U.S. Fish and Wildlife Service

Annual Report: Juvenile fish monitoring during the 2014 and 2015 field seasons within the San Francisco Estuary, California

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EXECUTIVE SUMMARY

The Delta Juvenile Fish Monitoring Program (DJFMP) has monitored juvenile Chinook Salmon *Oncorhynchus tshawytscha* within the San Francisco Estuary (Estuary) since 1976 using a combination of surface trawls and beach seines. Since 2000, three trawl sites and 58 beach seine sites have been sampled weekly or biweekly within the Estuary and lower Sacramento and San Joaquin Rivers. The objectives of the DJFMP Annual Report for the 2014 (August 1, 2013 to July 31, 2014) and 2015 (August 1, 2014 to July 31, 2015) field seasons were to (1) report water quality information collected concurrently while monitoring fish during the 2014 and 2015 field seasons, (2) document the fish assemblage structure at monitoring sites, (3) determine the abundance and distribution of naturally and hatchery produced juvenile Chinook Salmon migrating into and out of the Delta, (4) document the length frequency distributions of unmarked juvenile Chinook Salmon captured, and (5) discuss how the relative abundance indices of unmarked winter-run sized or older juvenile Chinook Salmon occurring near Sacramento informed real-time Delta Cross Channel (DCC) water operation decisions.

Environmental parameters. We generally observed high variation in water quality parameters across all trawl sites and seine regions. We observed slightly higher water temperatures in 2015 than in 2014, frequently exceeding 25°C in the summer months of both years. We also observed highly variable dissolved oxygen values in the lower San Joaquin River during the 2014 field season, which decreased to <3 mg/L during the winter, and increased to above 12 mg/L in the spring months. In general, turbidity was lower within the Central Delta and South Delta seine regions relative to other regions throughout most of the field seasons. Little distinct inter-annual patterns were observed in water conductivity in trawl sites or seine regions. Despite small variations in water temperature and conductivity between the 2014 and 2015 field seasons, there was a strong contrast in seasonal flow regimes between the two years. The 2014 field season was characterized by low variation in seasonal flows and a near absence of strong peak flow events in fall and winter months in comparison to 2015.

Fish assemblage. The fish assemblage was dominated by nonnative resident fish, and there was an overall decrease in fish captured during the 2015 field season compared to 2014. In general, anadromous-pelagic-nonnative species dominated at Chipps Island and resident pelagic-nonnative fish dominated at the Mossdale Trawl Site. In contrast, anadromous-pelagic-native fish were relatively more abundant at the Sacramento Trawl Site. The mean yearly catch-per-unit effort estimates among beach seine regions demonstrated that fish densities for most assemblage groups were relatively high during the 2014 field season and decreased slightly in 2015.

Proportional unmarked origin of Chinook Salmon. We estimated the origin of unmarked juvenile Chinook Salmon using the known ratio of unmarked to marked individuals in hatchery release groups, and observed that nearly all juvenile salmon runs captured using beach seines since the 2000 field season were of natural origin. Conversely, most of the hatchery origin fish were captured using trawls. This suggests that hatchery juvenile Chinook Salmon may be less likely to occur in unobstructed near shore habitats within the San Francisco Estuary than natural origin juvenile Chinook Salmon.

Sacramento Catch Index. The DJFMP calculated a Sacramento Catch Index (SCI) using the relative abundance indices of unmarked winter-run sized or older juvenile Chinook Salmon near Sacramento. The SCI did not trigger any modified DCC operations in the 2014 field season. However, the Sacramento Trawl SCI or the Sacramento Beach Seine SCI exceeded the threshold of the salmon decision process on 10 sampling dates during the 2015 field season. This, in conjunction with other criteria, either triggered or maintained the closure of the DCC gates on 8 occasions.

Liberty Island Seine. The DJFMP conducted beach seining at Liberty Island from March 2010 through February 2012 under the BREACH III agreement with the California Department of Fish and Wildlife. Sampling has continued from February to June in 2013 to 2015. The BREACH III study was intended to provide information regarding how abiotic and biotic factors control vegetation colonization and expansion and subsequent responses by higher trophic levels. In addition, DJFMP sampling at Liberty Island provides baseline data that can serve as a reference site for future restoration efforts at Liberty Island and other north Delta sites in conjunction with the EcoRestore (previously Bay Delta Conservation Plan) and the Fish and Wildlife Service Operational Criteria and Plan Biological Opinion, respectively. Results from the 2014 and 2015 field seasons showed trends consistent with the inter-annual variation observed collectively from the six seine regions, with juvenile Chinook exhibiting over an order of magnitude higher mean catch per unit effort (CPUE) from the 2014 field season to 2015. Seasonally, most of this difference occurred during the months of February and March, which is also consistent with results from other seine region sites across the North Delta.

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ACRONYMS

The following acronyms have been used in this report:

CI—Confidence interval
CDFW—California Department of Fish and Wildlife
CDWR—California Department of Water Resources
CPUE—Catch-per-unit effort
CVP—Central Valley Project
CWT—Coded wire tag
DAT—Data Assessment Team
DCC—Delta Cross Channel
DJFMP—Delta Juvenile Fish Monitoring Program
DOSS—Delta Operations for Salmon and Sturgeon working group
ESA—Endangered Species Act
FL—Fork length
IEP—Interagency Ecological Program
KDTR—Kodiak trawl
KLCI—Knights Landing Catch Index
LDC—Length-at-capture-date criteria
LFWO—Lodi Fish and Wildlife Office
MWTR—Mid-water trawl
NMFS—National Marine Fisheries Service
PSMFC—Pacific States Marine Fisheries Commission
RM—River mile
RMIS—Regional Mark Information System
SCI—Sacramento Catch Index
SD—Standard deviation
SE—Standard error
SJRGA—San Joaquin River Group Authority
SWP—State Water Project
SWRCB—State Water Resources Control Board
USBR—United States Bureau of Reclamation
USFWS—United States Fish and Wildlife Service
USGS—United States Geological Survey
WOMT—Water Operations Management Team

LONG-TERM MONITORING

Introduction

The San Francisco Estuary (Estuary) is notably the largest estuary in California and provides spawning habitat, nursery habitat, and migratory pathways for over 40 freshwater, estuarine, euryhaline, marine, and anadromous fish species (Moyle 2002). Historically, the Estuary was maintained by natural runoff from an estimated 40% of California's surface area (Nichols et al. 1986). However, increases in agriculture and urbanization throughout California over the last century, coupled with California's Mediterranean climate (i.e., wet winters and dry summers), have necessitated intense water management within the Estuary and its watershed. The damming of most rivers, confinement of channels, and water diversions and exports has subjected the Estuary to artificial flow regimes that can have profound impacts on aquatic habitats and organisms (Stevens and Miller 1983; Nichols et al. 1986; Brandes and McLain 2001; Bunn and Arthington 2002; Kimmerer 2002; Feyrer and Healey 2003). As a result, fish species of management concern within the Estuary have been monitored and studied, in part, by the Delta Juvenile Fish Monitoring Program (DJFMP) of the Lodi Fish and Wildlife Office (LFWO, formerly Stockton Fish and Wildlife Office) to assess and minimize the effects of water operations on fish populations.

The DJFMP, as part of the Interagency Ecological Program, has been monitoring populations of juvenile Chinook Salmon *Oncorhynchus tshawytscha* (hereafter Chinook) within the Sacramento-San Joaquin Delta (Delta) and its watershed since 1976 (Dekar et al. 2013). The DJFMP and its goals have evolved based on water management needs and endangered species listings. Prior to 1992, the DJFMP conducted annual monitoring between April and June to assess the effects of water operations on the inter- and intra-annual abundance and distribution of primarily juvenile fall-run Chinook within the Delta and lower Sacramento River. Following the listing of Sacramento River winter-run Chinook as endangered by the State of California in 1989 (CDFW 2005) and by the National Marine Fisheries Service in 1994 (59 FR 440), the DJFMP expanded the long-term sampling program to one that operated between October and June to collect more information on all races of juvenile Chinook in the Estuary. The DJFMP was further expanded in 1995 to sample year-round, in part, to expand the temporal and geographic monitoring of resident fish and Central Valley Steelhead *Oncorhynchus mykiss* (Dekar et al. 2013). Today, year-round monitoring continues with an emphasis on populations of all races of Chinook in the Delta per the monitoring and reporting terms of the Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project (CVP) and State Water Project (SWP, NMFS 2009a).

In general, the fish data collected by the DJFMP are intended to provide basic biological and demographic information that can be used to assess trends over time. The first section of this report will focus on the DJFMP's long-term observations of juvenile Chinook and fish assemblage structure. The objectives of the annual report for the 2014 (August 1, 2013 to July 31, 2014) and 2015 (August 1, 2014 to July 31, 2015) field seasons were to (1) report water quality information collected concurrently while monitoring fish during the 2014 and 2015 field seasons, (2) document the fish assemblage structure at monitoring sites, (3) determine the abundance and distribution of naturally and hatchery produced juvenile Chinook migrating into and out of the Delta, and (4) document the length frequency distributions of unmarked juvenile Chinook. Although the water quality data are intended to document the spatial and temporal variation of potential fish habitat characteristics within the Estuary and lower rivers, rigorous fish-habitat analyses are beyond the scope of this report.

Methods

<u>Monitoring Locations</u>

The San Francisco Estuary consists of three distinct segments: the Sacramento-San Joaquin Delta, Suisun Bay, and San Francisco Bay (Moyle 2002). During the 2014 and 2015 field seasons, the DJFMP sampled fishes at 3 trawl sites and 56 beach seine sites located within the lower Sacramento and San Joaquin Rivers, at and between the entry and exit points of the Delta, Liberty Island, and within the San Francisco Bay (Figure 1; Table A.1).

We used surface trawls to examine the relative abundance of fishes migrating into and out of the Delta. Trawl sites were located at the entry (Sacramento and Mossdale trawl sites) and exit (Chipps Island Trawl Site) points of the Delta (Figure 1Figure 1; Table A.1). In general, the DJFMP sampled each trawl site three days per week, with ten tows per day throughout the 2014 and 2015 field seasons. Trawl sites were generally sampled Monday, Wednesday, and Friday each week throughout the field season to maximize temporal coverage. The California Department of Fish and Wildlife (CDFW) has traditionally sampled the Mossdale Trawl Site, following similar methodologies, in place of the DJFMP between April and June (SJRGA 2009). Data collected from both the DJFMP and CDFW at the Mossdale Trawl Site are included in this report.

We used beach seines to quantify the spatial distribution of fishes occurring in unobstructed shallow near-shore habitats (e.g., beaches and boat ramps ≤ 1.2 m in depth) throughout the lower Sacramento and San Joaquin Rivers, Liberty Island, and the Estuary. Beach seine sites were stratified into six geographic seine regions: (1) Lower Sacramento River, (2) North Delta, (3) Central Delta, (4) South Delta, (5) Lower San Joaquin River, and (6) San Francisco and San Pablo Bay (Figure 1; Table A.1). Seine regions were delineated by proximity to canals or water bypasses where fish may be diverted from historical migration routes.

In this dynamic system, occasional changes in river flow or environmental conditions prevent sampling or make it necessary to temporarily relocate seine sites (e.g., tidal conditions, or submerged or floating aquatic vegetation blocking access to sites). If new seine sites were needed, we attempted to relocate the site to another location with similar habitat (e.g., hydrogeomorphic characteristics) that was less than 100 m from the original site.

Accessibility of beach seine sites in the San Joaquin River Seine Region varied in difficulty between flow conditions. During the 2000–2015 field seasons, when the discharge of the lower San Joaquin River dropped below 51 m^3/s boat access to specific beach seine locations became difficult, so only sites that were accessible from land were sampled (Table A.1). To accommodate for the inaccessible sites we sampled alternative sites, some of which were over 100 m from the original sampling locations. We discontinued the use of alternative sites in the San Joaquin River Seine Region in the 2014-2015 field seasons in order to decrease biases in fish abundance and distribution patterns caused by changing sites during variable flow conditions; and only the sites that were sampled when the river was above 51 m^3/s during the 2000–2013 field seasons were sampled throughout the entire 2014 and 2015 field seasons. More information on monitoring site modifications can be found in the LFWO Metadata file at https://www.fws.gov/lodi/juvenile_fish_monitoring_program/jfmp_index.htm.

