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 September 2015 – June 2016[1]

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LIST OF ABBREVIATIONS AND ACRONYMS

BBY	Bismark Brown
BO	Biological Opinion
BY	Brood year
CA	California
CAMP	Comprehensive Assessment and Monitoring Program
CDEC	California Data Exchange Center
cfs	Cubic feet per second
CDFW	California Department of Fish and Wildlife
cm	Centimeter
CNFH	Coleman National Fish Hatchery
CPUE	Catch per unit of effort
CVP	Central Valley Project
CWT	Coded wire tag
DCC	Delta Cross Channel
FL	Fork length
km	kilometer
LAD	Length at date
LSNFH	Livingston Stone National Fish Hatchery
mm	Millimeter
NMFS	National Marine Fisheries Service
NTU	Nephelometric turbidity units
QAQC	Quality assurance and quality control
rkm	River kilometer
RST	Rotary screw trap
SD	Standard deviation
SWP	State Water Project
USFWS	United States Fish and Wildlife Service
VIE	Visible Implant Elastomer
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 (CA) to obtain information on the temporal distribution, relative abundance, and run composition 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 that use two paired rotary screw traps (RST) outfitted with 2 8-foot cones. 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 Section 10(a)(1)(A) Permit (14808-4M) issued by the National Marine Fisheries Service (NMFS).

The monitoring program entered its 20th consecutive year of sampling at the Knights Landing monitoring site beginning on September 16, 2015. Sampling concluded on June 20, 2016, for a total of 280 days of sampling.

During the season, 17,745 unmarked (adipose fin intact) juvenile Chinook salmon were captured. Peak catch occurred during calendar week 2 through 4, when 13,948 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 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, 51 (0.2%) were assigned to winter-run, 926 (5.2%) were assigned to spring-run, 16,767 (94.5%) were assigned to fall-run, and 1 (<0.1%) were assigned to late fall-run. Trap efficiency data were applied to catch totals to produce run-specific passage estimates. The passage estimate for fall-run was 8,434,470; for spring-run was 357,030; and for winter-run was 11,472. An estimate was not produced for late fall-run Chinook because too few individuals were captured to create a reliable estimate.

A total of 469 hatchery origin 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, releases of brood year (BY) 2015 fall- and late fall-run Chinook salmon were completed by Coleman National Fish Hatchery (CNFH). Additionally, releases of BY 2015 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 469 hatchery origin Chinook salmon captured, 52 (10.7%) were identified as winter-run, 55 (11.7%) were identified as late fall-run, 159 (33.9%) were identified as spring-run, and 203 (42.3%) were identified as fall-run. The hatcheries upstream of the sampling site do not produce spring-run Chinook; therefore, it is assumed that catch of hatchery origin spring-run Chinook are of fall-, late fall- or winter-run Chinook which have fork lengths that overlap with natural origin spring-run Chinook.

A total of 11 natural origin steelhead was captured by the Knights Landing RSTs during the sampling season. These fish were caught from weeks 3 through 13. A total of 57 hatchery origin steelhead was captured by the Knights Landing RSTs. These fish were caught from week 2 through week 15.

Environmental data collected at the sampling site included: river flow volume, water temperature, water transparency, and water turbidity. Sacramento River discharge was recorded at each trap check measured 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 39) had a weekly mean of 6,104 cubic feet per second (cfs). River flows at the end of the sampling season (week 25) had a weekly mean of 3,645 cfs. Flows varied throughout the sampling season. In week 11, weekly mean flows peaked at 26,170 cfs and the lowest weekly mean flows of 2,910 cfs was observed in week 19. Weekly mean water temperature at the start of the survey period was 18.7°C. Temperatures varied throughout the survey period with a low weekly mean temperature of 7.2°C (week 53) and a high mean temperature of 23.7°C (week 23). Mean weekly water transparency varied between a high of 204.8 centimeters (cm) during week 48 to a low of 7.3 cm during week 11. Mean weekly turbidity at the sampling site varied from a low of 3.2 nephelometric turbidity units (NTU) during week 48 to a high of 200.3 NTU during week 3.

INTRODUCTION

The purpose of the Middle Sacramento River Juvenile Salmonid Emigration Monitoring Program is to develop information on the temporal distribution, relative abundance and run composition 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 its tributaries provide spawning and rearing habitat for four native runs 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 0.8 km downstream of Knights Landing, CA, at rkm 144. Data collected on 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 including the CNFH and LSNFH (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 January through May. 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 emigrate as smolts, or rear for longer periods and emigrate 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 fry, smolts or as yearlings during the months of November through May. 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).

Adult Central Valley 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 of juveniles 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 natural origin populations. Prior to releasing fish into the Sacramento River, these hatcheries externally mark all of their steelhead production and one quarter 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 Central Valley salmonids coupled with environmental alterations along migration corridors has put great strain on 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 from the mid-1800's through 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 river temperatures and increasing river channelization while reducing natural river flows, natural cover and natural gravel recruitment necessary for successful spawning.

Rivers in the Central Valley have also been altered and channelized with levees to aid in flood protection of urban areas 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 river flow regimes, altering flow magnitude and reducing available habitat. 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 competition, 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 upon 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 Sacramento River, its tributaries 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 operations 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 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 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 to water managers emigration trends and approximate numbers of juvenile salmonids entering the Delta. Data collected by the Program were distributed to constituents by CDFW on a per-trap-check basis; the traps were serviced, data were gathered, and 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 environmental conditions.
3. Estimate emigrating salmonid numbers in the middle Sacramento River above the Delta.
4. Develop a long-term dataset on emigration with which to compare changes over time.

