeny captured in rotary screw traps.

6) Determine growth of individuals recaptured in rotary screw traps, identified through genetic analyses.

7) When efforts would not otherwise preclude meeting the above objectives, and when approved by the Restoration Program, opportunistically support additional California fisheries studies by providing data or field samples (e.g., supply fish for pathological analyses for the California-Nevada Fish Health Center, provide lamprey tissue samples for UC Davis to help address population structure and gene flow factors in California).

2.0 Materials and Methods

2.1 Study Sites and Schedule

Rotary screw traps are frequently used to monitor juvenile salmon movements and estimate production (Thedinga et al. 1994; Volhardt et al. 2007; Pilger et al. 2019). Rotary screw traps (2.4-m diameter) were placed at four locations in Reaches 1–2 (Figure 1) of the Restoration Area: Owl Hollow (RM 259), Scout Island (RM 250), Highway 99 (Highway 99; RM 243), and San Mateo crossing (RM 212). Redd locations were considered for RST placement and installation was contingent upon site accessibility and suitability. Proper trap operation requires adequate water depth (approximately half the depth of the cone diameter, or ~1.2 m deep) to allow unimpeded rotation of the RST cone and sufficient velocity (nominally 0.8–2.0 m/s; Volhardt et al. 2007) to physically rotate the cone. Traps were placed in the thalweg to maximize the volume of water sampled. For production estimates, ideal placement of RSTs is at the downstream extent of the spawning area (Volhardt et al. 2007); screw traps interspersed between redds allow for estimates of survival and site-specific production rates within the spawning area. During 2020 SJRRP redd and carcass surveys, 73 redds were detected, the majority (97.3 percent) of which were upstream of the Owl Hollow RST (Demarest et al. 2022). The Scout Island RST is located downstream of an abandoned in-river mine pit that likely affects movement patterns of juvenile salmon in Reach 1. It is also approximately midway between the upstream Owl Hollow RST and downstream Highway 99 RST. The Highway 99 RST was placed downstream of all observed spring-run salmon redds (Demarest et al. 2022) and is near the most downstream extent of adult fall-run Chinook Salmon spawning in the Restoration Area (Castle et al. 2016). The RST at San Mateo Crossing was selected because this location was upstream of significant impediments to fish movement (e.g., Mendota Dam and Sack Dam) and provided an opportunity to estimate survival and production through Reach 2.

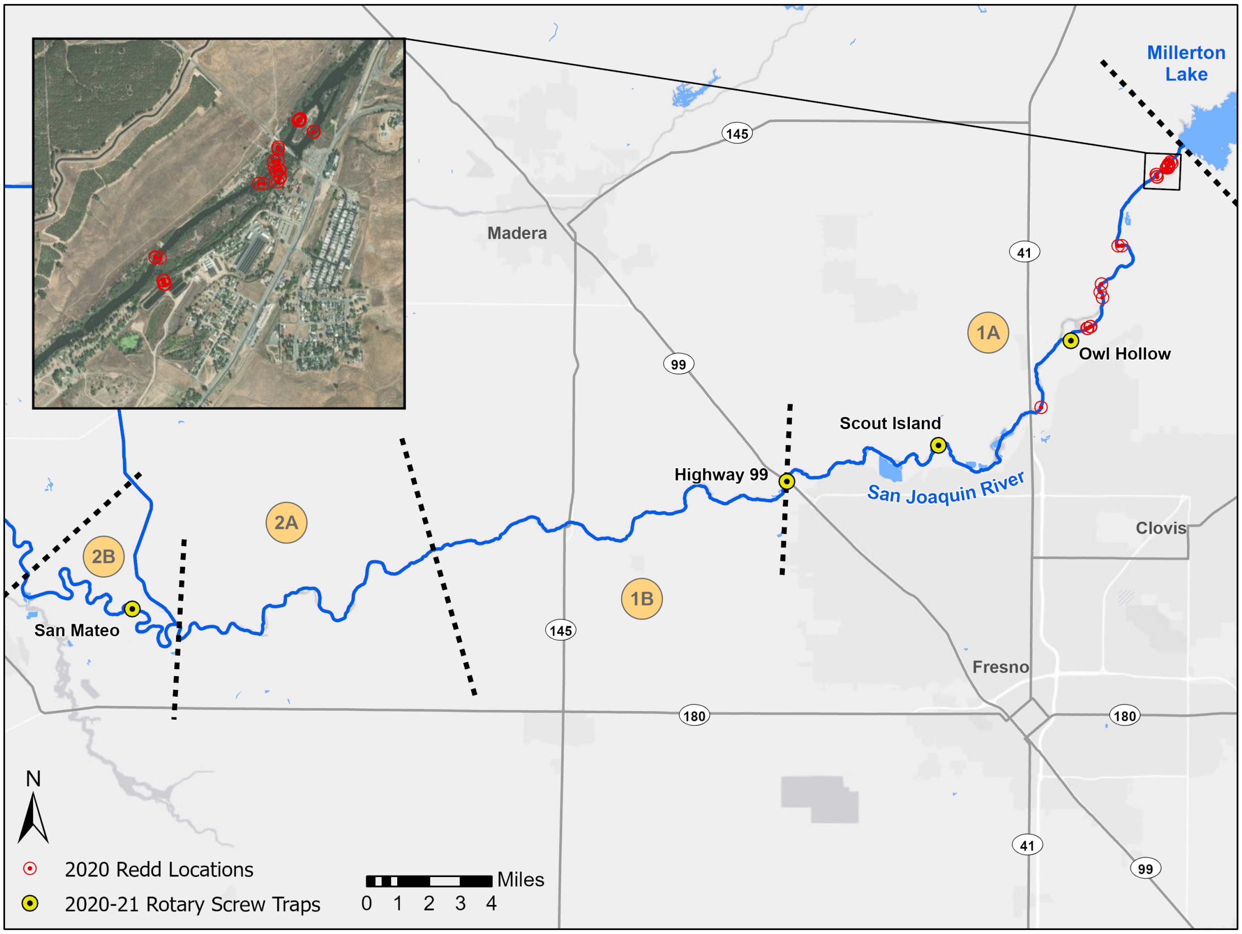

Figure 1.—Recorded salmon redds (open red circles) and rotary screw trap locations (solid yellow/black circles) in the San Joaquin River Restoration Area during the 2020–21 sampling season. Black dashed lines indicate reach/subreach delineations, and the numbered circles indicate those subreaches. Map provided by Andrew Minks, Bureau of Reclamation, Sacramento, California.

Periods of trap operation are listed in Table 1. As a result of the limited catch at downstream locations during the 2019–20 sampling season (Hutcherson et al. 2023), and to capture yearling fish that may have remained in the spawning grounds (Bourret et al. 2016), the three downstream RSTs were operated beginning October 2020, one month earlier than in previous seasons. The Owl Hollow RST was placed into operation November 1. Sampling at the San Mateo RST was suspended April 30 when water temperatures at the location reached the Section 10(a)(1)(A) threshold of 24°C. Trap operation at Owl Hollow was halted May 16 after a mechanical malfunction and was it was decided not to return it to operation with the limited catch rates at that time. And the Scout Island and Highway 99 RSTs were removed from operation May 28, following reduced rates of capture indicated continued operation was no longer necessary.

Table 1.— Sampling dates for rotary screw trap (RST) locations during 2020–21 sampling season.

RST Site	Start	Stop
Owl Hollow	November 1, 2020	May 17, 2021
Scout Island	October 2, 2020	May 28, 2021
Highway 99	October 2, 2020	May 28, 2021
San Mateo	October 5, 2020	April 30, 2021

2.2 Trap Placement and Operation

At all but the San Mateo location, RSTs were secured with a 13-mm (1/2-in.) wire rope attached high enough from the water surface to allow passage for recreational river usage (e.g., kayakers, fishermen). Affixed to the highline was a snatch block that permitted lateral positioning of the RST for optimal operation. Each RST was attached to the snatch block with two 10-mm (3/8-in.) wire ropes—one connected to the front of each RST pontoon. Two additional 10-mm (3/8 in.) wire ropes connected to the snatch block were secured on either side to the high line using wire rope clips that prevented lateral movement after the RST was suitably located. These also allowed for repositioning the screw trap from the shoreline after loosening the clamps from each side. Buoys and lights placed up and downstream of each RST alerted recreationalists to its presence. Figure 2 illustrates the installed Owl Hollow RST in operation. Site conditions at the San Mateo RST location were such that the trap could be located adjacent to the river margin, allowing the wire ropes to be situated at water level on only one side of the river (no high line needed).

Figure 2.—Owl Hollow rotary screw trap attached to high line wire rope via snatch block (not visible) and smaller diameter wire ropes (made apparent to recreationalists using pink flagging). Lateral rope, connected to shoreline, on downstream side of trap prevents excessive swaying.

Following installation, traps were lowered into the fishing position. They were checked daily for proper operation and to remove captured fish. Site conditions were recorded, including trap operation (i.e., rotating or not), temperature, dissolved oxygen, and turbidity. Additionally, dissolved oxygen and temperature loggers were also affixed to each trap that recorded values at 30-minute intervals throughout the season. Debris loads were categorically annotated (low, medium, high) based on the proportion of the live well filled with debris (no debris to one-third full, one- to two-thirds full, and more than two-thirds full, respectively) and subsequently cleared. Traps were scrubbed as necessary to remove accumulated algae/debris. Captured fish were enumerated and processed (see *Fish Processing* below) and released downstream of the RST. When any of the RSTs could not be checked in a 24-hour period (e.g., flood releases exceeding safe operation), personnel raised and secured the cone in the non-fishing position until safe operation could resume.

2.3 Fish Processing

Fish were removed daily during RST checks. Salmon were anesthetized in a solution of 40–60 mg/L MS-222 (tricaine methanesulfonate) before processing. Wild fish were differentiated from efficiency fish (see *Efficiency Tests* section below) by the presence of an adipose fin and lack of identifying marks. They were measured for fork (FL; mm) and total length (TL; mm), and a tissue sample was collected from the caudal fin for genetic analysis. Salmon greater than 45mm FL were weighed (nearest 0.1 g). Salmon were classified as yolk-sac fry, fry, parr, smolt, or yearling based on criteria in Volkhardt et al. (2005); Cramer Fish Sciences (CFS 2014) provides a Smolt Index Protocol that further elaborates on this differentiation and the RST protocol (USFWS 2008) includes a visual representation of fish within each age class. Anesthetized fish were allowed recovery time in a bucket of fresh water prior to release. When trap-specific capture totals exceeded 90 individuals, 90 spring-run Chinook Salmon were subsampled, and the remainder enumerated.

Bycatch were identified to species, when possible. In some cases, fish too small to identify without the aid of magnification (e.g., young-of-year *Micropterus* and cyprinid spp.) were identified only to family or genus. Bycatch were enumerated and measured to total length (TL; nearest mm). In cases where numbers of any one species exceeded 20 at an RST, a subsample of 20 fish was measured for length, and the remaining fish were enumerated. Bycatch are not discussed within the body of this report, but data are available in Appendix A. Likewise, fish submitted for additional analyses (e.g., Fish Health Center histopathology analyses) are available in Appendix B. After processing and recovery, all fish were transported in the recovery bucket and released approximately 30 m downstream of the RST to minimize the likelihood of recapture at the same location.