In general, we sampled fishes at the beach seine sites one day per week, one time per day throughout the 2014 and 2015 field seasons within all seine regions except the Lower San Joaquin River and the San Francisco and San Pablo Bay seine regions. The beach seine sites that were located within the Lower San Joaquin River Seine Region were generally sampled one day per week, one time per day from January 1 to July 31 and one day every two weeks from August 1 to December 31. The beach seine sites that were located within the San Francisco and San Pablo Bay Seine Region were generally sampled one day every two weeks, one time per day throughout the 2014 and 2015 field seasons based on the low occurrence of fish species of management concern.

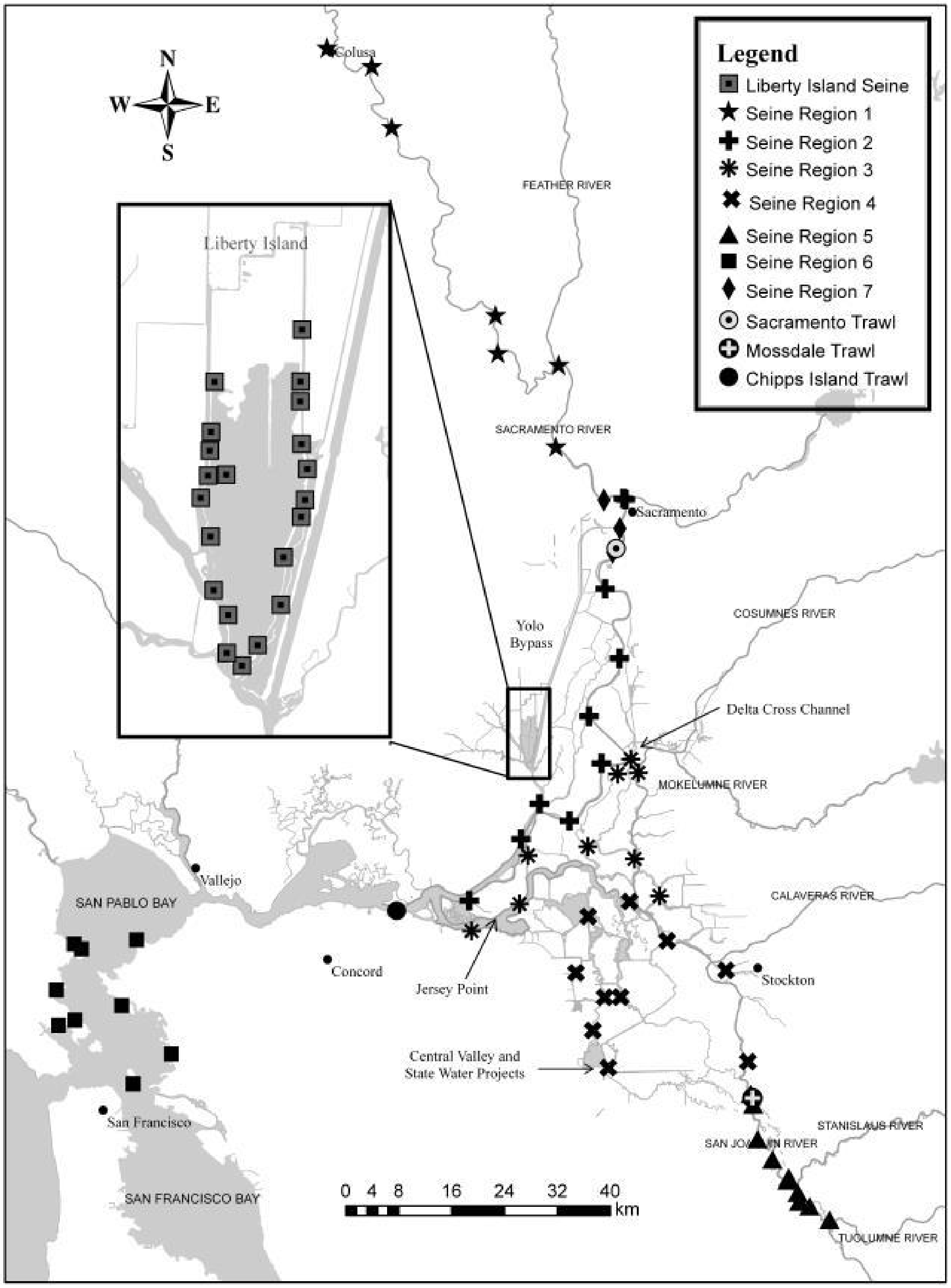


Figure 1. Sites sampled during the 2014 and 2015 field season within the lower Sacramento and San Joaquin Rivers and San Francisco Estuary.

Trawl Methodology

We sampled at trawl sites using Kodiak (KDTR) and mid-water (MWTR) trawls. The DJFMP exclusively uses a MWTR at the Chipps Island Trawl Site and a KDTR at the Mossdale Trawl Site. The DJFMP exclusively used a MWTR at the Sacramento Trawl Site prior to 1994, and has used a KDTR from October to March and a MWTR for the remainder of each field season thereafter (Dekar et al. 2013). The KDTR has been used in place of the MWTR at the Sacramento Trawl Site from October to March to maximize the capture of larger Chinook and to provide more robust juvenile winter-run Chinook catch indices (Dekar et al. 2013).

During each sampling day, we attempted ten 20-minute tows between approximately 7am and 1pm at all trawl sites. All tows were conducted mid-channel and facing upstream at the Sacramento and Mossdale trawl sites, which constitute a reach length of approximately 6.5 km and 3 km, respectively. In contrast, tows were generally conducted facing both upstream and downstream in the north, south, and middle portions of the channel at the Chipps Island Trawl Site based on tidal influence on net water velocities. The Chipps Island Trawl Site constitutes a reach length of approximately 4 km. The MWTR and KDTR nets were towed by one and two boats, respectively, in the top few meters of the water column at a speed necessary and distance apart (for KDTR) to ensure that the net mouth remained fully extended and submerged. The measure of the distance traveled during each tow was recorded using a calibrated mechanical flow meter (General Oceanics, Model #2030) deployed alongside the boat. In general, the Sacramento MWTR net was towed at speeds between 0.7–1.0 meters per second (m/s), the Chipps Island MWTR net was towed at speeds between 0.9–1.12 m/s, and the KDTR nets were towed at speeds between 0.45–0.67 m/s at both the Mossdale and Sacramento trawl sites.

The Sacramento MWTR net was composed of six panels, each decreasing in mesh size towards the cod end (Figure 2). The mesh size for each panel ranged from 20.3 cm stretch at the mouth to 0.6 cm stretch just before the cod end. The cod end was composed of 0.3 cm weave mesh. The fully extended mouth size was 4.15 by 5 m. Two depressors and hydrofoils enabled the net to remain at the top few meters of the water column while sampling. Depressors were made of 0.7 cm thick stainless steel (one on each side of the net lead line) and were attached to the net with shackles to extend the bottom line of the mouth. Hydrofoils were made of 0.7 cm thick aluminum plates with split floats (one on each side of the net float line) and were attached to the net with shackles to extend the top of the net at the water surface. On each side of the net, the depressor and hydrofoil were connected to the boat using a 30.5 m Amsteel rope bridle (0.64 cm diameter). The net was fished approximately 30 m behind the boat.

The MWTR net used at the Chipps Island Trawl Site was larger and similar in construction to the MWTR net used at the Sacramento Trawl Site (Figure 3). There were five panels, each with decreasing mesh size towards the cod end. The mesh size for each panel ranged from 10.2 cm stretch at the mouth to 2.5 cm stretch just before the cod end. The cod end was composed of 0.8 cm knotless material. The fully extended mouth size of the Chipps Island MWTR net was 7.64 by 9.65 m. The depressors and hydrofoils of the Chipps Island MWTR were larger and were connected to the boat identically to those on the Sacramento MWTR. On each side of the net, the depressor and hydrofoil were connected to the boat using a 30.5 m Amsteel rope bridle (0.6 cm diameter) attached to a 15.2 m tow rope (0.95 cm diameter). As a result, the Chipps Island MWTR net was fished approximately 45 m behind the boat.

The KDTR nets used at the Mossdale and Sacramento trawl sites were composed of five panels, each decreasing in mesh size towards a live box at the cod end (Figure 4A). The mesh size for each panel ranged from 5.1 cm stretch at the mouth to 0.6 cm stretch just before the live box. The live box (36 cm wide by 36 cm tall by 49 cm long) was composed of 0.18 cm thick aluminum that was perforated with 0.46 cm diameter holes. The live box contained several internal baffles to minimize fish mortality and stress due to flow pressure. The fully extended mouth size of the KDTR nets were 1.96 by 7.62 m. A float line and lead line enabled the nets to remain at the top few meters of the water column while sampling. Additionally, at the front of each wing of the net was a 1.83 m metal bar with floats at the top and weights at the bottom to keep depth constant while sampling. The KDTR nets were towed behind two boats sitting approximately 4.5 m apart (Figure 4B). The KDTR nets were connected to the boats using a 2.3 m rope bridle (2.4 cm diameter) attached to a 30.5 m tow rope (0.95 cm diameter), which was attached to the metal bar on each side of the net. The net was fished approximately 31 m behind the boats.

At the end of each MWTR tow, the net was retrieved by the towing vessel using winches to collect all the fishes observed in the cod ends. At the end of each KDTR tow, the two towing vessels (i.e., net and chase boats) would maneuver alongside each other, and the chase boat would transfer its tow rope to the net boat. Subsequently, the crew on the chase boat would travel downstream to the live box connected to the KDTR, retrieve, secure, and pull the live box from the water into the boat (Figure 5). All fishes collected from the cod end or live box were placed in a holding container filled with river water for processing. Lastly, the crew would determine the condition of each tow as either “normal” (defined as no twists, snags, or tears in the net, little to no [<5%] debris in/on the net, and no [<5%] blockage between the mouth of the net to the live box), “fair” (defined as partial twists, snags, or small tears in the net, some [5–25% coverage] debris in/on the net, or partial [5–25%] blockage between the mouth of the net to the live box), or “poor” (defined as complete twists, snags, or large tears in the net, heavy [>25% coverage] debris in/on the net, or near complete [>25%] blockage between the mouth of the net to the live box).