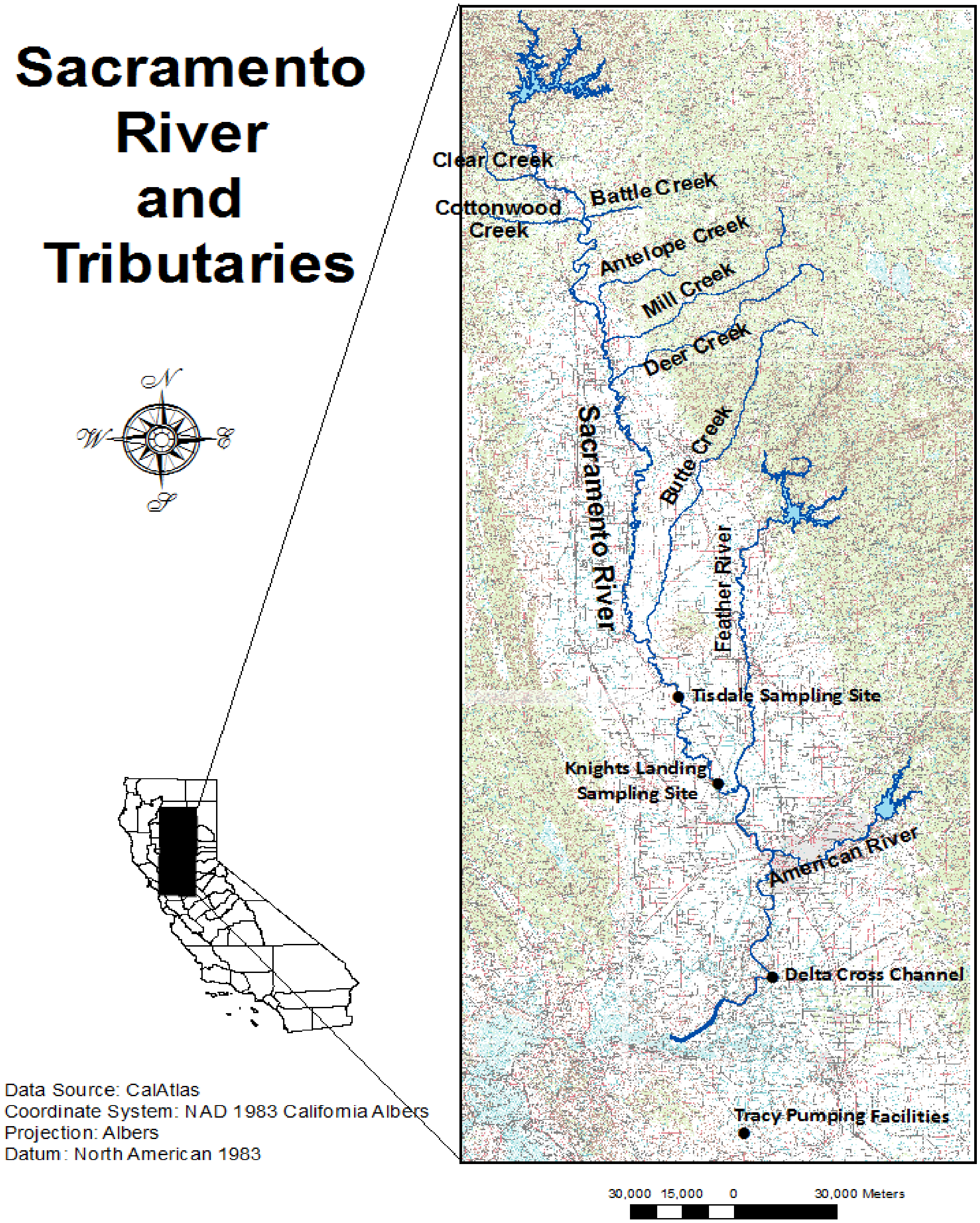

Figure 1. Map of the upper Sacramento River and tributaries depicting locations of the CDFW juvenile monitoring sites, the Delta Cross Chanel Gates and the C.W. Bill Jones (Tracy) pumping facility.

METHODS

Juvenile salmonid emigration monitoring at the Knights Landing sampling site began on September 16, 2015, and concluded on June 20, 2016, for a total of 280 days of continuous sampling. RSTs 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 run composition. A detailed description of RST use and operation is described in Kennen *et al*. (1994) and Volkhardt *et al*. (2007).

The Program outfitted two RSTs with 8-foot 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 with 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 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, 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.

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 measured 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 NTUs. River discharge volume, measured in cubic feet per second (cfs), was obtained from the California Data Exchange Center (CDEC 2016) 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. Run was assigned to juvenile Chinook based on FL using the LAD run 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 YOY age class, fish measuring 100 mm to 300 mm were yearlings, and fish over 300 mm were adults. Catch per unit of effort (CPUE) for each run 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 assumed 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 or otolith data analysis.

Up to 20 adipose fin-clipped, hatchery origin Chinook salmon of each run per trap maintenance event were collected. The absence of the adipose fin indicates the presence of a 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 CDFW 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 were 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 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 Bismarck 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 release site, approximately 2 miles upstream, 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 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 (September 16, 2015, through June 20, 2016) was 9,340 cfs (6,636 cfs standard deviation (SD)). Maximum flow volume recorded was 27,100 cfs during week 11 on March 14, and minimum flow volume recorded was 2,910 cfs during week 19 on May 5. (Figure 2, Table 1)

During the 2015/2016 sampling season there were three distinct flow events which varied in magnitude and duration. The first of these flow events began during week 49 when flows increased from a weekly average of 4,571 cfs to 13,633 cfs during week 52. After declining to a weekly average of 5,190 cfs during week 53, flows again increased to average of 24,105 cfs during week 4. Weekly flow averaged above 10,000 cfs through week 6. The final flow event began during week 9 when average weekly flows increased from 7,397 cfs to 26,343 cfs during week 11. Average weekly flows remained below 10,000 cfs from week 15 through the end of sampling in week 25. Combined Chinook salmon catch during these events were 378, 14,893, and 1,773, respectively, making up 94% of the season’s total juvenile Chinook salmon catch.

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 14.8 °C (4.9°C SD). The minimum water temperature observed was 6.7 °C recorded during week 1 on January 3, while the maximum water temperature of 25.6 °C was recorded on June 1, week 23. (Figure 2, Table 1)

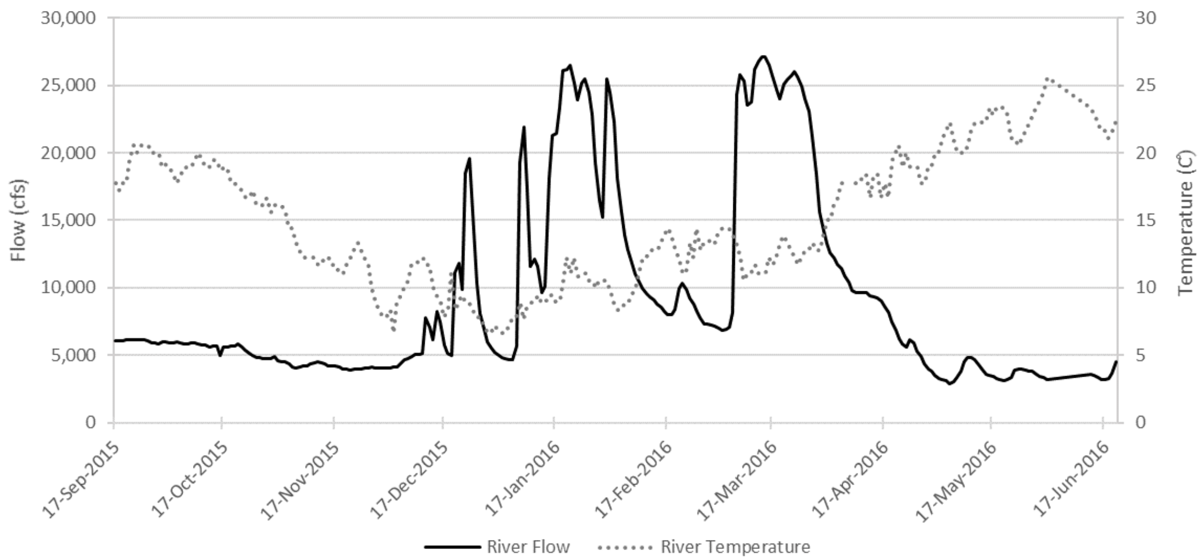

Figure 2. Daily water temperature (C°) values collected at the sampling site between September 16, 2015, and June 20, 2016. Water flow rate was recorded by CDEC, Wilkins Sough gauge and reported in cubic feet per second (cfs).

