California Department of Fish and Wildlife

North Central Region

Middle Sacramento River Juvenile Salmon and Steelhead Monitoring Project

Timing, Composition, and Abundance of Juvenile Salmonid Emigration in the Sacramento River Near Knights Landing October 2014 – June 2015[1]

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LIST OF ABBREVIATIONS AND ACRONYMS

BO	Biological Opinion
BY	Brood year
CDEC	California Data Exchange Center
CFS	Cubic feet per second
CDFW	California Department of Fish and Wildlife
cm	Centimeter
CNFH	Coleman National Fish Hatchery
CVP	Central Valley Project
CWT	Coded wire tag
ESA	Endangered Species Act
DCC	Delta Cross Channel
FL	Fork length
km	kilometer
LAD	Length at date
mm	Millimeter
NMFS	National Marine Fisheries Service
NTU	Nephelometric turbidity units
OCAP	Operations Criteria and Procedures
QAQC	Quality assurance and quality control
rKm	River kilometer
RPAs	Reasonable and Prudent Alternatives
RPM	Revolutions per minute
RST	Rotary screw trap
SWP	State Water Project
YOY	Young-of-the-year

EXECUTIVE SUMMARY

The North Central Region of the California Department of Fish and Wildlife operates a juvenile salmonid monitoring program on the Sacramento River in California to obtain information on the temporal distribution, relative abundance, and composition of race and species of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*) emigrating from the upper Sacramento River to the Sacramento-San Joaquin Delta (Delta). These data are collected at two separate locations and use two paired rotary screw traps (RST) outfitted with 2.4m cone. The most downstream location is 0.8 kilometers (km) downstream of Knights Landing, CA at Sacramento River kilometer (Rkm) 144. Data collection is permitted under an Endangered Species Act (ESA) Section 10(a)(1)(A) Permit issued by the National Marine Fisheries Service (NMFS).

The monitoring program entered its 19th consecutive year of sampling at the Knights Landing monitoring site beginning on October 1, 2014. Sampling concluded on June 05, 2015 for a total of 34 weeks of sampling.

During the season, 7,912 unmarked (adipose fin intact) juvenile Chinook salmon were captured in 8,151.62 hours of sampling, yielding an average CPUE of 0.97 salmon per hour. Peak catch occurred during calendar week 6, when 4,445 unmarked juvenile Chinook were captured. Juvenile Chinook salmon were identified to run using length-at-date (LAD) criteria developed by Fisher (1992) and modified by Greene (1992). The LAD based run assignment is a widely used technique in the Central Valley for identifying juvenile Chinook salmon when multiple runs are present (Harvey 2011). Of the 7,912 unmarked juvenile Chinook salmon captured, 191 (2.4%) were identified as winter-run, 428 (5.4%) identified spring-run, 7,271 (91.9%) identified as fall-run, and 22 (0.3%) identified as late fall-run. Trap efficiency data was applied to catch totals to produce run-specific passage estimates. The passage estimate for fall-run was 1,749,022; for spring-run was 119,944; and for winter-run was 24,047. An estimate was not produced for late fall-run chinook because no efficiency data was available during their observed emigration timing at Knights Landing.

A total of 478 hatchery produced Chinook salmon was captured by the Knights Landing RSTs. These fish were identified by a missing adipose fin which is removed by hatchery staff prior to fish release. During the sampling period, four releases of brood year (BY) 2014 late fall-run Chinook salmon were completed by Coleman National Fish Hatchery (CNFH). Additionally, two releases of BY 2014 winter-run Chinook salmon were completed by Livingston Stone National Fish Hatchery (LSNFH). These releases occurred upstream of the Knights Landing sampling site. Of the 478 hatchery produced Chinook salmon captured, 390 (81.6%) were identified as winter-run, 39 (8.2%) were identified as late fall-run, 46 (9.6%) were identified as spring-run and 3 (0.6%) were identified as fall-run. The hatcheries upstream of the sampling site do not produce spring-run Chinook and the CNFH's production releases of its BY 2014 fall-run Chinook were released in the Sacramento Delta rather than in-river. It is assumed that all marked Chinook salmon observed were from the releases completed upstream of the sampling site.

A total of six natural origin steelhead was captured by the Knights Landing RSTs during the sampling season. These fish were caught in weeks 6, 7 and 21. During the sampling period, two steelhead releases were performed by CNFH upstream of the sampling site. A total of 120 hatchery produced steelhead was captured by the Knights Landing RSTs. These fish were caught between week 2 and week 14.

Environmental data collected at the sampling site included the following parameters: river flow volume, water temperature, water transparency, and water turbidity. Sacramento River discharge was recorded at each trap check as reported by the California Data Exchange Center (CDEC) Wilkins Slough gauge. These data were averaged over the calendar week for reporting. River flows at the start of the sampling season, week 40, had a weekly mean of 4,300 cubic feet per second (CFS). River flows at the end of the sampling season, week 23, had a weekly mean of 4,215 CFS. Flows varied throughout the sampling season. In week 51, weekly mean flows peaked at 25,329 CFS and the lowest weekly mean flows of 3,637 were observed in week 42 CFS. Weekly mean water temperature at the start of the survey period (week 40) was 20.0°C. Temperatures varied throughout the survey period with a low weekly mean temperature of 7.1°C (week 1) and a high mean temperature of 22.2°C at the end of the survey period (week 23). Mean weekly water transparency varied between a high of 185.5 centimeters (cm) during week 41 to a low of 16.5 cm during week 51. Mean weekly turbidity at the sampling site varied from a low of 2.8 nephelometric turbidity units (NTU) during week 41 to a high of 360.2 NTU during week 50.

INTRODUCTION

The purpose of the Middle Sacramento River Juvenile Salmonid Emigration Monitoring Program is to develop information on the temporal distribution, relative abundance and composition of race and species of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*) emigrating from the upper Sacramento River to the Delta. The upper Sacramento River and associated tributaries provide spawning and rearing habitat for four native races of Chinook salmon: Sacramento River winter-run (Federal and State listed endangered), Central Valley spring-run (Federal and State listed threatened), Central Valley late fall-run and Central Valley fall-run, as well as native Central Valley steelhead trout (Federal listed threatened). The monitoring program consists of two sampling locations; one near the Tisdale Weir at rKm 196 and one located 0.8km downstream of Knights Landing, CA at Rkm 144. Information presenting the annual timing, composition and abundance of Sacramento River salmonids observed at the Tisdale Weir sampling location is detailed in a separate document. The Knights Landing sampling site is the most downstream monitoring site on the Sacramento River above the confluence with large salmonid bearing tributaries, specifically the American and Feather Rivers located at Sacramento River 96.7 Rkm and 128.8 Rkm, respectively. All salmonids captured by the RSTs at Knights Landing are assumed to be produced in the upper Sacramento River and its tributaries (Figure 1).

Juvenile Chinook salmon emigrate from the upper Sacramento River and its tributaries toward the Delta in a wide range of life stages (Healey 1991). Juvenile fall-run Chinook salmon have a residency period of one to seven months and typically migrate March through July. Juvenile spring-run Chinook salmon have a longer period of stream residency, between three and fifteen months, and may migrate as recently emerged fry, rear for a short period and migrate as smolts, or rear for longer periods and migrate as yearlings. Young-of-year (YOY) spring-run migrate between the months of March and June and between November and April as yearlings. Winter-run juveniles have a residency period of five to ten months and will migrate as YOY or as yearlings during the months of November through May, and may migrate as recently emerged fry, rear for a period and migrate as smolts or rear for longer periods and migrate as yearlings. Juvenile late fall-run Chinook salmon may also migrate as emerged fry, as smolts or as yearlings and typically migrate during the months of November through May (Fisher 1994; Yoshiyama *et al*. 1998).

Adult Central Valley winter steelhead trout generally enter the Delta August through October and spawn December through April. Adult migration and spawning timing may be highly variable depending on river flows and water temperatures during migration periods. Juveniles may rear in their natal stream or affiliated tributary stream for 1-3 years. Juveniles may emigrate anywhere between 1-3 years of age, but generally leave for the ocean at 2 years of age (Hallock 1989).Emigration timing may be highly variable and may occur at any time of the year. However, most juveniles emigrate during spring months with a smaller emigration occurring during fall months.

Two federal fish hatcheries, CNFH and LSNFH (substation of CNFH), located upstream from the sampling location, collectively produce winter-, fall- and late fall-runs of Chinook salmon, as well as Central Valley steelhead trout. These fish help supplement the in river produced populations. Prior to releasing fish into the Sacramento River, these hatcheries externally marked their steelhead production and externally marked a portion of the Chinook salmon production by removing the adipose fin. Externally marked Chinook are also given a coded wire tag (CWT). A small percentage of these hatchery released fish were captured by the RST's.

