California Department of Fish and Wildlife
North Central Region

Monitoring for the Development of a Sacramento River Watershed Spring-Run Chinook Salmon Juvenile Production Estimate

Timing, Composition, and Abundance of Juvenile Salmonid Emigration in the Lower Feather River Near Star Bend October 2022 – July 2023[1]

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[1] Conducted by the California Department of Fish and Wildlife with funding from the California Department of Water Resources

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

BY	brood year
BBY	Bismarck Brown Y
CAMP	Comprehensive Assessment & Monitoring Program
CDEC	California Data Exchange Center
CDFW	California Department of Fish and Wildlife
cfs	cubic feet per second
CI	Confidence Intervals
FRFH	Feather River Fish Hatchery
FSB	Feather River at Boyd's Landing above Star Bend
CPUE	catch per unit effort
CWT	coded wire tag
DWR	California Department of Water Resources
FL	fork length
ft	feet
JPE	juvenile production estimate
LAD	length-at-date
mm	millimeter
NTU	nephelometric turbidity units
RM	river mile
QAQC	quality assurance/quality control
RST	rotary screw trap
SWP	State Water Project
TL	total length
YOY	young-of-year

EXECUTIVE SUMMARY

This report presents the results for the second season of monitoring at the lower Feather River rotary screw trap (RST) near Star Bend (River Mile (RM) 17.5) from October 2022 through July 2023. The RST project was operated by the California Department of Fish and Wildlife (CDFW) North Central Region Anadromous Fisheries Program to obtain information on the temporal distribution, relative abundance, and race composition of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*), with a focus on spring-run Chinook salmon, emigrating through the lower Feather River. The project collected data using two paired RSTs outfitted with 8-ft diameter cones located approximately one mile downstream of the Star Bend Park and Boat Ramp in Yuba County. The lower Feather River (Star Bend) RST monitoring site began trapping on October 17, 2022 and concluded July 4, 2023, for a total of 10,617 hours of sampling.

Environmental data collected during the daily trap checks included river discharge, water temperature, turbidity, and dissolved oxygen levels. The data was averaged over the calendar week (Sunday-Saturday) for reporting purposes. Lower Feather River discharge was recorded from the Department of Water Resources (DWR) California Data Exchange Center (CDEC) Feather River at Boyd's Landing Above Star Bend (FSB) gauge (DWR, 2024). The mean weekly discharge reached a low in calendar week 51 of 1,722 cubic feet per second (cfs), and a high of 39,887 cfs in week 11. The maximum and minimum mean weekly water temperatures were 20.7 °C in week 27, and 7.9°C in week 9, respectively. Mean weekly turbidity reached its lowest in week 44 at 1.58 nephelometric turbidity units (NTU) and was highest in week 1 with a mean of 35.6 NTU. Dissolved oxygen ranged from 2.23 mg/L to 16.5 mg/L, in weeks 42 and 15, respectively.

The lower Feather River RST caught totals of 2,753 juvenile Chinook salmon and 295 steelhead during the 2022-2023 monitoring season. Unmarked and marked (adipose fin-clipped) Chinook salmon catch was 2,320 and 433, respectively. Peak catch of unmarked juvenile Chinook salmon occurred in week 52, when 453 unmarked juvenile Chinook salmon were captured. The breakdown of unmarked Chinook salmon catch by run for the season was 289 (12.5%) spring-run, 6 (0.3%) winter-run, 8 (0.3%) late fall-run, and 2,017 (86.9%) fall-run. Marked juvenile Chinook salmon catch at the lower Feather River RST accounted for 15.7% (n=433) of the total juvenile Chinook salmon catch. All marked juvenile Chinook salmon caught at this trapping location during the 2022-2023 monitoring season were assumed to be hatchery juvenile Chinook salmon released from the Feather River Fish Hatchery (FRFH). Of the total steelhead catch, 97.6% were marked (n=288). All marked steelhead were classified as yearlings and unmarked juvenile steelhead (n=7) were classified as young-of-the-year (YOY).

Ten trap capture efficiency trials were performed using a mark and recapture methodology for an overall average efficiency of 0.17% with 90% confidence intervals (CI) of 0.02% - 0.33%. The expanded passage estimate for unmarked juvenile Chinook salmon emigrating past the Star Bend RST site was 1,868,139, with lower and upper estimates of 990,818 and 16,308,747,

respectively. Expanded passage estimates by run were: 1,620,192 fall run, 3,731 late fall-run, and 244,216 spring-run. Winter-run were not included in the expanded passage estimate for unmarked juvenile Chinook salmon nor was a winter-run passage estimate calculated since winter-run captured at this location were most likely to be non-natal rearing.

INTRODUCTION

CDFW operates a RST monitoring site on the lower Feather River in the High Flow Channel at RM 17.5, approximately 1 mile downstream of Star Bend Park and Boat Ramp in Yuba County (Figure 1). Monitoring at this location was implemented in January 2022 to support the development of a juvenile production estimate (JPE) for spring-run Chinook salmon in the Sacramento River Watershed as required by Condition of Approval 7.5.2 of Incidental Take Permit (ITP) 2081-2019-066-00 issued by CDFW to DWR for the long-term operation of the State Water Project (SWP). The Star Bend monitoring site augments existing juvenile salmonid monitoring conducted on the lower Feather River by DWR near RM 46 (Herringer Riffle) in the High Flow Channel and RM 60 (Eye Side Channel) in the Low Flow Channel (Figure 1). The Star Bend site is located downstream of where Honcut Creek (RM 44) and the Yuba River (RM 27.5) enter the lower Feather River and is the lowest juvenile salmonid monitoring site on the lower Feather River prior to the confluence with the Sacramento River (Figure 1). The additional data collected at the Star Bend site will help to inform a more accurate estimate of the number of juvenile spring-run Chinook salmon (and other juvenile salmonids) emigrating from the Feather River Watershed to the Sacramento River thence the Delta. In addition to contributing data to the spring-run JPE effort, other objectives of this monitoring site include: collecting data on the temporal distribution, abundance, and run composition of other juvenile Chinook salmon and steelhead trout emigrating through the lower Feather River; comparing the movements of emigrating salmonids in varying environmental conditions; and providing data on juvenile salmonids emigrating to the Delta to inform resource and water agency managers regarding real-time water operations decisions. This report provides a summary of the RST monitoring conducted on the lower Feather River at RM 17.5 from October 17, 2022 through July 4, 2023.

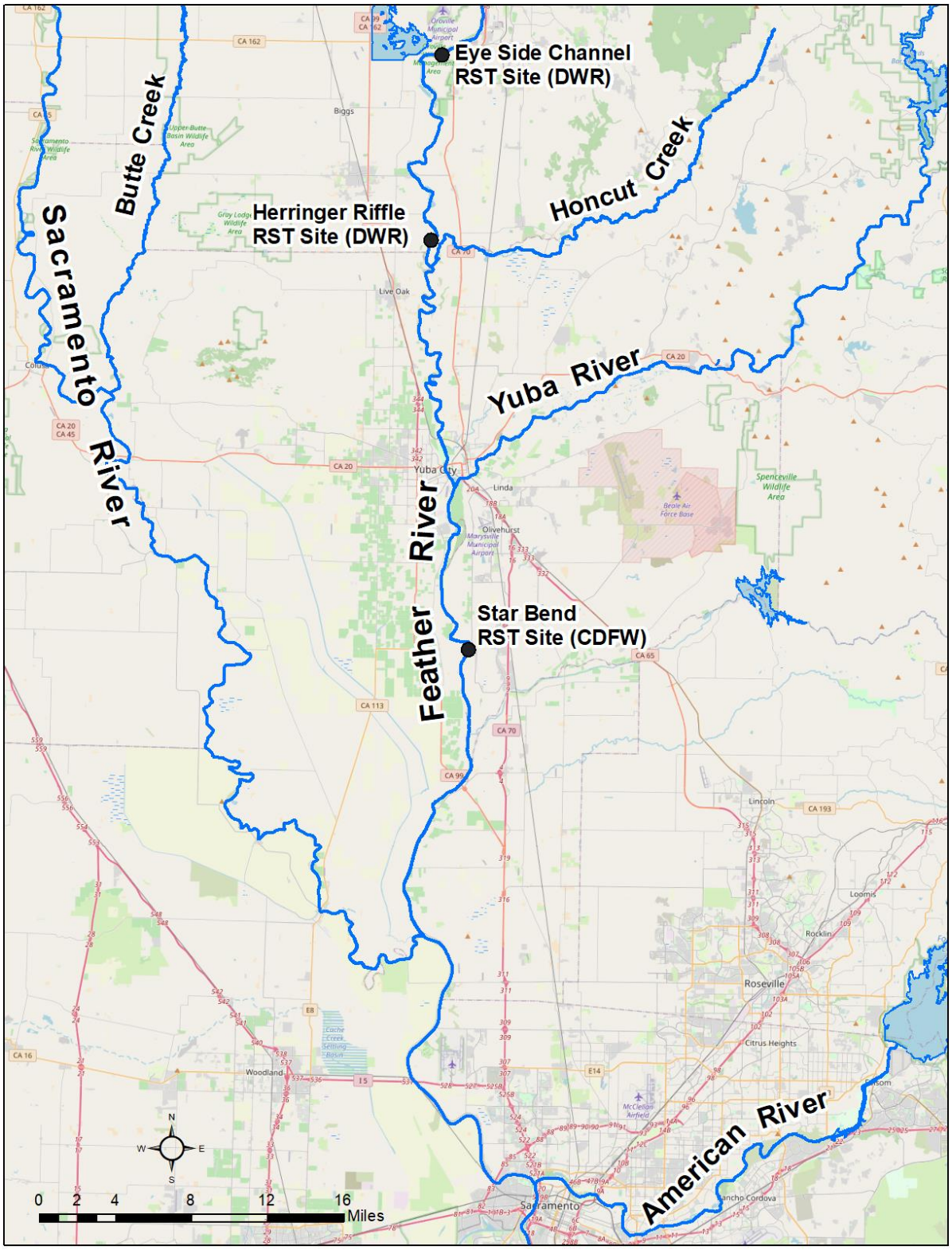

Figure 1. Map of the upper Sacramento River and tributaries depicting the locations of the juvenile salmonid RST sampling sites on the lower Feather River at Eye Side Channel, Herringer Riffle, and Star Bend.