The minimum water transparency recorded at the sampling site was 1.3 cm during week 4 on January 20. The maximum water transparency recorded was 262.9 cm recorded during week 49 on November 30. Mean water transparency for the sampling season was 74.8 cm (51.7 cm SD). (Figure 3, Table 1)

Turbidity at the sampling site varied from a low of 2.6 NTU recorded during week 48 on November 28 to a high of 467 NTU recorded during week 4 on January 20. Mean turbidity during the sampling season was 34.1 NTU (45.1 NTU SD) (Figure 3, Table 1).

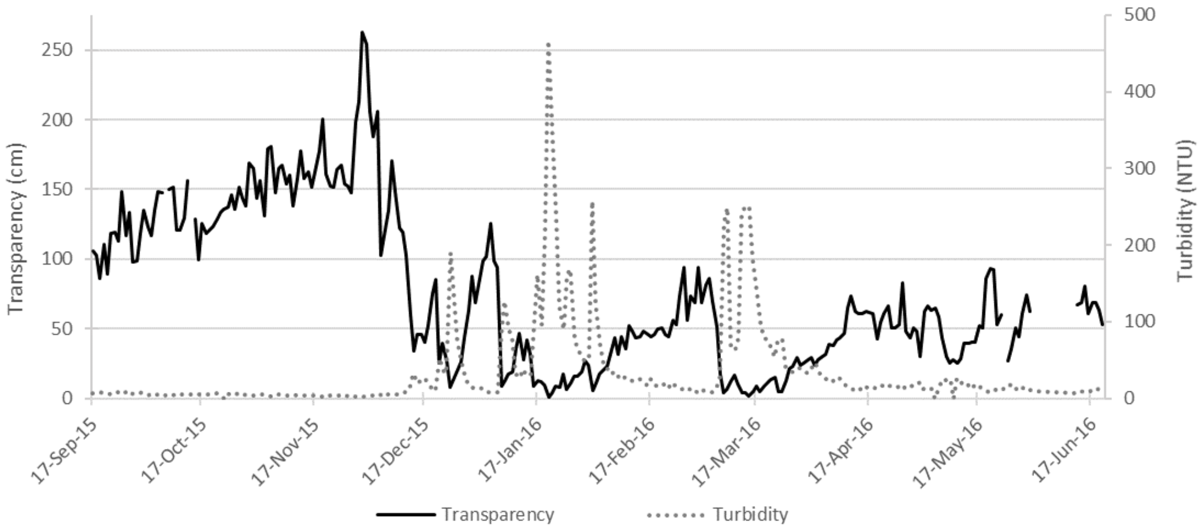

Figure 3. Daily water transparency (cm) and turbidity (NTU) values collected at the sampling site between September 16, 2015, and June 20, 2016.

Table 1. Weekly summaries of environmental conditions recorded at the rotary screw traps located on the Sacramento River near Knights Landing, California, from September 16, 2015, through June 20, 2016.

Week	Beginning Date	Mean Water Temperature (C°)	Mean River Flow (cfs)	Mean Secchi Depth (cm)	Mean Water Turbidity (NTU)
38	9/14/2015	18.7	6,104	104.5	6.6
39	9/21/2015	20.1	6,003	118.1	6.9
40	9/28/2015	18.6	5,910	134.2	5.0
41	10/5/2015	19.3	5,770	138.0	5.4
42	10/12/2015	18.5	5,690	126.8	5.5
43	10/19/2015	16.6	5,071	140.4	5.3
44	10/26/2015	15.8	4,604	154.6	4.3
45	11/2/2015	12.8	4,224	158.9	4.2
46	11/9/2015	11.7	4,299	163.8	3.7
47	11/16/2015	12.3	3,969	164.4	4.2
48	11/23/2015	9.0	4,060	204.8	3.2
49	11/30/2015	9.8	4,571	152.4	5.0
50	12/7/2015	10.9	6,709	73.9	16.1
51	12/14/2015	9.0	9,599	49.2	27.2
52	12/21/2015	7.5	9405	41.5	62.5
53	12/28/2015	7.2	5,190	68.6	15.4
1	1/4/2016	7.5	7,313	88.1	20.8
2	1/11/2016	8.6	13,466	28.8	60.4

Week	Beginning Date	Mean Water Temperature (C°)	Mean River Flow (cfs)	Mean Secchi Depth (cm)	Mean Water Turbidity (NTU)
3	1/18/2016	10.1	23,286	11.5	200.3
4	1/25/2016	10.9	23,764	11.8	131.7
5	2/1/2016	9.6	19,664	17.9	93.9
6	2/8/2016	10.4	11,341	37.4	30.9
7	2/15/2016	13.4	8,557	45.9	22.1
8	2/22/2016	12.5	9,244	53.3	16.8
9	2/29/2016	13.6	7,240	76.6	10.6
10	3/7/2016	12.9	17,291	35.5	86.3
11	3/14/2016	11.4	26,171	7.3	171.6
12	3/21/2016	12.8	25,214	9.2	75.4
13	3/28/2016	12.9	20,200	23.3	37.1
14	4/4/2016	16.6	11,786	31.5	31.8
15	4/11/2016	17.9	9,596	56.2	17.1
16	4/18/2016	18.5	7,943	57.7	14.9
17	4/25/2016	18.7	5,440	58.6	15.5
18	5/2/2016	20.4	3,404	55.2	15.3
19	5/9/2016	20.8	4,164	34.2	23.0
20	5/16/2016	22.8	3,601	49.8	14.6
21	5/23/2016	21.7	3,610	60.1	12.8
22	5/30/2016	23.7	3,528	58.6	12.3
24	6/6/2016	22.5	3,395	69.4	8.5
25	6/20/2016	21.7	3,645	63.4	12.8

Summary of Chinook Salmon Emigration

All runs and juvenile life stages of Chinook salmon were represented in the RST catch during the sampling season. A total of 18,214 juvenile salmon was captured, of which 17,745 unmarked (adipose intact) Chinook salmon accounted for 97.5% of total catch. Unmarked Chinook salmon include naturally spawned winter-run, spring-run, fall-run and late fall-run. Marked Chinook salmon catch totaled 469, or 2.5% of total catch.

The first and last juvenile Chinook salmon were caught during week 39, on September 24, and week 20, on May 16, respectively. Peak catch occurred during weeks 2 through 4 where 13,948 Chinook salmon, approximately 79% of the season total catch, were captured over 502 hours of monitoring.