2.4 Efficiency Tests

Accurate estimation of RST efficiency is needed to determine total passage of juvenile salmon past each installed trap. Since RST efficiency can be affected by variables like environmental conditions and fish sizes (Pilger et al. 2019), each of the four RSTs was evaluated at regular intervals to determine trap efficiency through the sampling season. For each RST location, efficiency releases were completed every 1 to 3 weeks (on average, every 1.6 weeks across release locations; see Appendix B for more details), using marked hatchery fish. During the 2020–21 sampling season, efficiency fish were released December 8, 2020 to May 13, 2021. These were spring-run Chinook Salmon raised at the SCARF. As of this document, all juvenile salmon released into the Restoration Area are required to receive a coded wire tag (CWT) prior to release. Two sizes of CWT are available, half-size (0.5 mm) and full size (1.1 mm). For full size CWTs, fish were required to be a minimum of 55 mm FL for tagging, and only fish tagged with a full-size CWT received a colored fin tag.

Since fry are primarily captured during the early portion of the sampling season at the upstream sample sites, three efficiency evaluations were completed at each of the two upstream RSTs (Owl Hollow and Scout Island) using groups of half-size CWT salmon; fish as small as 35 mm FL were tagged with half-size CWTs during the 2020/21 sampling season. These evaluations were completed mid-December through early-January at both upstream RSTs. Each fish was fin-clipped prior to release, to permit identification thereafter. Releases were completed as described below for the marked efficiency fish.

Beginning late January, all subsequent efficiency releases used fish tagged with full-size CWTs and marked using a needleless, CO_2-powered injector (NEWWEST Technologies, LLC., Santa Rosa, CA). Tag color was provided by using tattoo ink and diluted 12-to-1 with distilled water. Fish were size-graded prior to marking, and the size variation was limited to no more than 10 to 15 mm for each release group. Replicate groups were uniquely colored and marked (Figure 3). By varying the color and fin combinations for every RST and release date, staff could ascribe recaptured fish to specific releases. A subsample of 100 fish/release site replicate were measured (FL/TL [mm]; weight [g]) to describe morphometrics of each group. Fish were typically given a 48-h recovery period prior to release.

Figure 3.—Example of hatchery-reared, marked spring-run Chinook Salmon *(Oncorhynchus tshawytscha*) used for rotary screw trap efficiency tests. Of note: for demonstration purposes, all of the four fins used to indicate specific efficiency release groups are shown marked here. Fish in specific release groups typically only have one fin marked.

Following recommendations made in the Fish and Wildlife Service's Comprehensive Assessment and Monitoring Program, rotary screw trap protocol (CAMP protocol; USFWS 2008), fish were released 400–800 m upstream of each RST location. Fish were released at civil twilight because wild salmon outmigration typically occurs at night (Chapman, et al. 2013).

During subsequent RST checks, staff recorded the location/color of the mark of salmon having such markings. Following initial efficiency testing, all salmon subsequently captured the remainder of the field season were checked for the presence of a colored mark. Fish processing and release procedures were like those for wild salmon and are outlined in the *Fish Processing* section above, though no tissue samples were collected from efficiency release fish.

2.5 Analyses

2.5.1 Genetic Analyses

The Southwest Fisheries Science Center Santa Cruz Laboratory received 1,213 tissue samples from juvenile Chinook Salmon captured in RSTs and 52 tissue samples from emergence traps from the San Joaquin River during the 2020–21 trapping season. Using standard laboratory protocols, DNA was extracted, and all individuals genotyped with a set of 214 microhaplotype genetic markers (Baetscher et al. 2018), which consists mostly of highly variable markers for pedigree analysis, as well as a small set (n = 10) for identification of genotypes in the chromosome 28 region strongly associated with seasonal migration timing in Chinook Salmon (i.e., fall- vs. spring- vs. winter-run; Thompson et al. 2020). These microhaplotype markers also include the majority of the 96 single-nucleotide polymorphism (SNP) markers that have been employed throughout the project to date (Clemento et al. 2014). Importantly, since this set of loci has been used to genotype all SCARF broodstock individuals, their progenitors at the Feather River Hatchery, and a comprehensive baseline of Central Valley and other Chinook

Salmon populations, they allow both parentage-based analyses, as well as stock identification and traditional population genetic analyses.

Analysis of these samples proceeded incrementally. Duplicate genotypes from fish sampled multiple times, analogous to recaptures in a mark-recapture framework, were first identified. Size data were analyzed to estimate growth rates of these recaptured fish. With respect to all tissue samples collected, it was determined that some of the captured salmon were not offspring of the spring-run broodstock released into the system. An attempt was made to assign these juvenile fish to multiple pools of adults, both those known in the system, and others potentially contributing offspring to juvenile production—potential parents included SCARF captive broodstock adults and broodstock from the Feather River Hatchery (the source of SCARF broodstock and their siblings). For juveniles sampled from the RSTs that were not assigned to two parents, an alternative analysis technique was employed (COLONY software; Jones and Wang 2010) that allows for identification of single parents, when only one has been sampled, and the *de novo* assembly of full-sibling groups by inferring the genotypes of unsampled parents.

2.5.2 Rotary Screw Trap Efficiency and Production

Trap efficiency is based on the ratio of recaptured, marked fish, to the total number of released, marked fish. These ratios can be applied to the number of wild fish captured to estimate the total number of fish (i.e., those juveniles produced from in-river redds, regardless of maternal origin) moving past each RST. *Post hoc* genetic analysis of tissue samples collected from salmon permitted the opportunity to reveal potential recaptures at all RST locations. Any recaptures at the same location were only counted during the initial instance of capture. Under the constraints of RST efficiency evaluations, several assumptions were made (Volhardt et al. 2007; USFWS 2008):

- hatchery fish are representative of wild fish, both in size and behavior
- all fish have equal probability of capture
- marked fish remain readily identifiable within each efficiency interval
- all released fish move downstream and have an equal opportunity to encounter downstream RSTs
- trap efficiency is constant within each efficiency interval
- the population is closed

Seasonal production was estimated using the daily catch and the corresponding RST efficiency rate at each trap location for spring-run Chinook Salmon—since these estimates rely on the total number of wild salmon captured at each RST, production can also be considered the total number of spring-run Chinook Salmon passing each RST location. Any other captured salmonids (e.g., fall-run Chinook Salmon, other *Oncorhynchus spp.*) were excluded from these analyses. Production at each RST was estimated both as a total of all spring-run Chinook Salmon and, more specifically, as a function of maternal origin. Based on results of the genetic analysis, juveniles were ascribed to a maternal origin of one of three classes: SCARF broodstock, adult salmon captured during Trap and Haul efforts in Reaches 4 and 5, or unknown adults. The following description for evaluating production was used for both approaches, with the aforementioned distinctions considered.

The following stratified mark-recovery approach from (Carlson et al. 1998), and further outlined in (Volhardt et al. 2007) and the CAMP protocol ([USFWS] 2008), was used to estimate production and associated variance for each efficiency interval:

$$\hat{n}_i = \frac{u_i(M_i + 1)}{m_i + 1}$$

$$v(\hat{n}_i) = \frac{(M_i + 1)(u_i + m_i + 1)(M_i - m_i)u_i}{(m_i + 1)^2(m_i + 2)}$$

Where n_i is the estimated production and $v(n_i)$ is the variance for the production estimates in interval i, u_i is the unmarked fish in interval i, M_i is the number of marked fish released in interval i, and m_i is the number of marked fish recaptured in the corresponding RST during interval i. Interval i constitutes the period between one efficiency release group and the next. Prior to the first release, and following the last, the nearest efficiency estimate was used to estimate fish production during such periods. For example, the first efficiency release at Highway 99 was January 31. Trap efficiency calculated at this interval was used to estimate production of wild fish from trap installation until the next efficiency release on February 14.

At each RST, total production and the associated variance over the sampling season is the sum across all efficiency release periods:

$$\hat{N} = \sum_{i=1}^{n} \hat{n}_i$$

$$V(\hat{N}) = \sum_{i=1}^{n} v(\hat{n}_i)$$

Traps were occasionally placed in the non-fishing position (e.g., over holidays, during periods of high flows when trap access was considered unsafe). Furthermore, trap operation was sometimes inhibited as a result of debris preventing RST rotation. To account for fish that would have otherwise been captured during these periods, missed salmon were calculated by the slope of the line across the non-fishing period using catch before and after this interval:

$$c_i = (d_i)\left[{}^{(c_n - c_0)}\big/_{(D_{NF} + 1)}\right] + c_0$$

Where c_i is the catch on day, d_i, of the non-fishing period, c_0 is the catch the day before the non-fishing period, c_n is the catch the day after the non-fishing period, and D_{NF} is the total days in the non-fishing period.

2.5.3 Survival of Wild Salmon

Two methods were used for estimating survival. The first, described here, is an approach that evaluates differences in total wild salmon estimates at each RST location (Thedinga et al. 1994; Pyper and Justice 2006). One assumption of this approach, though, is that juvenile production occurs upstream of the RST locations. Therefore, estimates at downstream RSTs would account for losses through those respective sections between RST locations, and be indicative of downstream survival. While not all redds were located upstream of Owl Hollow, the majority (~97.3 percent; 71 of 73 redds) were identified upstream of this location during redd surveys from August–November 2020 (Demarest et al. 2022). The pro of using wild salmon is that it is the most direct approach to estimate absolute survival across the sampling season. By estimating how many salmon are produced from the spawning grounds in Reach 1 and successfully emigrate beyond downstream RSTs, these efforts will provide data towards answering Objective 2 above as well as the fry-to-smolt survival objective established in the Fisheries Framework (SJRRP 2018).

2.5.4 Survival of Efficiency Release Groups

The second method used to estimate survival relies on recaptured efficiency fish, which are hatchery-reared fish identified with a color-fin mark combination. Because residence time of wild salmon encompasses the entire season, and since specific redds from which each fish emerges are not readily identifiable, estimating environmental changes contributing to survival is not currently possible with this cohort. Conversely, each efficiency group is introduced to the river at a specific location and time and recaptured fish are readily identifiable because of the applied colored fin marks. Since efficiency fish often move more rapidly than wild fish (Hutcherson et al. 2021) and they are easily identifiable, evaluating effects of environmental conditions on survival is more feasible using these fish. Survival using efficiency fish release groups was estimated using the same process outlined in Hutcherson et al. (2021):

> Survival…was estimated using the recapture of marked fish between RSTs (Hutcherson et al. 2020). The…total number of marked fish from each efficiency test, released at upstream RSTs, and surviving to the Highway 99 RST, is estimated as the sum product,
>
> $$\sum \left({}^{1}/_{e_i}\right) m_{ij}$$
>
> using the following matrices:
>
> $$\begin{bmatrix} e_1 \\ e_2 \\ \vdots \\ e_i \end{bmatrix} \begin{bmatrix} m_{11} & m_{12} & \dots & m_{1j} \\ m_{21} & m_{22} & \dots & m_{2j} \\ \vdots & \ddots & \ddots & \vdots \\ m_{i1} & m_{i2} & \dots & m_{ij} \end{bmatrix}$$

Where e_i is the efficiency of the Highway 99 RST during interval i, m_{ij} is the number of marked fish from the upstream efficiency group j (from either upstream RST releases), captured in the i^{th} interval. Survival for each marked release is then estimated using:

$$\frac{\left[\Sigma\left({}^{1}/_{e_i}\right) m_{ij}\right]}{M_j}$$

where Mj is the total number of marked fish, M, released in group j. See Appendix B for an example.

Survival estimates were calculated for each release group between release location and the next downstream RST (i.e., Owl Hollow–Scout Island, Scout Island–Highway 99, Highway 99–San Mateo). The average across all efficiency release groups, for each stretch of river between RST locations, was then calculated. Table 2 identifies the stretches between RST locations and the total river miles in between. In addition to the difference in total distance between RSTs, unique factors, specific to each stretch, might also affect juvenile salmon survival (e.g., presence of mine pits, indistinct thalweg). To help standardize survival estimates between stretches and provide meaningful comparisons that could exist because of specific conditions, when stretches are unequal lengths, survival was calculated as a function of RM. Survival by RM was calculated by x^{1}/RM, where x is the initial survival estimate for the release group, and RM is the total river miles between RST locations (Table 2).