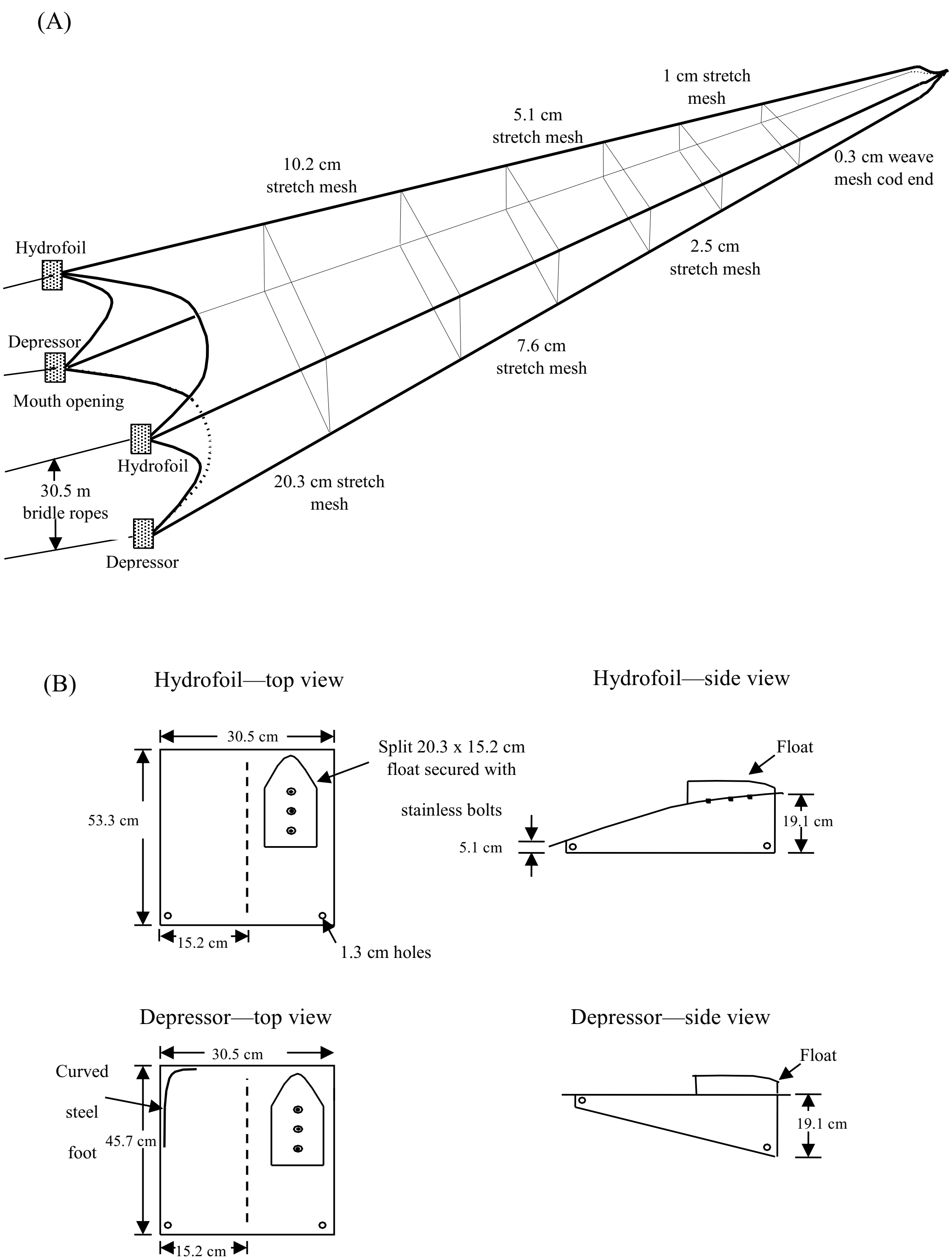


Figure 2. Schematic drawing of the (A) mid-water trawl net and (B) hydrofoils and depressors used at the Sacramento Trawl Site during the 2014 and 2015 field seasons.

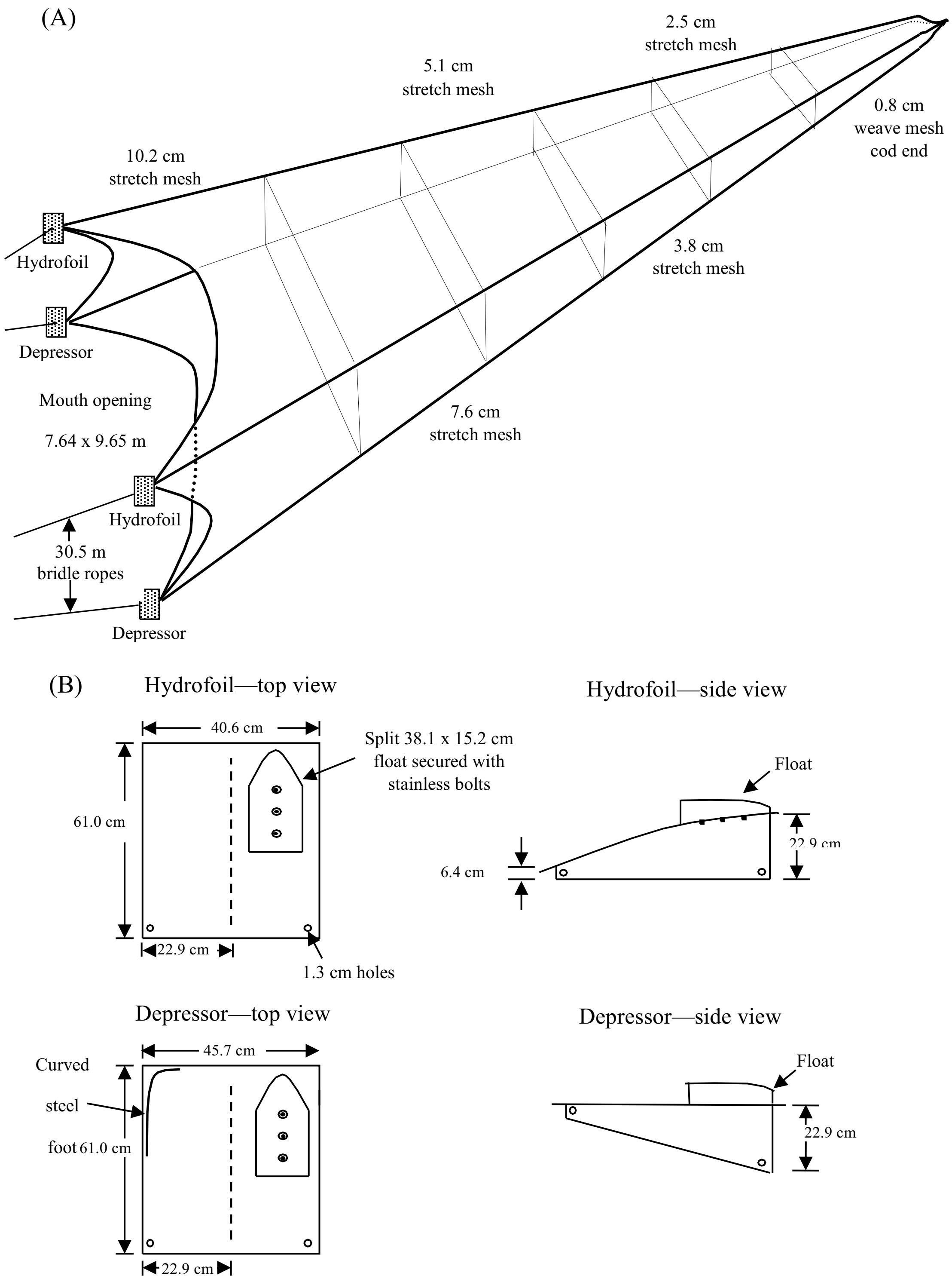


Figure 3. Schematic drawing of the (A) mid-water trawl net and (B) hydrofoils and depressors used at the Chipps Island Trawl Site during the 2014 and 2015 field seasons.

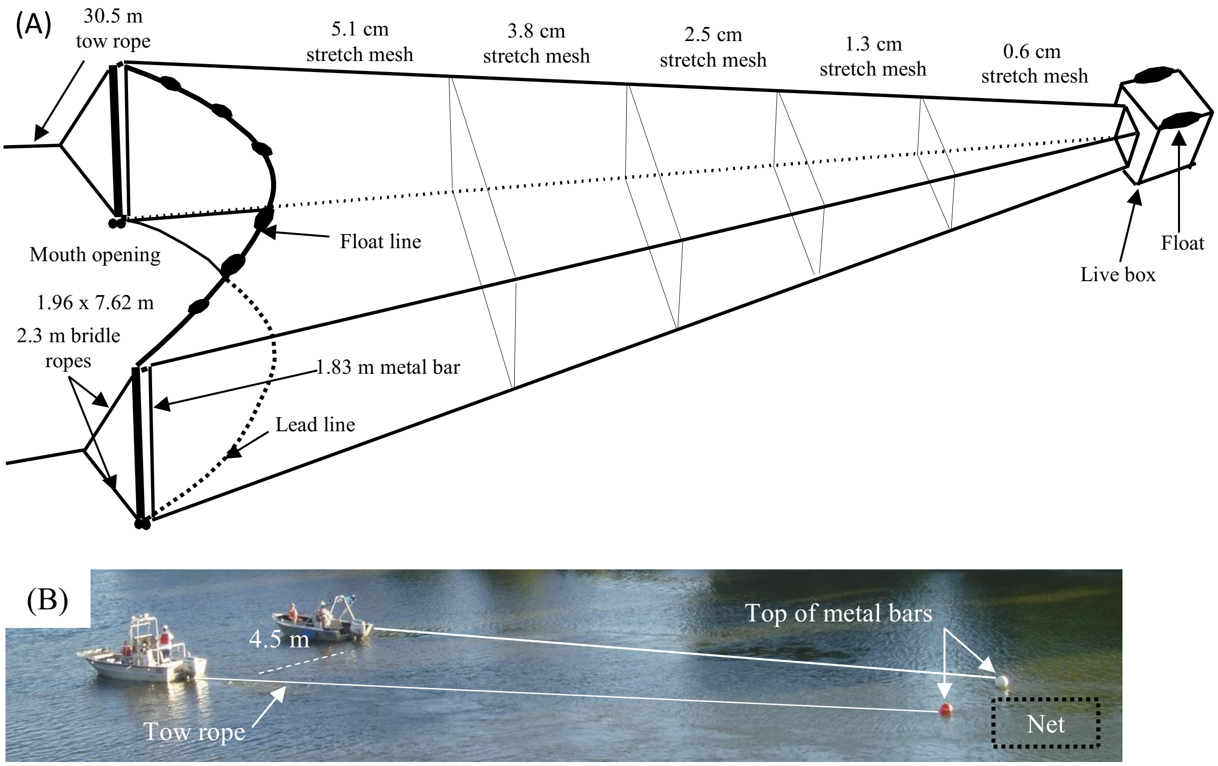


Figure 4. Schematic drawing of the (A) Kodiak trawl net used and (B) position of the boats during Kodiak trawling at the Sacramento and Mossdale trawl sites during the 2014 and 2015 field seasons.

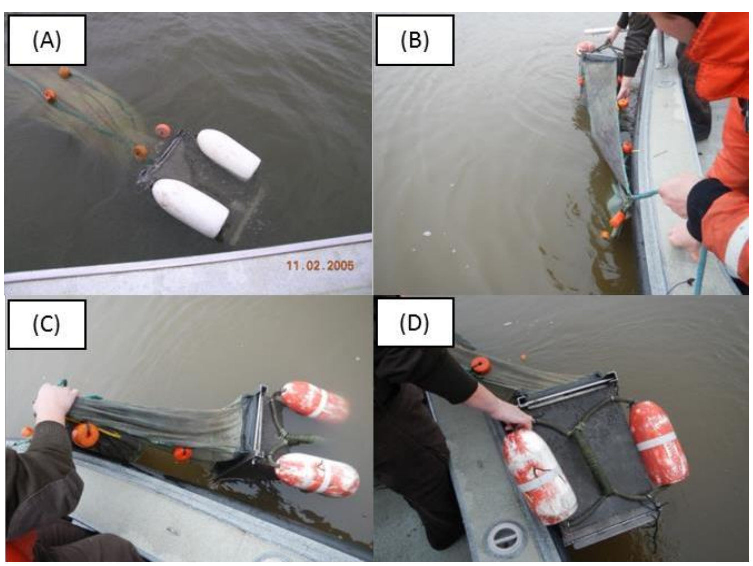


Figure 5. The Kodiak trawl (A) live box (B) being retrieved, (C) secured, and (D) pulled into the vessel.

Beach Seine Methodology

Sampling at beach seine sites was conducted approximately between 7am and 1pm. We sampled using a 15.2 by 1.3 m beach seine net with 3 mm delta square mesh, a 1.2 m bag in the center of the net, and a float line and lead line attached to 1.8 m tall wooden poles on each side. In general, beach seines were deployed along the shoreline by two crew members within unobstructed habitats including boat ramps, mud banks, and sandy beaches.
Rollers were added to the lead line of the beach seine to prevent the net from sinking into fine substrates, which would otherwise impede the completion of the seine haul. Based on comments within the beach seine database, this occurred at a total of 11 seine sampling events between August and September of the 2014 field season.