Natural origin Chinook Salmon

Winter-run Chinook

All unmarked winter-run Chinook salmon were assumed to be natural origin as all upstream releases of hatchery origin Chinook were externally marked by the removal of the adipose fin prior to release. A total of 51 naturally produced winter-run Chinook salmon was caught by the

RSTs. The first fish of this run was caught during week 39, on September 24. Winter-run were consistently present in the RSTs during week 39 through week 10. Peaks in catch were observed during week 52 (n=14) and week 2 (n=10) with 14 winter-run sized fish accounting for approximately 47% of the season total catch of this run and a CPUE of 0.09. All winter-run captured during the sampling period were BY 2015 based on their size at capture. (Table 2)

Table 2. Summary of the weekly catch of natural origin juvenile winter-run Chinook salmon from September 16, 2015, through June 20, 2016. Weeks during the monitoring season not presented here resulted in zero catch of this run.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
39	9/21/2015	286.6	1	0.003	38	38	38	-
42	10/12/2015	294.5	1	0.003	36	36	36	-
50	12/7/2015	153.6	4	0.026	76	70	85	6.5
51	12/14/2015	129.4	6	0.046	76	65	87	8.4
52	12/21/2015	150.7	14	0.093	76	56	90	9.1
1	1/4/2016	206.6	1	0.005	81	81	81	-
2	1/11/2016	218.7	10	0.046	82	69	93	8.1
3	1/18/2016	139.6	9	0.064	92	75	115	13.4
4	1/25/2016	143.7	3	0.021	91	90	92	1.0
9	2/29/2016	295.3	1	0.003	122	122	122	-
10	3/7/2016	201.9	1	0.005	91	91	91	-

Spring-run Chinook

A total of 926 unmarked spring-run Chinook salmon was caught by the RSTs. The first spring-run sized fish was caught during week 50 on December 15. Spring-run emigration timing appeared bimodal with two peaks in catch occurring during weeks 52 through 4 (n=102) and weeks 13 through 16 (n=746). All juvenile spring-run Chinook salmon sampled by the RSTs were BY 2015 based on size at capture. (Table 3)

Table 3. Summary of the weekly catch of natural origin juvenile spring-run Chinook salmon from September 16, 2015, through June 20, 2016. Weeks during the monitoring season not presented here resulted in zero catch of this run.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
50	12/7/2015	153.6	4	0.026	37	36	38	1.0
51	12/14/2015	129.4	6	0.046	38	37	39	0.8
52	12/21/2015	150.7	58	0.385	40	39	43	1.1
53	12/28/2015	59.6	1	0.017	40	40	40	-
2	1/11/2016	218.7	33	0.151	45	43	51	2.0
3	1/18/2016	139.6	21	0.150	49	45	60	4.4

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
4	1/25/2016	143.7	6	0.042	50	47	57	3.9
5	2/1/2016	83.2	1	0.012	66	66	66	-
7	2/15/2016	277.0	1	0.004	65	65	65	-
8	2/22/2016	304.5	1	0.003	56	56	56	-
9	2/29/2016	295.3	2	0.007	61	59	62	2.1
10	3/7/2016	201.9	4	0.020	64	62	65	1.3
11	3/14/2016	124.5	6	0.048	69	65	79	5.2
12	3/21/2016	183.2	26	0.142	77	67	93	7.7
13	3/28/2016	298.5	207	0.693	77	70	92	3.9
14	4/4/2016	238.4	246	1.032	78	73	89	3.0
15	4/11/2016	274.8	122	0.444	84	77	99	4.0
16	4/18/2016	295.2	171	0.579	84	80	95	3.0
17	4/25/2016	329.9	7	0.021	91	85	99	5.0
18	5/2/2016	325.2	2	0.006	90	90	90	0.0
19	5/9/2016	270.7	1	0.004	96	96	96	-

Fall-run Chinook

A total of 16,767 unmarked fall-run Chinook salmon was caught by the RSTs. The first fall-run was caught during week 50, on December 15, and fall-run Chinook were present throughout the remainder of the survey period with few exceptions. Catch peaked during weeks 2 through 5 with a total of 14,702 fall-run captured, representing approximately 88% of total natural origin fall-run Chinook catch. All juvenile fall-run Chinook salmon sampled by the RSTs were BY 2015 based on size at capture. (Table 4)

Table 4. Summary of the weekly catch of natural origin juvenile fall-run Chinook salmon from September 16, 2015, through June 20, 2016. Weeks during the monitoring season not presented here resulted in zero catch of this run.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
50	12/7/2015	153.6	1	0.007	33	33	33	-
51	12/14/2015	129.4	3	0.023	35	34	36	1.0
52	12/21/2015	150.7	237	1.573	36	30	39	1.5
53	12/28/2015	59.6	11	0.185	36	35	39	1.4
1	1/4/2016	206.6	9	0.044	38	36	41	1.5
2	1/11/2016	218.7	4306	19.689	37	33	43	1.8
3	1/18/2016	139.6	5977	42.815	37	31	45	1.9
4	1/25/2016	143.7	3584	24.941	38	29	46	2.0
5	2/1/2016	83.2	835	10.036	38	31	48	2.5
6	2/8/2016	209.3	74	0.354	39	34	52	3.4
7	2/15/2016	277.0	30	0.108	44	35	54	5.8

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
8	2/22/2016	304.5	27	0.089	45	25	55	7.1
9	2/29/2016	295.3	21	0.071	48	39	57	5.4
10	3/7/2016	201.9	86	0.426	41	32	62	7.9
11	3/14/2016	124.5	221	1.775	44	31	65	8.4
12	3/21/2016	183.2	191	1.043	45	26	69	9.8
13	3/28/2016	298.5	194	0.650	55	33	72	12.8
14	4/4/2016	238.4	128	0.537	66	38	75	8.7
15	4/11/2016	274.8	123	0.448	72	44	79	6.4
16	4/18/2016	295.2	542	1.836	75	55	82	4.0
17	4/25/2016	329.9	21	0.064	75	61	85	7.3
18	5/2/2016	325.2	11	0.034	84	80	89	3.1
19	5/9/2016	270.7	39	0.144	81	66	94	7.0
20	5/16/2016	274.3	5	0.018	81	75	86	4.2

Late fall-run Chinook

A total of 1 unmarked late fall-run Chinook salmon was captured during week 52 on December 24. All juvenile late fall-run Chinook salmon sampled by the RSTs were BY 2015 based on size at capture. (Table 5)

Table 5. Summary of the weekly catch of natural origin juvenile late fall-run Chinook salmon from September 16, 2015, through June 20, 2016. Weeks during the monitoring season not presented here resulted in zero catch of this run.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
52	12/21/2015	150.7	1	0.007	120	120	120	-

Hatchery Origin Chinook Salmon

Upstream production releases from CNFH and LSNFH consisted only of winter-run (n=419,690), fall-run (n=12,160,858) and late fall-run (n=474,938) Chinook. 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 origin fish under the guidelines of the Constant Fractional Marking Program (Palmer-Zwahlen et al 2019). Hatchery origin winter-run and late fall-run Chinook salmon are to be 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. Of the total winter-run Chinook salmon released by LSNFH, 2,638 (0.6%) were marked but not tagged, 941 (0.2%) were tagged but not marked, and 246 (0.1%) were not marked or tagged. The remainder were marked and tagged (n=415,865, 99.1%). Of the total late fall-run Chinook salmon released by CNFH, 1,700 (0.4%) were marked but not tagged, 8,975 (1.9%) were tagged but not marked, and 339 (0.1%) were not marked or tagged. The remainder were marked and tagged (n=463,924, 97.7%). Fall-run Chinook salmon are fractionally marked at a rate of 25%. Of the total fall-run Chinook released by CNFH, 2,779 (<0.1%) were marked but not tagged, 907 (<0.1%) tagged but not marked, 9,123,440 (75.0%) were not marked or tagged, and 3,033,741 (24.9) were marked and tagged. (Table 6)

Following releases, 469 adipose fin-clipped Chinook salmon were subsequently captured by the RSTs consisting of all 4 runs using the LAD criteria for run determination: 52 winter-run (10.7%), 159 spring-run (33.9%), 203 fall-run (42.3%), and 55 late fall-run (11.7%).