BACKGROUND

The Feather River contains spawning and rearing habitat for Chinook salmon and steelhead. Historically, there were 211 river miles of habitat available for anadromous fish on the Feather River. Much of the existing spawning grounds are now barred by the Oroville Dam and the Fish Barrier at RM 67 (NMFS 2014). The loss of upstream spawning grounds, which geographically separated spring-run spawning from fall-run spawning on the Feather River, has resulted in hybridization between the two runs (DWR, 2021). This has made run-identification, run-specific research, and targeted mitigation on the Feather River especially challenging. Anadromous spawning in the Feather River is currently limited to approximately 25 miles of habitat below Oroville Dam (DWR, 2021).

All four runs of Chinook salmon have been observed in the Feather River; however, the predominant runs are fall-run and spring-run. Juvenile late fall-run-sized Chinook salmon have been captured in the RSTs on the lower Feather River; however, their population status and use of spawning areas is unknown. Adult winter-run are not known to spawn in the Feather River, however recent otolith analysis found that 44-65% of sampled winter-run adults reared in non-natal habitats as juveniles (Phillis et al. 2018; Maslin et al. 1998). Therefore, it is likely that juvenile winter-run observed in the Feather River are non-natal rearing. Juvenile Chinook salmon emigrate from the Feather River towards the Delta over a wide range of life stages. Juvenile fall-run have a residency of one to seven months and typically migrate March through July. Juvenile spring-run typically emigrate through the lower Feather River beginning in mid-November and extending through June. Juvenile spring-run Chinook salmon may emigrate as YOY from December through spring, or rear over summer and migrate as yearlings in the fall (DWR, 2021). Juvenile late fall-run Chinook salmon may also migrate as emerged fry, smolts, or yearlings, and typically migrate during the months of November through May (Fisher 1994; Yoshiyama et al. 1998). Winter-run fry emergence occurs in the upper Sacramento River beginning in June and fish may emigrate as fry or rear for varying periods of time and move downstream from summer through the following April. The lower Feather River RST would likely see non-natal rearing winter-run juveniles during the October to April period, with timing varying with flow.

The Feather River population of *O. mykiss* has a mix of migratory and non-migratory life histories. Adult steelhead generally enter the Delta from August through October and migrate upstream to spawn December through April. Adult steelhead are observed returning to the FRFH in late October and are spawned from December through February. Adult steelhead migration and spawning timing may be highly variable depending on river flows and water temperatures during migration periods. Feather River juvenile and adult steelhead begin emigrating between November and July, with a majority moving downstream between March and May (Kurth 2012). Juvenile steelhead may rear in their natal stream or associated tributary streams for 1-3 years, but generally leave for the ocean at 2 years of age (Hallock, 1989).

The FRFH, located at the Fish Barrier Dam, was constructed in the mid-1960's by DWR as mitigation for the loss of anadromous fish habitat (NMFS 2014). The FRFH produces both fall-run and spring-run Chinook salmon, as well as steelhead trout. Spring-run Chinook salmon and steelhead releases are generally 100% marked by removal of the adipose fin (ad-clipped) and internally tagged with coded wire tags (CWTs), while fall-run releases contain 25% marked/CWT tagged individuals. Historical in-river releases of juvenile fall-run Chinook salmon from FRFH typically included the single release of 1 million fish in late April at Boyd's Pump Boat Launch (RM 22.4) located approximately 5 miles upstream of the lower Feather River RST. Additional fall-run produced at the FRFH are released annually into San Francisco and San Pablo Bays; however, these fish do not impact catch numbers in the RST and therefore are not considered for RST analyses. Historical in-river releases of spring-run Chinook salmon typically include three paired releases of approximately 336,000 fish at Boyd's Pump Boat Launch and Gridley Boat Launch (RM 49.9; approximately 32.4 miles upstream of the RST site) in early March, late March, and April for a total of 2 million hatchery spring-run Chinook salmon. Historical releases of steelhead typically consist of 450,000 yearling steelhead released into the lower Feather River at Boyd's Pump Boat Launch in February. When available, some steelhead may also be released into Thermalito Afterbay to support the local fishery, but like Bay releases, these fish do not impact catch numbers in the RST and are not included in RST analyses. Release strategies for Chinook salmon and steelhead may vary annually based on river conditions (e.g., temperature and flow) and hatchery production (L. McNabb, pers. comm., 2023).

The reduction of available habitat in the Feather River has resulted in increased population density of salmonids, contributing to increased disease and parasite transmission (PFMC, 2019). Higher river temperatures and higher parasite density negatively impact the ability of salmonids to resist disease (Ray et al. 2012). *Ceratonova shasta* is a myxosporean salmonid parasite that causes hemorrhaging and necrosis of the intestine of salmon and trout. Recent studies have documented an up to 83% prevalence of severe *C. shasta* infection in wild juvenile Chinook salmon sampled between RM 59 and RM 22 of the high flow channel of the Feather River. In these studies, most of the infected fish collected were in a diseased state and expected to die from clinical symptoms shortly post-collection. Studies monitoring the infectivity of salmon with *C. shasta* on the Sacramento River show this pathogen to be present and have an infection rate of up to 93% (J. Llamas, pers. comm., 2021). *C. shasta* is likely a significant factor in juvenile Chinook salmon survival, especially for those spawned sections of the watershed with a high parasite load, such as the Feather River (Foott et al. 2023).

Another stressor impacting salmon populations in the Feather River and greater Central Valley is Thiamine Deficiency Complex (TDC). TDC was first recognized in Central Valley hatcheries in early 2020 when juvenile Chinook salmon were observed swimming in corkscrew patterns and dying at unusually high rates. TDC has since been linked to the ocean diet of returning adult Chinook salmon populations. Specifically, scientists hypothesize that adult female Chinook salmon in the ocean who consume an abundance of anchovies, which are rich in the enzyme thiaminase that breaks down thiamine, return to rivers to spawn with depressed thiamine concentrations in their eggs and produce thiamine deficient offspring (NOAA Fisheries 2021).

TDC causes loss of equilibrium, abnormal swimming patterns, lethargy, and early life-stage mortality (Mantua et al. 2021). Emigrating juvenile salmon with TDC have inhibited swimming behavior and are more vulnerable to predation on their journey to the ocean. The FRFH initiated a thiamine treatment protocol for spring-run Chinook salmon in 2021; currently adults, eggs, and fry are given thiamine treatment. While some hatcheries have treated returning adult Chinook salmon with some success, there is currently no effective method to treat TDC for naturally spawning adults or juveniles (Bell 2022). The effects of TDC on survival of juvenile Chinook salmon in the Sacramento watershed is not well understood, and research is ongoing, including the extent of thiamine deficiency in hatchery versus natural origin fish.

In addition to pathogens and TDC, current water management practices throughout the Delta and its tributaries, including the Sacramento River watershed, can affect the survival of emigrating salmonids. Understanding the abundance and timing of emigrating salmonids is crucial in making informed water management decisions. Various operational restrictions have been placed on water diversion projects within the Delta and its tributaries to protect listed salmonids. Real-time data analyses of juvenile salmonid timing, abundance, and emigration improves resource agency and water managers ability to understand the effects of water operations on salmonids and develop protective measures to maximize water project management flexibility while providing protection to migrating salmonids. Data from the lower Feather River RST site is used to adaptively manage water project operations in the Delta. Juvenile salmonid monitoring on the lower Feather River provides valuable real-time data on emigration patterns and abundance to inform the spring-run Chinook salmon JPE and adaptive operations to reduce impacts on Chinook salmon while still facilitating water exportation. It also provides an opportunity to study the life cycle of salmonids and collect information about what influences juvenile survival during emigration through the Feather River watershed.

CDFW issued Incidental Take Permit No. 2081-2019-066-00 (2020 SWP ITP) on March 31, 2020, to DWR for the long-term operation of the State Water Project. Pursuant to section 2081(b) of the Fish and Game Code, the 2020 SWP ITP includes Conditions of Approval (COAs) for the incidental take of Delta smelt, longfin smelt, winter-run Chinook salmon, and spring-run Chinook salmon. This monitoring program was created by the 2020 SWP ITP to provide salmonid data from the lower Feather River to inform several COAs from the ITP, specifically COA 7.5.2 (New and Ongoing Monitoring Required to Develop and Establish a Spring-run Chinook Salmon JPE) and COA 8.1.2 (Salmon Monitoring Team).

- COA 7.5.2 of the 2020 SWP ITP requires the development of a JPE for spring-run Chinook salmon to increase understanding regarding the impacts water operations have on the spring-run Chinook salmon population in the Sacramento River Watershed and inform the development of mitigation measures to reduce take of spring-run Chinook salmon at Delta fish salvage facilities. Data from the RST monitoring site on the lower Feather River at RM 17.5 will be used along with other datasets from salmonid monitoring programs in the Sacramento River Watershed to inform the development of JPE modeling approaches.

- COA 8.1.2 of the ITP requires a real-time operations monitoring team, called the Salmon Monitoring Team (SaMT), to meet weekly from October through June, to consider and discuss survey data, salvage data, and other pertinent biotic and abiotic factors to provide advice for real-time management of SWP operations to DWR, CDFW, and the Water Operation Management Team (WOMT) to minimize take of winter-run and spring-run Chinook salmon in the Delta. One of the weekly tasks of the SaMT includes estimating the percentage of juvenile winter-run and young-of-year (YOY) spring-run Chinook salmon that are present upstream of the Delta, in the Delta, or have exited the Delta past Chipps Island. The SaMT uses data from the lower Feather River RST monitoring site, among other datasets, to understand the movement of juvenile salmon in the Sacramento River to estimate the number of winter-run and spring-run Chinook salmon that have entered the Delta.

METHODS

Salmonid monitoring at the Star Bend trapping site on the lower Feather River occurs from October/November through June each emigration season. RSTs are the standard fisheries monitoring device used for this and many other juvenile salmonid emigration monitoring programs. RSTs utilize a large aluminum cone enclosed in a perforated screen suspended between two pontoons that rotates with moving water to sample fish moving downstream. The force of moving water (stream flow) on the baffles inside the cone causes it to rotate. Fish enter the upstream end of the rotating cone, become confined inside the cone, and are carried rearward and held in a live box. A detailed description of RST use and operation is available in Kennen et al. (1994) and Volkhardt et al. (2007).