Table 2.—Rotary screw trap stretches, and river miles between trap locations, used to evaluate survival of juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) released during rotary screw trap efficiency evaluations during 2020–21 monitoring efforts.

Rotary screw trap stretches	River Miles Between Rotary Screw Traps
Owl Hollow–Scout Island	8.4
Scout Island–Highway 99	7.1
Highway 99–San Mateo Crossing	31.1

To evaluate potential differences in survival between the Owl Hollow and Scout Island reach, and the Scout Island to Highway 99 reach, a paired t-test was used. Only releases within 24 hours of one another were used for comparison. The Highway 99 to San Mateo reach was not evaluated due to the number of zeros in the data set (six of nine efficiency release groups).

Date of release, water temperature, flow, and average size of the fish within each release group were initially considered for analysis to determine factors influencing survival rates. Water temperature was collected using temperature loggers deployed at each RST during the sampling season (Figure 1). Daily averages were calculated from 30-minute continuous logging intervals. Flow data were downloaded from the California Data Exchange Center website (CDEC.water.ca.gov) from gaging stations downstream of Friant Dam near Lost Lake Recreation Area (RM 265), near Highway 41 (RM 255), and downstream of Chowchilla Bifurcation Structure (RM 216). Average daily flow was calculated using 15-min recorded intervals from those three gaging stations. Fork and total length (mm), and weight (g) were recorded for 10 percent of each efficiency group, for each RST, during the tagging process.

Pearson Product Moment Correlation was used to evaluate collinearity among the independent variables: date of release, average flow following release, average water temperature following release, and average fork length of each efficiency release group. Among these variables, date of release, temperature, and fish size had a significantly strong correlation ($r > 0.9$, $p < 0.01$). Flow, temperature, and fish size may be a predictor of downstream migration rates (Solomon 1978; Giorgi et al. 1997; Sykes et al. 2009); however, since date of release shares a correlation with temperature and fish size (i.e., as the season progresses, fish are growing and water temperatures are increasing), date of release was further excluded from these analyses. Best subsets regression was used to evaluate the flow, temperature, and fish size with relation to survival from Owl Hollow to Scout Island and from Scout Island to Highway 99. Variance inflation factors (VIF) in excess of four indicated multicollinearity in these models; factors were reduced as necessary and the appropriate regression analyses completed. For the previously mentioned reason, the Highway 99 to San Mateo reach was not included in these analyses. An alpha value, $\alpha = .05$, was used to determine statistical significance in the aforementioned analyses.

2.5.5 Daily growth rate

Recaptures of wild salmon, identified through genetic analyses, were used to evaluate growth rates in the Restoration Area. The difference in recorded weights between capture events was divided by the total days between recapture to determine absolute growth, or the daily growth rate (Hopkins 1992). Only salmon captured more than two weeks apart were included in these analyses to permit suitable time for measurable growth between capture events, permitting fish to recover from handling stress, and allowing sufficient time between measuring where the precision of the measuring equipment would have negligible effects on measured weights. When the initial event of capture included salmon less than 45 mm TL, the initial weight was estimated based on length weight regressions from the current season. Results are compared to juvenile objectives in Fisheries Framework ([SJRRP] 2018).

3.0 Results

3.1 Salmon Capture at Rotary Screw Traps

A total of 1,461 salmon were captured across the four RSTs during the 2020–21 field season (Table 3). Of the total catch, 1,213 fish were sampled for genetic analyses (Garza and Clemento 2023). Of those, 27 were excluded from the analyses due to missing data at 100 loci or more of the genetic markers. All but five of the processed samples were determined to be spring-run at the Region of Strongest Association (RoSA) markers (Figure 4). Four of those five fish were non-Chinook salmon, based on genetic analyses, and the fifth sample was determined to be a non-Chinook salmonid based on length-at-date. Of the tissue samples where maternal origin was determined, a total of 810 were from trap and haul adults released in Reach 1 after capture in Reaches 4–5 and 288 were from broodstock fish released in Reach 1 from the SCARF. The maternal identification of the remaining samples was categorized as "unknown." The difference between the total fish captured and processed samples were the result of either fish not sampled for analysis (e.g., instances of high capture when plus counts were recorded, fish not sampled before being returned to the river), or where processing issues precluded determination. These fish were categorized based on length-at-date—Figure 4 identifies captured fish by total length (mm) and date of capture. A prediction band (99 percent confidence that spring-run Chinook Salmon lie within this band) was developed from the genetically identified spring-run fish to help distinguish between spring-run Chinook Salmon and non-spring-run salmonids captured. Salmonids captured during the 2020–21 sampling season that were identified as non-Chinook salmonids through genetic analyses were likely either hatchery escapees or offspring from resident salmonids. Only fish classified as spring-run Chinook Salmon during the 2020–21 sampling season were included in production and survival estimates.

Table 3.—Total salmon (*Oncorhynchus spp.*) captured during 2020–21 rotary screw trap operation in the San Joaquin River Restoration Area. Italicized numbers indicate total fish, by subgrouping (maternal origin), captured within respective groups (in bold). The "unknown" category includes those fish that were not sampled for genetic analyses or with insufficient data for genotyping, and ultimately categorized based on length-at-date.

	Owl Hollow	**Scout Island**	**Highway 99**	**San Mateo**	**Totals**
Spring-run Chinook Salmon	1,180	88	186	2	1,456
Trap & Haul	706	51	97	1	855
Broodstock	227	21	41	1	290
Unknown	247	16	48	0	311
Other salmonids	4	0	1	0	5

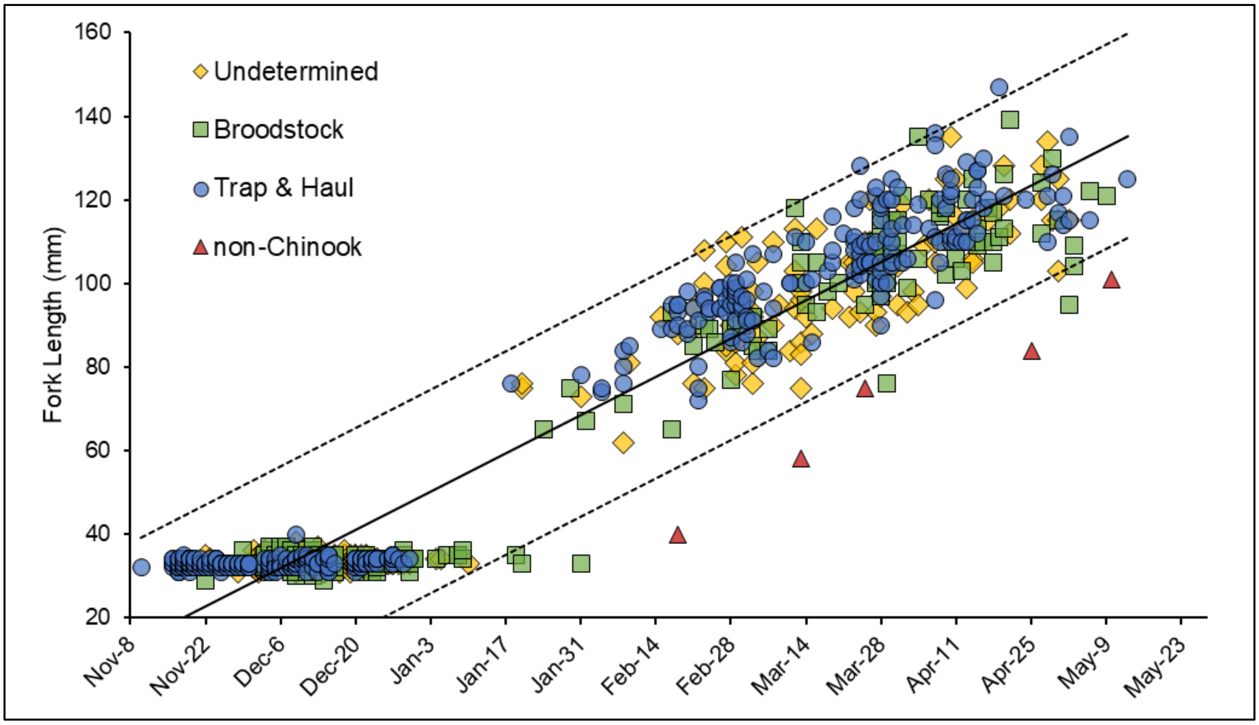

Figure 4.—Genetic results of sampled fish and subsequent prediction bands (dashed lines; 99 percent) based on size and date of capture for spring-run Chinook Salmon (*Oncorhynchus tshawytscha*) captured during the 2020–21 sampling season. Unknown fish (identified by yellow diamonds) had insufficient genetic data to confidently categorize. Non-Chinook salmonids were either identified via genetic analyses (n=4) or otherwise categorized based on length-at-date and lack of identifying genetic results (n=1).

The majority of spring-run Chinook Salmon were captured as fry from November–January at the Owl Hollow RST (Figure 5). There was a period of reduced catch mid-January and relatively few parr-sized salmon (40–60 mm FL) were captured (Figure 4). After this period of time, the majority of fish captured the remainder of the season were predominately smolts (> 60 mm FL), captured across the four RST locations.