Table 6. Summary of hatchery origin juvenile Chinook salmon and steelhead trout by CNFH and LSNFH, released upstream from the Knights Landing sampling site from September 16, 2015, through June 20, 2016.

Run or Species	Week	Release Dates	Number marked with CWT	Number marked without CWT	Number unmarked with CWT	Number Unmarked	Release location[1]
Late Fall	50	12/9/2015	253,957	923	6,556	339	CNFH
Late Fall	50	12/11/2015	76,525	777	388	-	CNFH
Late Fall	52	12/22/2015	67,148	0	678	-	CNFH
Late Fall	3	1/12/2016	66,294	0	1,353	-	CNFH
Winter	8	2/17/2016-2/18/2016	415,865	2,638	941	246	LRP
Fall	11	3/14/2016	214,826	857	0	647,824	CNFH
Fall	13	3/22/2016	324,065	-	0	973,032	CNFH
Fall	15	4/7/2016	1,391,663	1,179	232	4,184,565	CNFH
Fall	16	4/12/2016	634,026	734	675	1,908,277	CNFH
Fall	18	4/29/2016	469,161	-	-	1,409,742	CNFH
Steelhead	1-2	1/4/2016-1/9/2016	-	585,127	-	6,235	BB

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

Winter-run Chinook

A total of 52 hatchery origin juvenile winter-run Chinook salmon was captured by the RSTs. The first hatchery origin winter-run based on LAD criteria was captured during week 3 which was prior to the first release of hatchery-reared 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 origin winter-run was captured during week 11. All hatchery origin winter-run Chinook were BY 2015 (Table 7).

Table 7. Summary of weekly catch of hatchery origin juvenile winter-run Chinook salmon from September 16, 2015, through June 20, 2016. Weeks during the monitoring season not presented here resulted in zero catch of this run.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
3	1/18/2016	139.6	1	0.007	88	88	88	-
8	2/22/2016	304.5	24	0.079	95	79	109	7.8
9	2/29/2016	295.3	20	0.068	97	80	109	7.8
10	3/7/2016	201.9	6	0.030	95	90	100	3.9
11	3/14/2016	124.5	1	0.008	93	93	93	-

Spring-run Chinook

A total of 159 hatchery origin juvenile Chinook was identified as spring-run Chinook salmon using LAD methodology; however, upstream hatcheries do not produce spring-run Chinook. 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 and fall-run production releases from CNFH (Table 8).

Table 8. Summary of weekly catch of hatchery origin juvenile spring-run Chinook salmon from September 16, 2015, through June 20, 2016. Weeks during the monitoring season not presented here resulted in zero catch of this run.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
9	2/29/2016	295.3	1	0.003	73	73	73	-
10	3/7/2016	201.9	1	0.005	76	76	76	-
13	3/28/2016	298.5	23	0.077	76	71	80	2.4
14	4/4/2016	238.4	66	0.277	79	74	85	2.6
15	4/11/2016	274.8	35	0.127	83	77	94	3.8
16	4/18/2016	295.2	32	0.108	84	80	92	3.5
19	5/9/2016	270.7	1	0.004	98	98	98	-

Fall-run Chinook

A total of 203 hatchery origin fall-run Chinook was captured. The first of these was captured during week 12 on March 21 following upstream releases. The last hatchery origin fall-run Chinook was captured during week 20. (Table 9)

Table 9. Summary of weekly catch of hatchery origin juvenile fall-run Chinook salmon from September 16, 2015, through June 20, 2016. Weeks during the monitoring season not presented here resulted in zero catch of this run.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
12	3/21/2016	183.2	1	0.005	64	64	64	-
13	3/28/2016	298.5	3	0.010	69	69	70	0.6
14	4/4/2016	238.4	12	0.050	72	68	74	1.6
15	4/11/2016	274.8	25	0.091	75	67	79	2.9
16	4/18/2016	295.2	144	0.488	75	64	81	3.8
17	4/25/2016	329.9	4	0.012	78	71	83	5.1
19	5/9/2016	270.7	13	0.048	80	72	90	5.4

Late Fall-run Chinook

A total of 55 hatchery origin late-fall Chinook salmon was captured. The first hatchery origin late fall-run was captured during week 50 on December 14 and the last hatchery origin late fall-run was captured during week 5, on February 2; all were BY 2015 (Table 10).

Table 10. Summary of weekly catch of hatchery origin juvenile late fall-run Chinook salmon from September 16, 2015, through June 20, 2016. Weeks during the monitoring season not presented here resulted in zero catch of this run.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
50	12/7/2015	153.6	18	0.117	133	102	167	16.8
51	12/14/2015	129.4	3	0.023	137	123	160	20.3
52	12/21/2015	150.7	10	0.066	139	115	170	16.4
53	12/28/2015	59.6	1	0.017	162	162	162	-
1	1/4/2016	206.6	1	0.005	122	122	122	-
2	1/11/2016	218.7	1	0.005	120	120	120	-
3	1/18/2016	139.6	20	0.143	167	143	190	15.4
5	2/1/2016	83.2	1	0.012	128	128	128	-

Summary of Steelhead Trout Emigration

Both, natural origin and hatchery-produced steelhead were captured at Knights Landing. Like Chinook salmon, hatchery origin 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 591,362 hatchery origin steelhead was released by CNFH, of which 6,235 (0.01%) possessed an adipose fin. For the purposes of this report, any steelhead captured by the RSTs which had an intact adipose fin was assumed to be of natural origin.

A total of 68 steelhead trout was captured. Eleven of these were of natural origin and 57 were of hatchery origin. The first and last natural origin steelhead trout were caught during week 2, on January 11, and week 15, on April 12, respectively. Peak catch occurred during week 6 where 62 steelhead trout, or 49.2% of the season's total catch, were captured over 180 hours of monitoring.

Natural Origin Steelhead Trout

A total of 11 natural origin steelhead trout was captured by the RSTs. One was classified as a young-of-year, measuring less than 100 mm. Ten were categorized as yearlings, measuring between 100 mm and 200 mm FL. The first and last captures occurred during week 3 and week 13, respectively. Peak catch occurred during week 13 (27% of total), and the peak CPUE (0.024/hour) occurred during week 5. (Table 11)

Table 11. Summary of weekly catch of natural origin juvenile steelhead trout from September 16, 2015, through June 20, 2016. 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
3	1/18/2016	139.6	1	0.007	226	226	226	-
4	1/25/2016	143.7	2	0.014	250	249	250	0.7
5	2/1/2016	83.2	2	0.024	208	206	209	2.1
6	2/9/2016	209.3	1	0.005	242	242	242	-
10	3/7/2016	201.9	1	0.005	262	262	262	-
11	3/14/2016	124.5	1	0.008	222	222	222	-
13	3/28/2016	298.5	3	0.010	180	55	244	108.3

Hatchery Origin Steelhead Trout

A total of 57 hatchery origin steelhead trout was captured by the RSTs. Release data provided by CNFH identify these as yearling BY 2015 steelhead. (Table 12)