For this project two RSTs were linked together, each with a 2.4 m (8 ft) diameter cone and anchored in place on the east side (river left) of the lower Feather River. The traps were secured with an anchor upstream, and two lines to the bank; one laterally and one diagonally. These connections allowed the trap position to be altered with flow and debris level. During average flow conditions, the RSTs were approximately 20 ft from the left bank and utilized full cone sampling. During periods of high flow traps may have been adjusted to sample closer to the bank to avoid breaking anchor lines, and half-cone sampling may have been used to reduce debris load following the condition-dependent sampling schedule. Half-cone sampling was also used during FRFH releases of steelhead and spring-run Chinook salmon from Boyd's Pump Boat Launch to reduce catch mortalities and excessive catch of the released fish. These actions were taken to avoid the exceedance of permitted take for each species.

The traps were serviced every 24 hours during the sampling season unless fish catch rates during hatchery releases required more frequent checks. During each check, traps were cleaned, fished out, and reset once every 24 hours. During each trap check staff collected data on RST operation including time of servicing, average cone revolutions per minute, total number of cone revolutions since last check, trap conditions (intake debris and live well debris),

and water velocity entering each cone. River depth was measured with a Garmin Striker 4 depth finder. Velocity was measured with the Global Water flow probe (model FP111).

Water quality data, including water temperature, conductivity, and dissolved oxygen was measured daily during each trap check with a YSI water quality meter (model Pro 2030). Additionally, a water sample was collected at the trap and analyzed for turbidity using a LaMotte 2020wi Turbidimeter upon returning to the office. An electronic Onset HOBO temperature logger was set in the river left cone livewell for the duration of the trapping period to record water temperature every hour. River discharge volume was recorded from the CDEC FSB gauge (DWR, 2024). River flow was important to record because it influences juvenile emigration patterns and may create hazardous working conditions for staff or limit safe boat access during low flow.

All fish captured in the RSTs were identified to species and recorded. Salmonid catch was measured to fork length (FL), and non-salmonid bycatch were measured to total length (TL) to the nearest millimeter (mm). A total of 10 individuals were measured per bycatch species, after which they were plus counted. Juvenile salmonids missing an adipose fin are assumed to be of hatchery origin. Generally, juvenile salmonids with an intact adipose fin are assumed to be of natural origin; however, hatchery releases may not be 100% marked in all years, so these fish may be a mix of hatchery and natural origin. Juvenile Chinook salmon were assigned a run (i.e., spring-run, fall-run, late fall-run, or winter-run) based on FL using the length-at-date criteria (LAD; Green 1992). For steelhead and Chinook salmon, up to 50 individuals were measured per category: marked Chinook salmon (spring-run, fall-run, late fall-run or winter-run), unmarked Chinook salmon (spring-run, fall-run, late fall-run or winter-run), marked steelhead, and unmarked steelhead. If salmonid catch exceeded 50 individuals in a category, the excess fish were plus counted. Steelhead were categorized into age classes based on FL measurements: Fish < 100 mm were assigned YOY, fish between 100 to 300 mm were assigned yearling, and fish >300 were considered adults. Live Chinook salmon were assigned 1 of 5 developmental life stages (alevin, fry, parr, silvery parr, or smolt) based on visual appearance. The presence or absence of visual symptoms of *C. shasta* was recorded for each measured juvenile Chinook salmon. No life stages were recorded for mortalities because appearance rapidly changes. No life stages were assigned to tallied individuals. Any hatchery spring-run Chinook salmon mortalities captured following the FRFH release of fall-run on April 11, 2023 (week 15) were collected for CWT retrieval to confirm run identification.

Data was recorded on waterproof datasheets, then transported to the CDFW Chico field office and reviewed for quality assurance and quality control (QAQC). Data summaries of target species were updated daily and regularly uploaded to the California Cooperative Anadromous Fish and Habitat Data Program (CalFish; https://www.calfish.org/Home.aspx) to provide public access to real-time catch data. Data was also entered into the Comprehensive Assessment and Monitoring Program (CAMP) database developed for passage analyses and reporting. The database was then verified for QAQC at the end of the trapping season using standard protocols before passage estimates were generated.

Trap efficiency was evaluated using mark recapture methods (Volkhardt 2007). Groups of 491-1,040 juvenile Chinook were marked externally using Bismarck Brown Y (BBY) or Visible Implant Elastomer (VIE) tags and held overnight, then released 1 river mile upstream from the RST site. Fish were distributed across the stream when released. All juvenile Chinook salmon used in efficiency trials were sourced from FRFH. Passage estimates for juvenile Chinook salmon were generated for each race of Chinook salmon by expanding catch to represent 100 percent effort. To expand catch to reflect 100 percent effort, the mean weekly catch was divided by effort (hours) and adjusted for 336 total hours in a week[2]:

100% effort = mean weekly catch / (trap effort hours/actual hours in a week)

Passage estimates with lower and upper estimates were calculated for unmarked Chinook salmon races by dividing the estimated expanded catch by the average trap efficiency. Upper and lower passage estimates were calculated by dividing the expanded catch by the lower and upper 90 percent confidence intervals of the average trap efficieny.

CPUE for each run of Chinook salmon and steelhead was evaluated by dividing the total number of fish captured by the total hours of sampling. In this report, environmental and CPUE data are combined into weekly averages to evaluate trends and help normalized variation in conditions and effort. Sample weeks begin on Sunday and end on Saturday, and each week of the year is assigned a number in accordance with the Julian calendar.

RESULTS

Environmental Conditions

Environmental conditions, including river discharge, water temperature, turbidity, and dissolved oxygen levels, were monitored and recorded daily throughout the sampling season (Table 1). River discharge, as measured at the CDEC FSB gauge, averaged 2,697 cubic feet per second (cfs) at the beginning of the monitoring season in week 42, and averaged 3,591 cfs at the end of the season in week 27. The peak overall discharge during the monitoring season was 52,986 cfs on March 20, 2023 in week 12. The mean weekly discharge reached a low in week 51 of 1,722 cfs, and a high of 39,887 in week 11 (**Error! Reference source not found.**) (DWR, 2024).

[2] 336 hours = 24 hours per day x 7 days x 2 traps

Table 1. Weekly data summary of environmental conditions, including mean water temperature (°C), mean river discharge (cfs) (DWR 2024), mean water turbidity (NTU), and mean dissolved oxygen, recorded at the lower Feather River RST monitoring site from October 17, 2022 through July 4, 2023.

Week	Start of Week	Discharge (CFS)	Temperature Temp (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)
42	10/16/2022	2,697	17.6	2.59	2.23
43	10/23/2022	2,692	14.9	1.81	2.54
44	10/30/2022	2,747	13.2	1.58	2.62
45	11/6/2022	2,719	12.1	2.73	9.06
46	11/13/2022	2,342	11.0	2.86	14.60
47	11/20/2022	2,045	10.3	4.86	14.93
48	11/27/2022	2,002	9.7	4.92	15.03
49	12/4/2022	2,374	9.8	12.54	14.57
50	12/11/2022	2,376	8.9	15.29	14.79
51	12/18/2022	1,722	8.6	10.03	15.31
52	12/25/2022	4,984	9.5	20.30	15.64
1	1/1/2023	14,601	9.2	35.60	15.75
2	1/8/2023	17,381	9.8	21.44	14.92
3	1/15/2023	16,855	9.0	20.10	15.35
4	1/22/2023	5,371	8.5	14.06	15.55
5	1/29/2023	3,303	8.0	11.35	15.98
6	2/5/2023	3,602	9.1	11.98	15.58
7	2/12/2023	3,219	8.9	6.97	15.88
8	2/19/2023	2,851	8.7	5.07	15.65
9	2/26/2023	4,619	7.9	11.43	15.91
10	3/5/2023	11,113	8.6	6.43	16.03
11	3/12/2023	39,887	9.4	16.73	16.38
12	3/19/2023	36,739	9.6	9.89	15.76
13	3/26/2023	21,541	9.5	9.14	16.18
14	4/2/2023	13,849	10.5	5.85	16.30
15	4/9/2023	13,100	12.2	5.70	16.46
16	4/16/2023	18,519	11.9	5.71	15.55
17	4/23/2023	21,822	13.9	5.73	15.57
18	4/30/2023	20,689	12.2	4.97	14.77
19	5/7/2023	11,853	13.5	4.19	15.16
20	5/14/2023	21,912	14.3	4.27	14.60
21	5/21/2023	21,045	14.4	4.52	14.03
22	5/28/2023	13,327	15.0	3.09	14.97
23	6/4/2023	13,488	14.7	2.90	15.17
24	6/11/2023	12,065	16.8	3.14	13.75
25	6/18/2023	6,494	17.6	2.66	12.94
26	6/25/2023	4,716	19.5	2.54	12.18
27	7/2/2023	3,591	20.7	N/A	N/A

The maximum and minimum mean weekly water temperatures during the sampling season were 20.7°C in week 27 and 7.9°C in week 9. Figure 2 provides a detailed visual interpretation of the temperature trend throughout the 2022-2023 season.

Mean weekly turbidity during the sampling season reached its lowest in week 42 at 1.58 NTU and was highest in week 1 with a weekly mean of 35.60 NTU (Figure 2). Over the monitoring season, turbidity generally mirrored the rise and fall of river flow.