The beach seines were generally deployed by two crewmembers starting from the downstream portion of each site to limit disturbance (e.g., displacement of sediment into the site). Crew member 1 pulled the seine into the water, perpendicular from the shoreline, as crew member 2 secured the opposite end of the seine to the shoreline (Figure 6A). After reaching a depth of up to 1.2 m, a distance of up to 15 m, or an obstacle; crew member 1 stopped and measured the distance (i.e., length) to the shoreline and depth to the nearest 1 m and 0.1 m, respectively (Figure 7). Obstacles were defined as any structure that could compromise safety or gear efficiency; e.g., steep banks or holes, fast water current, submerged aquatic vegetation, or large woody debris. If the depths of the seine varied between measurements, the seine depth was obtained by averaging the two depth measurements. Next, crew member 2 carried their end of the seine to crew member 1 and placed it in the same location as crew member 1. The seine was then distributed from that point upstream and as parallel to the shoreline as possible by crew member 1 (Figure 6B). Lastly, crew members 1 and 2 pulled the ends of the seine simultaneously toward and perpendicular to the shoreline while attempting to maintain the starting width (Figure 6C). The net was continuously pulled towards the shoreline until the lead line of the seine bag was on shore (Figure 6D). After the seine haul was completed, all fish were collected from the bag and other parts of the seine and placed in a holding container filled with river water for processing. The crew would then determine the condition of the sample as either "normal" (defined as no twists, snags, or tears in the net, and the seine was pulled steadily while keeping the lead line in contact with the substrate and float line at or above the water's surface), "fair" (defined as partial twists, snags, or small tears in the net, but the seine was pulled steadily while keeping the lead line in contact with the substrate and float line at or above the water surface), or "poor" (defined as complete twists, snags, or large tears in the net, or the seine was not pulled steadily, or the lead line was not in contact with the substrate, or float line was below the water surface).

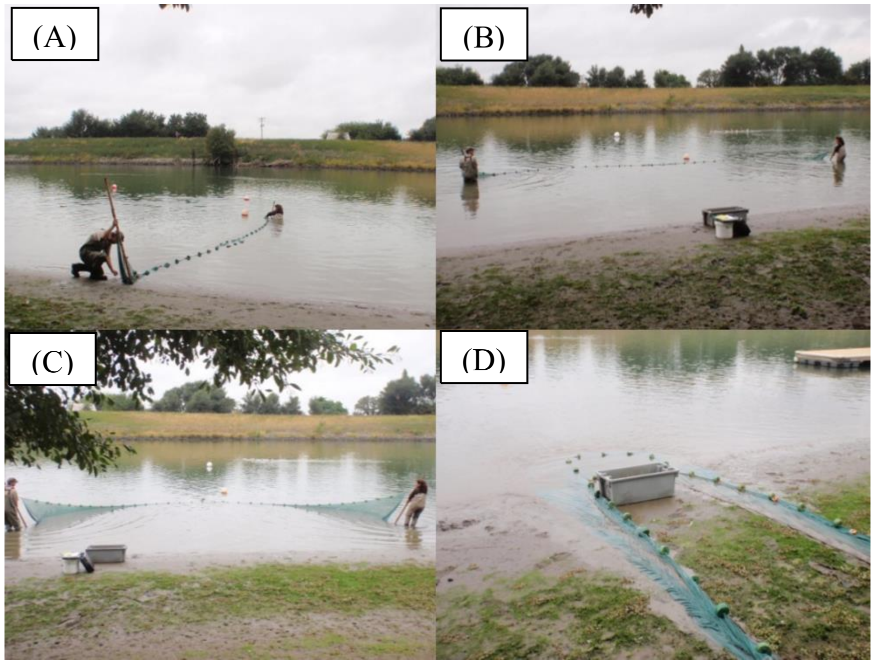


Figure 6. Photographs of the Delta Juvenile Fish Monitoring Program (DJFMP) conducting a beach seine at station SR024E on the bank of the Sacramento River: seine (A) deployed downstream of site, (B) distributed upstream parallel to the shoreline (C) pulled in toward the shoreline, and (D) position at the end of a haul.

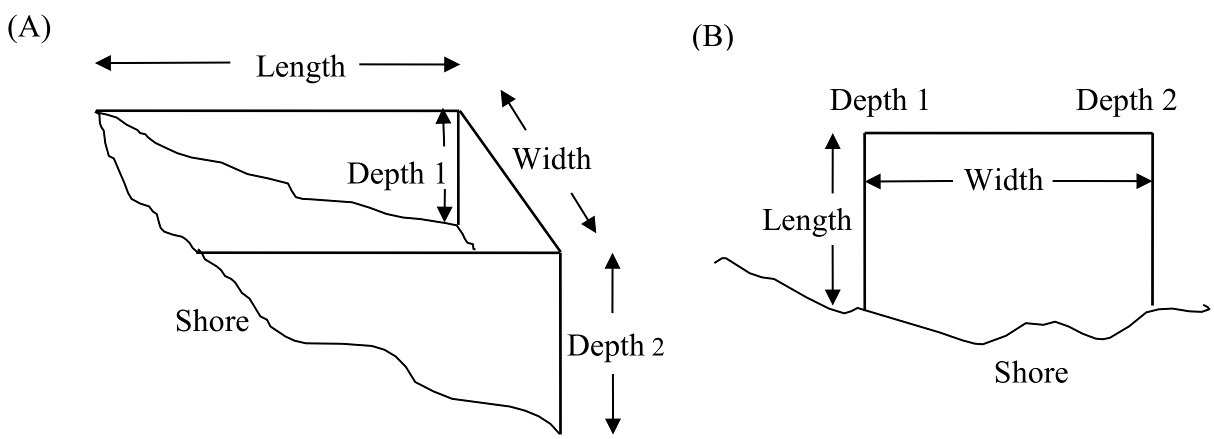


Figure 7. Schematic diagram of beach seine measurements: (A) three-dimensional view and (B) overhead view.

Fish Processing

We identified all fish in each sample that were ≥ 25 mm fork length (FL) to species or race, with the exception of five species that were readily identified at ≥ 20 mm FL: Sacramento Splittail *Pogonichthys macrolepidotus*, Three-spine Stickleback *Gasterosteus aculeatus*, Western Mosquito Fish *Gambusia affinis*, Rainwater Killifish *Lucania parva*, and Sacramento Sucker *Catostomus occidentalis*. Prior to release at the site of capture, we measured fish to the nearest 1 mm FL. If greater than 50 individuals of a Chinook race, as designated by the river length-at-capture-date criteria (LDC, see paragraph below), or other species listed under the Endangered Species Act (ESA) were captured, a subsample of 50 individuals was randomly measured for FL and the rest were counted and not measured (referred to as a "plus count"). If greater than 30 individuals of a non-listed species were captured, a subsample of 30 individuals was randomly measured for FL and the rest were counted and not measured. Fish that could not be accurately identified in the field were preserved and brought back to the laboratory. The identification of preserved fishes was then confirmed with the use of dichotomous keys or with the aid of a microscope.

Only juvenile Chinook with missing (clipped) adipose fins were considered marked fish. In general, fish possessing other forms of marks or tags (e.g., stain dye, disc tags, acoustic tags) were not included within this report to further minimize the influence of recaptures and/or unnatural occupancy induced by other fishery investigations. Stain dye marked juvenile Chinook released near the Mossdale Trawl Site were only used to estimate trawl efficiency (see "Absolute Abundance Calculation" section). All clipped juvenile Chinook observed during the 2014 and 2015 field seasons were considered hatchery-reared and were brought back to the lab to process the coded wire tag (CWT).

Recovered CWTs can provide important biological information to natural resource managers (e.g., an individual's race, hatchery of origin, and the date and location released). Therefore, all clipped Chinook were euthanized in the field and brought back to the laboratory. We then removed, read, and recorded the tag code of all CWTs recovered. We obtained corresponding tag information (e.g., race and release location) from the Regional Mark Information System (RMIS) maintained by the Pacific States Marine Fisheries Commission (PSMFC 2017). Details regarding CWT recoveries during the 2014 and 2015 field seasons can be found in "Appendix A" section.

The race of all unmarked juvenile Chinook was determined using the river LDC developed by Fisher (1992) and modified by Greene (1992). The assumptions associated with the river LDC for the Sacramento-San Joaquin River basin include that (1) spawning of fall-run Chinook occurs between October 1–December 31, (2) spawning of late fall-run Chinook occurs between January 1–April 15, (3) spawning of winter-run Chinook occurs between April 16–August 15, (4) spawning of spring-run Chinook occurs between August 16–September 30, and (5) growth rate of juveniles is identical among all races of Chinook (Fisher 1992). Although one or more of these assumptions are likely violated (Fisher 1994; Yoshiyama et al. 1998), the river LDC is currently widely used by managers, and is the only cost effective and logistically feasible way to differentiate between the different races of juvenile Chinook in the field. Fisher (1994) noted that Chinook races within the Central Valley do appear to spawn at distinctly separate time periods except for fall- and spring-run due to the loss of headwater habitats (e.g., resulting from dams), forced coexistence, and subsequent hybridization within the Sacramento River basin (Cope and Slater 1957; Slater 1963). As a result, many of the Chinook characterized as spring-run by the river LDC may actually be fall-run. Additionally, some genetic analyses of DNA genotypes have demonstrated the inaccuracy of the river LDC that has been used to determine Chinook races within the San Francisco Estuary, especially between fall- and spring-run salmon (e.g., Banks et al. 2000; Greig et al. 2003; Banks et al. 2014). Although the LDC does an adequate job of identifying winter run, many of the fish falling within the winter run size using the LDC, are actually from another run (Pyper et al, 2013). We used the river LDC to differentiate between unmarked winter-run sized and a combined group of fall-, late fall-, and spring-run sized juvenile Chinook. The race designations used in this report should be considered a rough approximation and not interpreted as definitive. See the following section called "Estimate of Hatchery and Natural Origin Juvenile Chinook Salmon" for information on how unmarked hatchery versus natural origin Chinook are determined.

All juvenile Chinook collected at the Mossdale Trawl Site and within the Lower San Joaquin River Seine Region were classified as fall-run regardless of their length at the date of capture, and thus included in the fall-, late fall-, and spring-run group, because fall-run Chinook are reportedly the only race to still occur within the San Joaquin River and its main tributaries (Yoshiyama et al. 1998). Although the South and Central Delta seine regions are located within the San Joaquin River basin, there is potential for late fall-, winter-, and spring-run juveniles of Sacramento River origin to migrate into the interior delta through Georgiana Slough, the Delta Cross Channel (DCC), Three-Mile Slough and in the lower San Joaquin River. Therefore, the river LDC was still used to determine the race of juvenile Chinook within the South and Central Delta seine regions.

Water Quality

We measured water temperature, dissolved oxygen, turbidity, and conductivity immediately before each trawl and during or after each seine haul during the 2014 and 2015 field seasons. We have consistently measured water temperature at all monitoring sites during or immediately before each sampling occasion since the late 1970s. Additionally, we have consistently measured dissolved oxygen, turbidity, and conductivity at all monitoring locations since January of 2012.

We used a YSI 85 or YSI PRO 2030 meter to measure water temperature to the nearest 0.1˚C, dissolved oxygen to the nearest 0.01 mg/L, and conductivity to the nearest 0.01 microsiemen/centimeter (µS/cm) for freshwater or millisiemen/centimeter (mS/cm) for salt water. Turbidity was measured using a HACH 2100Q turbidity meter to the nearest 0.01 nephelometric turbidity unit (NTU). All measurements or samples were collected 20–30 cm below the surface of the water.

We presented the raw temperature, dissolved oxygen, turbidity, and conductivity estimates by month for each trawl site and beach seine region during the 2014 and 2015 field seasons as box plots (median and percentiles) to demonstrate the spatial and temporal variability of the water quality conditions representative of our monitoring sites during sampling.

Fish Assemblage

We classified fish species into seven distinct assemblage groups based on shared origin, habitat requirements, and life history strategies (Moyle 2002): (1) anadromous-benthic-native, (2) anadromous-pelagic-native, (3) anadromous-pelagic-nonnative, (4) benthic-native, (5) benthic-nonnative, (6) pelagic-native, and (7) pelagic-nonnative (Table A.2). All juvenile unmarked Chinook captured were considered members of the anadromous-pelagic-native group. No marked Chinook or marked steelhead were included in any of the assemblage groups, though unmarked hatchery Chinook and unmarked Steelhead were included (see next subsection, Estimate of Hatchery and Natural Origin Juvenile Chinook Salmon).