The abundance of native, anadromous salmonids in California's Central Valley has dropped precipitously because of anthropogenic changes to the environment. Loss of spawning and rearing habitat for the Central Valley salmonids coupled with environmental alterations along migration corridors has put great strain on the natural populations.

Much of the historic spawning habitat for Central Valley salmonids is no longer accessible. Construction of dams on many of the major salmonid bearing streams during the mid-1800's and mid-1900's blocked access to over 72% of salmonid holding, spawning, and rearing areas (Yoshiyama *et al*. 2001). Dams can create unsuitable habitat downstream of the impoundment by increasing in-river temperatures and increasing river channelization while reducing natural river flows, natural cover and natural gravel recruitment necessary for successful spawning.

Streams in the Central Valley have also been altered and channelized with levees to aid in flood protection of city developments and assist in agricultural water needs. These agricultural activities may further compromise water quality with urban and agricultural runoff which often contains pollutants such as pesticides, fertilizers, and treated effluent. Increases in water turbidity from such contaminants can increase water temperatures which affect juvenile survival (Brandes and Mclain 2001, Moyle 2002). Loss of suitable rearing habitat reduces juvenile survivability during emigration which results in a reduction in the salmon population.

The demand for diverted water and associated water transfer activities in the California Central Valley alter aquatic ecosystems by creating unnatural in-river flow regimes, altering flow magnitude and reducing available habitat. These factors can have an overall negative impact on juvenile salmonid survival. Unscreened water diversions in migration corridors may directly impact juvenile salmonids through entrainment mortality. Entrainment of juvenile salmonids may occur at screened water diversions as well; two such diversions are the Harvey Banks Delta Pumping Plant (SWP) and the C.W. Bill Jones Pumping Plant (CVP) (Kimmerer 2008).

The altered aquatic environment in the Central valley may promote the success of non-native fish species. Non-native fishes can negatively affect native species through predation, disrupting food webs, reshaping ecosystem functions, introducing disease, or displacing native species (Mount *et al.* 2012). The introduction of highly efficient piscivores such as the smallmouth bass (*Micropterus dolomieu*), largemouth bass (*M. salmoides*), and striped bass (*Morone saxatilis*) into the Delta in the late 1800's (Dill 1997), has had considerable impacts to native salmonid stocks. These non-native fish have been observed to forage on native salmonids at greater rates than even the largest native piscivore, the Sacramento pikeminnow (*Ptychocheilus grandis*) (Nobriga and Feyer 2007). Non-native piscivores occur in nearly all habitats used by emigrating and rearing salmonid juveniles including spawning grounds in the

Upper Sacramento River and tributaries, the Sacramento River migration corridor, and the Delta.

Protecting juvenile salmonids as they emigrate from their natal waters toward the Delta and onward to the Pacific Ocean is essential to maintain the existence of the remaining salmonid stocks in the Central Valley. Various restrictions have been placed upon water diversion projects within the Delta to protect juveniles during peak emigration periods. Having a near real-time estimate of abundance and emigration timing for protected salmonid species improves the ability to implement and adapt protective measures, enhancing overall protection of salmonids while augmenting water management practice flexibility.

NMFS recognized SWP and CVP Delta water operation practices to be hazardous to listed salmonid species by identifying loss at the south Delta pumping facilities or migratory delay and fish disorientation in the interior Delta. NMFS suggested Reasonable and Prudent Alternatives (RPAs) that would enable water export activities to continue in compliance with the Federal Endangered Species Act including adaptive operations of the Delta Cross Channel (DCC) gates to decrease potential entrainment into the interior Delta (NMFS 2009).

CVP/SWP operations under the 2009 NMFS Operations Criteria and Procedures (OCAP) biological opinion (BO) rely on data collected by the California Department of Fish and Wildlife (CDFW) Middle Sacramento River Juvenile Salmonid Emigration Monitoring Program (Program) near Knights Landing to inform DCC gate operations. Additionally, monitoring data from Knights Landing are used to identify and relay emigration trends and approximate numbers of juvenile salmonids entering the Delta to managers. Data collected by the Program were distributed to constituents by CDFW on a per-trap-check basis; the traps were serviced; data were gathered; data were summarized in an electronic format and then distributed via email the same day.

The primary goals of the Knights Landing program are:

1. Provide early warning of emigrating listed salmonids moving toward the Delta so the CVP and SWP projects can modify their water export activities, including DCC Gate closures for up to three days.
2. Document passage of emigrating salmonids including timing, relative abundance, and response to environmental conditions.
3. Estimate emigrating salmonid numbers in the lower Sacramento River above the Delta.
4. Develop a long-term dataset on emigration with which to compare changes over time.

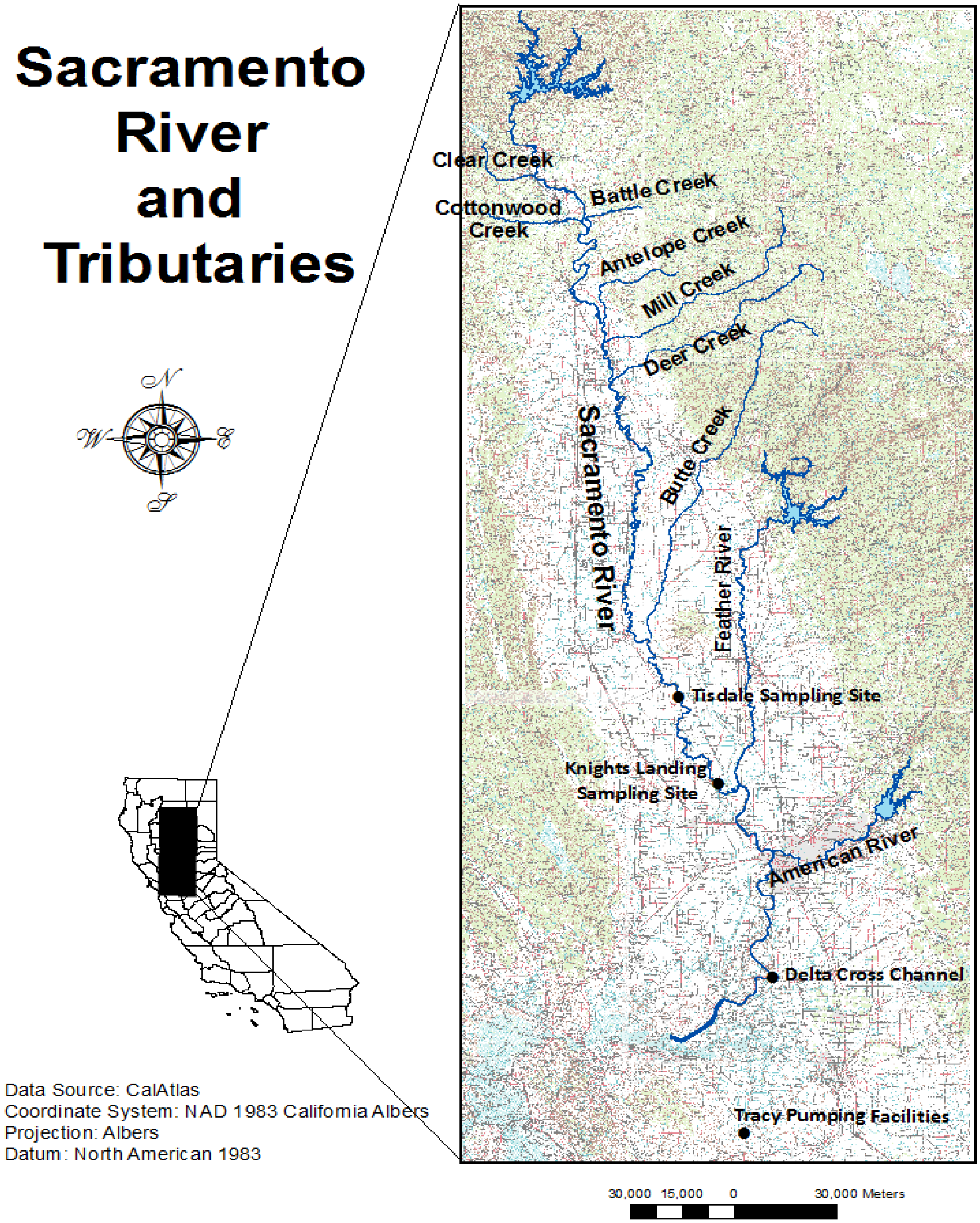

Figure 1. Map of the upper Sacramento River and tributaries depicting locations of the CDFW juvenile monitoring sites, the Delta Cross Chanel Gates and the C.W. Bill Jones (Tracy) pumping facility.