Table 12. Summary of weekly catch of hatchery origin juvenile steelhead trout from September 16, 2015, through June 20, 2016. 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	1/11/2016	218.7	12	0.055	216	142	257	29.0
3	1/18/2016	139.6	16	0.115	230	209	260	15.8
4	1/25/2016	143.7	5	0.035	232	212	249	14.2
5	2/1/2016	83.2	11	0.132	226	205	251	16.0
6	2/8/2016	209.3	1	0.005	275	275	275	-
8	2/22/2016	304.5	1	0.003	230	230	230	-
9	2/29/2016	295.3	1	0.003	237	237	237	-

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation
10	3/7/2016	201.9	1	0.005	212	212	212	-
11	3/14/2016	124.5	2	0.016	232	210	254	31.1
12	3/21/2016	183.2	4	0.022	231	211	260	23.7
13	3/28/2016	298.5	1	0.003	211	211	211	-
14	4/4/2016	238.4	1	0.004	310	310	310	-
15	4/11/2016	274.8	1	0.004	250	250	250	-

Trap Efficiency Trials and Passage Estimates

A total of 11,029 juvenile Chinook salmon was marked and used in 12 efficiency trials in 2016. The mean efficiency for the season was 0.52%. During the trials, salmon were marked externally using either BBY stain, or VIE tags of a specified color: pink, blue, orange, or purple. BBY staining was used on a total of 6,485 fish during weeks 2, 3, 4, 15, and 16. The lowest BBY recapture rate was 0.17% during weeks 3 and 4, and the highest recapture rate was 1.31% during week 2. VIE tags were used on a total of 4,544 fish and trials took place during weeks 6-8, 11-15, and 17. The highest recapture rate was 1.36% during week 14. No tagged fish were recovered during weeks 6-8, 12-13, 15, and 17. (Table 13)

Table 13. Summary of capture efficiency trials initiated from September 16, 2015, through June 20, 2016.

Week	Dates	Mark Type	Marked Released	Marked Recaptured	Efficiency (%)
2	1/10/2016-1/16/2016	BBY	3202	43	1.34%
3-4	1/23/2016-1/29/2016	BBY	2864	5	0.17%
6	2/10/2016	VIE (pink)	632	0	0.00%
7	2/17/2016	VIE (blue)	479	0	0.00%
8	2/24/2016	VIE (orange)	489	0	0.00%
11	3/16/2016	VIE (purple)	490	1	0.20%
12	3/23/2016	VIE (orange)	488	0	0.00%
13	3/30/2016	VIE (purple)	470	0	0.00%
14	4/6/2016	VIE (orange)	516	7	1.36%
15	4/13/2016	VIE (pink)	473	0	0.00%
15-16	4/16/2016-4/22/2016	BBY	419	1	0.24%
17	4/27/2016	VIE (orange)	507	0	0.00%

Passage Estimates

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 9,434,470 fall-run, 357,030 spring-run, and 11,472 winter-run Chinook salmon passed the monitoring site between September 16, 2015, and June 20, 2016. No passage estimate was calculated for late fall-run Chinook salmon as too few individuals were captured to create a reliable estimation. (Table 14)

Table 14. Estimates of natural origin Chinook salmon that passed the Knights Landing sampling location from September 16, 2015, through June 20, 2016, and associated 95% confidence interval (CI).

Run	Passage	Lower 95% CI	Upper 95% CI
Fall	8,434,470	4,299,600	16,482,460
Spring	357,030	195,073	739,450
Winter	11,472	8,264	14,559

Non-target Species

Non-target species include all fishes observed that were not Chinook salmon or steelhead. A total of 5,618 non-target fishes representing 34 species was captured, 10 of which are native to the Sacramento River and its tributaries and 24 are introduced species (Table 15). Some related genera catch totals were combined because juveniles have similar morphological features. For example, Pacific and river lamprey (*Lampetra* 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 September 16, 2015, and June 20, 2016.

Common Name	Scientific Name	Number Captured	Mean FL (mm)	Min FL (mm)	Max FL (mm)	Standard Deviation
Threadfin Shad	*Dorosoma petenense*	1,790	90	39	170	12.7
Sacramento Splittail	*Pogonichthys macrolepidotus*	1,015	39	21	406	35.6
Inland Silverside	*Menidia beryllina*	575	58	20	171	18.4
Sacramento Pikeminnow	*Ptychocheilus grandis*	427	85	28	250	28.2
Bluegill	*Lepomis macrochirus*	321	42	23	140	16.6
Mosquitofish	*Gambusia affinis*	232	31	18	67	6.5
Golden Shiner	*Notemigonus crysoleucas*	149	54	22	129	30.6
Unknown Sunfish	*Centrarchidae spp.*	149	40	21	77	12.7
Goldfish	*Carassius auratus*	130	48	22	400	41.8
White Crappie	*Pomoxis annularis*	89	46	20	245	32
Unknown Crappie	*Pomoxis spp.*	71	31	23	47	7.1
Black Crappie	*Pomoxis nigromaculatus*	69	77	33	300	57.9

Common Name	Scientific Name	Number Captured	Mean FL (mm)	Min FL (mm)	Max FL (mm)	Standard Deviation
Pacific Lamprey	*Entosphenus tridentatus*	65	141	42	482	69.7
Unknown Centrarchid	*Centrarchidae spp.*	54	32	19	47	7.6
Unknown Bass	*Micropterus spp.*	53	23	12	38	4.1
River Lamprey	*Lampetra ayresi*	51	148	90	510	56.1
Unknown Lamprey	*Lampetra spp. OR Entosphenus spp.*	40	144	109	166	12.9
Unknown Minnow	*Cyprinidae spp.*	40	30	20	46	5.6
Common Carp	*Cyprinus carpio*	38	383	20	780	317.7
Redear Sunfish	*Lepomis microlophus*	27	78	45	212	44.4
Sacramento Sucker	*Catostomus occidentalis*	27	166	22	650	205.9
Green Sunfish	*Lepomis cyanellus*	24	59	33	130	20.6
White Catfish	*Ameiurus catus*	23	174	50	368	110.3
Smallmouth Bass	*Micropterus dolomieu*	21	150	33	345	69
Red Shiner	*Cyprinella lutrensis*	18	53	31	135	6.2
Brown Bullhead	*Ameiurus nebulosus*	13	178	48	432	106.3
Warmouth	*Lepomis gulosus*	13	55	35	85	11.1
Striped Bass	*Morone saxatilis*	12	305	40	520	158.4
Three-Spined Stickleback	*Gasterosteus aculeatus*	12	34	28	45	4.7
American Shad	*Alosa sapidissima*	11	98	30	342	90.3
Channel Catfish	*Ictalurus punctatus*	10	175	53	622	183.3
Spotted Bass	*Micropterus punctulatus*	9	162	90	420	111.2
Tule Perch	*Hysterocarpus traskii*	8	69	33	156	43.9
Black Bullhead	*Ameiurus melas*	6	135	114	168	21.7
Fathead Minnow	*Pimephales promelas*	6	54	47	61	5.8
Largemouth Bass	*Micropterus salmoides*	5	53	31	90	28.4
Unknown Catfish	*Ictaluridae spp.*	5	136	17	490	201
California Roach	*Hesperoleucus symmetricus*	3	51	37	65	14
Wakasagi	*Hypomesus nipponensis*	3	57	43	75	16.4
Hardhead	*Mylopharodon conocephalus*	2	69	49	88	27.6

Common Name	Scientific Name	Number Captured	Mean FL (mm)	Min FL (mm)	Max FL (mm)	Standard Deviation
Hitch	*Lavinia exilicauda*	2	114	98	130	22.6

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 2015/2016 sampling season there were three distinct flow events which varied in magnitude and duration. While catch data resolution, sampling effort, 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.