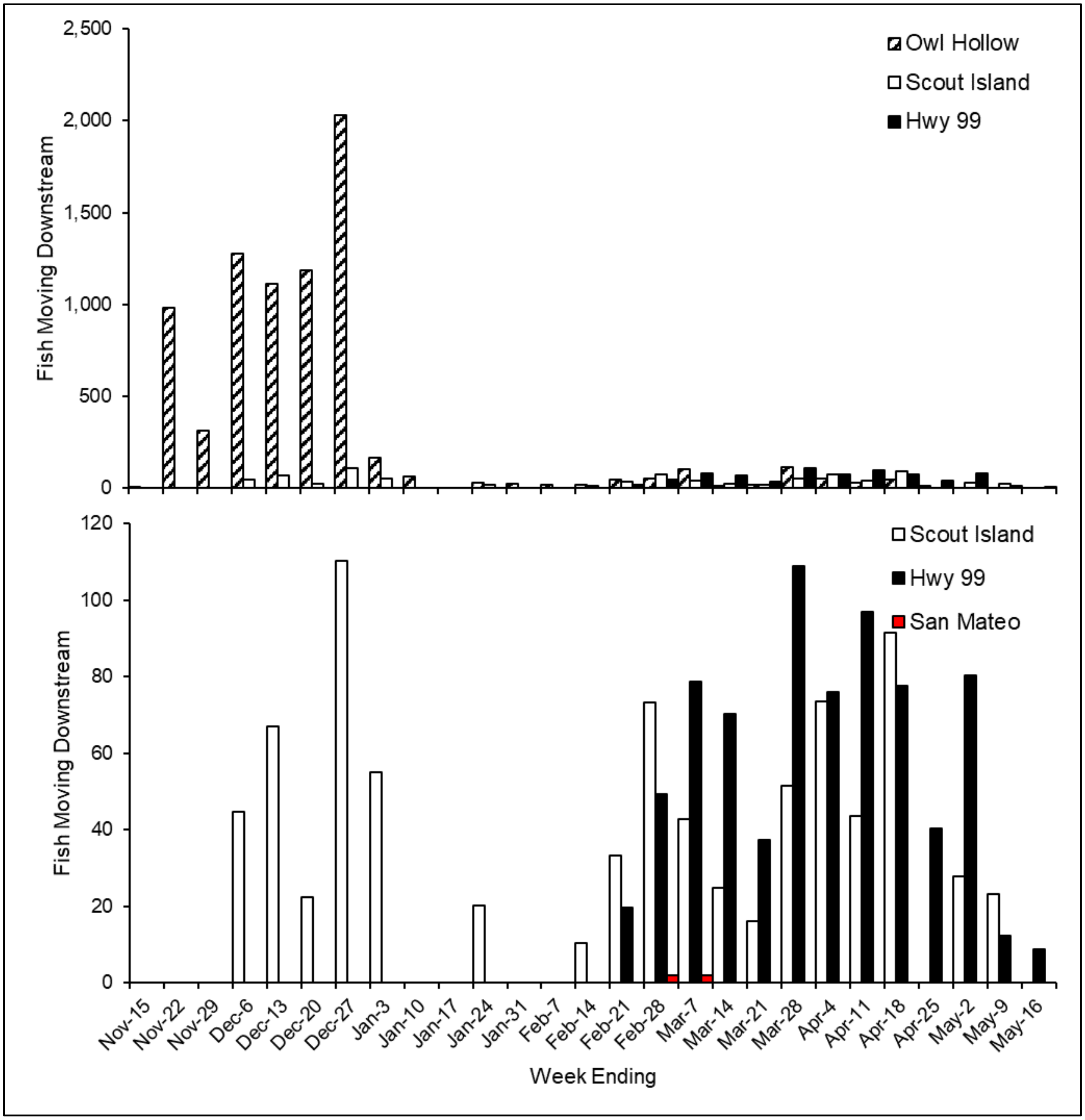

Figure 5.—Weekly estimates of spring-run Chinook Salmon (*Oncorhynchus tshawytscha*) at each rotary screw trap (RST) location in Reaches 1–2 of the San Joaquin River Restoration Area during the 2020–21 sampling season. The top figure includes the three upstream RSTs and the bottom figure depicts total salmon at each of the three downstream RSTs—note the difference in the scale of the y-axis between the top and bottom figure.

3.2 Rotary Screw Trap Efficiency and Production

Mean RST trap efficiencies ranged from 10.6–24.5 percent (Table 4). Efficiency estimates for each interval at the four RST locations are presented in Appendix C.

Table 4.—Average rotary screw trap (RST) efficiency estimates and corresponding standard deviation, for groups of marked juvenile Chinook Salmon released during the 2020–21 monitoring season.

RST Location:	Efficiency (percent):	±Std. Dev. (percent):
Owl Hollow	17.7%	6.0%
Scout Island	10.6%	4.7%
Highway 99	23.1%	5.1%
San Mateo	24.5%	28.6%

Weekly production estimates for spring-run Chinook Salmon were greatest at Owl Hollow during November and December, declining the remainder of the season. At Owl Hollow, the production estimate for spring-run Chinook Salmon was 7,713 ± 2,102 (± 95 percent CI; Figure 6). The total estimated salmon passing the Scout Island and Highway 99 RST was 832 (±196) and 776 (± 105), respectively. And the total salmon estimated to have made it to San Mateo was almost nonexistent at only 4 salmon (± 4). Of the progeny where the maternal identification was known (based on genetics), estimates of trap and haul salmon at Owl Hollow exceeded those of broodstock progeny three-to-one (Figure 7); however, the trap and haul progeny are only represented by 10 female adults and broodstock progeny at Owl Hollow are ascribed to a known 36 females (Figure 8). When evaluating average female production at Owl Hollow for the progeny whose maternal identification was known, trap and haul females produced, on average, about 10 times as many offspring as broodstock adults (Figure 9).

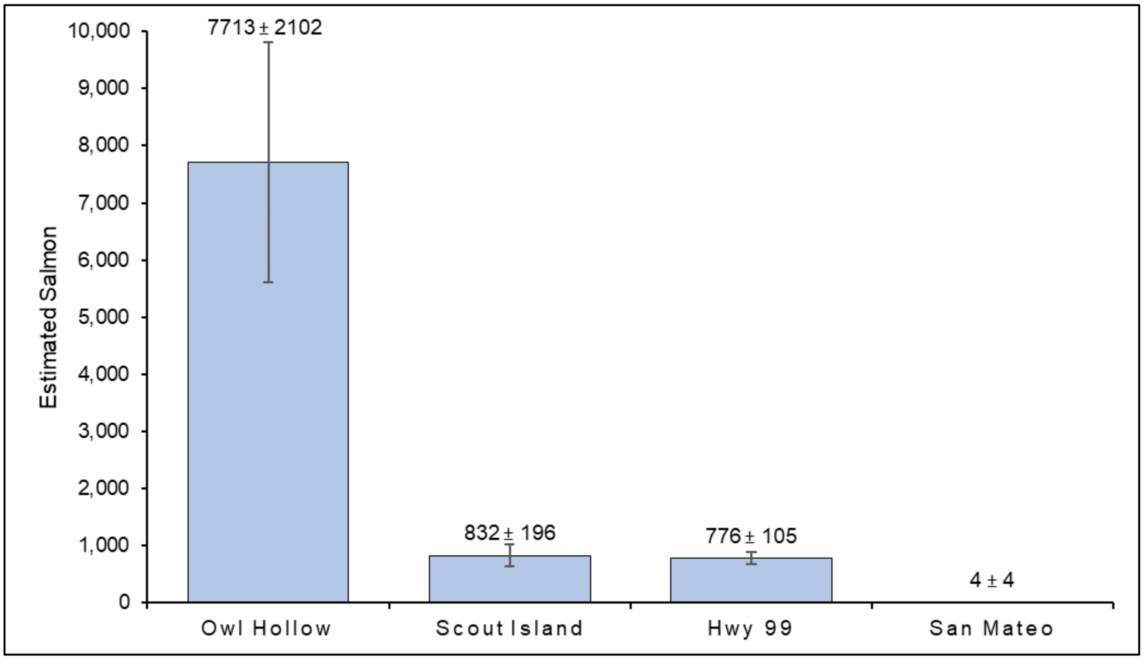

Figure 6.—Total (± 95 percent confidence interval) estimated juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) passing each rotary screw trap location in Reaches 1 and 2 of the San Joaquin River Restoration Area during the 2020–21 sampling season.

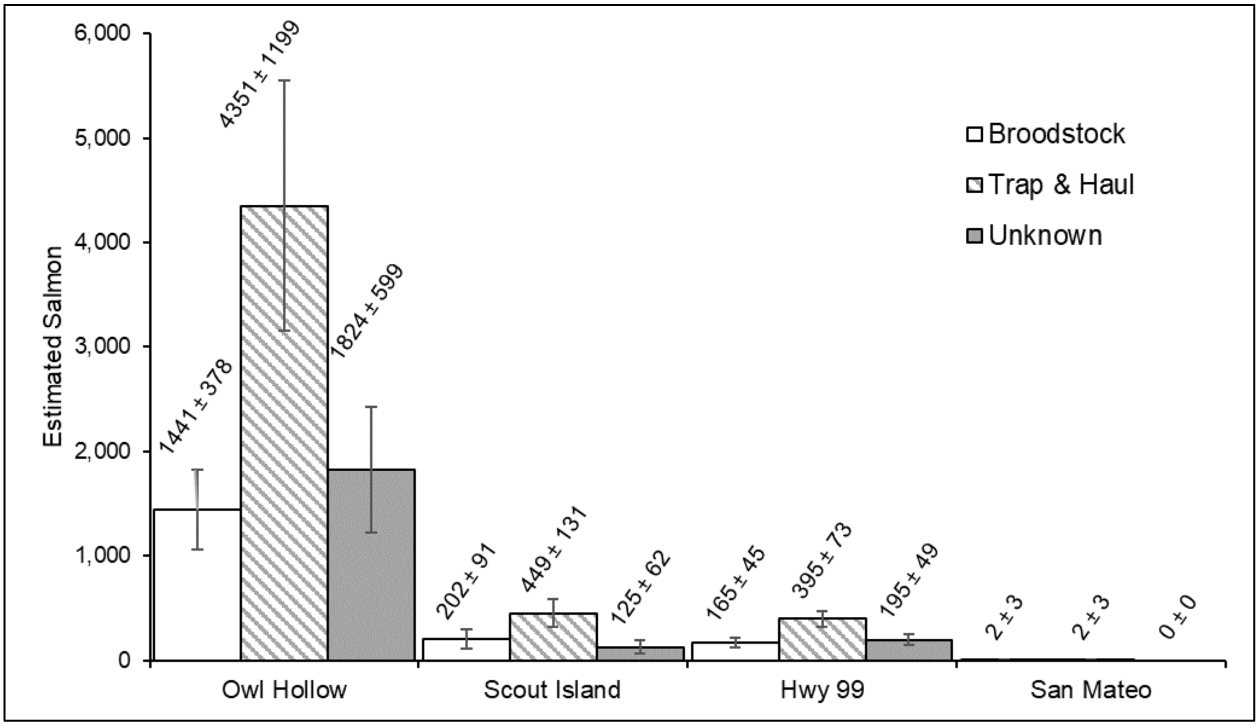

Figure 7.—Total spring-run Chinook Salmon (*Oncorhynchus tshawytscha*), by maternal origin, estimated at each rotary screw trap location in Reaches 1–2 of the San Joaquin River Restoration.

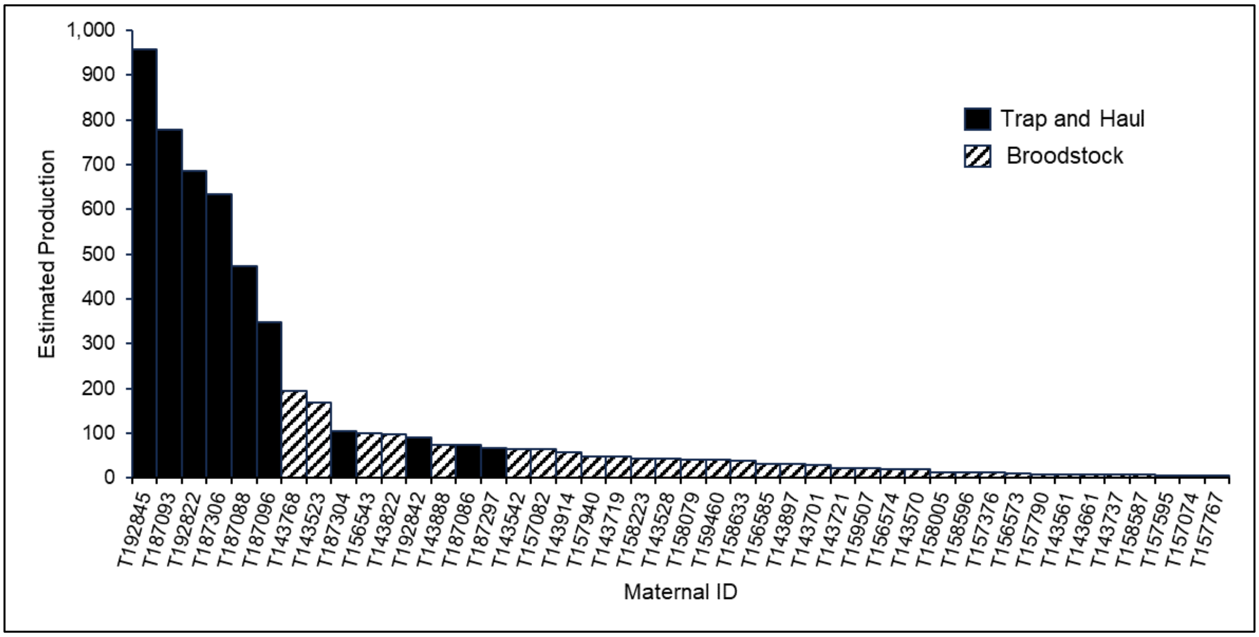

Figure 8.—Estimated family group size of Chinook Salmon (*Oncorhynchus tshawytscha*), as a function of maternal ID and origin (i.e., broodstock adults or trap and haul-captured salmon), passing the Owl Hollow rotary screw trap during the 2020–21 sampling season.