METHODS

Juvenile salmonid emigration monitoring at the Knights Landing sampling site began on October 1, 2014 and concluded on June 05, 2015, for a total of 239 days of continuous sampling. Rotary screw traps were used for sampling as they allow for data to be collected on juvenile salmonid presence and passage over time, age and size at emigration, emigration timing, and species and race composition. A detailed description of RST use and operation is described in Kennen *et al*. (1994) and Volkhardt *et al*. (2007).

The Knights Landing Program outfitted two RSTs with 2.4-m diameter cones secured to one another and anchored in place on the east side of the Sacramento River channel (river left). The channel position of the RSTs fluctuated slightly based on Sacramento River flow. During baseflow conditions, the RSTs were positioned in the thalweg approximately 10-m from the east bank. During high flow conditions the RSTs were within approximately 3.4-m of the east bank

Servicing of the RSTs was completed in accordance to a condition dependent sampling schedule which is an approach where environmental conditions dictate trap operation. Daily trap checks were the baseline approach to sampling under normal conditions where river flows were stable (less than 10,000 CFS) and in-river debris was minimal. As river conditions changed or an increase in catch was observed, various trap servicing and configuration methods were employed. (Appendix A)

Personnel accessed the RSTs using CDFW vessels which were moored on the Sacramento River at Knights Landing. These vessels included a 30’ pontoon work boat and a 19’ Design Concepts Delta Angler. Both were outfitted with the equipment necessary to collect data and maintain the RSTs.

During each trap servicing, crews collected data specific to the performance of each RST including time since last RST service, average cone revolutions per minute (RPM), total cone revolutions since last RST service, total hours sampled, water velocity entering each RST cone, and depth of water where the RSTs were positioned. Water velocity was evaluated using a Global Water flow probe (model FP111) and water depth at each trap was estimated using a handheld electronic depth finder.

$$Total\ hours\ sampled\ = \frac{Total\ cone\ revolutions}{Ave\ RPM*60}$$

Environmental data collected and recorded during each RST service included water temperature, water transparency, water turbidity, and river discharge volume. Water temperature was recorded over time using an electronic Onset HOBO temperature logger and during each trap service with a handheld H-B USA standard liquid thermometer. Water transparency at the sampling location was calculated during each trap service using a Secchi disc following standard protocols (Orth 1983). Water turbidity was measured by collecting two water samples during each trap service and analyzed using an HF Scientific DRT-15CE turbidimeter, then averaged and reported in Nephelometric Turbidity Units (NTU). River discharge volume, measured in in cubic feet per second (CFS), was obtained from the California Data Exchange Center (CDEC 2015) gauge at Wilkins Slough, which is located upstream from the town of Knights Landing. River flow was an important factor for the program to consider as river flows are known to influence juvenile emigration patterns and may create hazardous working conditions for personnel working on the traps.

All fishes captured in the RSTs were identified to species and measured to the nearest millimeter (mm). Salmonids greater than 40 mm fork length (FL) were weighed to the nearest tenth of a gram. Race was assigned to juvenile Chinook based on FL using the LAD race identification tables (Greene 1992). Life stages were assigned based on visual appearance and recorded as alevin, fry, parr, silvery parr, or smolt. Steelhead life stage was estimated based on FL measurements. Fish measuring < 100 mm were assigned to the young-of-the-year (YOY) age class, fish measuring 100mm to 300mm were yearlings, and fish over 300mm were adults. Catch per unit of effort (CPUE) for each race of Chinook salmon and steelhead trout was evaluated by calculating total number of fish captured divided by the total hours of sampling. Non-salmonids were measured to total length (TL), no weights were recorded. For reporting purposes, all salmonids possessing an intact adipose fin (unmarked) were considered to be of natural origin. It is recognized that portions of hatchery production releases contain unmarked and untagged juvenile Chinook, however, identifying them against their natural origin counterparts is not possible without genetic data.

Up to 20 adipose fin-clipped, hatchery produced Chinook salmon of each race per trap maintenance event were collected. The absence of the adipose fin indicates the presence of a coded wire tag (CWT) identifying the hatchery of origin, release date, release location, and release group size. These fish were taken to a CDFW laboratory for removal of the CWT. The CWTs were read by DFW staff and cross referenced with information provided by the federal hatcheries.

All data were recorded on water-proof datasheets, transported to the CDFW Region 2 Headquarters office, and checked for quality assurance and quality control (QAQC). Data summaries were e-mailed to resource agencies and various stakeholders on the same day to provide real-time reporting of trap catch data. Following the initial data quality check, data were entered into the Comprehensive Assessment & Monitoring Program (CAMP) database platform developed by the United States Fish and Wildlife Service (USFWS) for analysis and reporting. Following database entry, data was again verified for QAQC using standardized protocols.

In this report, Chinook salmon and steelhead trout data were combined into weekly sums to evaluate trends in salmonid emigration timing and abundance, and to help in normalizing variation in effort and trap efficiency trials. Sample weeks began on a Sunday and ended on a Saturday, and each week of the year was assigned a number in accordance with the Julian calendar.

Trap efficiency was evaluated using mark-and-recapture methods (Volkhardt 2007). Groups of juvenile Chinook were marked externally using either Visible Implant Elastomer (VIE) tags or a biological stain. Juvenile Chinook externally marked with VIE tags were first collected from CNFH. A minimum of 1000 fish were obtained and transported to our tagging station to be marked. Fish marked with the biological stain were sourced from the sampling location. When RST catch of juvenile Chinook salmon was sufficient, a minimum of 150 fish were externally marked using Bismark Brown (BBY) biological stain. Trap efficiency release groups were held overnight near the sampling location to assess mortality. Upon release, groups were distributed across the river channel in small groups. The upstream release site was selected as it was assumed that marked fish would evenly distribute across the channel and have an equal chance of being captured again by the RSTs, but not too far upstream that predation on marked fish would impact the efficiency trials.

Passage estimates were generated for Chinook salmon using the functions embedded in the RST data management and access platform developed by the USFWS CAMP. The CAMP RST platform estimates daily passage by dividing daily catch by a daily estimate of efficiency derived from efficiency trials conducted during the season. Daily catch is expanded during times where no sampling was conducted or where the half cone fishing configuration was utilized. To estimate passage during times where no sampling was conducted, the platform smooths observed catch per unit effort (CPUE) through time, similar to a moving average. The CPUE is then multiplied by the number of hours the trap was not operational during the 24-hour period to estimate catch for that day. To expand catch during times where the half cone sampling configuration was utilized, daily catch was doubled as it is assumed that modifying the trap to half cone fishing reduces effort by half. To estimate efficiency every day of the season, the Platform utilizes a b-spline smoothing method to model daily efficiency. Steelhead trout life history creates uncertainty when applying trap capture efficiencies to estimate passage and passages estimates were not produced for steelhead trout.

RESULTS

Environmental Conditions

Mean daily flow reported at the CDEC Wilkins Slough gauge during the sampling season (October 1, 2014 through June 5, 2015) was 7,118 CFS (5,658 CFS standard deviation (SD)). Maximum flow volume recorded was 27,000 CFS during week 50 on December 13 and minimum flow volume recorded was 3,475 CFS during week 17 on April 23. (Figure 2, Table 1)

Water temperatures generally decreased from the start of sampling efforts during week 40 through week 1, then generally increased through the end of the sampling season. Mean water temperature during the sampling period was 15.2 °C (6.9°C SD). The minimum water temperature was 6.1 °C recorded during week 1 on January 3, while the maximum water temperature of 22.8 °C was recorded on June 5, week 23. (Figure 2, Table 1)

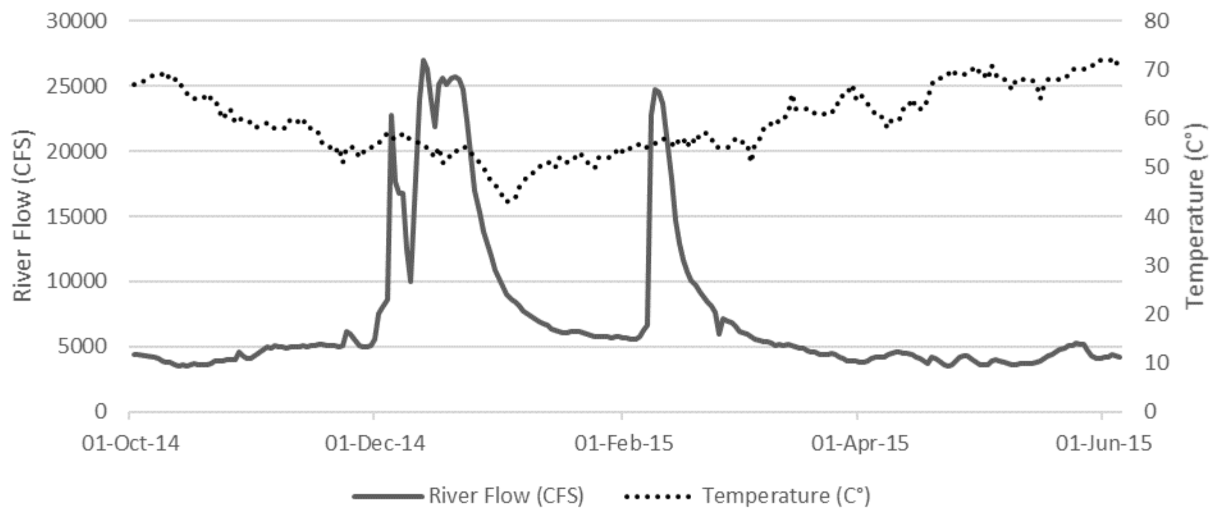

Figure 2. Daily water temperature (C°) values collected at the sampling site between October 1, 2014 and June 5, 2015. Water flow rate was reported by CDEC, Wilkins Sough gauge and reported in cubic feet per second (cfs).