Estimate of Hatchery and Natural Origin Juvenile Chinook Salmon

In general, hatcheries have used CWTs, indicated by clipped adipose fins, to mark all hatchery produced late fall-, winter-, and spring-run juvenile Chinook in the Central Valley (Kevin Niemela, USFWS, personal communication; Williams 2006). However, a small proportion of late fall-, winter-, and spring-run Chinook fin clips are missed during tagging at the hatchery, and recorded in RMIS as unmarked (Kevin Niemela, USFWS, personal communication; PSMFC 2017). Conversely, the marking and CWT tagging rates of hatchery reared juvenile fall-run Chinook have varied considerably (5–95%; Johnson 2004). Starting in 2007, Central Valley hatcheries began implementing the constant fractional marking of hatchery produced juvenile fall-run Chinook, where at least 25% of individuals within each hatchery release group are marked and have a CWT inserted (Nandor et al. 2010). Because unmarked hatchery reared juvenile Chinook are still being released into the Central Valley, there is considerable uncertainty concerning the origin (i.e., naturally or hatchery produced) of unmarked juvenile Chinook observed during DJFMP monitoring. This uncertainty impacts the program's ability to inform research or management decisions concerning natural origin juvenile Chinook (Williams 2006; Dekar et al. 2013).

Therefore, we developed an equation to estimate the origin of juvenile Chinook observed during the 2000 to 2015 field seasons. We applied the equation to all races of juvenile Chinook to account for any possible unmarked proportion of a hatchery release group, either caused by intentional unmarking (fall-run), or fin clip failure during tagging (late fall-, winter-, and spring-run).We estimated the number of unmarked hatchery origin juvenile Chinook (H_s) for each sample (e.g., trawl tow or seine haul) and race group as:

$$H_s = \sum (C_g \; x \; P_g) \qquad (1)$$

where s indexes an individual sample (i.e., a beach seine haul or trawl tow), g indexes a CWT release group, C_g represents the total number of marked individuals collected from the CWT release group, and P_g represents the proportion of unmarked to marked individuals within the CWT release group. P_g was obtained from state and federal hatchery records (PSMFC 2017). The primary assumption of this approach was that marked and unmarked individuals within a CWT release group have identical capture probabilities and availability during sampling.

We included juvenile Chinook that were reported as fall- and spring-run hybrids in hatchery records in the combined fall-, late fall-, and spring-run group. We also included all other hybrid-run juvenile Chinook without race descriptions in this group based on unlikely hybridization between winter-run Chinook and other races (Slater 1963). Additionally, we omitted any CWT release groups that were associated with "wild type" origin juvenile Chinook based on these groups being experimental and rare.

We then summed the total number of unmarked hatchery origin juvenile Chinook observed within a sample day for each race group and monitoring site (H_d). Subsequently, we estimated the number of natural origin juvenile Chinook for each race group and monitoring site within a sample day (W_d) as:

$$W_d = O_d - H_d \qquad (2)$$

where O_d denotes the total number of unmarked juvenile salmon observed during a sample day for a race group and monitoring site. If the estimated number of unmarked hatchery origin individuals exceeded the total number of unmarked juvenile Chinook observed for a race group during a sample day at a monitoring location (occurred in < 1% of samples), we designated all unmarked individuals observed as unmarked hatchery individuals. All clipped juvenile Chinook included in the analysis were considered to be of hatchery origin.

Prior to 2000, large groups of unmarked fall-run juvenile Chinook were regularly released by the state and federal hatcheries throughout the Delta that were not associated with any marked group (Kevin Niemela, USFWS, personal communication; PSMFC 2017). Consequently, our approach to estimate the number of natural and hatchery origin juvenile Chinook at our monitoring locations could not be applied to our catch data for the fall-, late fall-, and spring-run group prior to 2000. As a result, all unmarked fall-, late fall-, and spring-run fish observed prior to the 2000 field season were considered to have an unknown origin. After 2000, groups containing only unmarked individuals were released at Battle Creek, Sacramento River, Feather River, and downstream of Chipps Island. We assumed that unmarked releases downstream of Chipps Island would not bias our estimation of fish origin because most juvenile Chinook were likely actively migrating downstream and observations of CWT individuals released at these locations are minimal.

To minimize the impact of unmarked hatchery releases at other locations, we estimated periods of time when individuals from these unmarked hatchery release groups likely occurred within the Delta. We considered all unmarked individuals observed while monitoring during these periods of time to have unknown origin. We estimated periods of occupancy within the Delta using the observed travel times of individual CWT fish released from each of the locations where groups containing only unmarked hatchery fish have been released (i.e., Battle Creek, Feather River, Sacramento River at Verona, and Sacramento River at Red Bluff Diversion Dam) to the entry (Sacramento Trawl Site) and exit (Chipps Island Trawl Site) locations of the Delta (Table 1). To incorporate uncertainty, we defined the periods of occupancy using the time (i.e., days) between when the first and last 2.5% of marked fish were detected at either Sacramento or Chipps Island relative to the release date of unmarked hatchery groups (Table 1). CWT fish released in the Sacramento River at Verona and the Red Bluff Diversion Dam took longer to reach the Chipps Island and Sacramento trawl sites than CWT fish released at Battle Creek or Feather River. The longer travel times may have been the result of fewer observations of CWT fish originating from the Sacramento River at Verona and the Red Bluff Diversion Dam release sites, resulting in higher uncertainty in the estimated days of occupancy within the Delta. Alternatively, the releases at Verona and the Red Bluff Diversion Dam may have contained higher proportions of fry (Pat Brandes, USFWS, personal communication), which move less quickly through the Delta than smolts (Kjelson et al. 1982) and may have caused the longer travel times.

Table 1. The estimated period (days) of occupancy of CWT fish between when CWT fish were released at locations where unmarked releases occurred and captured at the Chipps Island and Sacramento trawl sites during the 2000–2015 field seasons. See Tables A.20 and A.21 for further detail on race designations.

Release location	Capture location (trawl site)	N (# of CWT fish observed)	Days between capture of first 2.5% of fish and release date	Days between capture of last 2.5% of fish and release date	Estimated days of occupancy within Delta
Battle Creek	Chipps Island	5936	7	30	25
	Sacramento	2832	5	21	
Feather River	Chipps Island	1296	4	33	33
	Sacramento	190	2	35	
Sacramento River at Verona	Chipps Island	67	24	76	74
	Sacramento	107	2	28	
Sacramento River at Red Bluff Diversion Dam	Chipps Island	121	28	75	71
	Sacramento	30	4	66	

Relative Abundance Calculations

We standardized the samples collected within a day for each assemblage and for the origin groups of winter-run sized and the fall-, late fall-, and spring-run sized group of juvenile Chinook to catch-per-unit effort (CPUE) as fish per unit volume sampled (fish/10,000 m^3) using the following equations:

$$Seine\ CPUE_d = \frac{\sum(Catch_s)}{\sum(0.5 \cdot Depth_s \cdot Width_s \cdot Length_s)} \cdot 10{,}000 \quad (3)$$

$$Trawl\ CPUE_d = \frac{\sum(Catch_s)}{\sum(Distance\ traveled_s \cdot Net\ mouth\ area)} \cdot 10{,}000 \quad (4)$$

where s indexes individual samples (i.e., a beach seine haul or trawl tow), and d indexes sample days. Effort was measured by the volume of water sampled by a beach seine, KDTR, or MWTR. By assuming a constant slope from the shore to the maximum seine depth, the volume of the water sampled using beach seines was calculated by using 0.5 multiplied by the depth. Because the MWTR and KDTR nets do not open completely while under tow and net mouth dimensions vary within and among tows (USFWS 1993), we used previously quantified estimates of mean net mouth area for this report. The mean net mouth area for MWTR nets used for the Chipps Island and Sacramento trawl sites were obtained from 3–4 physical measurements taken while sampling and were reported as 18.58 m^2 and 5.08 m^2, respectively (USFWS 1993). The mean net mouth area for KDTR nets used for the Mossdale and Sacramento trawl sites were obtained by extrapolating from the mean net mouth area of the MWTRs and were reported as 12.54 m^2 (USFWS 1998).

We examined the spatial and temporal trends of the relative abundance by averaging and comparing CPUE estimates at monthly and yearly scales. The primary assumption associated with these CPUE comparisons is that gear efficiency (i.e., detection probabilities) is constant over time at each trawl or seine site, and comparable among trawl sites and seine regions. We treated Chinook races and origin groups or assemblage groups, seine regions, trawl sites, and gear types separately for all mean CPUE calculations. Because the number of samples collected varied within and among weeks for sites within seine regions and trawl sites, data were summarized using weekly, monthly, and yearly CPUE averages to minimize the overweighting of sample days and/or locations. To limit the bias of diel effects or variable gear efficiency on CPUE value comparisons, we only averaged samples collected between 07:00 am and 04:00 pm, and excluded those of poor condition (i.e., compromised gear deployment) within our calculations.

The mean weekly CPUE was calculated for each trawl site and seine region as the sum of the daily CPUE for a trawl or seine site during each sample week divided by the number of days sampled each sample week. Subsequently, the mean weekly CPUE values were averaged among seine sites within regions. A sample week was defined as Sunday to Saturday. However, sample weeks including the first or last day of the field season only included days falling within the field season. The mean monthly CPUE was calculated as the sum of the mean weekly CPUE for a trawl site or seine region during each calendar month divided by the number of sample weeks sampled each calendar month. If a sample week occurred in more than one calendar month, the sample week was assigned to the calendar month that contained the start of the sample week. We switch between gear types (KDTR and MWTR) at Sacramento Trawl Site during October and April each field season. The last sample week of March of the 2014 field season included the first two sampling days with the midwater trawl in April. Therefore, we presented the monthly CPUE averages for both KDTR and MWTR samples during March of the 2014 field season. The last sample week of September and March of the 2015 field season included the first two sampling days of October and April, respectively. Therefore, we presented the monthly CPUE averages for both KDTR and MWTR samples during September and March of the 2015 field season. This also resulted in the KDTR CPUE for September and the MWTR CPUE for March of the 2015 field season at the Sacramento Trawl Site each being generated from only 2 sample days, occurring within one week. Similarly, the MWTR CPUE for March of the 2014 field season also had only two sample days, occurring within one week. The mean yearly CPUE was calculated as the sum of the mean monthly CPUE for a trawl site or seine region during each field season divided by the number of months sampled each field season.

We calculated and graphed the mean monthly CPUE of Chinook and assemblage groups to make intra-annual comparisons during the 2014 and 2015 field seasons. For inter-annual comparisons of CPUE for juvenile Chinook and assemblage groups, we calculated and graphed mean yearly CPUE values starting in the 2000 field season for most trawl sites and seine regions. Confidence limits were omitted from the CPUE figures since uncertainty could not be accurately quantified after the computational series of averages. Thus, values presented are estimates and may incorporate a high degree of uncertainty.

In general, sampling methods have remained consistent from before the 2000 field season to the present, including year-round sampling and standardized methods and gears. However, we calculated mean yearly CPUE values for the Mossdale Trawl Site only during the 2004 through 2015 field seasons for juvenile Chinook and assemblage groups because the start of year-round sampling did not occur until January 2003. Prior to the 2004 field season, the only months consistently sampled at the Mossdale Trawl Site were April through June. We have not reported April through June data prior to 2004 because these data have been already reported annually by the CDFW. We also calculated mean yearly CPUE values during the 1995 through 2013 field seasons year-round for both race groups of juvenile Chinook at the Chipps Island Trawl Site, based on the site's historical context for monitoring juvenile salmonids. Prior to the 1995 field season, the Chipps Island Trawl Site was only consistently sampled from April through June to target juvenile fall-run Chinook smolts. We calculated mean yearly CPUE values using April through June at the Chipps Island Trawl Site during the 1978 through 2015 field seasons for juvenile fall-, late fall-, and spring-run Chinook to extend our historical coverage. Though the relative abundances for the fall-, late fall-, and spring-run race groups are not presented individually, the total catch of each race of juvenile Chinook caught in the 2014 and 2015 field seasons can be found in Tables A.3 and A.4.