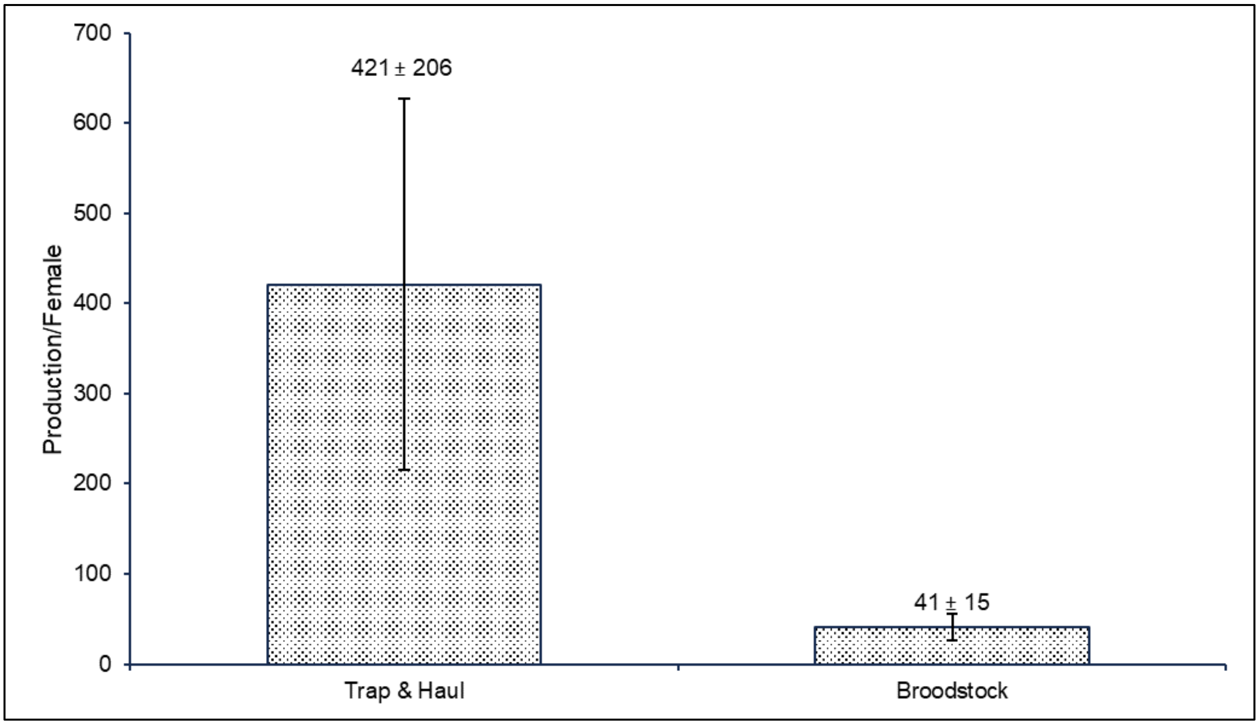

Figure 9.—Average spring-run Chinook Salmon (*Oncorhynchus tshawytscha*) production per female, at the Owl Hollow rotary screw trap, as a function of maternal origin. Error bars represent the 95 percent confidence interval of the mean.

3.3 Survival of Wild Salmon

Since nearly all surveyed redds were upstream of the Owl Hollow RST (71 of 73 surveyed redds, or ~97.3 percent; Demarest et al. 2022), survival to downstream RSTs was estimated by evaluating the difference in total salmon moving past each RST location (Figure 6). Overall survival from Owl Hollow to Scout Island was 10.8 percent (Table 5). Survival from Scout Island to Highway 99, though, was much greater (by a factor of 5.8 to 8.7), depending on maternal origin. And survival to San Mateo, regardless of origin was negligible. Again, it is important to note that this method of estimating survival relies on the assumption that production estimates are upstream of the Owl Hollow RST. If the limited number of redds (n = 2) identified downstream of Owl Hollow produced salmon that were subsequently captured at downstream RSTs, then survival estimates would be biased higher since these salmon would not have been included in upstream estimates.

Table 5.—Survival estimates, using wild Chinook Salmon (*Oncorhynchus tshawytscha*) at each rotary screw trap location in Reaches 1–2 of the Restoration Area of the San Joaquin River. “OH” is Owl Hollow; “SI” is Scout Island; “H99” is Highway 99; “SM” is San Mateo.

	Overall	**Broodstock**	**Trap & Haul**
OH–SI	10.8%	14.0%	10.3%
SI–H99	93.3%	81.6%	87.8%
H99–SM	0.5%	1.2%	0.5%

3.4 Survival of Efficiency Release Groups

Average survival of efficiency release groups was greatest from Owl Hollow to Scout Island, across that reach and when standardized to account for differences in distances in each section between RSTs (Table 6). Survival was lowest between Highway 99 and San Mateo. Across locations, efficiency group survival tended to decrease as the season progressed (Figure 10). As a function of RM, Owl Hollow to Scout Island survival was 90.8 percent, Scout Island to Highway 99 was 82.0 percent, and Highway 99 to San Mateo was 29.1 percent.

Table 6.—Mean and 95 percent confidence interval (CI; 1.96*standard error) of survival of groups of salmon, released at each rotary screw trap, during the 2020–21 sampling season in the San Joaquin River Restoration Area. Survival is described from Owl Hollow (OH) to Scout Island (SI), SI to Highway 99 (H99), and H99 to San Mateo (SM), overall (upper table) and standardized to river mile (RM; lower table).

	OH–SI	SI–H99	H99–SM
Mean	46.4%	29.4%	0.5%
95% CI	±9.9%	±8.5%	±0.5%

	OH–SI (RM)	SI–H99 (RM)	H99–SM (RM)
Mean	90.8%	82.0%	29.1%
95% CI	±2.4%	±6.2%	±28.5%

Best subsets regression, using adjusted-R^2 as the criteria, identified temperature and average length, but not flow, as the model best suited for survival analyses for both Owl Hollow to Scout Island and Scout Island to Highway 99; however, VIF-values among both models (Owl Hollow to Scout Island survival, Highway 99 to San Mateo survival) indicated collinearity among the included variables (VIF=4.01 and 4.09, respectively). Therefore, final regression analyses were completed using the best-fit model (i.e., removing the variable with the lowest r^2 value with regards to predicting survival [Giorgi et al. 1997]); in both instances, the best fit model included temperature as the independent variable (Figure 11).

Linear regression indicated temperature was not significant when predicting survival within the section from Owl Hollow to Scout Island ($\beta = -0.05$, $R^2 = 0.31$, $F(1,8) = 3.61$, $p = 0.09$) nor as a function of RM ($\beta = -0.02$, $R^2 = 0.35$, $F(1,8) = 4.21$, $p = 0.07$; Figure 10). Temperature was considered significant, though, when predicting survival from Scout Island to Highway 99, both within the entire section ($\beta = -0.04$, $R^2 = 0.60$, $F(1,8) = 11.87$, $p = 0.01$) and as a function of RM ($\beta = -0.03$, $R^2 = 0.60$, $F(1,8) = 11.93$, $p = 0.01$).

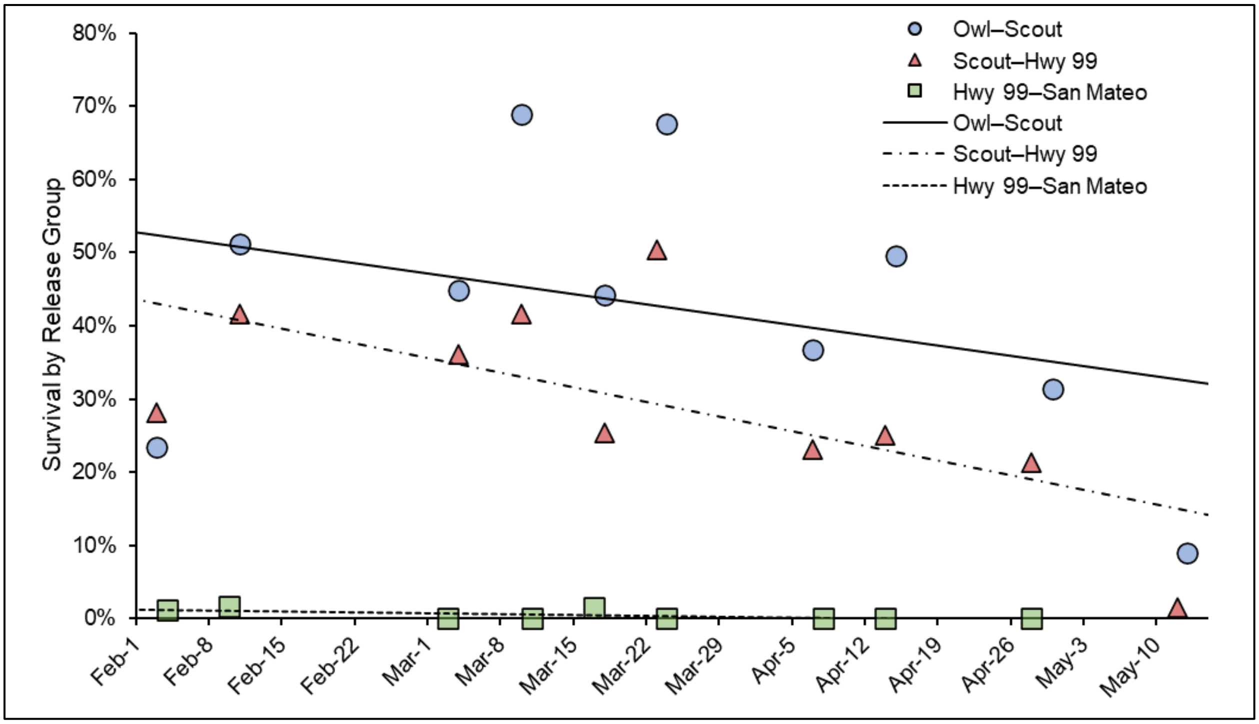

Figure 10.—Survival estimates of hatchery-reared Chinook Salmon (*Oncorhynchus tshawytscha*) released for rotary screw trap efficiency evaluations during the 2020–21 sampling season in the San Joaquin River Restoration Area. Estimates are for total efficiency fish surviving to the next downstream location.