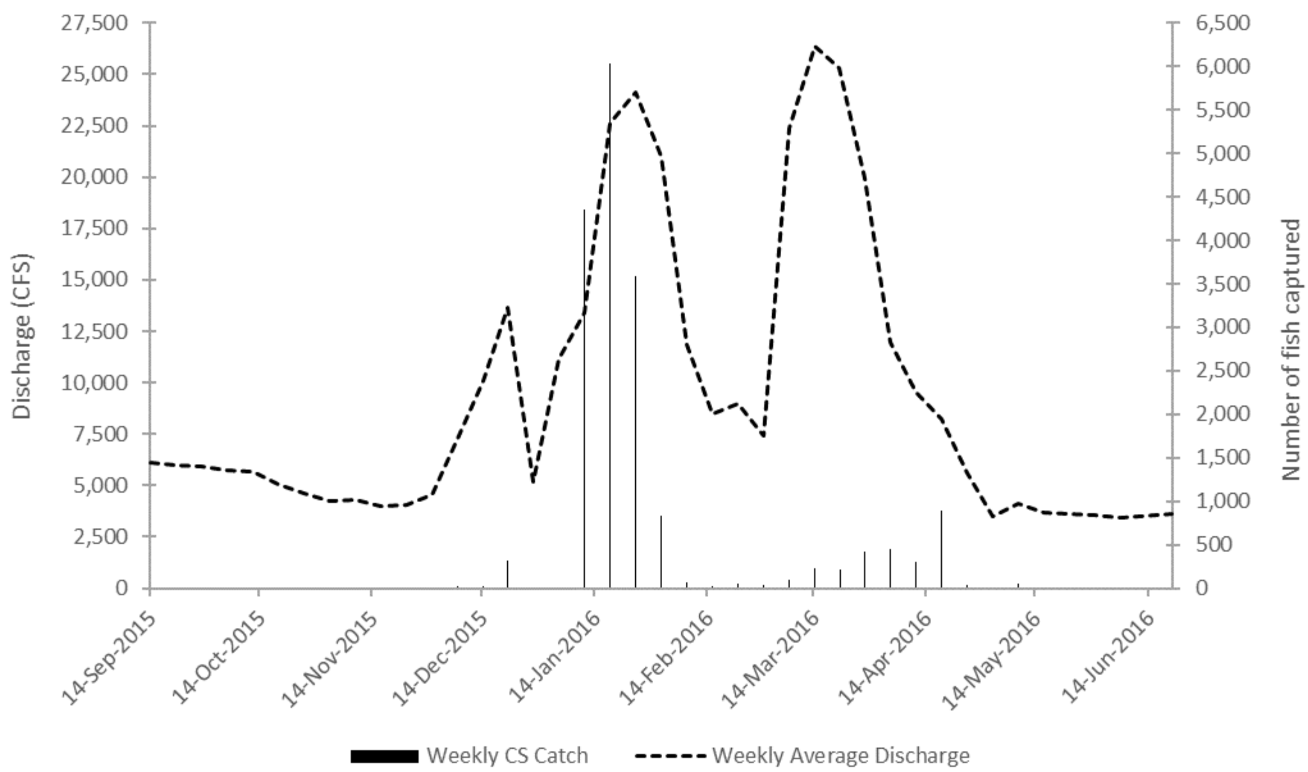

Figure 4. Weekly average flow measured at the CDEC Wilkins Slough gauge and total weekly catch of Chinook salmon between September 16, 2015, and June 20, 2016.

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 the main channel from point of origin to the sampling site. In times of excessive river flow, upstream flood control diversions, including Moulton, Colusa, and Tisdale weirs, 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 which is downstream of the Knights Landing sampling site. When this occurs, observed increases in emigration can be muted at the Knights Landing sampling site affecting the ability to forecast the presence of juvenile salmonids that may be drawn into CVP and SWP facilities.

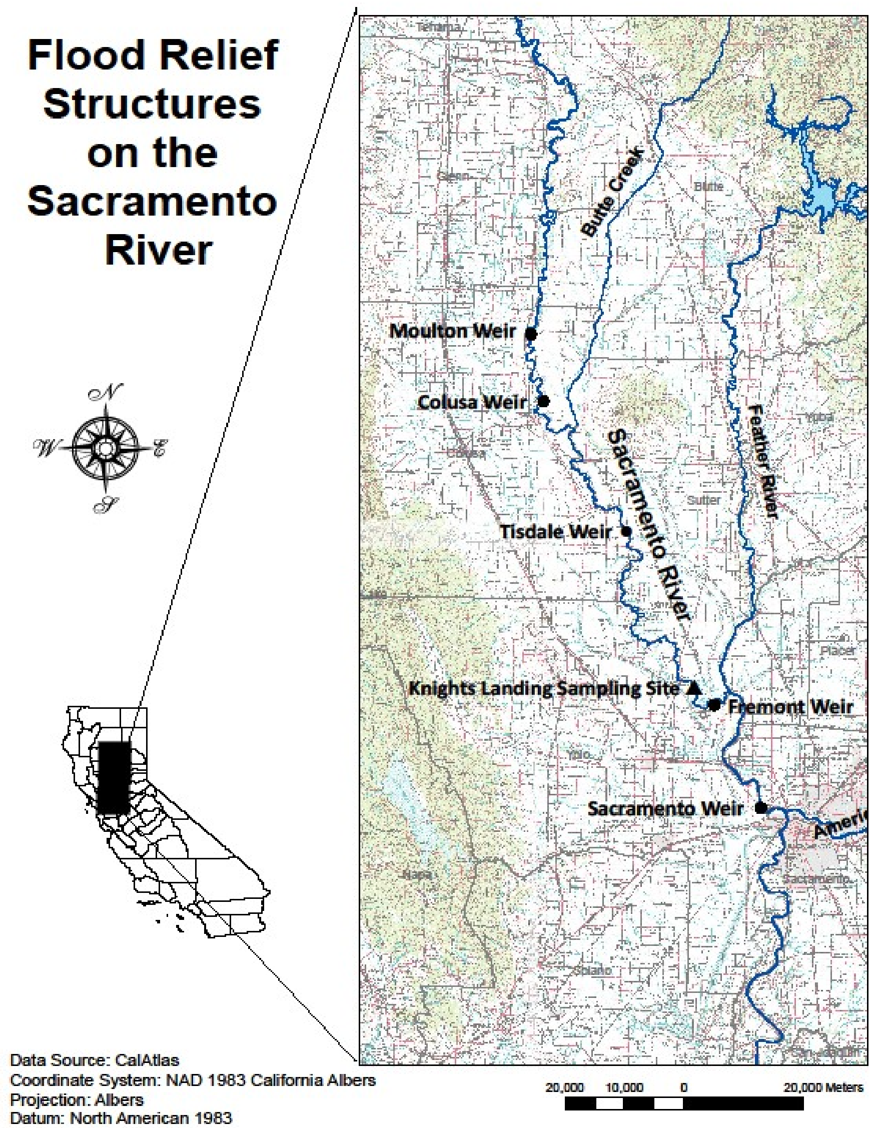

Figure 5. Map of the upper and middle Sacramento River and tributaries depicting location of the CDFW juvenile monitoring site in relation to flood relief structures.