Absolute Abundance Calculation

The absolute abundances of juvenile Chinook of each length at date group of winter-run sized salmon and the combined fall-, late fall-, and spring-run sized salmon group immigrating into and emigrating out of the Delta were estimated on a monthly scale from the 1978 to 2015 field seasons using the data collected at the Sacramento, Mossdale, and Chipps Island trawl sites. Annual comparisons of the absolute abundance of juvenile Chinook were limited to years and months when sampling was relatively consistent. The monthly absolute abundance (N) of (1) marked, (2) natural origin, (3) hatchery origin, and (4) unknown origin juvenile Chinook for both juvenile winter-run sized, and fall-, late fall-, and spring-run sized group were estimated using the methods modified from USFWS (1987) as:

$$N_i = \frac{n_i}{t_i \cdot \overline{TRR}} \tag{5}$$

where i indexes months, n_i represents the total number of juveniles collected at the trawl site during a month, t_i represents the fraction of time the trawl site was sampled during a month, and $\overline{TRR}$ represents the mean trawl recovery rate at the trawl site. The assumption of this approach is that juvenile salmon are equally distributed in time as they migrate past the trawl sites and are never recaptured. It also assumes that the efficiency of the trawls is constant in space (i.e., throughout all sampling conditions) and time (i.e., within and among months).

The trawl recovery rate $\overline{TRR}$ for the Chipps Island trawl was estimated using the capture of CWT juvenile Chinook released approximately 10 and 12 km upstream of the Chipps Island Trawl Site at Sherman Island or Jersey Point. We estimated the TRR for the Sacramento trawl using the capture of CWT juvenile Chinook released approximately 4 and 8 km upstream of the Sacramento Trawl Site at Miller Park and the Broderick Boat Ramp, respectively. The $\overline{TRR}$ was calculated separately for the MWTR and KDTR nets used at the Sacramento Trawl Site to reflect possible differences in net efficiency. Lastly, we estimated the TRR for the Mossdale trawl using the capture of CWT and dye marked juvenile Chinook released approximately 3 km upstream of the Mossdale Trawl Site at Mossdale Crossing. The TRR for each trawl site was calculated as:

$$TRR_k = \frac{n_{recovered}}{n_{available}} \tag{6}$$

where k indexes release groups at a release site, $n_{recovered}$ represents the total number of CWT juvenile Chinook within a release group collected at the trawl site, and $n_{available}$ represents the number of CWT juvenile Chinook within a release group available for collection at the trawl site. Recognizing that the TRR can vary among release groups based on differences in sampling effort, $n_{available}$ was estimated for each release group as:

$$n_{available} = n_{released} \cdot t \tag{7}$$

where $n_{released}$ represents the total number of CWT juvenile Chinook within a release group and t represents the fraction of time the trawl site was sampled from the first recovery to the last recovery of CWT juvenile Chinook in the release group. The assumption of this approach is that juvenile Chinook within a release group are equally distributed in time and have 100% survival.

A release group was defined as a group of similarly tagged or marked (CWT or spray dyed) juvenile Chinook that had the same hatchery origin and were released at the same location and time. A total of 131 CWT releases have occurred at Sherman Island or Jersey Point between the 1989 and 2015 field seasons. Forty-seven CWT releases have occurred at Miller Park and Broderick Boat Ramp between the 1988 and 2009 field seasons. We calculated the $\overline{TRR}$ for the Chipps Island Trawl Site and the Sacramento Trawl Site using the recoveries from all the groups released at Sherman Island and Jersey Point, and at Miller Park and Broderick Boat Ramp, respectively, to maximize sample size and obtain a more robust estimate. The average fork lengths for the release groups near Chipps Island and Sacramento trawl sites ranged from 70–179 mm and 56–138 mm, respectively, which corresponds to the majority of unmarked juvenile Chinook historically collected at these locations. All CWT release group data were obtained through the Regional Mark Information System (PSMFC 2017). To maximize sample size, we estimated the $\overline{TRR}$ for the Mossdale Trawl Site using the recoveries of all CWT and spray dye release groups. Although the stain dye releases often reused marks (i.e., dye colors) within seasons, these releases were spaced at least 7 days apart and we determined that approximately 98% of CWT individuals released at Mossdale Crossing were detected at the Mossdale Trawl Site within 7 days from being released. A total of five CWT releases have occurred at Mossdale Crossing since the 2003 field season. There were two releases that were listed as Jersey Point, however RMIS notes that a proportion of the fish were released at Mossdale due to truck malfunction (PSMFC 2017). These fish were not included in the efficiency estimate because of the uncertainty associated with their release information. In addition, the CDFW has released 48 stain dye marked groups of hatchery reared juvenile Chinook at Mossdale Crossing to estimate trawl efficiency at the Mossdale Trawl Site since the 1997 field season (SJRGA 2009; Steve Tsao, CDFW, personal communication).

The $\overline{TRR}$ was calculated for each trawl site as an average of TRRs weighted by the number of individuals within each release group. To incorporate uncertainty in the estimated $\overline{TRR}$, the monthly absolute abundance estimates were calculated using the $\overline{TRR}$ and its 95% confidence interval (CI). The intervals should be considered minimum confidence limits because they only incorporate the uncertainty associated with the $\overline{TRR}$ estimates. We calculated absolute abundance estimates at the Chipps Island Trawl Site from April through June during the 1978 through 2015 field seasons for the fall-, late fall-, and spring-run sized juvenile Chinook group. We also calculated annual absolute abundance estimates during the 1995–2015, 2000–2015, and 2004–2015 field seasons at the Chipps Island, Sacramento, and Mossdale trawl sites, respectively, for both winter-run sized and the fall-, late fall-, and spring-run sized groups of Chinook.

Length Frequency

We plotted length frequency distributions to assess temporal size shifts for all unmarked juvenile Chinook Salmon during the 2014 and 2015 field seasons for each seine region and trawl site. In cases where Chinook were “plus counted” (i.e., only counted and not measured within a sample) the FLs of the unmeasured fish were obtained by extrapolating from the fish that were measured within the sample. For example, if 100 individuals were plus counted within a sample and 20% of the measured individuals had a FL of 45 mm, we assumed that 20 of the 100 plus counted individuals also possessed a FL of 45 mm. Because we categorized the race of unmarked juvenile Chinook using the river LDC, we reported the length frequency distribution of all unmarked juvenile Chinook together for each seine region and trawl site without any race distinction to avoid bias.

River Flow Conditions

River flow data were obtained from the USGS and CDWR (USGS 2014; CDWR 2014). We obtained mean daily discharge data at the Colusa (River Mile [RM] 144) and Freeport (RM 48) gauging stations on the lower Sacramento River, and at the Vernalis (RM 114) gauging station on the lower San Joaquin River to represent the primary flow inputs into the Estuary. Further, estimates of the daily Delta outflow past Chipps Island towards the San Francisco Bay, which takes into account water exports, were obtained from Dayflow (CDWR 2014). We also obtained water year type classifications for the Sacramento and San Joaquin River basins from the California Data Exchange Center (CDWR 2014b).

We presented the mean monthly CPUE of Chinook races and fish assemblage groups along with mean monthly discharge during the 2014 and 2015 field seasons. Similarly, we compared the yearly CPUE of Chinook races and fish assemblage groups along with mean yearly discharge at each trawl site and seine region. The CPUE of fishes within the Lower Sacramento River Seine Region, North Delta Seine Region, and the Sacramento Trawl Site were compared to discharge data measured at Freeport. The CPUE data from the Lower San Joaquin River Seine Region, South Delta Seine Region, Central Delta Seine Region, and the Mossdale Trawl Site were compared to discharge data measured at Vernalis. Finally, the CPUE of fishes within the Chipps Island Trawl Site and San Francisco and San Pablo Bay Seine Region were related to estimated Delta outflow. These comparisons were selected to broadly represent what fish experience, in terms of average daily flow, at the sampling locations.

Results and Discussion

During the 2014 and 2015 field seasons, 9,038 trawl samples were collected without any malfunctions in gear that would preclude effective sampling by the net. We completed 2,801 trawls at the Chipps Island Trawl Site, 3,239 trawls at the Mossdale Trawl Site, and 2,998 trawls at the Sacramento Trawl Site. The trawl tows were evenly distributed throughout the 2014 and 2015 field seasons (Tables A.5 and A.6). As a result, we considered the inter- and intra-annual trawl catch comparisons robust due to minimal spatial and temporal bias.

During the 2014 and 2015 field seasons, 3,977 seine samples were collected without any gear malfunctions that would undermine catch performance by the net. There was considerable spatial and temporal variability in the number of samples collected at sites within nearly all seine regions during the 2014 and 2015 field seasons (Tables A.7–A.18), similar to the 2010 to 2013 field seasons (Speegle et al. 2013, Barnard et al. 2015). For example, on average approximately 60% and 40% of the historically sampled sites within the South Delta Seine Region were effectively sampled during sample weeks within the 2014 and 2015 field seasons, respectively (Tables A.13 and A.14). The number of samples collected within the South Delta Seine Region during the 2014 (n=293) and 2015 (n=205) field seasons were considerably lower than the previous decade's annual average (mean= 329, SE=15.7). In addition, on average approximately 70% and 58% of the historically sampled sites within the Lower San Joaquin Seine Region were effectively sampled during sample weeks within the 2014 and 2015 field seasons, respectively (Tables A.15 and A.16). As a result, catch data associated with these seine regions may contain both inter- and intra-annual bias.

Throughout the 2014 and 2015 field seasons, the inability to effectively sample seine sites resulted from the expansion of submerged, emergent, and floating aquatic vegetation, and low river discharge (Table A.19). The DJFMP is currently investigating the feasibility of implementing a stratified random sampling design for boat electrofishing to supplement beach seining within the San Francisco Estuary. New sampling methods are needed to establish non-biased representative catch data within all near-shore littoral habitats within the lower rivers and Delta, not just those at beaches and boat ramps.

Within this report, seine catch data were primarily used to evaluate the general temporal and spatial distribution patterns (i.e., occupancy) of fish within the San Francisco Estuary. Although the spatial and temporal variability of the samples collected within seine regions can affect occupancy patterns (e.g., discerning between false absence and true absence within sites and regions; differential detection probability between sites), the DJFMP seine catch data documents the presence of fishes at a given time and location (Tables A.5–A.18). However, detection probability and the probability of reporting false absences (present but not captured) remain unknown.

Water Quality

We collected 52,274 water quality samples during the 2014 and 2015 field seasons: 13,121 water temperature, 13,073 conductivity, 13,015 dissolved oxygen, and 13,065 turbidity samples. The intra-annual variability in water temperature was consistent among the beach seine regions and trawl sites during the 2014 and 2015 field seasons (Figures 8 and 9). Temperature ranged from 3.6 to 29.6°C among our seine regions and trawl sites during the 2014 field season and 5.7 to 28.8°C during the 2015 field season. Water temperatures, on average, were highest within the lower San Joaquin River, South Delta and Central Delta regions relative to other regions during the summer of both field seasons. Further, the summer temperatures were, on average, higher during the 2015 field season relative to the 2014 field season within all regions. Temperatures often exceeded 25°C during the summer (June through August) of the 2014 and 2015 field seasons; critically dry years within both the Sacramento River and San Joaquin River Basins (Table A.19).

We observed dissolved oxygen values ranging from 2.1 to 20.7 mg/L among our seine regions and trawl sites during the 2014 field season and 2.2 to 18.46 mg/L among our seine regions and trawl sites during the 2015 field season (Figures 10 and 11). In general, dissolved oxygen was slightly higher during the winter season and lower during the summer season for all seine regions and trawl sites during both field seasons. Spring of the 2014 field season had a very wide range of dissolved oxygen levels, especially in the Lower San Joaquin River and South Delta seine regions (Figure 10). The most variation in the 2015 sampling season was in the spring in the San Joaquin River seine region as well. During the 2014 field season, we observed the dissolved oxygen increase to above 12 mg/L on average in the San Joaquin seine region in August. All regions had individual readings above 12 mg/L and below 4 mg/L at various times throughout the year, though not consistently enough to be reflected in the monthly averages. Both extremes tended to occur February through June. This is likely due to agricultural nutrient inputs supporting increased primary production followed by increased bacterial respiration supported by excess nutrients or increased detritus from aquatic plants and algae (Dunne and Leopold 1978).