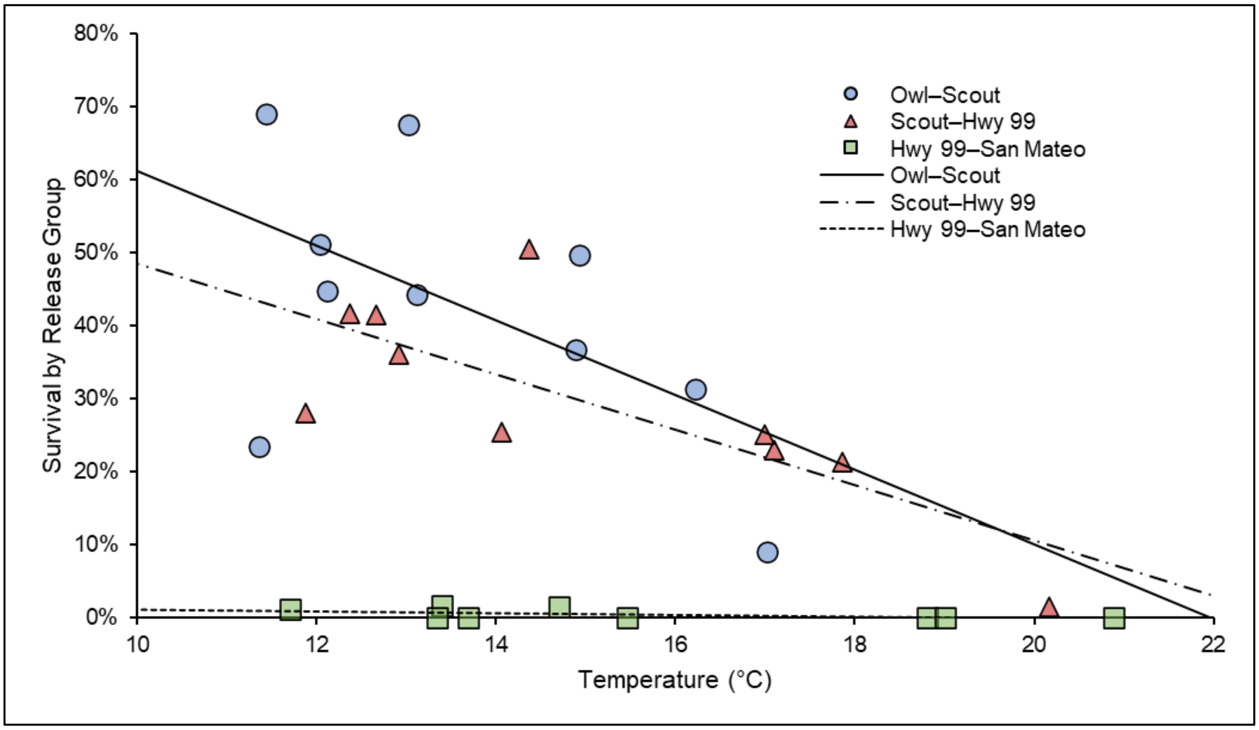

Figure 11.—Survival estimates for juvenile Chinook Salmon (*Oncorhynchus tshawytscha*), by efficiency release group, as a function of temperature, during the 2020–21 rotary screw trap sampling season, in the San Joaquin River Restoration Area.

3.5 Emigration Timing

Initial salmon detection at the Owl Hollow RST started mid-November (November 10) and slowed towards the end of December (Figure 5). Initial catch at the Scout Island RST started December 4, slowing mid-January—this was delayed when compared to the Owl Hollow RST but followed a similar pattern. However, at both locations, catch rates increased again beginning late January/early February and continued into late April at the Owl Hollow RST and early May at the Scout Island RST. While there was a single salmon captured mid-December at Highway 99, consistent catch did not start until late January, peaking late March, and concluding May 13, 021 (Figure 12). Flow data were collected from the California Data Exchange Center (California Data Exchange Center) using the Highway 41 gaging station (H41) located in Reach 1 of the Restoration Area. The downstream-most trap at San Mateo had relatively few captures of wild salmon, which occurred early-February to early-May. All RST operations were ceased May 28, 2021, following a period without catch after May 13.

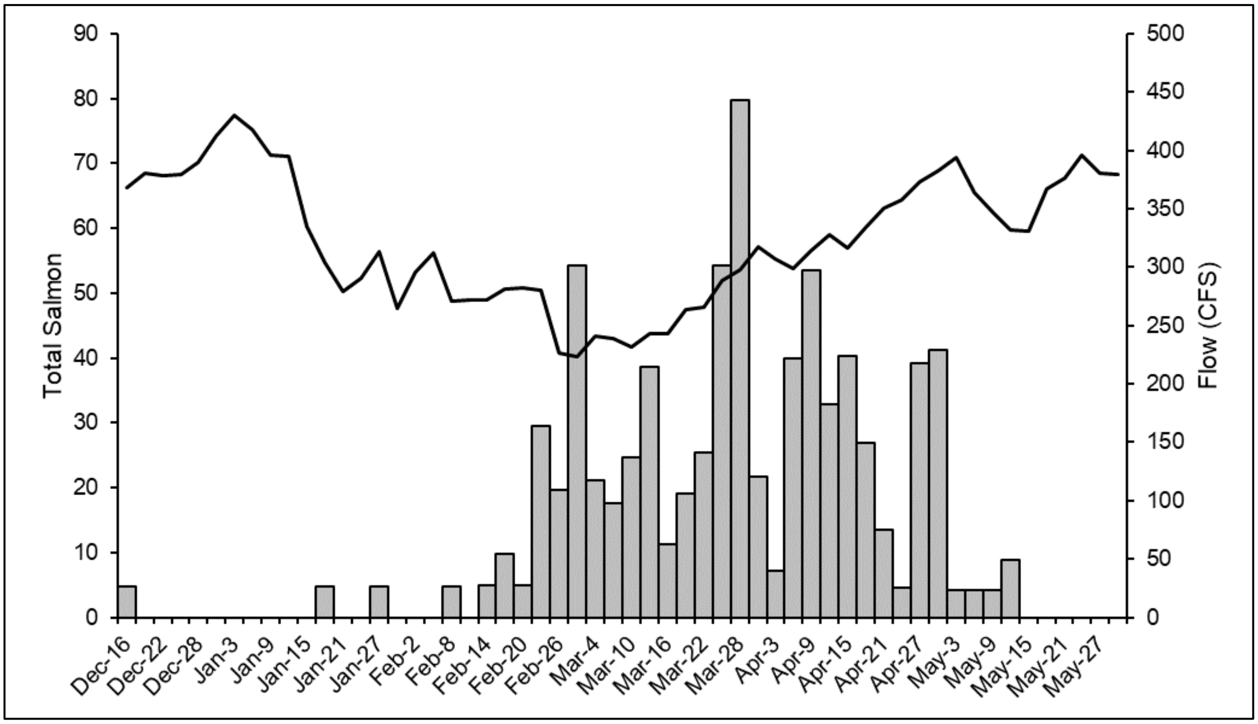

Figure 12.—Downstream movement of spring-run Chinook Salmon (*Oncorhynchus tshawytscha*; left vertical axis; 3-day intervals following the listed date) during 2020–21 field season at Highway 99, with respect to average flow during the concurrent period (CFS, measured at Highway 41; right vertical axis).

Comparing timing and estimates of total salmon moving past the Owl Hollow and Highway 99 RSTs gives an indication of potential differences that might occur between hatchery-raised adults and their progeny and those of natural returning fish, released via trap and haul efforts (Figure 13).

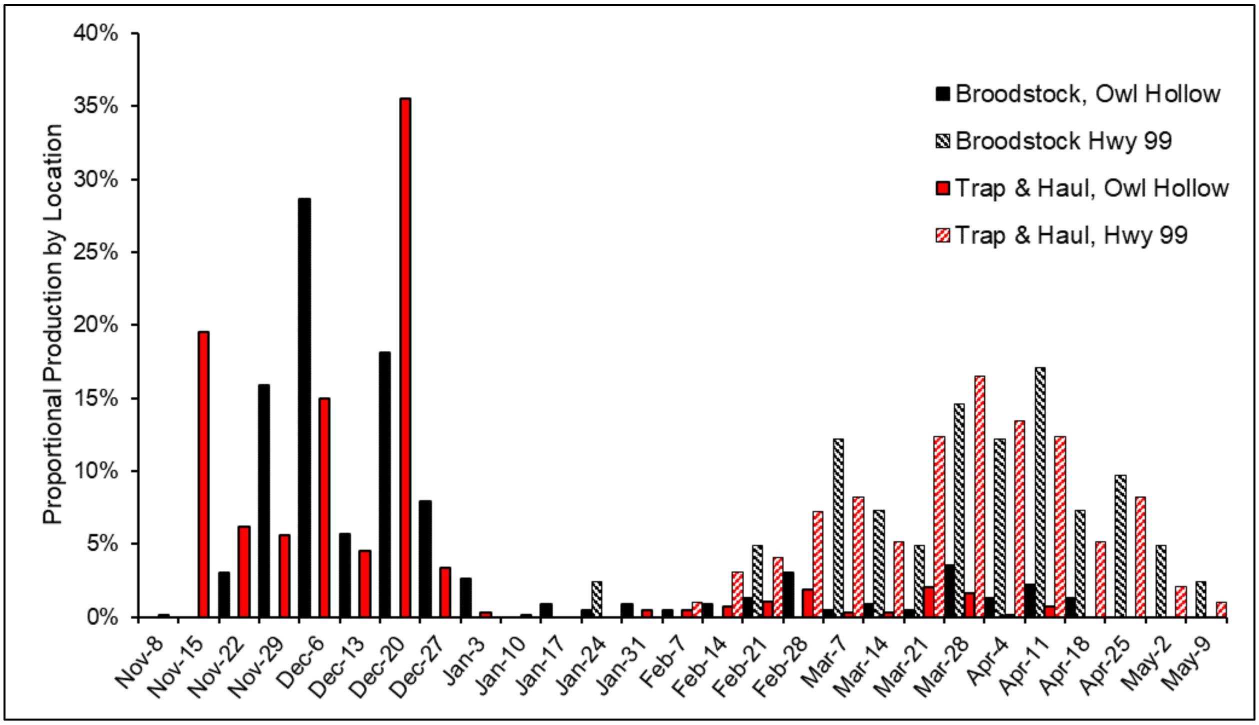

Figure 13.—Proportional weekly production, as a function of maternal origin and rotary screw trap location, at Owl Hollow (solid bars) and Highway 99 (patterned bars).

3.6 Growth Rate

A total of 14 recaptured salmon were included for estimating daily growth. These fish were subsequently captured between 14 and 134 days after the initial capture event. Of these 14 salmon, the initial capture event for 6 was before the fish were greater than 45 mm TL; therefore, the initial weight was estimated based on length-weight regressions from spring-run salmon captured this season. The average daily growth rate was 0.13 ± 0.11 g/d (mean ±1.96*standard error).

4.0 Discussion

Flows were relatively stable during 2020–21 and the RSTs were able to fish through nearly the entire sampling season—of note, though is that the Owl Hollow RST was removed mid-May after the trap sustained some damage but was otherwise no longer catching salmon; the San Mateo trap was stopped at the end of April when temperature thresholds exceeded the limit for sampling. Early in the season, fry were predominately captured at upstream RSTs—primarily Owl Hollow. Because very few fry and almost no parr were captured downstream, relative to the total proportion of salmon captured throughout the season, this suggests that salmon initially move downstream of spawning grounds shortly after emergence but tend to hold/rear upstream of Scout Island. However, unlike previous sampling seasons, catch at Owl Hollow continued the remainder of the season and the total fish estimated moving past this location was, at times, similar to other downstream RST locations (Figure 5; Hutcherson et al. 2020; 2021; 2023). This catch also included a number of smolts, suggesting these fish remained in upstream sections of Reach 1 before migrating downstream. As compared to the previous sampling seasons, the 2020–21 season lacked some of the pulse flow conditions in which salmon in those prior seasons were exposed. This could have resulted in reduced downstream movement during earlier periods of the 2020–21 season. Nonetheless, as the sampling season progressed, fewer fish were captured at Owl Hollow and, subsequently, the Scout Island and Highway 99 RSTs became the primary capture locations. Offspring of both broodstock females and trap and haul females tended to arrive at similar times during the 2020–21 sampling season; conversely, during the previous sampling year, juveniles from broodstock fish tended to arrive later at RST locations and moved over a shorter period when compared to offspring from naturally returning adults (Hutcherson et al. 2023).