Examining the effect of weir overtopping events on salmonid emigration monitoring may be accomplished through comparison of salmonid capture by sampling season and by monitoring location, 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 18,214 Chinook salmon was caught during the 2015/2016 sampling year which is significantly less than the 2013/2014 total catch of 106,592 Chinook salmon. During the 2015/2016 sampling year, the Sacramento River flood relief weirs were overtopped 3 times resulting in a combined 59 days allowing emigrating salmonids to enter the flood plain habitats of the Sutter Bypass. Moulton Weir overtopped during week 11 for two days. Colusa and Tisdale Weirs overtopped during weeks 3 through 5 and then again during weeks 10 through 12 for a total of 25 and 34 days, respectively. An apparent decrease in trends of Chinook salmon catch was observed following the first spilling events at Colusa and Tisdale Weirs possibly indicating significant portions of the emigrating Chinook salmon population entered the Sutter Bypass. (Figure 6)

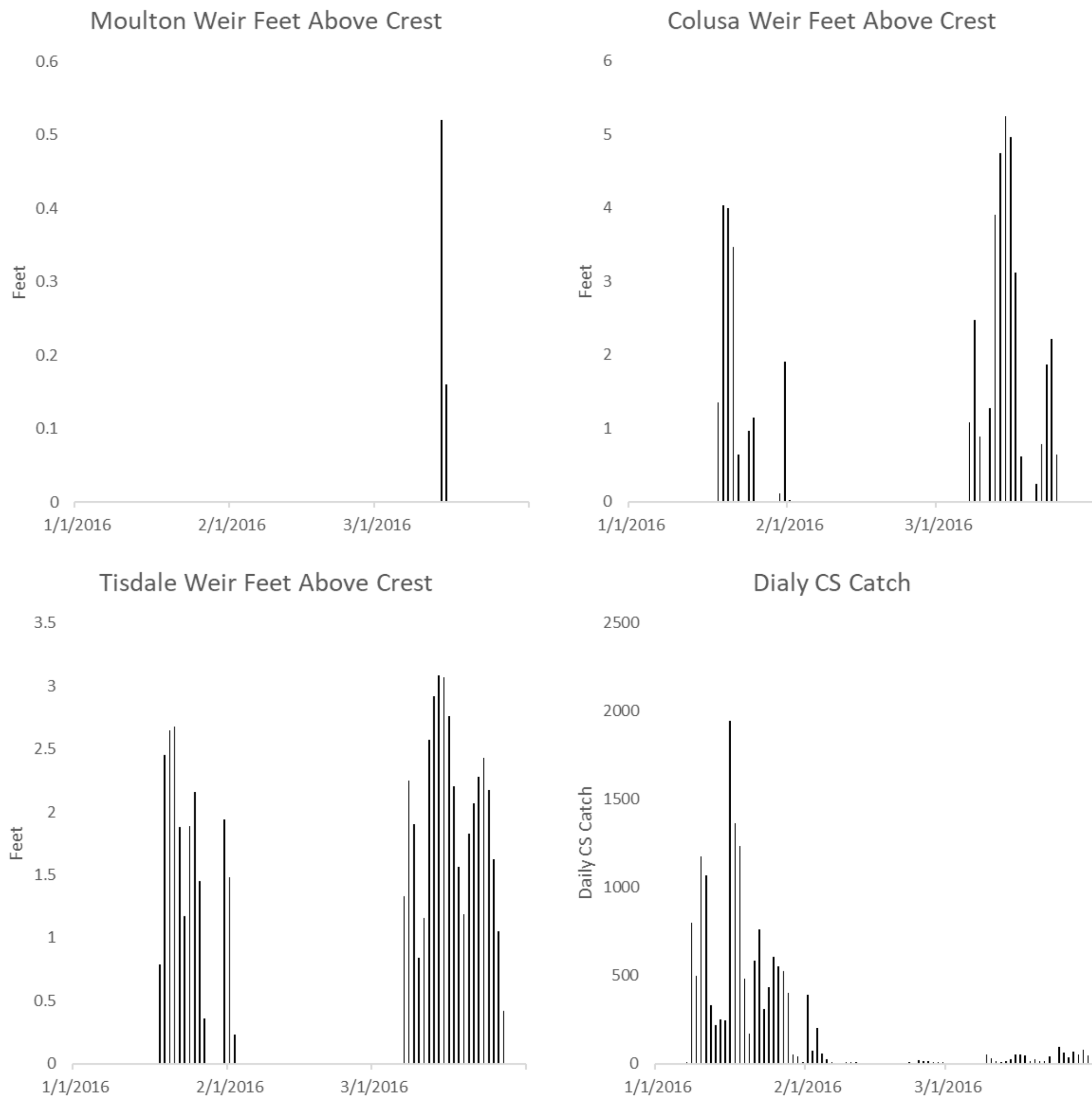

Figure 6. Daily average elevation above the weir crests at Moulton, Colusa and Tisdale weirs and total Chinook salmon catch January through March 2016, at Knights Landing on the Sacramento River.

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 main channel. The difference in catch between the 2013/2014 and 2015/2016 survey years may demonstrate the influence active flood relief weirs have on observations at monitoring locations and salmon emigration routes. This could be validated by 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 (Table 16).

Table 16. Potential for the 2015 water year overtopping events to influence salmonid capture data for natural origin and hatchery origin Chinook salmon by run and yearling steelhead trout. Natural origin late fall-run were omitted from this table because of low catch numbers (n=1).

ESU/Origin	Weeks	Date range	Proportion of catch following overtopping events
Fall-run (natural origin)	51 to 20	12/15/2015 to 5/16/2016	46.0% (n=8,641)
Spring-run (natural origin)	51 to 19	12/15/2015 to 5/12/2016	85.9% (n=796)
Winter-run (natural origin)	39 to 10	9/24/2015 to 3/9/2015	17.6% (n=9)
Fall-run (hatchery)	12 to 19	3/21/2016 to 5/15/2016	100% (n=203)
Spring-run (hatchery)	8 to 19	2/28/2016 to 5/11/2016	100% (n=159)
Winter-run (hatchery)	3 to 11	1/18/2016 to 3/17/2016	100% (n=52)
Late fall-run (hatchery)	51 to 5	12/14/2015 to 2/3/2016	1.8% (n=1)
Steelhead (natural origin)	6 to 21	2/10/2015 to 5/25/2015	100% (n=6)
Steelhead (hatchery)	2 to 14	1/13/2015 to 4/7/2015	100% (n=120)

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 salmonid emigration as they move toward the Delta. Data collected during the 2015/2016 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 at Knights Landing;
4. Contributed to the long-term dataset on emigration which is used 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 should be targeted at better defining entrainment into the Sutter Bypass.

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Sampling Options

Additional Options During High Flow Periods***

Conditions	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.