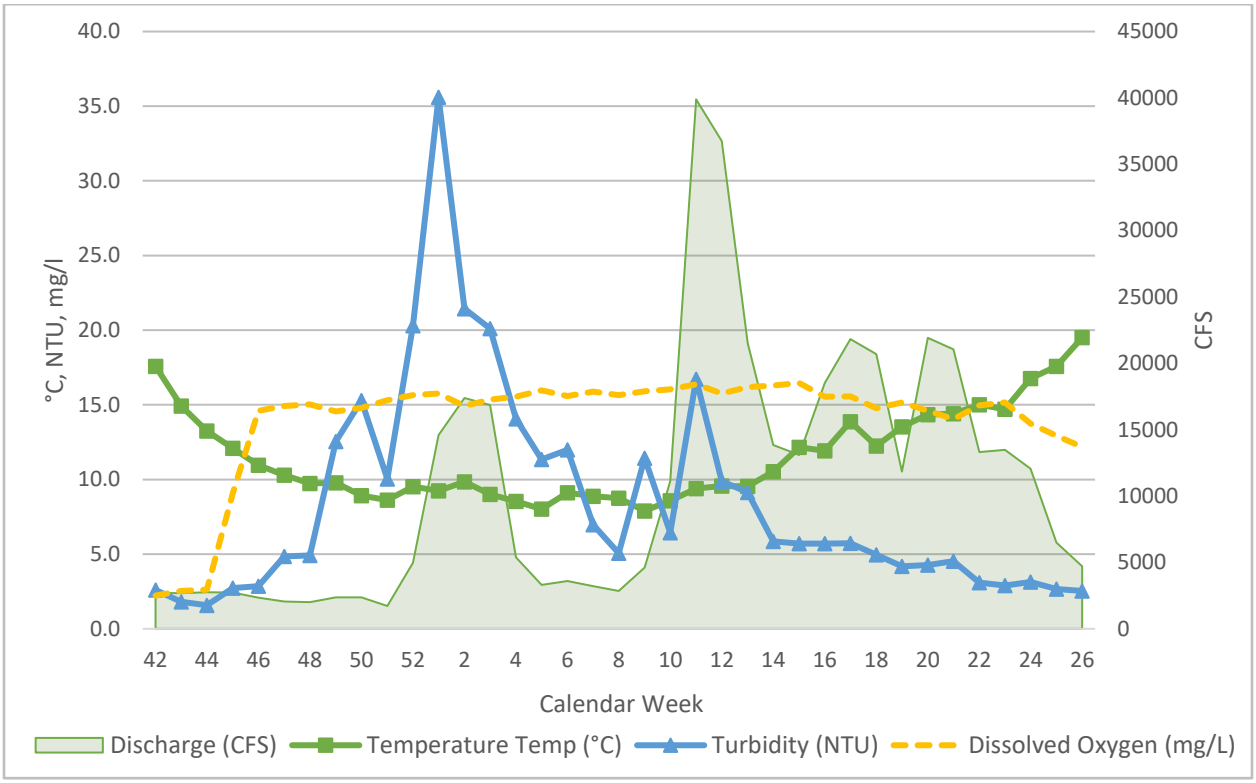

Figure 2. Mean weekly discharge recorded from the California Data Exchange Center Feather River at Boyd's Landing above Star Bend gauge plotted with mean weekly water temperature, dissolved oxygen, and turbidity recorded on the lower Feather River near Star Bend from October 17, 2022 (week 42) through July 4, 2023 (week 27).

Dissolved oxygen measured at the RST site during the sampling season ranged from 2.23 mg/L in week 42 to 16.46 mg/L in week 15 (Figure 2). Over the monitoring season, dissolved oxygen concentrations generally decreased as temperatures increased, as expected.

Summary of Juvenile Chinook Salmon Catch

All salmonids captured at the lower Feather River RSTs were assumed to be produced in the Feather River and its tributaries either naturally in-river or at the FRFH, except juvenile winter-run Chinook salmon, which likely originated from the upper Sacramento River Watershed and

used the lower Feather River for non-natal rearing. During the 2022-2023 sampling season, the lower Feather River RST monitoring site captured all four runs of juvenile Chinook salmon present in the Sacramento River watershed: spring-run, fall-run, late fall-run, and winter-run. Juvenile Chinook salmon were observed in all five life stages during the season: alevin, fry, parr, silvery parr, and smolt. A total of 2,753 juvenile Chinook salmon were captured during the sampling period of October 17, 2022 through July 4, 2023. A total of 2,320 individuals were unmarked (intact adipose fin), making up 84.27% of the total catch. Unmarked salmon included natural origin spring-, fall-, winter-, and late fall-runs, as well as unmarked hatchery origin fall-run. Marked juvenile Chinook salmon catch totaled 433 fish, or 15.73% of total catch.

The first juvenile Chinook salmon (n=4) were caught on December 3, 2023 and were identified as spring-run. Peak catch occurred in week 16, where 386 unmarked and 134 marked juvenile Chinook salmon were captured with a CPUE of 1.28 fish per hour. This week had 18.9% of the total catch over the 32-week season and took place during a hatchery release of fall-run Chinook salmon from FRFH where 75% of the fish were unmarked. The last juvenile Chinook salmon was caught during week 26, on June 27 and was identified as fall-run. Table 2 provides a more in-depth weekly summary of marked and unmarked catch throughout the season.

Table 2. **Summary of weekly catch of marked and unmarked juvenile Chinook salmon at the lower Feather River RST monitoring site from December 3, 2022 (week 48) through July 4, 2023 (week 27), with a breakdown of catch by run and natural versus hatchery-origin.**

Calendar Week	Natural					Hatchery-origin				
	Fall	Spring	Winter	Late fall	Sum	Fall	Spring	Winter	Late fall	Sum
48	0	4	0	0	4	0	0	0	0	0
49	13	95	0	0	108	0	0	0	0	0
50	20	22	0	0	42	0	0	0	0	0
51	10	4	0	0	14	0	0	0	0	0
52	442	9	2	0	453	0	0	0	0	0
1	23	2	0	0	25	0	0	0	0	0
2	64	20	0	0	84	0	0	0	0	0
3	150	39	4	0	193	0	0	0	0	0
4	153	14	0	0	167	0	0	0	0	0
5	80	10	0	0	90	0	0	0	0	0
6	33	1	0	0	34	0	0	0	0	0
7	39	3	0	0	42	0	0	0	0	0
8	15	1	0	0	16	0	0	0	0	0
9	167	7	0	0	174	0	0	0	0	0
10	74	3	0	0	77	0	0	0	0	0
11	34	0	0	0	34	2	23	0	0	25
12	14	1	0	0	15	5	28	0	0	33
13	32	0	0	0	32	4	28	0	0	32
14	35	3	0	0	38	1	18	0	0	19
15	30	1	0	1	32	37	113	0	0	150
16	341	44	0	1	386	106	28	0	0	134
17	41	2	0	0	43	14	4	0	0	18
18	19	0	0	0	19	4	0	0	0	4
19	77	4	0	4	85	13	0	0	0	13
20	10	0	0	1	11	0	0	0	0	0
21	12	0	0	0	12	3	0	0	0	3
22	39	0	0	1	40	1	1	0	0	2
23	26	0	0	0	26	0	0	0	0	0
24	16	0	0	0	16	0	0	0	0	0
25	6	0	0	0	6	0	0	0	0	0
26	2	0	0	0	2	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0
Totals:	**2017**	**289**	**6**	**8**	**2320**	**190**	**243**	**0**	**0**	**433**

Unmarked Juvenile Chinook Salmon Catch

Spring-run Chinook Salmon

A total of 289 unmarked juvenile spring-run Chinook salmon were observed this season, making up 12.5% of the overall unmarked catch. The first unmarked spring-run was caught December 3, 2022 in week 48; the last unmarked spring-run was caught May 12 in week 19 (Figure 2). Peak catch occurred during week 49 when 95 individuals were trapped, representing 33% of the total unmarked spring-run captured throughout the sampling season. The CPUE was calculated to be 0.35 during this period. Table 3 provides a summary of unmarked spring-run catch for the 2022-2023 sampling season. All unmarked juvenile spring-run Chinook salmon sampled by the RSTs were assumed to be brood year (BY) 2022 based on size at capture.

Table 3. Summary of weekly catch of unmarked juvenile spring-run Chinook salmon at the lower Feather River RST monitoring site from October 17, 2022 through July 4, 2023 including effort, catch per unit effort, and average, minimum, and maximum fork length of captured juvenile salmon. Weeks with zero catch of unmarked juvenile spring-run Chinook salmon are not included in this table.

Week	Start of Week	Total Catch	Effort (Hours)	Catch Per Unit Effort	Average FL (mm)	Minimum FL (mm)	Maximum FL (mm)
48	11/27/2022	4	329.8	0.01213	37	36	39
49	12/4/2022	95	270.0	0.35179	36	34	39
50	12/11/2022	22	225.1	0.09773	37	36	39
51	12/18/2022	4	261.3	0.01531	39	38	40
52	12/25/2022	9	273.3	0.03294	42	40	49
1	1/1/2023	2	27.5	0.07260	45	44	46
2	1/8/2023	20	77.0	0.25958	50	44	56
3	1/15/2023	39	268.1	0.14545	50	36	61
4	1/22/2023	14	338.7	0.04133	54	47	63
5	1/29/2023	10	314.1	0.03183	56	50	65
6	2/5/2023	1	214.2	0.00467	56	56	56
7	2/12/2023	3	325.0	0.00923	62	58	70
8	2/19/2023	1	332.9	0.00300	71	71	71
9	2/26/2023	7	349.0	0.02006	62	61	64
10	3/5/2023	3	275.5	0.01089	73	64	79
12	3/19/2023	1	119.8	0.00834	73	73	73
14	4/2/2023	3	297.5	0.01008	84	79	94
15	4/9/2023	1	244.7	0.00409	82	82	82
16	4/16/2023	44	407.3	0.10802	87	84	100
17	4/23/2023	2	228.7	0.00874	92	88	95
19	5/7/2023	4	717.0	0.00558	98	96	100
	Total Catch	**289**					

Fall-run Chinook Salmon

A total of 2,017 unmarked fall-run juvenile Chinook salmon were captured during the 2022-2023 monitoring season at the lower Feather River RST monitoring site. Fall-run made up the majority of catch, with 87% of the overall unmarked juvenile Chinook salmon catch. The first fall-run was caught December 7, 2022 in week 49; the last fall-run was caught June 27 in week 26. Peak catch occurred during week 52 when 442 fall-run were trapped, representing 21.9% of the total unmarked fall-run captured throughout the sampling season. The CPUE was calculated to be 1.617 during this period. Table 4 provides a summary of unmarked fall-run catch for the 2022-2023 sampling season. All unmarked juvenile fall-run Chinook salmon sampled by the RSTs were assumed to be BY 2022 based on size at capture.

Table 4. Summary of weekly catch of unmarked juvenile fall-run Chinook salmon at the lower Feather River RST monitoring site from October 17, 2022 through July 4, 2023 including effort, catch per unit effort, and average, minimum, and maximum fork length of captured juvenile salmon. Weeks with zero catch of unmarked juvenile fall-run Chinook salmon are not included in this table.