The minimum water transparency recorded at the sampling site was 6.1cm during week 50 on December 13. The maximum water transparency recorded was 234.7cm recorded during week 41 on October 8. Mean water transparency for the sampling season was 73.9cm (40.1cm SD). (Figure 3, Table 1)

Turbidity at the sampling site varied from a low of 1.4 NTU recorded during week 43 on October 24 to a high of 850 NTU recorded during week 6 on February 9. Mean turbidity during the sampling season was 31.1 NTU (77.4 NTU SD). (Figure 3, Table 1)

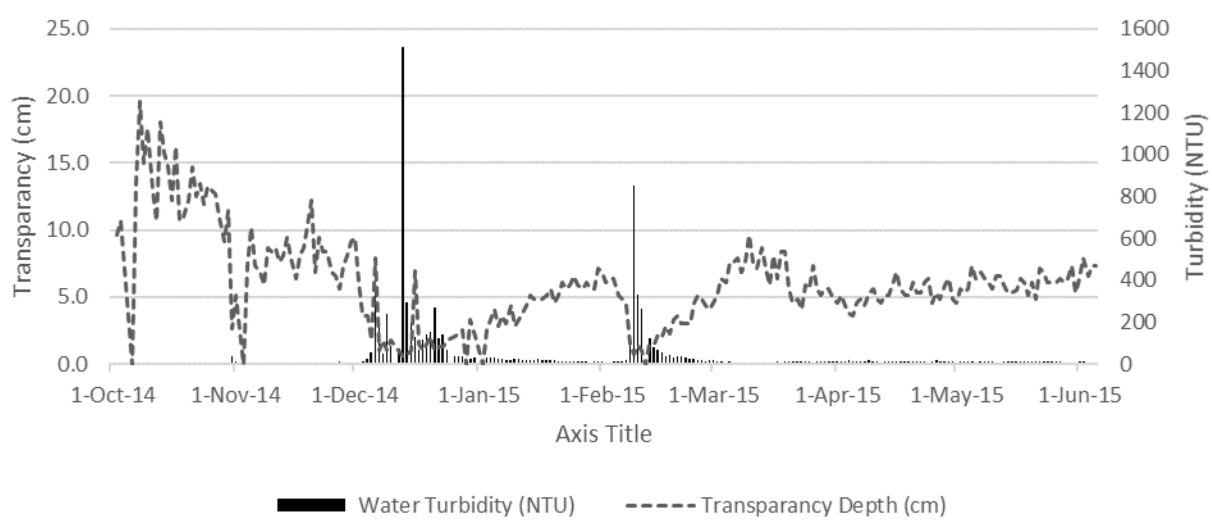

Figure 3. Daily water transparency (cm) and turbidity (NTU) values collected at the sampling site between October 1, 2014 and June 5, 2015.

Table 1. Weekly summaries of environmental conditions recorded at the rotary screw traps located on the Sacramento River near Knights Landing, California, during the period of October 1, 2014 through June 5, 2015.

Week	Beginning Date	Mean Water Temperature (C°)	Mean River Flow (CFS)	Mean Secchi Depth(cm)	Mean Water Turbidity (NTU)
40	10/1/2014	20.0	4,300	141.7	5.6
41	10/5/2014	20.1	3,780	185.5	2.8
42	10/12/2014	18.0	3,637	157.2	3.5
43	10/19/2014	16.2	4,033	150.2	2.9
44	10/26/2014	15.1	4,305	76.7	17.7
45	11/2/2014	14.8	4,959	95.8	7.4
46	11/9/2014	14.4	5,074	96.2	7.1
47	11/16/2014	11.9	5,364	107.1	5.4
48	11/23/2014	12.1	5,551	89.7	7.3
49	11/30/2014	13.5	14,710	35.3	146.8
50	12/7/2014	12.3	21,228	23.9	360.2
51	12/14/2014	11.6	25,329	16.5	145.0
52	12/21/2014	10.4	16,100	28.7	41.5
53	12/28/2014	8.1	10,850	24.4	34.1
1	1/4/2015	7.1	8,386	39.0	27.7
2	1/11/2015	9.9	6,969	45.7	19.3
3	1/18/2015	10.9	6,149	59.7	18.0
4	1/25/2015	10.8	5,859	71.4	12.6
5	2/1/2015	11.8	5,663	75.3	10.0
6	2/8/2015	12.8	17,962	29.1	223.6
7	2/15/2015	12.9	13,000	24.9	68.6
8	2/22/2015	13.2	8,271	44.0	28.6
9	3/1/2015	12.8	6,534	60.5	14.2
10	3/8/2015	13.7	5,407	94.1	8.1
11	3/15/2015	16.4	5,047	88.4	8.4
12	3/22/2015	16.3	4,500	66.6	11.7
13	3/29/2015	18.1	4,026	66.2	12.3
14	4/5/2015	16.2	4,113	52.3	14.3
15	4/12/2015	16.3	4,465	62.3	13.2
16	4/19/2015	18.7	3,936	67.5	14.0
17	4/26/2015	20.7	3,976	67.5	13.2
18	5/3/2015	20.6	3,751	67.9	10.6
19	5/10/2015	19.7	3,695	75.0	11.1
20	5/17/2015	19.5	4,126	68.1	11.7
21	5/24/2015	20.7	5,086	74.5	11.3
22	5/31/2015	22.0	4,286	78.8	8.8
23	6/5/2015	22.2	4,215	88.4	7.5

Summary of Chinook Salmon Emigration

All races and juvenile life stages of Chinook salmon were represented in the RST catch during the sampling season. A total of 8,390 juvenile salmon were captured, of which 7,912 unmarked (adipose intact) Chinooks salmon accounted for 94.3% of total catch. Unmarked Chinook salmon include naturally spawned winter-run, spring-run, fall-run and late fall-run. Marked Chinook salmon catch consisted of 478, or 5.7% of total catch. Historically, upstream hatcheries produced and released into the Sacramento River above Red Bluff late fall-run, winter-run, and fall-run Chinook salmon. This year, due to unfavorable river conditions at the time of release, hatchery production of fall-run Chinook salmon were trucked to and released in the Delta. Winter-run and late-fall run Chinook were released in accordance to historic hatchery practices. Due to differential growth rates of hatchery produced fish some marked Chinook salmon captured by the RSTs were identified as fall-run and spring-run using LAD methodology.

The first and last juvenile Chinook salmon were caught during week 41, on October 9, and week 22, on May 28, respectively. Peak catch occurred during week 6 where 4,645 Chinook salmon, or 58.7% of the season total catch, were captured over 180 hours of monitoring.

In-river Produced Chinook Salmon

Winter-run Chinook

All unmarked winter-run Chinook salmon were assumed to be in-river produced as all upstream releases of hatchery origin Chinook were externally marked by the removal of the adipose fin prior to release. A total 191 naturally produced winter-run Chinook salmon were caught by the RSTs. The first fish of this run was caught during week 41, on October 9. Winter-run were consistently present in the RSTs during week 43 through week 52. Catch peaked during week 44 with 96 winter-run sized fish accounting for approximately 49% of the season total catch of this race and a CPUE of 0.64. All winter-run captured during the sampling period were BY 2014 based on their size at capture. (Table 2)

Table 2 Summary of the weekly catch of in-river produced juvenile winter-run Chinook salmon sampled from October 1, 2014 through June 5, 2015. Weeks during the monitoring season not presented here resulted in zero catch of this race.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
41	10/5/2014	306.1	1	0.003	43	43	43	n/a
43	10/19/2014	305.8	1	0.003	47	47	47	n/a
44	10/26/2014	150.0	96	0.640	54	37	72	8.6
45	11/2/2014	165.3	1	0.006	61	61	61	n/a
46	11/9/2014	295.8	3	0.010	61	54	73	10.2
47	11/16/2014	265.5	2	0.008	56	51	61	7.1
48	11/23/2014	157.9	3	0.019	75	54	88	18.6
49	11/30/2014	73.4	32	0.436	73	52	92	9.3
50	12/7/2014	41.4	3	0.072	74	73	75	1.0
51	12/14/2014	72.6	13	0.179	77	51	100	18.0