Turbidity samples ranged from 0.1 to 520 NTU and 0.8 to 823 NTU during the 2014 and 2015 field seasons, respectively (Figures 12 and 13). In general, the turbidity was lower within the Central Delta and South Delta seine regions relative to other regions throughout most of 2014 and lower in the South Delta and San Joaquin seine regions throughout most of 2015. In addition, the turbidity varied considerably within the San Pablo Bay Seine Region possibly due to wind and wave erosion during the spring and summer seasons. We also observed increased turbidity in December and February during the 2015 field season in all seine regions and trawl sites, possibly resulting from increased precipitation and discharge.

Conductivity varied considerably among trawl sites and seine regions during the 2014 and 2015 field seasons (Figures 14 and 15). We observed that conductivity was highest across all months within the San Francisco and San Pablo Bay Seine Region as well as the Chipps Trawl site. This was expected because the San Francisco and San Pablo Bay Seine Region is the closest in proximity to the Pacific Ocean and is the seine region most similar to a marine environment. Conversely, the conductivity within the Lower Sacramento River and North Delta seine regions, and at the Sacramento and Mossdale trawl sites, were lower and more consistent relative to other monitoring locations, which may be due to these sites being less exposed to tidal exchange. The conductance within the Central Delta and South Delta seine regions, and at the Chipps Island Trawl Site, were the most variable within and among months, possibly due to agricultural inputs, water operations, and tidal exchange. Few distinct inter-annual patterns were observed.

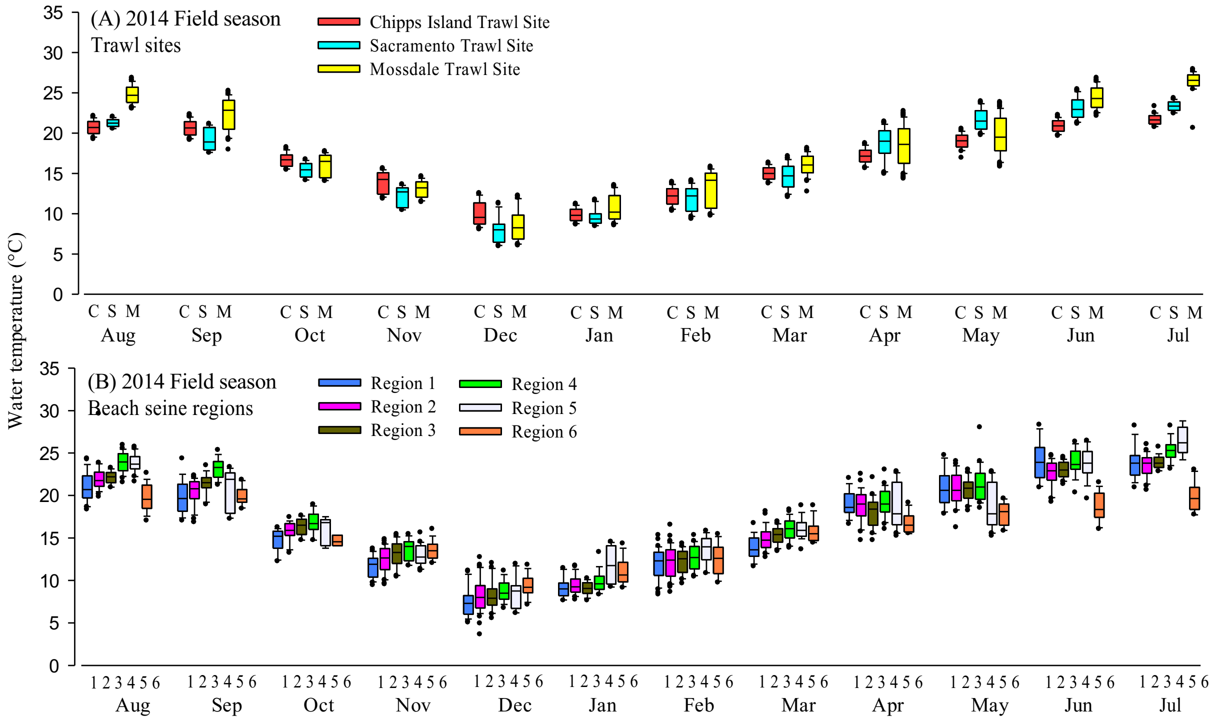


Figure 8. Water temperature data collected by month during sampling at the (A) Chipps Island (C), Sacramento (S), and Mossdale (M) trawl sites and within the (B) Lower Sacramento River (Region 1), North Delta (Region 2), Central Delta (Region 3), South Delta (Region 4), Lower San Joaquin River (Region 5), and San Francisco and San Pablo Bay (Region 6) seine regions during the 2014 field season. The boxes represent the 25th and 75th percentiles, the line within the box represents the median, the whiskers represent the 10th and 90th percentiles, and points represent outliers.

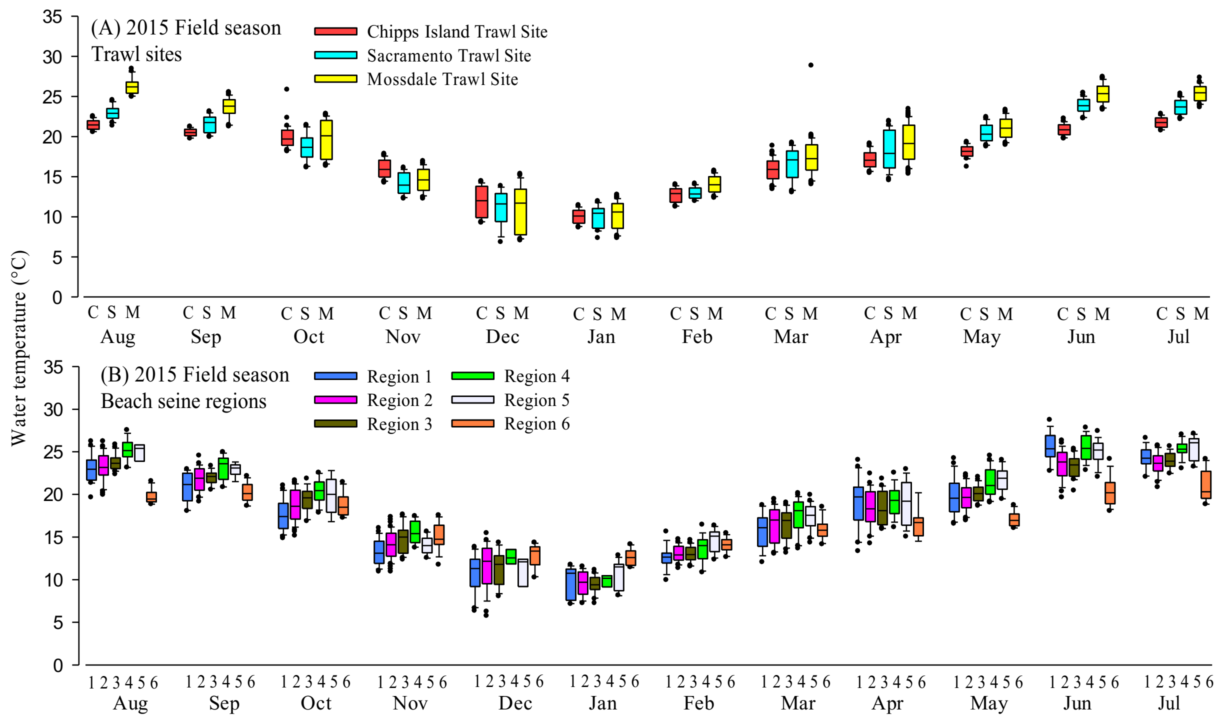


Figure 9. Water temperature data collected by month during sampling at the (A) Chipps Island (C), Sacramento (S), and Mossdale (M) trawl sites and within the (B) Lower Sacramento River (Region 1), North Delta (Region 2), Central Delta (Region 3), South Delta (Region 4), Lower San Joaquin River (Region 5), and San Francisco and San Pablo Bay (Region 6) seine regions during the 2015 field season. The boxes represent the 25th and 75th percentiles, the line within the box represents the median, the whiskers represent the 10th and 90th percentiles, and points represent outliers.

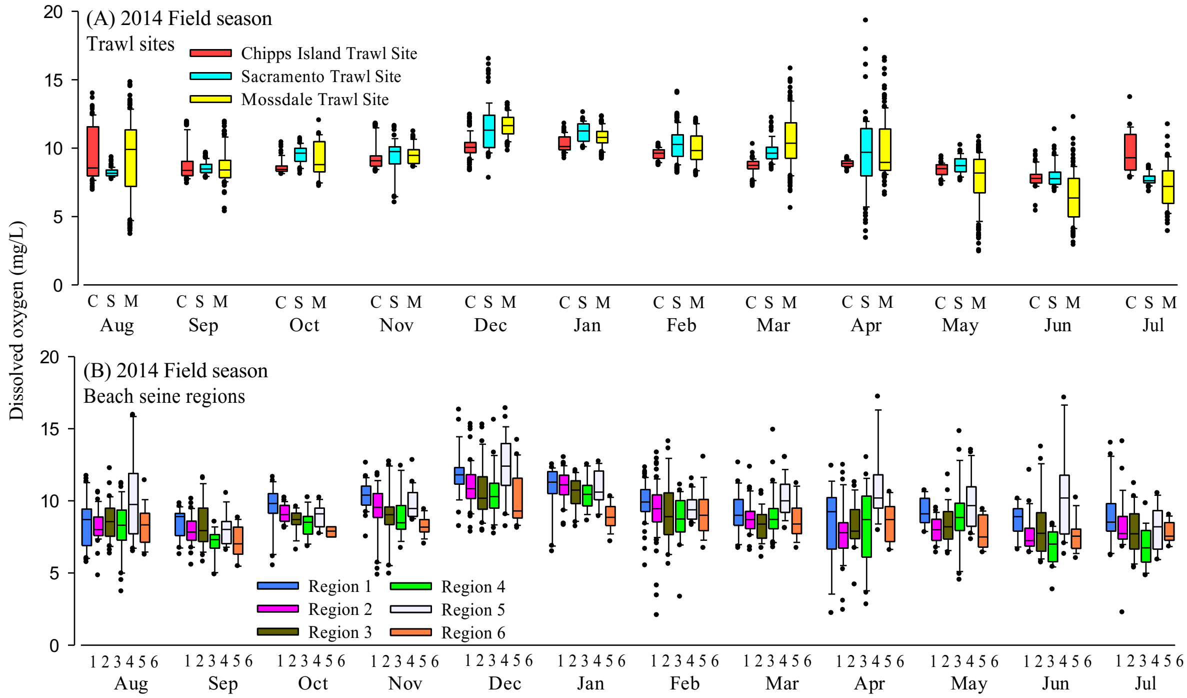


Figure 10. Dissolved oxygen data collected by month during sampling at the (A) Chipps Island (C), Sacramento (S), and Mossdale (M) trawl sites and within the (B) Lower Sacramento River (Region 1), North Delta (Region 2), Central Delta (Region 3), South Delta (Region 4), Lower San Joaquin River (Region 5), and San Francisco and San Pablo Bay (Region 6) seine regions during the 2014 field season. The boxes represent the 25th and 75th percentiles, the line within the box represents the median, the whiskers represent the 10th and 90th percentiles, and points represent outliers.