Week	Start of Week	Total Catch	Effort (Hours)	Catch Per Unit Effort	Average FL (mm)	Minimum FL (mm)	Maximum FL (mm)
49	12/4/2022	13	270.0	0.04814	33	30	34
50	12/11/2022	20	225.1	0.08885	34	31	35
51	12/18/2022	10	261.3	0.03826	35	34	37
52	12/25/2022	442	273.3	1.61754	36	30	39
1	1/1/2023	23	27.5	0.83494	34	32	40
2	1/8/2023	64	77.0	0.83065	36	31	43
3	1/15/2023	150	268.1	0.55941	37	28	45
4	1/22/2023	153	338.7	0.45170	37	30	47
5	1/29/2023	80	314.1	0.25468	37	31	49
6	2/5/2023	33	214.2	0.15404	36	26	45
7	2/12/2023	39	325.0	0.11998	37	32	54
8	2/19/2023	15	332.9	0.04505	38	33	53
9	2/26/2023	167	349.0	0.47847	38	29	55
10	3/5/2023	74	275.5	0.26861	37	32	60
11	3/12/2023	34	72.6	0.46807	37	28	48
12	3/19/2023	14	119.8	0.11682	43	35	61
13	3/26/2023	32	172.7	0.18533	42	33	70
14	4/2/2023	35	297.5	0.11764	48	31	75
15	4/9/2023	30	244.7	0.12258	62	35	76
16	4/16/2023	341	407.3	0.83719	71	20	87
17	4/23/2023	41	228.7	0.17925	73	58	84
18	4/30/2023	19	261.8	0.07258	76	63	85
19	5/7/2023	77	717.0	0.10740	77	50	90
20	5/14/2023	10	263.4	0.03796	76	47	97
21	5/21/2023	12	379.9	0.03159	79	56	94
22	5/28/2023	39	309.3	0.12609	83	64	100
23	6/4/2023	26	488.9	0.05318	79	57	109
24	6/11/2023	16	373.6	0.04282	83	68	96
25	6/18/2023	6	294.2	0.02040	82	73	91
26	6/25/2023	2	326.0	0.00613	77	68	86
	Total Catch	**2,017**					

Winter-run Chinook Salmon

The lower Feather River RST monitoring site caught six unmarked juvenile winter-run Chinook salmon during the 2022-2023 monitoring season. The first and last winter-run sized fish were

captured on December 31, 2022 and January 20, 2023, respectively. Winter-run made up 0.3% of total unmarked catch. Table 6 provides a summary of unmarked winter-run catch for the 2022-2023 sampling season. All juvenile winter-run Chinook salmon sampled by the RSTs were assumed to be BY 2022 based on size at capture.

Table 5. Summary of weekly catch of unmarked juvenile winter-run Chinook salmon at the lower Feather River RST monitoring site from October 17, 2022 through July 4, 2023 including effort, catch per unit effort, and average, minimum, and maximum fork length of captured juvenile salmon. Weeks with zero catch of unmarked juvenile late fall-run Chinook salmon are not included in this table.

Week	Start of Week	Total Catch	Effort (Hours)	Catch Per Unit Effort	Average FL (mm)	Minimum FL (mm)	Maximum FL (mm)
52	12/25/2022	2	273.3	0.00732	96	93	98
3	1/15/2023	4	268.1	0.01492	73	62	95
	Total Catch	**6**					

Late Fall-run Chinook Salmon

A total of 8 unmarked late fall-run Chinook salmon were captured during the 2022-2023 monitoring season at the lower Feather River RST monitoring site, making up 0.3% of the overall unmarked juvenile Chinook salmon catch. The first late fall-run was caught April 9, 2023 in week 15; the last late fall-run was caught June 1 in week 23. Peak catch occurred during week 19 when four late fall-run were trapped, the CPUE was calculated to be 0.005 during this period. Table 6 provides a summary of unmarked late fall-run catch for the 2022-2023 sampling season. All juvenile late fall-run Chinook salmon sampled by the RSTs were assumed to be BY 2022 based on size at capture.

Table 6. Summary of weekly catch of unmarked juvenile late fall-run Chinook salmon at the lower Feather River RST monitoring site from October 17, 2022 through July 4, 2023 including effort, catch per unit effort, and average, minimum, and maximum fork length of captured juvenile salmon. Weeks with zero catch of unmarked juvenile late fall-run Chinook salmon are not included in this table.

Week	Start of Week	Total Catch	Effort (Hours)	Catch Per Unit Effort	Average FL (mm)	Minimum FL (mm)	Maximum FL (mm)
15	4/9/2023	1	244.7	0.00409	34	34	34
16	4/16/2023	1	407.3	0.00246	25	25	25
19	5/7/2023	4	717.0	0.00558	37	35	38
20	5/14/2023	1	263.4	0.00380	42	42	42
22	5/28/2023	1	309.3	0.00323	34	34	34
	Total Catch	**8**					

Marked Juvenile Chinook Salmon Catch

A total of 433 marked juvenile Chinook salmon were observed during the 2022-2023 monitoring season at the lower Feather River RST site. The first marked juvenile Chinook salmon was caught on March 17, 2023 in week 11 and was assigned as spring-run by LAD

criteria. Catch of this fish occurred the day after FRFH released approximately 731,457 juvenile spring-run Chinook salmon into the Feather River at two locations upstream of the RST site (Table 7).

Table 7. Summary of hatchery-produced juvenile Chinook salmon and steelhead released by the Feather River Fish Hatchery at two locations upstream of the lower Feather River RST monitoring site during the sampling period from October 17, 2022 through July 4, 2023. Release date, species, run, average fork length (FL), total number of fish released, and percent of fish marked is provided for each release group.

Week	Release Date	Species	Run	Release Site	Average FL (mm)	Total Number Released	% Marked
6	2/6/23-2/10/23	Steelhead	N/A	Boyd's Pump	220	408,900*	100%
7	2/13/23-2/16/23	Steelhead	N/A	Boyd's Pump	220	408,900*	100%
11	3/16/2023	Chinook	Spring	Boyd's Pump	82	366,267	100%
11	3/16/2023	Chinook	Spring	Gridley Boat Ramp	82	365,190	100%
12	3/24/2023	Chinook	Spring	Boyd's Pump	86	362,343	100%
12	3/24/2023	Chinook	Spring	Gridley Boat Ramp	87	366,243	100%
15	4/11/2023	Chinook	Fall	Gridley Boat Ramp	70	508,111	25%
15	4/11/2023	Chinook	Spring	Boyd's Pump	93	450,885	100%
15	4/11/2023	Chinook	Spring	Gridley Boat Ramp	87	430,995	100%
16	4/21/2023	Chinook	Fall	Boyd's Pump	88	1,008,917	25%
16	4/21/2023	Chinook	Fall	Gridley Boat Ramp	75	504,488	25%

Peak catch of marked juvenile salmonids occurred in week 15, during which 150 marked juvenile Chinook salmon were caught. Trapping efforts were reduced by using half-cone during this week to reduce the potential for RST-related mortalities of hatchery released fish. To calculate CPUE during half-cone sampling, effort was halved. The estimated CPUE during the peak catch week for marked juvenile Chinook salmon was 0.613.

Marked Spring-run Chinook Salmon

A total of 243 marked spring-run Chinook salmon were captured during the 2022-2023 monitoring season at the lower Feather River RST monitoring site, making up 56% of the overall marked juvenile Chinook salmon catch. The first marked spring-run was caught on March 17, 2023 in week 11; the last was caught on May 29 in week 22. Peak catch occurred during week 15 when 113 marked spring-run were trapped, the CPUE was calculated to be 0.462 during this period. Table 68 provides a summary of marked spring-run catch for the 2022-2023 sampling

season. All juvenile spring-run Chinook salmon sampled by the RSTs were assumed to be BY 2022 based on size at capture.

Table 8. Summary of weekly catch of marked juvenile spring-run Chinook salmon at the lower Feather River RST monitoring site October 17, 2022 through July 4, 2023, including effort, catch per unit effort, and average, minimum, and maximum fork length of captured juvenile salmon. Weeks with zero catch of marked juvenile Chinook salmon are not included in this table.

Week	Start of Week	Total Catch	Effort (Hours)	Catch Per Unit Effort	Average FL (mm)	Minimum FL (mm)	Maximum FL (mm)
11	3/12/2023	23	72.6	0.31663	75	67	85
12	3/19/2023	28	119.8	0.23364	77	67	88
13	3/26/2023	28	172.7	0.16217	79	63	88
14	4/2/2023	18	297.5	0.06050	83	70	90
15	4/9/2023	113	244.7	0.46171	87	79	97
16	4/16/2023	28	407.3	0.06874	89	81	104
17	4/23/2023	4	228.7	0.01749	95	87	106
22	5/28/2023	1	309.3	0.00323	129	129	129
	Total Catch	**243**					

Marked Fall-run Chinook Salmon

A total of 189 marked fall-run Chinook salmon were captured during the 2022-2023 monitoring season at the lower Feather River RST monitoring site, making up 44% of the overall marked juvenile Chinook salmon catch. The first marked fall-run was caught on March 18, 2023 in week 11; the last marked fall-run was caught on May 29 in week 22. Peak catch occurred during week 16 when 106 fall-run were trapped, the CPUE was estimated to be 0.260 during this period. Table 69 provides a summary of marked fall-run catch for the 2022-2023 sampling season. All juvenile marked fall-run Chinook salmon sampled by the RSTs were assumed to be BY 2022 based on size at capture.

Table 9. Summary of weekly catch of marked juvenile fall-run Chinook salmon at the lower Feather River RST monitoring site from October 17, 2022 through July 4, 2023, including effort, catch per unit effort, and average, minimum, and maximum fork length of captured juvenile salmon. Weeks with zero catch of marked juvenile Chinook salmon are not included in this table.

Week	Start of Week	Total Catch	Effort (Hours)	Catch Per Unit Effort	Average FL (mm)	Minimum FL (mm)	Maximum FL (mm)
11	3/12/2023	2	72.6	0.02753	66	65	66
12	3/19/2023	5	119.8	0.04172	55	45	63
13	3/26/2023	3	172.7	0.01738	68	68	69
14	4/2/2023	1	297.5	0.00336	66	66	66
15	4/9/2023	37	244.7	0.15118	71	56	79
16	4/16/2023	106	407.3	0.26024	73	51	83
17	4/23/2023	14	228.7	0.06121	73	61	87
18	4/30/2023	4	261.8	0.01528	71	60	84
19	5/7/2023	13	717.0	0.01813	82	75	92
21	5/21/2023	3	379.9	0.00790	95	91	102
22	5/28/2023	1	309.3	0.00323	83	83	83
	Total Catch	**189**					

Summary of Steelhead Trout Catch

The lower Feather River RSTs caught 295 steelhead during the 2022-2023 sampling season. Of the total steelhead catch, 97.6% were ad-clipped (n=288). Only 7 of the 295 (2.37%) steelhead captured in the RSTs were unmarked. Any steelhead observed in the RSTs with an intact adipose fin were recorded as natural origin as 100% of hatchery steelhead released by FRFH were marked with adipose fin clips. The FRFH released 408,900 marked steelhead at Boyd's Pump Boat Launch from February 6, 2023 through February 16, 2023 (Table 7). All marked steelhead were caught following the February 6, 2023 release and were recorded as hatchery origin.