Regardless of sampling season, the proportion of salmon observed at downstream RSTs suggests that most of the spring-run cohort does not survive during this period of emigration; what is unclear is whether some factor (e.g., mine pits, predation) could be contributing to the low observed survival or if it is a function of residence time in the system. The limited capture of fry and delayed observation of smolts at downstream RSTs suggest salmon fry exhibit a preference towards some feature(s) in the areas upstream of Scout Island prior to smoltification and emigration—smoltification is the physiological processes that prepare salmon for seaward migration (Baggerman 1960) and is a complex interaction of the individual and environmental parameters, often correlated to photoperiod (Komourdjian et al. 1976) and temperature (Roper and Scarnecchia 1999). Of note, though, is that survival of efficiency fish is greater across sampling seasons when compared to wild salmon (Hutcherson et al. 2020; 2021; 2023). Efficiency fish released tended to move downstream quickly and were most often captured at downstream RST locations within the first week of release. And conversely to wild salmon, where survival is greater between Scout Island and Highway 99, survival of efficiency fish is greater between Owl Hollow and Scout Island and lower between Scout Island and Highway 99. This would seem to indicate that survival may be a factor of residence time in the system, and perhaps the rearing period for wild salmon corresponds to lower rates of survival.

The ability to pair genetic data provided by the Southwest Fisheries Science Center (NOAA Fisheries) with fish catch in RSTs continues to provide invaluable information for understanding patterns of emigration, growth, production, and survival. Identifying the maternal genotypes contributing to progeny captured in RSTs permits an understanding of the minimum number of redds contributing to production—i.e., for each maternal genotype identified, we know at least that as many redds produced offspring. Since individual progeny in the Restoration Area can be ascribed to specific females (i.e., maternal genotype), determining the difference in production estimates of individual family groups at specific RST locations may help understand survival and timing across RST locations (Figure 8). Future efforts will also include releasing tagged juveniles downstream of spawning grounds in Reach 1 to better understand survival to the first upstream RST. By combining family size estimates at the Owl Hollow RST with survival from the spawning grounds, it may be possible to estimate average redd production. Annual salmon escapement can be quite variable (Van Hyning 1968) which can affect total production in any given system; however, measuring production per redd may provide a means to evaluate long-term restoration efforts towards improving the capacity of the Restoration Area of the San Joaquin River to support sustainable populations of Chinook Salmon.

Juveniles recaptured during RST sampling efforts may help understand growth rates of juveniles in spawning and rearing grounds of the Restoration Area. Once again, the ability to identify these individuals through genetic analyses is invaluable—since captured/re-captured salmon are not readily identifiable, *post hoc* identification permits such evaluations. The Fisheries Framework objective for juvenile salmon growth rate during the spring is 0.4 g/d, and 0.07 g/d during summer. Though the sample size of recaptured fish meeting the criteria for evaluation is relatively small (n=14), spring growth rates (0.13 ± 0.11 g/d [mean ± 95 percent CI]) currently do not appear to meet the criteria for spring growth rates.

Like the 2019–20 sampling season, California Department of Fish and Wildlife staff were able to tag smaller salmon with half-size CWTs. This allowed earlier-season efficiency testing for RSTs than was previously available, providing more representative assessments of RST efficiency when smaller wild salmon were also present at upstream locations. However, since these smaller fish were only fin-clipped to identify them as efficiency-released individuals, this prevented distinguishing one release group from another or evaluating survival to downstream RSTs. These smaller-sized salmon will be tagged using color-fin combinations during future efforts to help distinguish amongst release groups and permit these evaluations. In addition, using the survival estimate methods described herein for efficiency fish, the release of smaller tagged fish near spawning grounds closer to Friant Dam may help better understand survival upstream of the first RST (Owl Hollow).

Ongoing efforts will be made to increase trap efficiency during periods of low flow with the use of wing walls/weirs, trap placement. Understanding juvenile salmon movements downstream of the Highway 99 location is necessary in determining migration patterns and survival in the remainder of the Restoration Area where conditions are generally considered less suitable for salmon. In subsequent sampling seasons, the downstream RST will be moved upstream to help identify which sections downstream of Highway 99 may be precluding most emigrating juveniles from surviving further downstream.

Continued monitoring of juvenile spring-run Chinook Salmon will provide metrics of survival and production in the Restoration Area. As methods are refined, the study design can be improved to provide more precise estimates of these values. Additionally, the continued collection of data through these early Restoration phases may help develop standards for future efforts. For example, coordinating length-at-capture data, which is often used to distinguish salmon runs in other California river systems (Johnson et al. 1992), across multiple sampling years and in conjunction with genetics may help distinguish unique cohorts of salmon present in the Restoration Area. This could help in future years when volitional passage is available for both spring- and fall-run salmon, when genetically testing all fish is not logistically or financially feasible.

While some non-Chinook salmonids were captured this season, the species was not ascribed. Kokanee (landlocked Sockeye Salmon; *O. nerka*) were captured during the 2018–19 sampling season (Hutcherson et al. 2021), likely escapees from the California Department of Fish and Wildlife San Joaquin Hatchery. Length-at-date regressions indicate these may be sufficient means to adequately parse these fish from spring-run Chinook Salmon; however, if it is determined that the specific identification of these fish is necessary, additional genetic analyses may be considered to positively identify such fish.

Future restoration activities include the construction of bypass structures at Sack Dam and Mendota Dam which, with remedies to other passage impediments in the Restoration Area, will create volitional passage opportunities for returning adult salmon to spawning grounds in Reach 1. Interim efforts may also present the opportunity to transport captured adult spring-run salmon to Reach 1, providing increased opportunities for spawning and production. Resultantly, biologists may be able to take advantage of using wild fish in lieu of hatchery fish to evaluate patterns of movement, seasonal growth rate, and survival. This, in turn, provides the opportunity to collect data pertaining to objectives established in the Fisheries Framework (SJRRP 2018). Evaluating salmon movement and numbers beyond the spawning areas in Reach 1 may provide estimates of survival and identify areas where unacceptable loss rates occur. Such information can be used to guide management decisions regarding future efforts in the Restoration Area.

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Appendix A: Bycatch

During the 2020–21 field season, 8,812 non-target fish, comprising 27 species were captured in the four rotary screw traps (Table A-1). Centrarchids were the most frequently encountered family captured during sampling efforts (40.3 percent). Black bass species (i.e., Largemouth and Spotted Bass) were the most numerous bycatch within the Centrarchid family, comprising 26.4 percent of the total bycatch throughout the season. The next most frequently captured species was Threadfin shad, which comprised 20.4 percent of the total bycatch. Of the 26 species captured, 7 were native: Kern Brook Lamprey (*Lampetra hubbsi*), Pacific Lamprey (*Entosphenus tridentatus*), Sacramento Pikeminnow (*Ptychocheilus grandis*), Sacramento Sucker (*Catostomus occidentalis*), Prickly Sculpin (*Cottus asper*), Riffle Sculpin (*C. gulosus*), and Threespine Stickleback (*Gasterosteus aculeatus*). Native species comprised 35.1 percent of the bycatch.

Table A-1.—Total season bycatch in all rotary screw traps during 2020–21 sampling season. Asterisk denotes native species to the San Joaquin River.

Family	Species	Common Name	Season Totals
Petromyzontidae	*Lampetra hubbsi*	Kern Brook Lamprey*	43
Petromyzontidae	*Entosphenus tridentatus*	Pacific Lamprey*	752
Petromyzontidae	*Petromyzontidae spp.*	Unidentified spp.*	706
Centrarchidae	*Micropterus spp.*	Black Bass spp.	2,326
Centrarchidae	*Pomoxis nigromaculatus*	Black Crappie	203
Centrarchidae	*Lempomis macrochirus*	Bluegill	664
Centrarchidae	*Lepomis cyanellus*	Green Sunfish	201
Centrarchidae	*Leopomis microlophus*	Redear Sunfish	149
Centrarchidae	*Lepomis gulosus*	Warmouth	10
Cyprinidae	*Cyprinus carpio*	Common Carp	1
Cyprinidae	*Pimephales promelas*	Fathead Minnow	1
Cyprinidae	*Notemigonus crysoleucas*	Golden Shiner	106
Cyprinidae	*Carassius auratus*	Goldfish	1
Cyprinidae	*Ptchocheilus grandis*	Sacramento Pikeminnow*	97
Ictaluridae	*Ameiurus spp.*	Bullhead spp.	8
Ictaluridae	*Ictalusus puntatus*	Channel Catfish	15
Ictaluridae	*Ameiurus catus*	White Catfish	21
Catostomidae	*Catostomus occidentalis*	Sacramento Sucker*	1,181
Cottidae	*Cottus asper*	Prickly Sculpin*	175
Cottidae	*Cottus gulosus*	Riffle Sculpin*	5
Cottidae	*Cottus spp.*	Unidentified spp.*	18
Gasterosteiade	*Gasterosteus aculeatus*	Threespine Stickleback*	119
Clupeidae	*Alosa sapidissima*	American Shad	2
Clupeidae	*Dorosoma petenense*	Threadfin Shad	1796
Cobitidae	*Misgurnus angullicaudatus*	Weather Loach	9
Percidae	*Percina macrolepida*	Bigscale Logperch	1
Poeciliidae	*Gambusia affinis*	Mosquitofish	202

Appendix B: Fish Health Center Histopathology Results

U.S. Fish & Wildlife Service
California-Nevada Fish Health Center
National Wild Fish Health Survey Sampling Report

San Joaquin River Fish Health Monitoring, 2021

Sample Dates: March – May 2021

Principal Investigator(s):

Name	Contact Information
Scott Foott	Scott_Foott@fws.gov
Ken Nichols	Ken_nichols@fws.gov

Objective:
Survey for selected fish pathogens in Chinook salmon and non-salmonid bycatch captured in association with San Joaquin Restoration Project monitoring activities.

Narrative Summary:
Chinook salmon – Fish were received on 3 dates: 19 March, 21 April and 5 May. The most significant finding was *Tetracapsuloides bryosalmonae* (myxozoan kidney parasite) in 7 of 17 fish received 5 May. While these were all early infections with little associated kidney inflammation, this parasite is common in out-migrant Chinook on the Merced River and can cause disease in Merced River Hatchery juvenile Chinook. A presumptive Microsporidian parasite was observed in the gill from one fish. No inflammation was associated with this infection. All Chinook were submitted as fixed samples for the histopathology assay, and no bacterial or viral culture assays were performed on these samples. See attached pathology report below for more information.

Non-salmonids – Fish were received on 2 dates: 21 April and 5 May. None of the target viral or bacterial pathogens were detected. Bacterial isolates from the complex of Aeromonad and Pseudomonad bacteria were detected in up to 25% of the fish with no associated pathology. This complex of bacteria are common in the environment and intestinal tract of fish and are common findings. All non-salmonid fish were shipped overnight on ice (dead). Fish from the May sample were delayed in shipping and arrived warm and in poor condition. Only virology and gross observation of parasites were attempted, and no bacteriology was performed.