52	12/21/2014	64.3	2	0.031	86	82	89	4.9
6	2/8/2015	180.0	5	0.028	108	101	125	10.2
7	2/15/2015	130.0	21	0.162	93	76	117	10.8
8	2/22/2015	166.6	4	0.024	93	85	100	6.1
13	3/29/2015	180.4	1	0.006	104	104	104	n/a
14	4/5/2015	311.5	1	0.003	110	110	110	n/a
15	4/12/2015	319.8	2	0.006	112	111	112	0.7

Spring-run Chinook

All unmarked spring-run Chinook salmon were assumed to be in-river produced as all upstream releases of hatchery origin Chinook were externally marked by the removal of the adipose fin prior to release. A total of 428 unmarked spring-run Chinook salmon were caught by the RSTs. The first spring-run sized fish was caught during week 43, on October 24. Spring-run emigration timing appeared bimodal with two peaks in catch occurring during weeks 51 (n=131) and 6 (n=57). All juvenile spring-run Chinook salmon sampled by the RSTs were BY 2014 based on size at capture. (Table 3)

Table 3. Summary of the weekly catch of in-river produced juvenile spring-run Chinook salmon sampled between October 1, 2014 through June 5, 2015. Weeks during the monitoring season not presented here resulted in zero catch of this race.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
43	10/19/2014	305.8	1	0.003	34	34	34	n/a
44	10/26/2014	150.0	1	0.007	33	33	33	n/a
49	11/30/2014	73.4	40	0.545	36	34	46	1.9
50	12/7/2014	41.4	68	1.641	37	35	46	1.6
51	12/14/2014	72.6	131	1.805	38	37	50	1.4
52	12/21/2014	64.3	12	0.187	41	39	49	2.8
53	12/28/2014	17.5	2	0.114	40	40	40	0.0
1	1/4/2015	134.9	8	0.059	44	42	47	2.0
2	1/11/2015	313.8	20	0.064	46	43	51	2.2
3	1/18/2015	338.7	4	0.012	47	45	48	1.4
4	1/25/2015	242.3	3	0.012	50	47	54	3.5
6	2/8/2015	180.0	57	0.317	60	53	70	4.3
7	2/15/2015	130.0	37	0.285	59	54	73	4.7
8	2/22/2015	166.6	3	0.018	68	56	75	10.7
11	3/15/2015	344.9	1	0.003	82	82	82	n/a
12	3/22/2015	309.7	1	0.003	87	87	87	n/a
13	3/29/2015	180.4	2	0.011	76	72	80	5.7
14	4/5/2015	311.5	9	0.029	86	76	99	7.3
15	4/12/2015	319.8	14	0.044	89	80	99	6.4
16	4/19/2015	320.3	6	0.019	96	90	108	6.7

17	4/26/2015	286.8	3	0.010	100	91	110	9.5
18	5/3/2015	313.2	5	0.016	101	90	114	9.6

Fall-run Chinook

All unmarked fall-run Chinook salmon were assumed to be in-river produced as all upstream releases of hatchery origin Chinook were externally marked by the removal of the adipose fin prior to release. A total of 7,271 unmarked fall-run Chinook salmon were caught by the RSTs. The first fall-run were caught during week 49, on December 6, and were present throughout the remainder of the survey period with few exceptions. Catch peaked on week 6 with a total of 4,383 fall-run captured, representing 60.2% of total in-river produced fall-run Chinook catch. All juvenile fall-run Chinook salmon sampled by the RSTs were BY 2014 based on size at capture. (Table 4)

Table 4*. Summary of the weekly catch of in-river produced juvenile fall-run Chinook salmon sampled* between October 1, 2014 and June 5, 2015. Weeks during the monitoring season not presented here resulted in zero catch of this race.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
49	11/30/2014	73.4	10	0.136	34	31	34	1.0
50	12/7/2014	41.4	90	2.172	34	28	36	1.5
51	12/14/2014	72.6	438	6.036	35	30	37	1.5
52	12/21/2014	64.3	52	0.808	36	30	39	1.8
1	1/4/2015	134.9	6	0.044	37	34	41	2.6
2	1/11/2015	313.8	33	0.105	40	36	43	2.1
3	1/18/2015	338.7	10	0.030	40	35	44	3.7
4	1/25/2015	242.3	6	0.025	39	35	47	4.4
5	2/1/2015	336.3	1	0.003	40	40	40	n/a
6	2/8/2015	180.0	4383	24.349	38	33	52	2.9
7	2/15/2015	130.0	2202	16.941	39	28	54	3.7
8	2/22/2015	166.6	21	0.126	40	34	52	4.5
10	3/8/2015	207.6	1	0.005	48	48	48	n/a
11	3/15/2015	344.9	1	0.003	47	47	47	n/a
12	3/22/2015	309.7	1	0.003	60	60	60	n/a
15	4/12/2015	319.8	1	0.003	71	71	71	n/a
18	5/3/2015	313.2	9	0.029	81	63	91	7.8
19	5/10/2015	302.8	2	0.007	87	84	89	3.5
21	5/24/2015	239.8	2	0.008	81	81	81	n/a
22	5/31/2015	288.4	2	0.007	81	80	82	1.4

Late fall-run Chinook

All unmarked late fall-run Chinook salmon were assumed to be in-river produced as all upstream releases of hatchery origin Chinook were externally marked by the removal of the adipose fin prior to release. A total of 22 unmarked late fall-run Chinook salmon were caught by the RSTs. The first late fall-run were caught during week 44, on October 31. Peak catch occurred during week 49 where eight (8) were captured, accounting for 36.4% of the season total catch of late fall-run Chinook. All juvenile late fall-run Chinook salmon sampled by the RSTs were BY 2014 based on size at capture. (Table 5)

Table 5. Summary of the weekly catch of in-river produced juvenile late fall-run Chinook salmon sampled between October 1, 2014 through June 5, 2015. Weeks during the monitoring season not presented here resulted in zero catch of this race.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
44	10/26/2014	150.0	4	0.027	76	75	78	1.5
49	11/30/2014	73.4	8	0.109	111	96	134	14.7
50	12/7/2014	41.4	1	0.024	98	98	98	n/a
51	12/14/2014	72.6	5	0.069	120	108	124	6.7
53	12/28/2014	17.5	1	0.057	125	125	125	n/a
1	1/4/2015	134.9	1	0.007	122	122	122	n/a
2	1/11/2015	313.8	2	0.006	153	120	185	46.0

Hatchery Produced Chinook Salmon

Upstream production releases from CNFH and LSNFH consisted only of winter-run and late fall-run Chinook and totaled 2,439,211. In prior years, CNFH would release hatchery produced fall-run Chinook salmon into the Sacramento River above Red Bluff. This year, due to unfavorable river conditions, hatchery produced fall-run Chinook salmon were trucked to and released in the Delta.

It is the intention of both hatcheries to mark, by the removal the adipose fin, and tag, with a CWT, at least 25 percent of hatchery produced fish under the guidelines of the Constant Fractional Marking Program (Palmer-Zwahlen et al 2019). Hatchery produced winter-run and late fall-run Chinook Salmon are 100% marked. However, due to error associated with the marking and tagging equipment utilized in this process, portions of each release were not marked and/or tagged. A total of 1,344,502 winter-run Chinook Salmon was released by LSNFH. Of this, 15,156, or 1.1%, were marked but not tagged, 29,618 (2.2%) were tagged, but not marked, and 890 (0.1%) were not marked or tagged. A total of 1,093,468 late fall-run Chinook salmon was released by CNFH. Of this, 8,610 (0.8%) were marked but not tagged, 28,536 (2.6%) were tagged but not marked, and 1,251 (0.1%) were not marked or tagged (Table 6).

Following the release, 478 adipose fin-clipped Chinook salmon were captured by the RSTs consisting of all 4 races using the LAD criteria for race determination: 390 winter-run (81.5%), 46 spring-run (9.6%), 3 fall-run (0.6%), and 39 late fall-run (8.1%).

Table 6. Summary of hatchery production of juvenile Chinook salmon and steelhead trout by CNFH and LSNFH, released upstream from the Knights Landing sampling site during the sampling period of October 1, 2014 through June 5, 2015.