Table **10** provides a summary of all juvenile steelhead catch for the 2022-2023 sampling season.

Table 10. Summary of weekly catch of marked and unmarked juvenile steelhead trout, including average fork length (mm), at the lower Feather River RST monitoring site from October 17, 2022 through July 4, 2023. Weeks with zero catch of juvenile steelhead are not included in this table.

Calendar Week	Start of Week	Marked Steelhead	Average FL (Marked) (mm)	Unmarked Steelhead	Average FL (Unmarked) (mm)
46	11/13/2022	0	N/A	1	81
50	12/11/2022	0	N/A	1	60
6	2/5/2023	40	210	0	N/A
7	2/12/2023	167	206	0	N/A
8	2/19/2023	45	208	0	N/A
9	2/26/2023	34	219	0	N/A
13	3/26/2023	1	180	0	N/A
16	4/16/2023	1	246	0	N/A
23	6/4/2023	0	N/A	2	49
24	6/11/2023	0	N/A	2	33.5
25	6/18/2023	0	N/A	1	45
	Total Catch	**288**		7	

Unmarked Steelhead Trout Catch

Unmarked juvenile steelhead catch consisted of seven individuals from week 46 through 25, with minimal increase in catch (greater than one steelhead) in weeks 23 and 24. The unmarked juvenile steelhead measured between 27 and 81 mm (averaging 50 mm) and thus were classified as YOY (less than 100 mm FL) and were assumed to be BY 2023.

Marked Steelhead Trout Catch

The lower Feather River RST caught a total of 288 marked steelhead starting in week 6 and continuing to week 16. Peak catch of marked juvenile steelhead occurred in week 7, with 167 individuals captured. Week 7 catch comprised 58% of the total steelhead catch and had a CPUE of 0.51.

Marked steelhead captured at the lower Feather River RSTs ranged in FL from a minimum of 109 mm to a maximum of 270 mm, with an average of 209 mm. All marked steelhead captured this season were classified as yearlings, from BY 2022.

Trap Efficiency Trials and Passage Estimates

A total of ten trap efficiency trails were performed during the 2022-2023 trapping season, during weeks 3, 6-9, 11-13, 15, and 16 (Table 11). During each trial, fish were stained with BBY or marked with VIE tags and released approximately one mile upstream from the RST location. The release groups contained between 491-1,040 marked fall-run Chinook salmon obtained from the FRFH. Trap efficiencies during trials ranged from 0% to 0.89% with an average efficiency of 0.17%. All recaptures occurred within seven days from the date of release.

Table 11. Summary of efficiency trials performed during the 2022-2023 lower Feather River RST trapping season, including release date, origin of fish, run, type of mark, total released, total recaptured, and percent efficiency.

Week	Release Date	Origin	Run	Mark	Total Released	Total Recaptured	% Efficiency
3	1/20/2023	FRFH	Fall	BBY	970	2	0.21%
6	2/11/2023	FRFH	Fall	BBY	936	0	0.00%
7	2/17/2023	FRFH	Fall	BBY	1010	9	0.89%
8	2/24/2023	FRFH	Fall	BBY	979	2	0.20%
9	3/3/2023	FRFH	Fall	BBY	935	3	0.32%
11	3/17/2023	FRFH	Fall	VIE	491	0	0.00%
12	3/24/2023	FRFH	Fall	VIE	536	0	0.00%
13	3/31/2023	FRFH	Fall	VIE	480	0	0.00%
15	4/15/2023	FRFH	Fall	VIE	980	1	0.10%
16	4/20/2023	FRFH	Fall	VIE	1040	0	0.00%
						Average	**0.17%**

The average trap efficiency of 0.17% and associated 90% confidence intervals (0.02%-0.33%) were used to calculate a passage estimate of 1,868,139, with lower and upper estimates of 990,818 and 16,308,747 respectively, for unmarked juvenile Chinook salmon emigrating in the lower Feather River near Star Bend between October 17, 2022 and July 4, 2023. This total estimated passage of unmarked juvenile Chinook salmon includes: 1,620,192 fall run, 3,731 late fall-run, and 244,216 spring-run (Table 12). Winter-run Chinook salmon were observed in catch during the 2022-2023 monitoring season; however, winter-run are not known to spawn in the Feather River Watershed, so any juvenile winter-run observed at this trapping location were likely exhibiting non-natal rearing behavior.

Table 12. Passage Estimates with upper and lower estimates calculated using average trap efficiency of 0.17% and 90% Confidence Intervals of .02%-.33% for unmarked juvenile Chinook salmon by run, including fall-run, spring-run, and late fall-run that passed the lower Feather River RST sampling site from October 17, 2022 through July 4, 2023. A passage estimate for winter-run was not calculated.

Statistic	Fall-run	Spring-run	Late Fall-run	Total Unmarked
Estimated Passage	1,620,192	244,216	3,731	1,868,139
Upper Estimate	14,144,184	2,131,990	32,572	16,308,747
Lower Estimate	859,313	129,526	1,979	990,818

Other Fish Captured

A total of 2,657 non-target fish species were trapped in the lower Feather River RSTs during the 2022-2023 sampling season. All fish bycatch were identified to species if possible, or to genera. Some juveniles were too small to be confidently identified and were recorded as unknown minnow or "other". Total length (TL) was measured for up to ten individuals for each bycatch species for each RST and the remaining fish were tallied. A total of 41 different fish species were observed as bycatch (Table 13).

Table 13. Summary of non-salmonid fish species by common and scientific name captured in the lower Feather River RSTs from October 17, 2022 through July 4, 2023, including the total number caught and average, minimum, and maximum total lengths for each species.

Common Name	Species Name	Total Catch	Average Total Length (mm)	Minimum Total Length (mm)	Maximum Total Length (mm)
American shad	*Alosa sapidissima*	5	137	96	250
Black bullhead	*Ameiurus melas*	1	25	25	25
Black crappie	*Pomoxis nigromaculatus*	4	53	31	105
Bluegill	*Lepomis macrochirus*	21	52	25	110
Brown bullhead	*Ameiurus nebulosus*	6	91	52	230
California roach	*Hesperoleucus symmetricus*	92	60	30	133
Channel catfish	*Ictalurus punctatus*	131	62	34	250
Common carp	*Cyprinus carpio*	678	57	27	90
Fathead minnow	*Pimephales promelas*	4	51	34	62
Golden shiner	*Notemigonus crysoleucas*	165	75	31	122
Goldfish	*Carassius auratus*	12	46	33	55
Green sunfish	*Lepomis cyanellus*	5	69	41	108
Hardhead	*Mylopharodon conocephalus*	101	70	25	182
Hitch	*Lavinia exilicauda*	12	79	42	104
Inland silverside	*Menidia beryllina*	26	64	41	97
Largemouth bass	*Micropterus salmoides*	3	103	88	118
Mosquitofish	*Gambusia*	202	33	19	55
Pacific lamprey	*Lampetra entosphenus*	58	151	110	255
Prickly sculpin	*Cottus asper*	6	70	28	96
Pumpkinseed	*Lepomis gibbosus*	4	140	108	160
Red shiner	*Cyprinella lutrensis*	2	107	100	114
Redear sunfish	*Lepomis microlophus*	10	148	43	200
Riffle sculpin	*Cottus gulosus*	29	50	22	129
River lamprey	*Lampetra ayresii*	10	143	124	169
Sacramento pikeminnow	*Ptychocheilus grandis*	267	80	27	230
Sacramento sucker	*Catostomus occidentalis*	31	42	21	187

Common Name	Species Name	Total Catch	Average Total Length (mm)	Minimum Total Length (mm)	Maximum Total Length (mm)
Smallmouth bass	*Micropterus dolomieu*	169	83	36	240
Speckled dace	*Rhinichthys osculus*	1	27	27	27
Spotted bass	*Micropterus punctulatus*	82	59	22	101
Striped bass	*Morone saxatilis*	10	96	22	250
Threadfin shad	*Dorosoma petenense*	1	250	250	250
Tule perch	*Hysterocarpus traskii*	41	79	30	155
Unknown bass (Micropterus)	*Micropterus sp.*	22	24	13	32
Unknown Centrarchid	*Centrarchidae*	76	29	21	45
Unknown lamprey	*Petromyzontidae*	127	146	100	182
Unknown minnow		70	27	15	42
Wakasagi / Japanese smelt	*Hypomesus nipponensis*	120	62	32	102
Warmouth	*Lepomis gulosus*	2	81	62	99
Western brook lamprey	*Lampetra richardsoni*	4	149	136	154
White catfish	*Ameiurus catus*	43	59	36	134
White crappie	*Pomoxis annularis*	3	102	91	122

DISCUSSION

The second season of juvenile Chinook salmon emigration monitoring occurred at the lower Feather River RST site near Star Bend from October 17, 2022 through July 4, 2023. The season was initiated 33 days before the first salmon were caught on December 3, indicating that the 2022-2023 monitoring period encompassed the start of juvenile Chinook salmon emigration in the lower Feather River. There were 260 potential trapping days during the 2022-2023 season; the traps were non-operational for a total of 30 days. Two large storm events, occurring from December 31, 2022 to January 14, 2023 and March 9, 2023 to March 20, 2023, (see Figure 3) resulted in rapid flow changes which altered the position of the traps and their vulnerability to debris, increased boating hazards, and created tension on the anchor lines, presenting unsafe working conditions for staff and leading to a cessation in trapping for a total of 17 days. The remaining non-operational days were due to either staffing limitations or low flows resulting in low to no cone revolutions regardless of the position of the traps in the stream channel. The monitoring season ended on July 4, 2023 due to insufficient flow to operate the traps; however, the gradual decline in catch over the last three weeks of trapping (Table 2) indicated that the number of remaining juvenile Chinook salmon emigrants had decreased. This observation

supports the assumption that the RST monitoring site near Star Bend sampled most of the 2022-2023 juvenile spring-run Chinook salmon emigration period in the lower Feather River.