Partners:

Name	Agency
Heather Swinney	US Fish and Wildlife Service
Zachary Sutphin	US Bureau of Reclamation

Results:

Species: Chinook Salmon Total Fish: 20

Tissue	Assay	No. Samp	Total Fish	No. Positive	Pathogen
Gill	Histopathology	20	20	1	Presumptive Microsporidean
Intestine	Histopathology	20	20	0	
Kidney	Histopathology	20	20	7	*Tetracapsuloides bryosalmonae*
Heart	Histopathology	3	3	0	

Species: Bluegill Total Fish: 24

Tissue	Assay	No. Samp	Total Fish	No. Positive	Pathogen
Kidney/Spleen	Viral Tissue Culture	6x3p	24	0	
Kidney	Bacteria Culture	12	12	3	Aeromonas/Pseudomonas complex

Species: Spotted Bass Total Fish: 22

Tissue	Assay	No. Samp	Total Fish	No. Positive	Pathogen
Kidney/Spleen	Viral Tissue Culture	5x5p	22	0	
Kidney	Bacteria Culture	12	12	3	Aeromonas/Pseudomonas complex

Species: Green Sunfish Total Fish:

Tissue	Assay	No. Samp	Total Fish	No. Positive	Pathogen
Kidney/Spleen	Viral Tissue Culture	2	10	0	
Kidney	Bacteria Culture	5	5	1	Aeromonas/Pseudomonas complex

Species: Channel Catfish Total Fish: 2

Tissue	Assay	No. Samp	Total Fish	No. Positive	Pathogen
Kidney	Viral Tissue Culture	2	2	0	
Kidney	Bacteria Culture	2	2	0	

Attachments:

PATHOLOGY REPORT

US Fish & Wildlife Service
CA-NV Fish Health Center
24411 Coleman Hatchery Rd
Anderson, CA 96007

phone 530-365-4271
fax 530-365-7150

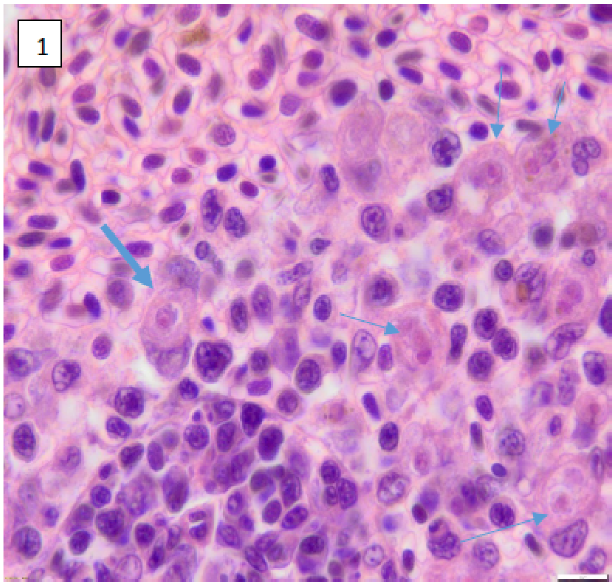
FHC Case No. : **21-066 / 083**
Submittal date: **April 20 and May 4, 2021 2021**
Sample Collector: **BOR**
Sample Site(s): **San Joaquin River, Hwy 99 trap**
Histological specimen examiner: **JS Foott**
Species **Spring-run Chinook**
Age: **smolt**
Tissues: kidney, gill, intestine, liver

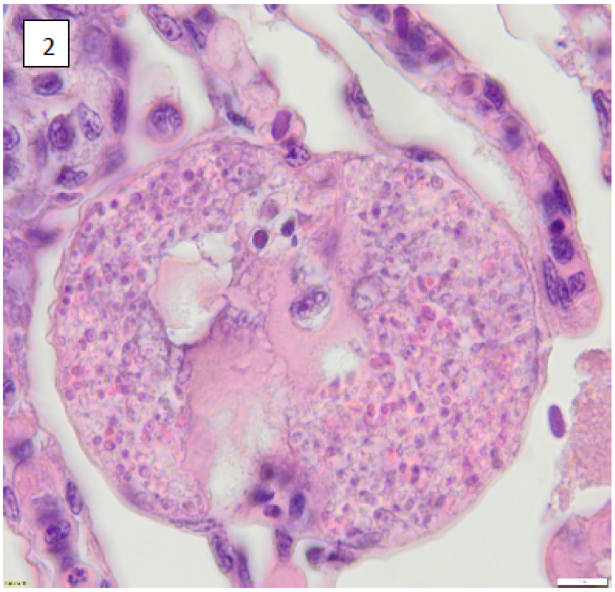
Fixative: **Davidson (xx), PREFER-ETOH (), 10%BF ( ), ZFIX ( ), Bouins ( )**
Stains: **Hematoxylin & eosin (xx), PAS ( ), Iron ( ) ACID FAST () Gram (xx)**
Block No. **12826-12827,12930-12946**
Block / slide deposition: **FHC**
Blood Smear (Number): **ND**
Bloodsmear Stain: **Lieshman-Giemsa ( ), DiffQuick( )**
Clinical chemistry: **ND**

19 smolts total
Fork length ranged from121-128mm (April 20, 2 fish), and 113 – 135mm (May4, 17 fish)

Summary

- No parasites or abnormalities observed in the April20 smolt samples (2)
- *Tetracapsuloides bryosalmonae (myxozoan kidney parasite) observed in 7 of 17 fish from the May4 samples (Figure 1). Infections characterized as early stage with the trophozoite stage found in the blood sinuses often associated with host macrophages (thick arrow). This is a progressive disease that can result in severe anemia and is common in the lower Merced River.*
    - *One gill section had numerous cysts containing an unidentified, presumptive microsporidian parasite (Fig2.). The gill function was judged to be largely unaffected by this infection.*
    - *Note: Neither Ceratomyxa shasta or Parvicapsula minibicornis myxozoans observed in the sample set.*
    - *The overall appearance of the various tissues was deemed normal in the 19 smolt sample set.*





Appendix C: Example of Calculating Survival for an Efficiency Release Group

The following is a hypothetical example of how a group of marked hatchery salmon, used to estimate RST efficiency, were used to estimate survival to downstream RST locations:

- For the sake of simplicity, let’s say there were three monthly efficiency periods during a season—March, April, and May where efficiency was evaluated and only two RST locations were used—Scout Island and Highway 99.
- At the beginning of each month, 600 efficiency fish were released at both RST locations.
    - The fish released just upstream of each RST provide trap efficiency estimates for that specific location and period (e.g., fish released just upstream of Highway 99 in March are used to estimate trap efficiency at Highway 99 for the period of March).
    - Some of the efficiency fish released at Scout Island will eventually swim downstream and encounter they Highway 99 RST, but not all fish released at Scout Island in March will necessarily make it to the Highway 99 RST in March. While the majority are likely to move downstream and encounter the Highway 99 RST in March, some may encounter the Highway 99 in April and some in in May.
    - Keeping in mind that no RST is 100 percent efficient in capturing downstream moving fish, the total number of fish captured at the Highway 99 RST from Scout Island would have to be extrapolated to provide an estimate of the actual number of downstream moving salmon that encounter or move past the Highway 99 RST.
- Evaluating a single efficiency group released in March, traveling from Scout Island to Highway 99.
    - A total of 50, 10, and 6 fish from Scout Island were captured at Highway 99 in March, April, and May, respectively.
- The calculated efficiency for the Highway 99 RST during March, April, and May, was 20, 10, and 15 percent, respectively.
- The survival of the efficiency group released in March at Scout Island would be the sum of the extrapolated totals of fish encountering the Highway 99 RST during each efficiency period evaluated (March, April, and May):
    - 50 fish captured in March from March-released Scout Island group at Highway 99 divided by 20 percent Highway 99 RST efficiency during March (50/0.2 = 250 fish), plus
    - 10 fish captured in April from March-released Scout Island group captured at Highway 99 RST divided by 10 percent Highway 99 RST efficiency in April (10/0.1 = 100 fish), plus
    - 6 fish captured in May from March-released Scout Island group at Highway 99 RST divided by 15 percent Highway 99 RST efficiency in May (6/0.15 = 40 fish).

- So, the total fish estimated to have encountered or moved past the Highway 99 RST from the March release group from Scout Island was 390 fish (250 fish in March +100 in April +40 in May).
- In this example, the total fish from that release group (n = 390) divided by the initial group size (n = 600) gives an estimated survival of 65 percent for that specific group (390/600 = 0.65).

Appendix D: Rotary Screw Trap Release Groups and Efficiency Estimates

Table D-1.—Marked efficiency release data for individual release groups during the 2020–21 sampling season at the Owl Hollow and Scout Island rotary screw traps. Data includes release group (i), location, interval which the release was considered, group size (M_i), and total marked fish recaptured (m_i) within efficiency interval.

Release interval (i)	Location	Start Interval	End Interval	# Released (M_i)	Recaptured (m_i)	Efficiency (m_i+1)/(M_i+1)
1	Owl Hollow	10/03/20	12/22/20	202	29	14.8%
2	Owl Hollow	12/22/20	01/07/21	203	37	18.6%
3	Owl Hollow	01/07/21	02/03/21	209	25	12.4%
4	Owl Hollow	02/03/21	02/11/21	627	139	22.3%
5	Owl Hollow	02/11/21	03/04/21	606	124	20.6%
6	Owl Hollow	03/04/21	03/10/21	600	141	23.6%
7	Owl Hollow	03/10/21	03/18/21	600	127	21.3%
8	Owl Hollow	03/18/21	03/24/21	600	150	25.1%
9	Owl Hollow	03/24/21	04/07/21	673	131	19.6%
10	Owl Hollow	04/07/21	04/15/21	700	131	18.8%
11	Owl Hollow	04/15/21	04/29/21	699	137	19.7%
12	Owl Hollow	04/29/21	05/13/21	600	52	8.8%
13	Owl Hollow	05/13/21	06/01/2021	700	29	4.3%
1	Scout Island	10/03/20	12/21/20	200	17	9.0%
2	Scout Island	12/21/20	010/6/21	175	15	9.1%
3	Scout Island	010/6/21	020/3/21	201	9	5.0%
4	Scout Island	020/3/21	02/11/21	599	113	19.0%
5	Scout Island	02/11/21	030/4/21	397	27	7.0%
6	Scout Island	03/04/21	03/10/21	598	110	18.5%
7	Scout Island	03/10/21	03/18/21	615	87	14.3%
8	Scout Island	03/18/21	03/23/21	555	60	11.0%
9	Scout Island	03/23/21	04/07/21	600	89	15.0%
10	Scout Island	04/07/21	04/14/21	601	50	8.5%
11	Scout Island	04/14/21	04/28/21	600	36	6.2%
12	Scout Island	04/28/21	05/12/21	600	51	8.7%
13	Scout Island	05/12/21	06/01/2021	599	38	6.5%

Table D-1 (continued)— Marked efficiency release data for individual release groups during the 2020–21 sampling season at the Highway 99 and San Mateo rotary screw traps. Data includes release group (*i*), location, interval which the release was considered, group size (M_i), and total marked fish recaptured (m_i) within efficiency interval.

Release interval (i)	Location	Start Interval	End Interval	# Released (Mi)	Recaptured (mi)	Efficiency (mi+1)/(Mi+1)
1	Highway 99	10/03/2020	02/10/2021	602	125	20.9%
2	Highway 99	02/10/2021	03/03/2021	600	121	20.3%
3	Highway 99	03/03/2021	03/11/2021	600	170	28.5%
4	Highway 99	03/11/2021	03/17/2021	699	198	28.4%
5	Highway 99	03/17/2021	03/24/2021	700	164	23.5%
6	Highway 99	03/24/2021	04/08/2021	600	165	27.6%
7	Highway 99	04/08/2021	04/14/2021	600	145	24.3%
8	Highway 99	04/14/2021	04/28/2021	693	154	22.3%
9	Highway 99	04/28/2021	05/12/2021	600	145	24.3%
10	Highway 99	05/12/2021	06/01/2021	600	67	11.3%
1	San Mateo	10/03/20	03/03/2021	300	151	50.5%
2	San Mateo	03/03/2021	03/11/2021	300	208	69.4%
3	San Mateo	03/11/2021	03/17/2021	160	0	0.6%
4	San Mateo	03/17/2021	03/24/2021	200	2	1.5%
5	San Mateo	03/24/2021	04/08/2021	195	19	10.2%
6	San Mateo	04/08/2021	06/01/2021	200	29	14.9%