Race or Species	Week	Release Dates	Number marked with CWT	Number marked without CWT	Number unmarked with CWT	Number Unmarked	Release location
Late-fall	49	12/1/2014	824,418	6,244	25,236	835	CNFH
Late-fall	49	12/4/2014	75,198	1,535	0	0	CNFH
Late-fall	51	12/18/2014	77,739	0	391	0	CNFH
Winter	5	2/4/2015-2/5/2014	977,355	7,779	25,627	0	LRP
Late-fall	5	2/5/2015	78,967	831	2,909	416	CNFH
Winter	5	2/5/2015-2/6/2015	321,483	7,377	3,991	890	LRP
Steelhead	53-1	1/2/2015-1/9/2015	0	684,100	0	3,110	BB

[1]LRP = Lake Redding Park; CNFH = Coleman National Fish Hatchery; BB = Bend Bridge.

Winter-run Chinook

A total of 390 hatchery produced juvenile winter-run Chinook salmon was captured by the RSTs. The first hatchery produced winter-run based on LAD criteria were captured during week 49 which was prior to the first release of winter-run Chinook. CWT data collected from these individuals confirmed these were late-fall run Chinook released from CNFH. It is likely that subsequent catch of hatchery origin LAD winter-run Chinook included individuals from the CNFH late fall-run releases. The last hatchery produced winter-run was captured during week 14. All hatchery produced winter-run Chinook were BY 2014 (Table 7).

Table 7. Summary of weekly catch of hatchery produced juvenile winter-run Chinook salmon sampled from October 1, 2014 through June 5, 2015. Weeks during the monitoring season not presented here resulted in zero catch of this race.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
49	11/30/2014	73.4	2	0.027	88	86	90	2.8
51	12/14/2014	72.6	2	0.028	96	94	98	2.8
1	1/4/2015	134.9	1	0.007	99	99	99	n/a
6	2/8/2015	180	173	0.961	92	71	141	12.3
7	2/15/2015	130	200	1.539	89	73	138	9.9
8	2/22/2015	166.6	10	0.06	95	76	115	12.2
10	3/8/2015	207.6	1	0.005	103	103	103	n/a
14	4/5/2015	311.5	1	0.003	115	115	115	n/a

Spring-run Chinook

A total of 46 hatchery origin juvenile Chinook was identified as spring-run Chinook salmon using LAD methodology. These fish were captured during weeks 6, 7, and 11. Based on length frequency information provided by CNFH and LSNFH, it is likely these fish were part of the winter-run production releases from LSNFH (Table 9).

Table 8. Summary of weekly catch of hatchery produced juvenile spring-run Chinook salmon sampled between October 1, 2014 through June 5, 2015. Weeks during the monitoring season not presented here resulted in zero catch of this race.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
6	2/8/2015	180	21	0.117	66	55	71	4.9
7	2/15/2015	130	24	0.185	67	57	72	4
11	3/15/2015	344.9	1	0.003	86	86	86	n/a

Fall-run Chinook

In years prior, releases of fall-run Chinook salmon produced by CNFH occurred in the Sacramento River above Red Bluff. This strategy promoted the imprinting of juvenile Chinook on their natal waters, the use of riverine rearing habitat, and a more natural Delta entry timing following diel and hydrological cues. This release strategy was not employed this year due to prolonged drought and river conditions expected to have deleterious effects on release groups (Jones 2015). Hatchery fall-run production releases were transported and released into the Delta. A total of three hatchery origin juvenile Chinook captured by the traps were identified as fall-run Chinook salmon using LAD methodology. Based on CWT length frequency information provided by CNFH and LSNFH, the individuals captured on December 6 and January 1 likely were part of the late fall-run hatchery production releases and the individual captured on February 14 was part of the winter-run hatchery production releases. (Table 9)

Table 9. Summary of weekly catch of hatchery produced juvenile fall-run Chinook salmon sampled between October 1, 2014 through June 5, 2015. Weeks during the monitoring season not presented here resulted in zero catch of this race.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
49	11/30/2014	73.4	1	0.014	178	178	178	n/a
5	1/30/2015	336.3	1	0.003	245	245	245	n/a
7	2/14/2015	130.0	1	0.008	52	52	52	n/a

Late Fall-run Chinook

A total of 39 hatchery origin late-fall Chinook salmon was captured. The first hatchery produced late fall-run were captured during week 49, on December 6 and the last hatchery produced late fall-run was captured during week 7, on February 14. All fish of this race captured by the RSTs were BY 2014 (Table 10).

Table 10. Summary of weekly catch of hatchery produced juvenile late fall-run Chinook salmon sampled between October 1, 2014 through June 5, 2015. Weeks during the monitoring season not presented here resulted in zero catch of this race.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
49	11/30/14	73.4	20	0.272	132	109	170	16.6
50	12/7/14	41.4	1	0.024	99	99	99	n/a
51	12/14/14	72.6	10	0.138	133	110	153	15.1
1	1/4/15	134.9	1	0.007	130	130	130	n/a
6	2/8/15	180.0	6	0.033	162	145	190	15.4
7	2/15/15	130.0	1	0.008	148	148	148	n/a

Summary of Steelhead Trout Emigration

Both, in-river-produced and hatchery-produced steelhead were captured by the RST's. Like Chinook salmon, hatchery produced steelhead are identified by the absence of an adipose fin, however a portion of the hatchery released steelhead retained their adipose fin because of error associated with the equipment that performs adipose fin removal. A total of 687,210 hatchery origin steelhead was released by CNFH, of which 3,110 (0.4%) possessed an adipose fin. For the purposes of this report, any steelhead captured by the RSTs which had an intact adipose fin was considered natural origin.

One hundred twenty-six steelhead trout were caught. Six of these were natural origin and 120 were hatchery origin. The first and last in-river produced steelhead trout were caught during weeks 2, on January 13, and 21, on May 25, respectively. Peak catch occurred during week 6 where 62 steelhead trout, or 49.2% of the season total catch, were captured over 180 hours of monitoring.

In-river Produced Steelhead Trout

A total of 6 in-river produced steelhead trout was captured by the RSTs. Five were categorized as yearlings, measuring between 100mm and 200mm FL, and were captured during weeks 6 and 7. One adult steelhead was caught during week 21 measuring over 300mm FL (Table 11).

Table 11. Summary of weekly catch of in-river produced juvenile steelhead trout sampled between October 1, 2014 through June 5, 2015. Weeks during the monitoring season not presented here resulted in zero catch of this species.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
6	2/8/2015	180	2	0.011	228	221	235	9.9
7	2/15/2015	130	3	0.023	264	253	278	12.7
21	5/24/2015	239.8	1	0.004	360	360	360	n/a

Hatchery Produced Steelhead Trout

A total of 120 hatchery produced steelhead trout was captured by the RSTs. Release data provided by CNFH identify these as yearling BY 2014 steelhead (Table 12).

Table 12. Summary of weekly catch of hatchery produced juvenile steelhead trout sampled between October 1, 2014 through June 5, 2015. Weeks during the monitoring season not presented here resulted in zero catch of this species.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
2	1/11/2015	313.8	6	0.019	235	202	250	17.4
3	1/18/2015	338.7	6	0.018	211	194	225	12.4
6	2/8/2015	180	60	0.333	222	181	255	17.8
7	2/15/2015	130	44	0.339	224	114	270	26.8
8	2/22/2015	166.6	1	0.006	136	136	136	n/a
13	3/29/2015	180.4	2	0.011	248	233	263	21.2
14	4/5/2015	311.5	1	0.003	249	249	249	n/a

Trap Efficiency Trials and Passage Estimates

Four efficiency trials were conducted during weeks 7, 8, 13, and 14 using fall-run Chinook salmon externally marked with Bismark Brown (BBY) stain or Visible Implant Elastomer (VIE) tags. The highest efficiency was observed during trials conducted during week 8 with a value of 2.34%. Efficiency values of 0% were observed during trials conducted in weeks 7, 13, and 14. Overall, a total of 5,231 fall-run fish was used in efficiency trials, and 30 of these fish were recaptured. The mean trap efficiency for the season was 0.57%. (Table 13)

Table 13. Summary of capture efficiency trials initiated between October 1, 2014 through June 5, 2015.

Week	Dates	Mark Type	Marked Released	Marked Recaptured	Efficiency (%)
7	2/8/2015-2/14/2015	BBY Stained	2870	0	0.00%
8	2/15/2015-2/21/2015	BBY Stained	1278	30	2.34%
13	3/25/2015-3/31/2015	VIE Tagged	570	0	0.00%
14	3/29/2015-4/7/2015	VIE Tagged	513	0	0.00%

Passage Estimate

Annual passage for each run was estimated from the beginning of the week where the first catch of that run was observed to the end of the week where the last catch of that run was observed. It is estimated that a total of 1,749,002 fall-run, 119,944 spring-run, and 25,047 winter-run Chinook salmon passed the monitoring site between October 10, 2014 and June 05, 2015 (Table 14).

Table 14. Estimates of in-river produced Chinook salmon that passed the Knights Landing sampling location between October 1, 2014 through June 5, 2015 and associated 95% confidence interval (CI).