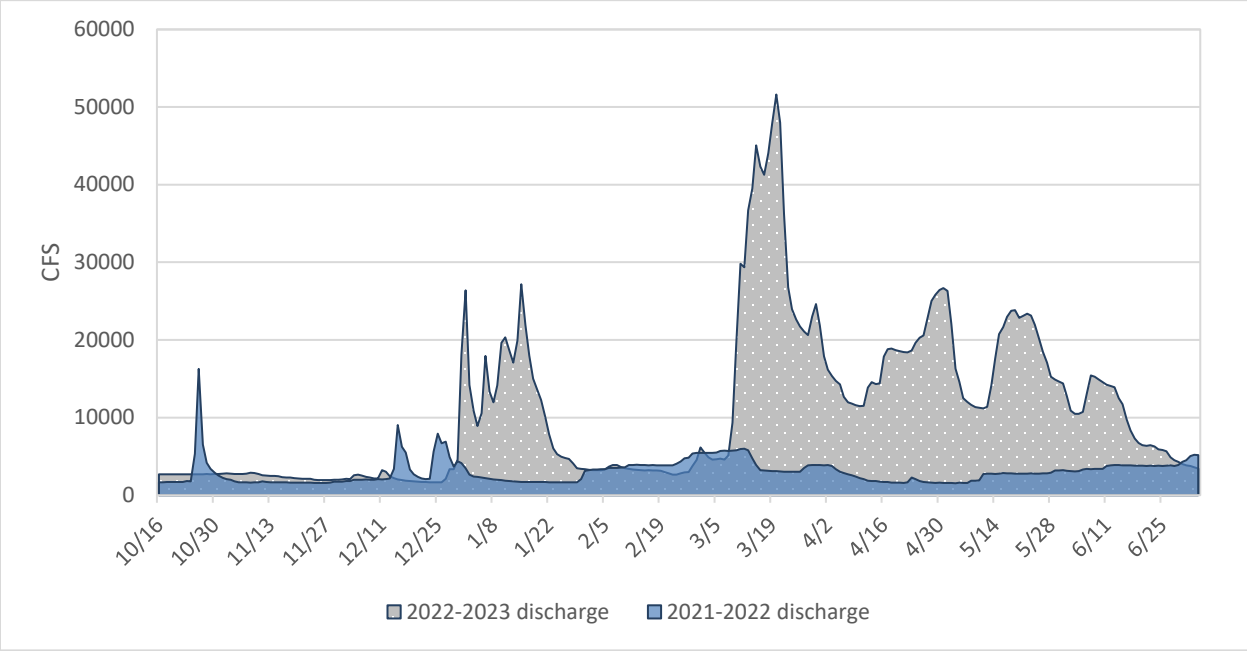

Figure 3. A comparison of daily river discharge in the lower Feather River near the Star Bend RST site recorded from the CDEC Feather River at Boyd's Landing Above Star Bend gauge during the 2022-2023 monitoring season from October 16, 2022 to July 4, 2023 and 2021-2022 monitoring season from October 16, 2021 to July 4, 2022 (DWR, 2024).

The 2022-2023 sampling effort captured a total of 2,320 unmarked juvenile Chinook salmon over 10,617 trapping hours at the lower Feather River RST site near Star Bend. The total catch from the 2022-2023 season was 21% lower than the 2021-2022 season's catch of 3,077 unmarked juvenile Chinook salmon over 6,808 trapping hours. Table 14 provides a comparison of total catch, sampling effort, efficiency data, and passage estimates of unmarked juvenile Chinook salmon for the 2021-2022 and 2022-2023 monitoring periods.

Table 14. A comparison of total catch, sampling effort (trapping hours), efficiency data, and passage estimates, with upper and lower passage estimates, of unmarked juvenile Chinook salmon generated for the lower Feather River at the Star Bend RST site across the 2021-2022 and 2022-2023 monitoring seasons.

Sampling Year	2021-2022	2022-2023
Sampling Period	**January-June**	**October-July**
Unmarked Catch Total	3,077	2,320
Trapping Hours Total	6,808	10,617
Number of Efficiency Trials	6	10
Average Efficiency	0.79%	0.17%
Standard Deviation	0.0117	0.0026
Confidence Interval	80%	90%
Passage Estimate	489,681	1,868,139
Lower Estimate	247,932	990,818
Upper Estimate	19,633,729	16,308,747

The loss of 17 trapping days during the large storm events may have contributed to the lower total catch during the 2022-2023 versus the 2021-2022 sampling season, as studies have shown juvenile salmonid emigration increases during large flow events (see Michel et al. 2013 and Giorgi et al. 1997). Specifically, the RSTs were not operating during peak flows in January and March when a large number of juvenile spring-run Chinook salmon may have passed the RST site, therefore resulting in lower overall catch.

The lower total catch during the 2022-2023 season may also be attributed to the comparatively wet water year (Figure 3) and corresponding increase in river discharge which created a wider, deeper channel, reducing the active sampling area and therefore the number of salmon captured in the traps. This is evident when comparing the average trap capture efficiency for the two seasons. The 2021-2022 season had an average trap efficiency of 0.79% during a drier water year with corresponding lower than average flows. The 2022-2023 season had an average trap efficiency of 0.17% during a wetter water year with corresponding higher than average flows. The lower percent average trap capture efficiency for the 2022-2023 season aligns with the supposition that the increased flow reduced sampling efficiency thereby resulting in a decrease in catch. Additionally, the lower average percent trap capture efficiency during the 2022-2023 season resulted in a higher passage estimate than the 2021-2022 season, as each individual salmon captured by the RST represented proportionally more fish passed. So, while the total catch of unmarked juvenile Chinook salmon was higher during the 2021-2022 season, this was likely due to increased efficiency due to low flows rather than an indication of more fish captured during the 2021-2022 season versus the 2022-2023 season.

During the 2022-2023 season, juvenile LAD winter-run Chinook salmon were captured for the first time at this monitoring location. Specifically, six unmarked winter-run sized salmon were captured between December 31 and January 20, 2023. Fin clips were collected from three individuals for genetic analysis, two were confirmed as winter-run and one was identified as spring-run. Winter-run Chinook salmon are not known to spawn in the Feather River and

studies have found that 44-65% of sampled winter-run adults had reared in non-natal habitats as juveniles (Phillis et al. 2018; Maslin et al. 1998). Therefore, it is likely that juvenile winter-run observed in catch at the Star Bend RST site in the lower Feather River were exhibiting non-natal rearing behavior. In future seasons, fin clips will be collected from all winter-run caught at the Star Bend RST site to confirm run identification.

The lower Feather River RSTs captured more unmarked juvenile spring-run Chinook salmon in 2022-2023 with a total of 289 versus the 37 caught in 2021-2022. The variation in unmarked spring-run salmon catch can be partially attributed to the difference of timing between the seasons. The first full day of trapping during the 2021-2022 season was January 20; by that time during the 2022-2023 season, 64% of the total spring-run catch had already occurred, therefore it is likely that many of the juvenile spring-run passed the Star Bend RST site prior to the start of trapping during the 2021-2022 season. The difference in spring-run catch between monitoring seasons could also be attributed to environmental factors. The 2022-2023 season had favorable emigration conditions, including higher flow, higher turbidity, and extended low water temperatures (Table 1), likely decreasing predation and disease effects and increasing migration speed and survival. Emigration conditions were less favorable and potentially lethal during the 2021-2022 season with low flows and elevated water temperatures, making fish more exposed to predators and vulnerable to disease and stress. The releases of spring-run from FRFH on March 16, March 24, and April 11, did not impact catch data for natural (unmarked) origin spring-run as 100% of fish released were marked.

Fall-run were the most abundant run of unmarked juvenile Chinook salmon caught at the lower Feather River RSTs, with a total of 2,017 fish, comprising 86.9% of the total 2022-2023 unmarked juvenile Chinook salmon catch. Fall-run emigration occurred in multiple peaks associated with periods of increasing flow (Figure 4).

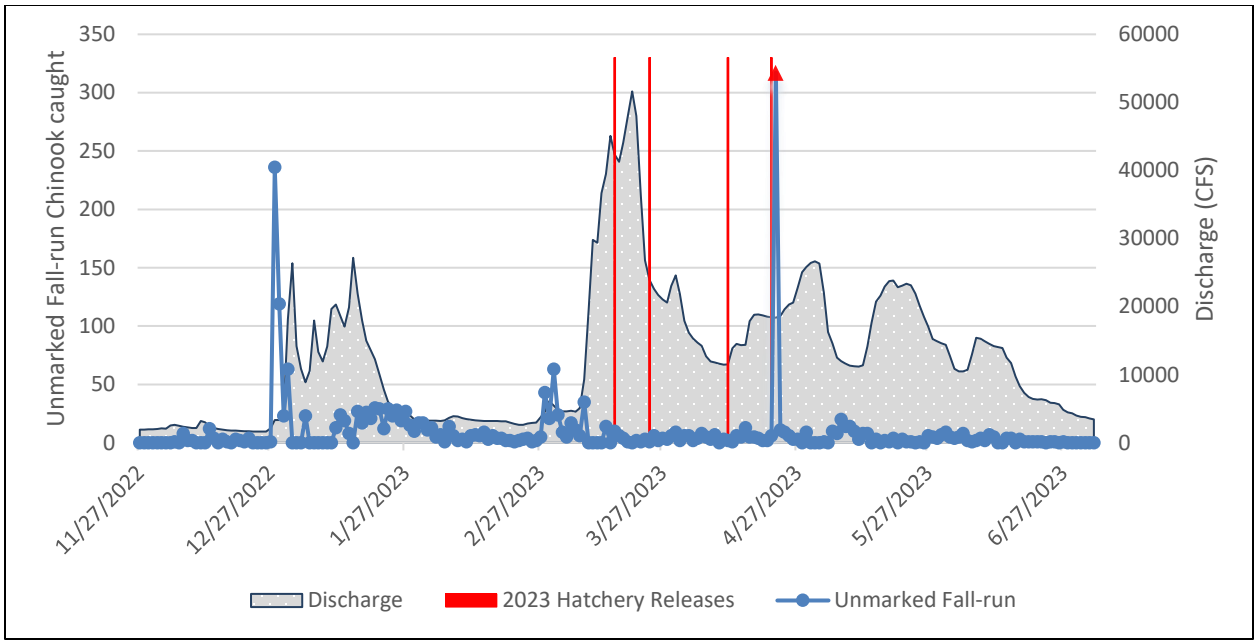

Figure 4. Unmarked fall-run Chinook salmon catch (indicated by the blue line) at the lower Feather River RST monitoring site during the 2022-2023 monitoring season compared with average weekly river discharge recorded from the CDEC Feather River at Boyd's Landing Above Star Bend gauge from November 27, 2022 to July 4, 2023 (DWR, 2024). Hatchery releases of juvenile Chinook salmon from the Feather River Fish Hatchery are indicated by red bars.