Race	Passage	Lower 95% CI	Upper 95% CI
Fall	1,749,022	1,418,516	2,305,963
Spring	119,944	93,533	155,659
Winter	25,047	20,407	32,697

Other Fish Captured

A total of 17,115 non-target fishes representing 13 families and 35 species was captured by the RSTs. Of the 35 species, 11 are native to the Sacramento River and its tributaries and 24 were introduced (Table 15). Some related genera catch totals were combined because juveniles have similar morphological features. For example, Pacific and river lamprey (Petromyzontidae spp.) ammocetes were combined and totaled 180 fish. Unknown sunfish (*Lepomis* spp.) and unknown bass (*Micropteris* spp.) were combined with other unknown centrarchids and totaled 126 fish. Lastly, juvenile minnows (Cyprinidae spp.), totaling 13,530 fish, were excluded from final percentages and, instead, were collectively inventoried due to ambiguity of identifying characteristics at larval stages. The remaining 3,585 fish were comprised of 41% native fishes and 59% non-native fishes.

Table 15. Summary of non-target fish species captured between October 1, 2014 and June 5, 2015.

Common Name	Scientific Name	Number Captured	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
Unknown minnow	Cyprinidae spp.	13,530	25	16	185	7.5
Sacramento pikeminnow	*Ptychocheilus grandis*	858	83	37	280	23.9
Mosquitofish	*Gambusia affinis*	604	31	13	48	5
Inland silverside	*Menidia beryllina*	471	66	23	112	14.7
Threadfin shad	*Dorosoma petenense*	285	95	43	165	18.8
Threespine stickleback	*Gasterosteus aculeatus*	227	33	24	47	3.6
Unknown lamprey	Petromyzontidae spp.	180	132	90	169	15.6
Largemouth bass	*Micropterus salmoides*	154	34	19	132	19
Golden shiner	*Notemigonus crysoleucas*	87	81	29	177	33.6
Bluegill	*Lepomis macrochirus*	66	42	21	126	19.5
Black crappie	*Pomoxis nigromaculatus*	63	126	20	360	73.4
Splittail	*Pogonichthys macrolepidotus*	55	77	19	325	96.3
Sacramento sucker	*Catostomus occidentalis*	44	78	19	360	77.4
White crappie	*Pomoxis annularis*	40	92	26	225	48.9
Pacific lamprey	*Entosphenus tridentatus*	34	157	108	500	103.9

White catfish	*Ameiurus catus*	32	211	38	490	101.2
Goldfish	*Carassius auratus*	29	59	42	89	13.3
River lamprey	*Lampetra ayresi*	28	126	108	160	12.5
Black bullhead	*Ameiurus melas*	26	110	44	177	38.3
Tule perch	*Hysterocarpus traski*	26	44	22	110	22.1
Brown bullhead	*Ameiurus nebulosus*	23	109	57	190	41.6
Red shiner	*Cyprinella lutrensis*	21	56	37	72	9.3
American shad	*Alosa sapidissima*	18	67	32	450	97.6
Common carp	*Cyprinus carpio*	14	98	46	184	44.2
Channel catfish	*Ictalurus punctatus*	11	198	62	500	154.1
Redear sunfish	*Lepomis microlophus*	11	135	24	219	69.2
Warmouth	*Lepomis gulosus*	10	62	45	77	10.5
Unknown Centrarchid	Centrarchidae spp.	126	34	18	52	12.2
Green sunfish	*Lepomis cyanellus*	6	55	50	62	4.8
Hardhead	*Mylopharodon conocephalus*	6	58	30	103	26.6
Smallmouth bass	*Micropterus dolomieu*	6	97	43	177	44.2
Striped bass	*Morone saxatilis*	5	317	260	400	71.4
Unknown catfish or bullhead	Ictaluridae spp.	5	71	71	71	NA
Fathead minnow	*Pimephales promelas*	3	42	28	58	15.2
Spotted bass	*Micropterus punctulatus*	3	111	76	180	59.8
Hitch	*Lavinia exilicauda*	2	97	70	123	37.5
Yellowfin goby	*Acanthogobius flavimanus*	2	139	134	143	6.4
Prickly sculpin	*Cottus asper*	1	100	100	100	NA
Riffle sculpin	*Cottus gulosus*	1	112	112	112	NA
Sacramento perch	*Archoplites interruptus*	1	98	98	98	NA
Unknown sculpin	*Cottus* spp.	1	24	24	24	NA

DISCUSSION

Several studies have suggested that increased flow, reduced water temperatures, and increases in water turbidity promote the downstream migration of juvenile salmonids (Michel *et al.* 2013, Kemp *et al.* 2005, Giorgi *et al.* 1997). During the 2014/2015 sampling season there were two distinct flow events where winter storms elevated river flows. While catch data resolution, trap capture efficiency, and uncertainty in the geographic distance fish travel prior to capture makes correlating emigration cues with catch data difficult, increases in juvenile salmonid presence were observed with each increase in flow (Figure 4), a trend that is similar to those observed in previous years. The first of these flow evets began in week 49 when the flows increased from 5,020 CFS on December 3 to 22,800 CFS on December 5. After declining to 9,930 CFS on December 10, flows again increased to 27,000 CFS on December 13. Flow remained above

20,000 CFS through December 24. Combined catch during this event was 918 Chinook, consisting of 573 fall-run, 45 late fall-run, 245 spring-run, and 54 winter-run, making up 10.9% of the season's total juvenile Chinook salmon catch. The second flow event began during week 6 when flows climbed over a short period of time from 6,640 CFS on February 7 to 24,700 CFS on February 9. Flows remained high through February 14. Combined catch during this event was 7,004 Chinook, consisting of 6,490 fall-run, 7 late fall-run, 131 spring-run, and 376 winter-run, making up 85% of the season's total juvenile Chinook salmon catch. Total catch from these two flow events resulted in 96% of the season's total juvenile Chinook salmon catch.

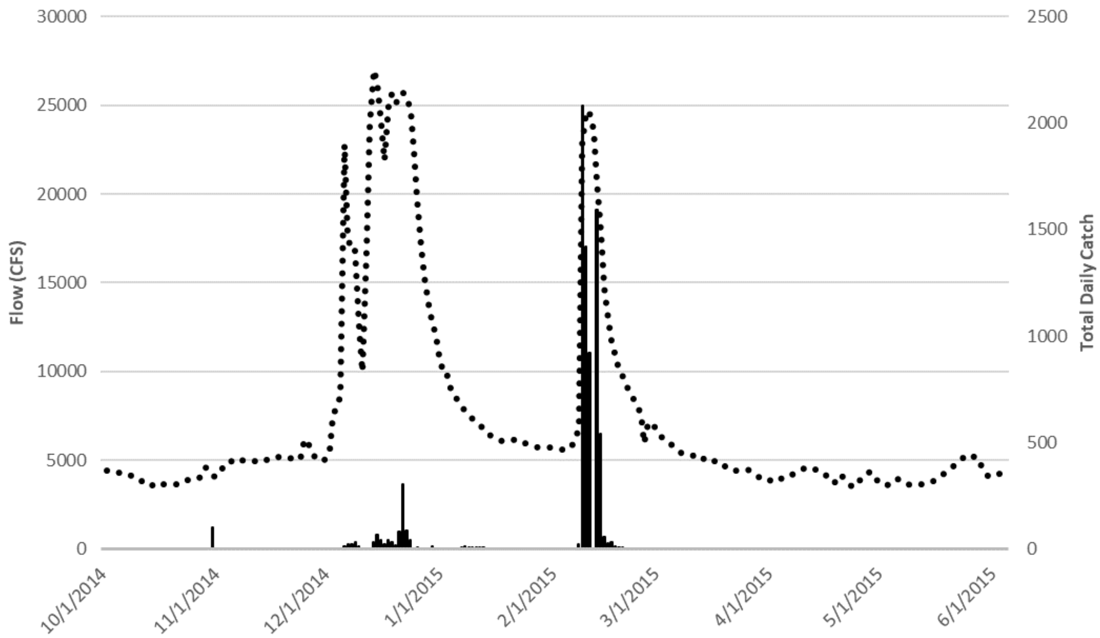

Figure 4. Daily flow measured at the CDEC Wilkins Slough Gauge and total daily catch of in-river produced Chinook salmon between October 1, 2014 and June 5, 2015.

An important factor affecting potential capture at the Knights Landing sampling site, and therefore passage estimates, is juvenile salmonid emigration routes. All juvenile salmonids emigrating down the Sacramento River are assumed to have the potential of being captured at the Knights Landing sampling site if they remain in-channel from point of origin to the sampling site. In times of excessive river flow, upstream flood control diversions, including Moulton Weir, Colusa Weir, and Tisdale Weir, divert Sacramento River flows and entrain juvenile salmonids in the Sutter Bypass (Figure 5). Salmonids emigrating through the Sutter Bypass are unable to return to the Sacramento River until they reach rKm 135 near the Fremont Weir.

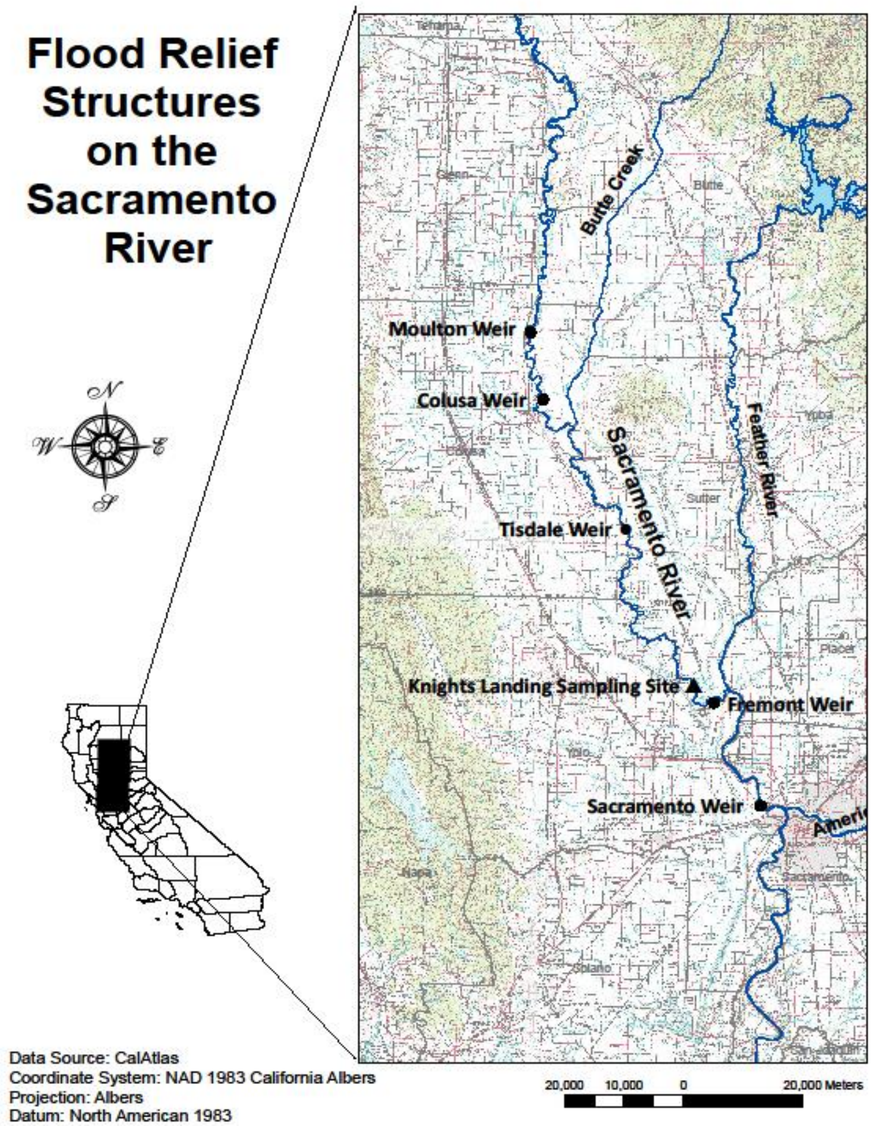

Figure 5. Map of the upper Sacramento River and tributaries depicting location of the CDFW juvenile monitoring site in relation to flood relief structures.

Comparison of salmonid capture by sampling season and by monitoring location may demonstrate the effect of weir overtopping events, with the caveat that other factors influencing capture must be taken into consideration (e.g., seasonal differences in juvenile production, flow, turbidity, predation, trap capture efficiency, etc.). For example, a total of 7,912 unmarked Chinook salmon were caught during the 2014/2015 sampling season which is significantly less than the 2013/2014 season total catch of 106,592 unmarked Chinook salmon. During the 2014/2015 sampling season, the Sacramento River flood relief weirs were overtopped for a combined 32 days allowing emigrating salmonids to enter the flood plain habitats of the Sutter Bypass. Moulton Weir overtopped during week 50 for three days. Colusa overtopped during weeks 50, 51, and then again during week 6 for a total of 11 days. Tisdale overtopped during week 50 through week 52 and then again during week 6 and week 7 for a total of 18 days. In contrast, during the 2013/2014 season there were no overtopping events and all emigrating juvenile salmonids were restricted to the confines of the Sacramento River's primary channel. The difference in catch between the 2013/2014 and 2014/2015 survey years may demonstrate the influence active flood relief weirs have on observations at monitoring locations. However, without comparisons of capture data at monitoring locations upstream of the weirs that convey flows into the Sutter Bypass (e.g., the Tisdale RST sampling location), it is difficult to identify what drives interannual variation in trap catch (Table 16).

Table 16. Potential for the 2015 water year overtopping event to influence salmonid capture data for in-river and hatchery produced Chinook salmon and yearling steelhead trout.

ESU/Origin	Capture range by week	Capture range by date	Effect on program capture
Fall-run (in-river)	49 to 22	12/6/2014 to 5/28/2015	100% (n=7,271) of catch occurred after overtopping event
Spring-run (in-river)	43 to 18	10/24/2014 to 5/1/2015	99.5 % (n=425) of catch occurred after overtopping event
Winter-run (in-river)	41 to 15	10/9/2014 to 4/11/2015	81.6% (n=156) of catch occurred after overtopping event
Winter-run (hatchery)	49 to 14	12/6/2014 to 4/3/2015	100% (n=438) of catch occurred after overtopping event
Late fall-run (in-river)	44 to 2	10/31/2014 to 1/10/2015	81.8% (n=18) of catch occurred after overtopping event
Late fall-run (hatchery)	49 to 7	12/6/2014 to 2/14/2015	100% (n=40) of catch occurred after overtopping event
Steelhead (in-river)	6 to 21	2/10/2015 to 5/25/2015	100% (n=6) of catch occurred after overtopping event
Steelhead (hatchery	2 to 14	1/13/2015 to 4/7/2015	100% (n=120) of catch occurred after overtopping event

Despite uncertainties in catch data introduced by weir overtopping events, data gathered from the sampling program does provide clear insight into juvenile salmonid migration timing and thus provides early warning of listed salmonids as they move toward the Delta. Data collected during the 2014/2015 Lower Sacramento River Juvenile Salmonid Emigration Program fulfilled the program's goals of:

1. Providing early warning of emigrating listed salmonids moving into the Delta so the CVP and SWP projects could modify their water export activities, including DCC Gate closures for a period sufficient to minimize entrainment of juveniles into the south Delta;
2. Documented passage of emigrating salmonids including timing, relative abundance, and response to environmental conditions;
3. Estimated emigrating salmon numbers in the lower Sacramento River above the Delta;

4. Contributed to the long-term dataset on emigration with which to compare changes over time.

As the Sutter Bypass may provide an important and needed rearing opportunity for juvenile salmonids in the Sacramento River corridor, future data collection efforts for the North Central Region's Sacramento River Juvenile Salmonid Monitoring Program will be targeted at better defining entrainment into the Sutter Bypass.

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Sampling Options

Conditions					Additional Options During High Flow Periods***		
	Daily Trap Check	Twice Daily Trap Checks	Continuous Monitoring During Daylight Hours	Half Cone Sampling (cones modified to reduce fishing effort)	Sub-sample (Random sampling within 12hr. periods)	Fishing One Trap (with half cone)****	Shore Sampling (traps secured to shore to avoid debris)****
0-10,000 CFS: Stable Flows							
0-10,000 CFS: Unstable Flows (> 3,500 CFS change in 12 hrs. at respective gages*)							
10,000-20,000 CFS: Stable Flows							
10,000-20,000 CFS: Unstable Flows (> 3,500 CFS change in 12 hrs. at respective gages*)							
> 20,000 CFS: Stable Flows							
> 20,000 CFS: Unstable Flows ** (> 3,500 CFS change in 12 hrs. at respective gages*)							

*CDEC gages: Sac. River below Wilkins Slough (WKL) for Knights Landing and Sac. River at Colusa (COL) for Tisdale Weir

**Sampling during high flows will be conducted depending on equipment, personnel safety, and logistical concerns. Sampling will be evaluate in real-time and may be discontinued for any of these reasons as well as if lethal take risk for listed species is high.

***High Flow period operations will be evaluated in real-time and may very with data needs, take risk, and equipment and personnel safety .

**** May have implications on trap capture efficiency and data comparability between sampling periods. Sampling will be conducted in a manner to allow for calculation of 24 hr. catch indices if possible.

Condition Dependent Sampling Schedule used to guide RST operations during varying environmental conditions.