Unmarked fall run catch at the lower Feather River RST site was visibly impacted by the release of partially marked (25%) fall-run Chinook salmon from the FRFH on April 21, 2023. Specifically, Figure 4 shows the highest daily catch of unmarked fall-run Chinook salmon (n=317) occurring on April 22, 2023, the day following the hatchery release. The April 21 release was the second and largest release of partially marked hatchery fall-run on the lower Feather River (Table 7). Conversely, no spike in unmarked fall run catch was observed following the release of partially marked (25%) fall-run Chinook salmon from the FRFH on April 11. However, the RSTs were operating in half-cone configuration at that time, which likely reduced sampling effort by half and subsequently decreased daily catch. Since no sizable change in daily natural origin fall-run catch was observed during the days following the April 11 hatchery release, it is assumed that the release had a small effect on natural catch data.

Unmarked juvenile Chinook salmon captured in the RSTs following hatchery releases of partially marked juvenile fall-run Chinook salmon are assumed to be a mix of hatchery and natural origin fish due to the inability to visually distinguish between unmarked hatchery and natural origin juvenile salmon. Further, juvenile salmon captured in the RSTs and identified as spring-run or fall-run using LAD criteria may be a mix of runs due to the overlap in emigration timing of spring-run and fall-run and run misidentification issues associated with the LAD criteria. For example, the 44 natural origin spring-run recorded on April 22, 2023 using LAD criteria may have been a mix of natural spring-run, natural fall-run, and unmarked hatchery origin fall-run from the April 21 partially marked fall-run release from FRFH (Table 7). Research by Brandes et

al. (2021) has shown extensive overlap in run-specific fork lengths of genetically identified juvenile Chinook salmon, indicating that the traditional LAD criteria (Greene, 1992) is a not an optimal method of run identification. Currently LAD criteria are the best available scientific methodology for determining juvenile Chinook salmon run during field sampling in the Central Valley. The spring-run JPE effort includes a run identification program, with the goal to improve run identification accuracy, simplicity, and speed through development of probabilistic length-at-date (PLAD) models and application of new genetic technology (see Bedwell et al., n.d.) that will provide a more accurate method for assigning Chinook salmon run to juveniles. Genetic sampling was conducted during both the 2021-2022 and 2022-2023 sampling seasons and will continue in future sampling seasons at the lower Feather River RST monitoring site and several other RST sites within the Sacramento River watershed to gather information for development of the PLAD model. due to the overlap in emigration timing of spring-run and fall-run and run misidentification in the field using LAD criteria (further discussed below).

Steelhead catch at the lower Feather River RST site consisted primarily of hatchery origin yearlings (n=288). Few unmarked (i.e., natural origin) individuals were captured (n= 7), and all were YOY. Some variation in the origin of steelhead catch (natural versus hatchery) may be attributed to higher avoidance of the traps by naturally adapted juveniles, as research has found lower threat avoidance behavior in hatchery raised versus wild spawned steelhead (Berejikian, 1995). The variation in origin of captured fish could also be influenced by the difference in local abundance. Specifically, hatchery origin steelhead were released in large numbers (n=408,900) four river miles upstream from the RST site on February 6 through 16, 2023; 72% of hatchery origin steelhead catch occurred in the two weeks following the initial release date. The increased density of fish in the water column during that two-week period likely resulted in a higher probability of capture when compared to natural origin steelhead. Natural origin steelhead may have emigrated downstream more gradually, so fewer individuals would be passing the trap trapping location at a single point, reducing the probability of capture.

Future monitoring seasons will illuminate more about trends in catch and the influence of environmental variables on salmonid migratory patterns at this monitoring site and will allow for a more precise analysis of the data collected over time. The 2022-2023 season's sampling efforts provided valuable salmonid emigration data to water management teams and fisheries agencies in real-time to adaptively manage Delta water operations and contribute to the development of JPE model approaches and PLAD development.

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REFERENCES

Azat, J. 2024. GrandTab 2024.05.20 California Central Valley Chinook Escapement Database Report. California Department of Fish and Wildlife

Bedwell, M., M. Baerwald, B. Harvey, N. Hendrix, J. Rodzen, S. Holley, and A. Allison. n.d. Spring-run Chinook salmon JPE race identification research and initial monitoring plan. Department of Water Resources, QEDA Consulting, and California Department of Fish and Game. Sacramento, CA.

Bell, H.N. 2022. Assessment of the Effects of Thiamine Deficiency on the Survival, Physiology, and Behavior of Early Life-Stage Winter-Run Chinook Salmon. UC Davis. ProQuest ID: Bell_ucdavis_0029M_21136. Merritt ID: ark:/13030/m5sg04ft. Retrieved from https://escholarship.org/uc/item/465026qq.

Berejikian, B.A.. 1995. The effects of hatchery and wild ancestry and experience on the relative ability of steelhead trout fry (Oncorhynchus mykiss) to avoid a benthic predator. Canadian Journal of Fisheries and Aquatic Sciences. 52(11): 2476-2482. https://doi.org/10.1139/f95-838

Brandes, P.L., B. Pyper, M. Banks, D. Jacobson, T. Garrison, and S. Cramer. 2021. Comparison of Length-at-Date Criteria and Genetic Run Assignments for Juvenile Chinook Salmon Caught at Sacramento and Chipps Island in the Sacramento–San Joaquin Delta of California. San Francisco Estuary and Watershed Science, 19(3).

California Department of Water Resources (DWR). 2024. California Data Exchange Center (CDEC), Feather River at Star Bend Gauge and Feather River near Gridley Gauge. Data retrieved June 2024 from http://cdec.water.ca.gov/.

California Department of Water Resources (DWR). 2021. Incidental Take Permit for the long-term operation of the State Water Project: 2021 water transfer monitoring plan. California Department of Water Resources, Division of Environmental Services, Oroville, CA.

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

Foott, J. S., J. Kindopp, K. Gordon, A. Imrie, and K. Hikey. 2023. Ceratonova shasta infection in lower Feather River Chinook juveniles and trends in water-borne spore stages. California Fish and Wildlife Scientific Journal. 109(2).Greene, S. 1992. California Department of Water Resources, Division of Environmental Services. Memo Report to R. L. Brown,

Division Chief, DWR Division of Environmental Services. Re: Estimated winter-run Chinook salmon salvage at the State Water Project and Central Valley Project Delta pumping facilities. Dated May 8, 1992.

Giorgi, A.E., T.W. Hillman, J.R. Stevenson, S.G. Hays, and C.M. Peven. 1997. Factors that influence the downstream migration rates of juvenile salmon and steelhead through the hydroelectric system in the mid-Columbia River basin. North American Journal of Fisheries Management 17(2): 268–282.

Greene, S. 1992. Daily fork-length table from data by Frank Fisher, California Department of Fish and Game. California Department of Water Resources, Environmental Services Department, Sacramento.

Hallock, R.J. 1989. Upper Sacramento River steelhead, (Oncorhynchus mykiss), 1952-1998. Report to the Fish and Wildlife Service. 85pp.

Kennen, J.G., S.J. Wisniewski, N.H. Ringler, and H.M. Hawkins. 1994. Application and modification of an auger trap to quantify emigrating fishes in Lake Ontario tributaries. North American Journal of Fisheries Management 14: 828 – 836.

Kurth, R. 2012. Migratory patterns of lower Feather River natural and hatchery-origin Oncorhynchus mykiss. Environmental biology of fishes, 96: 355-362

Mantua, N., Johnson, R., Field, J., Lindley, S., Williams, T., Todgham, A., Jeffres, C., Bell, H., Cocherell, D., Rinchard, J. and Tillitt, D., 2021. Mechanisms, impacts, and mitigation for thiamine deficiency and early life stage mortality in California's Central Valley Chinook Salmon. North Pacific Anadromous Fish Commission Technical Report, 17, pp.92-93.

Maslin, P., M. Lennox, J. Kindopp, and W. Mckinney (1998). Intermittent streams as rearing habitat for Sacramento River Chinook salmon (Oncorhynchus tshawytscha): 1998 Update. California State University, Chico, CA. August 10, 1997.

Michel, C.J., Ammann, A.J., Chapman, E.D., Sandstrom, P.T., Fish, H.E., Thomas, M.J., Singer, G.P., Lindley, S.T., Klimley, A.P., and Macfarlane, R.B. 2013. The effects of environmental factors on the migratory movement patterns of Sacramento River yearling late-fall run Chinook salmon (Oncorhynchus tshawytscha). Environmental biology of fishes, 96(2–3): 257–271.

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

National Oceanic and Atmospheric Association Fisheries (NOAA Fisheries). 2021. Monitoring thiamine deficiency in California salmon. September 28, 2021. NOAA Fisheries West Coast Region Science and Data. Retrieved December 2, 2023, from: https://www.fisheries.noaa.gov/west-coast/science-data/monitoring-thiamine-deficiency-california-salmon.

Pacific Fishery Management Council (PFMC). 2019. Salmon rebuilding plan for Sacramento River fall Chinook. Prepared for National Oceanic and Atmospheric Administration. Pacific Fishery Management Council

Phillis, C.C., A.M. Sturrock, R.C. Johnson, and P.W. Weber (2018). Endangered winter-run Chinook salmon rely on diverse rearing habitats in a highly altered landscape. Biological Conservation 217: 358-362.

Ray, R. A., R. A. Holt, and J. L. Bartholomew. 2012. Relationship Between Temperature and Ceratomyxa shasta–Induced Mortality in Klamath River Salmonids. Journal of Parasitology. 98(3): 520-526.

Volkhardt, G.C., S.L. Johnson, B.A. Miller, T.E. Nickelson and D.E. Seiler. Rotary Screw Traps and Inclined Plane Screen Traps. Pages 235-266 in D.H. Johnson, B.M. Shrier, J.S. O'Neal, J.A. Knutzen, X. Aguero, T.A. O'Neil, and T.N. Pearsons. 2007. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Yoshiyama, R. M., F.W. Fisher, and P.B. Moyle. 1998. Historical abundance and decline of Chinook salmon in the Central Valley region of California. North American Journal of Fisheries Management 18: 487-52.