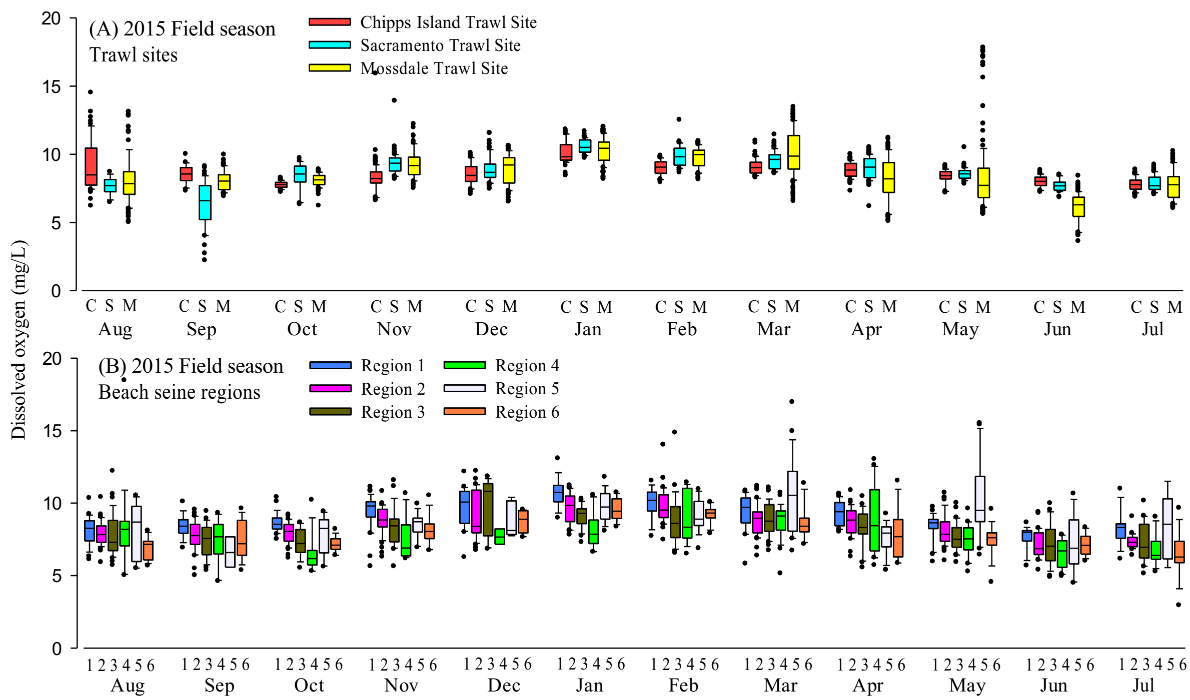


Figure 11. Dissolved oxygen data collected by month during sampling at the (A) Chipps Island (C), Sacramento (S), and Mossdale (M) trawl sites and within the (B) Lower Sacramento River (Region 1), North Delta (Region 2), Central Delta (Region 3), South Delta (Region 4), Lower San Joaquin River (Region 5), and San Francisco and San Pablo Bay (Region 6) seine regions during the 2015 field season. The boxes represent the 25th and 75th percentiles, the line within the box represents the median, the whiskers represent the 10th and 90th percentiles, and points represent outliers.

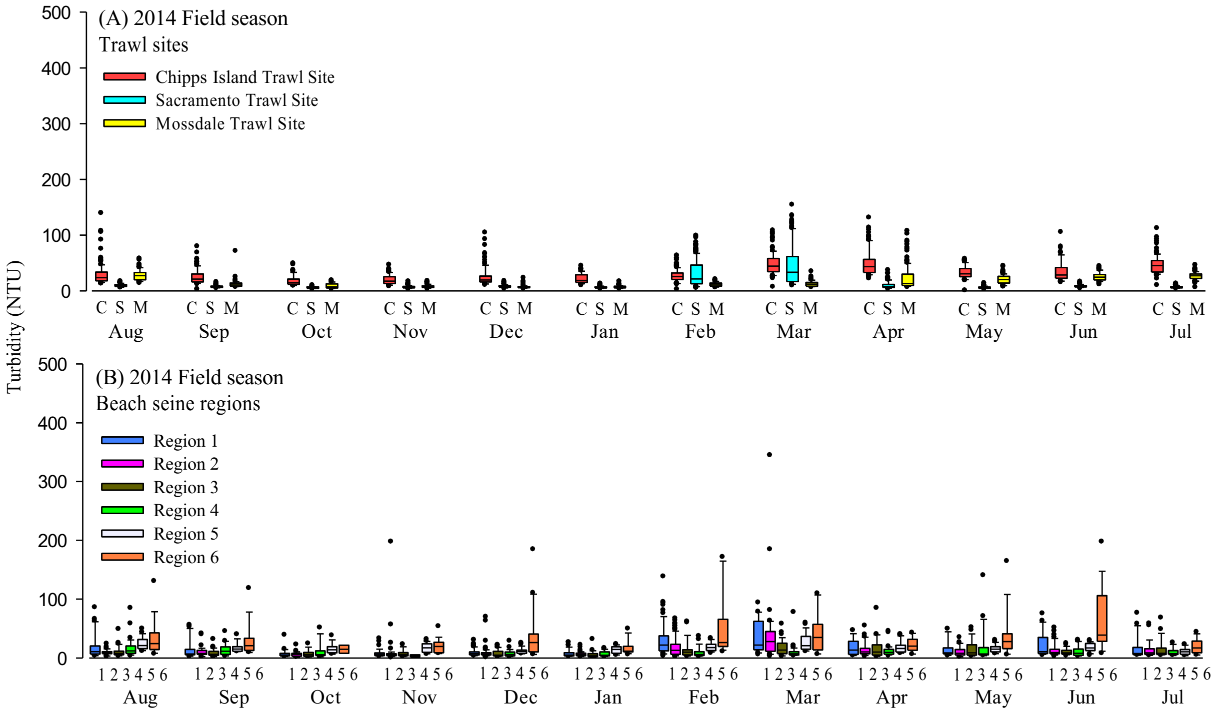


Figure 12. Turbidity data collected by month during sampling at the (A) Chipps Island (C), Sacramento (S), and Mossdale (M) trawl sites and within the (B) Lower Sacramento River (Region 1), North Delta (Region 2), Central Delta (Region 3), South Delta (Region 4), Lower San Joaquin River (Region 5), and San Francisco and San Pablo Bay (Region 6) seine regions during the 2014 field season. The boxes represent the 25th and 75th percentiles, the line within the box represents the median, the whiskers represent the 10th and 90th percentiles, and points represent outliers.

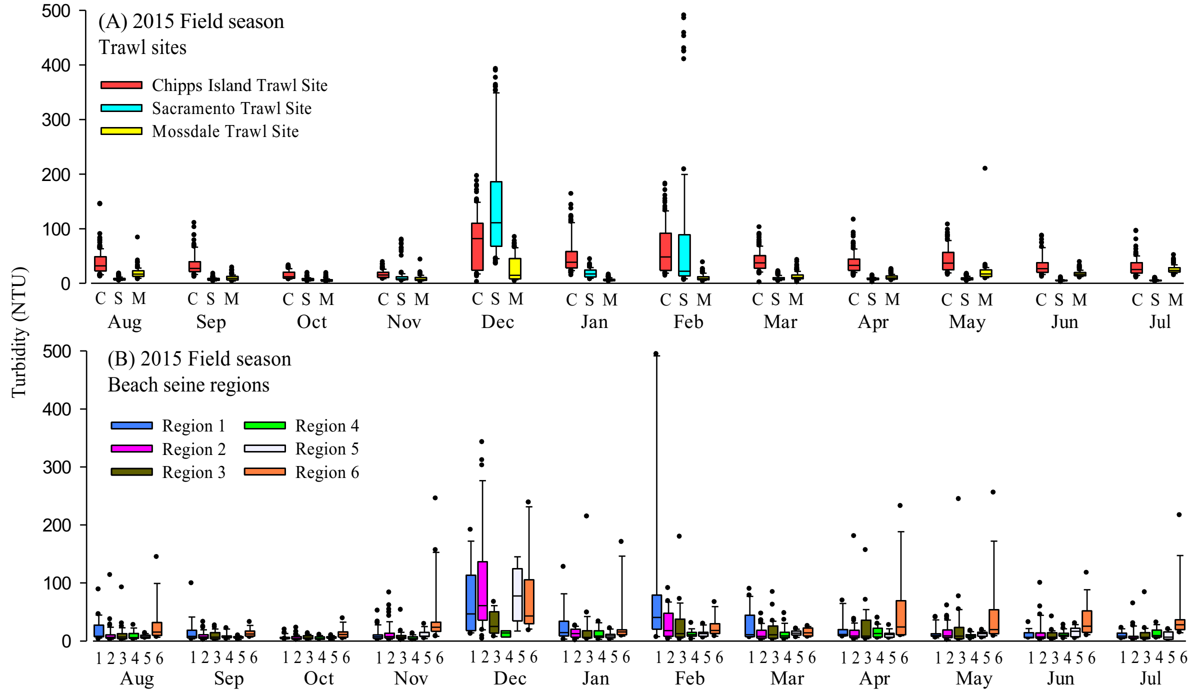


Figure 13. Turbidity data collected by month during sampling at the (A) Chipps Island (C), Sacramento (S), and Mossdale (M) trawl sites and within the (B) Lower Sacramento River (Region 1), North Delta (Region 2), Central Delta (Region 3), South Delta (Region 4), Lower San Joaquin River (Region 5), and San Francisco and San Pablo Bay (Region 6) seine regions during the 2015 field season. The boxes represent the 25th and 75th percentiles, the line within the box represents the median, the whiskers represent the 10th and 90th percentiles, and points represent outliers.

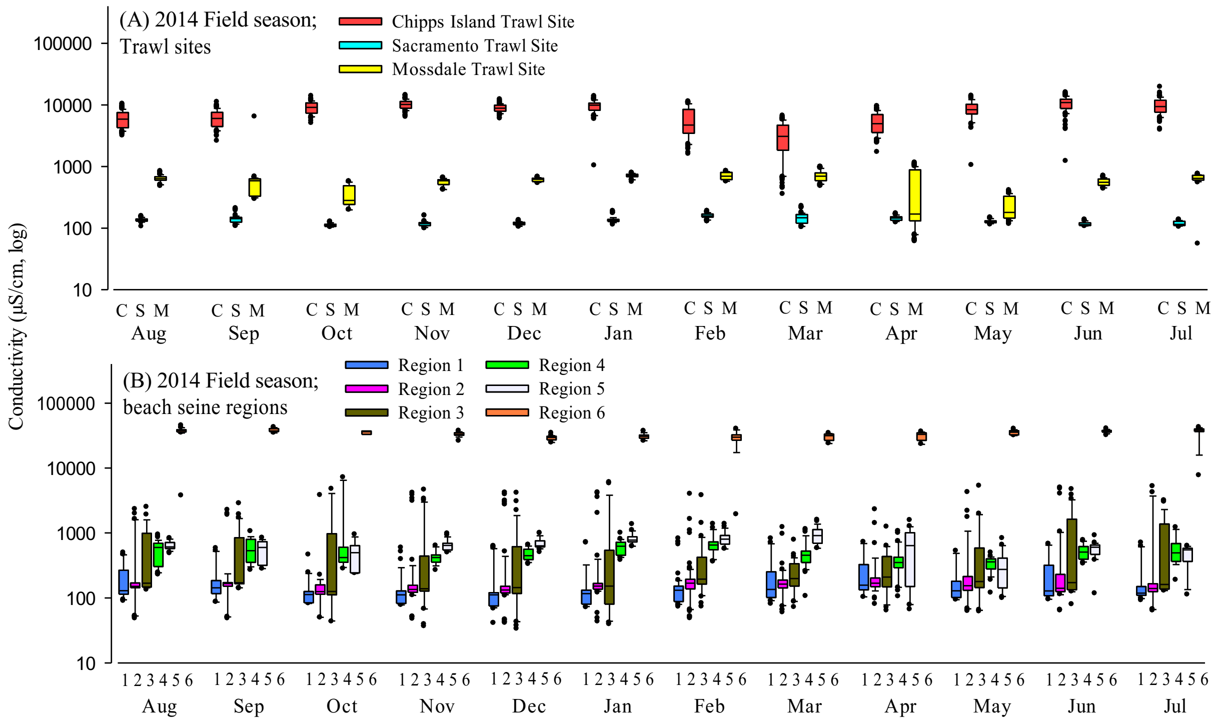


Figure 14. Conductivity data collected by month during sampling at the (A) Chipps Island (C), Sacramento (S), and Mossdale (M) trawl sites and within the (B) Lower Sacramento River (Region 1), North Delta (Region 2), Central Delta (Region 3), South Delta (Region 4), Lower San Joaquin River (Region 5), and San Francisco and San Pablo Bay (Region 6) seine regions during the 2014 field season. The boxes represent the 25th and 75th percentiles, the line within the box represents the median, the whiskers represent the 10th and 90th percentiles, and points represent outliers. The y-axis is presented on a common log scale.

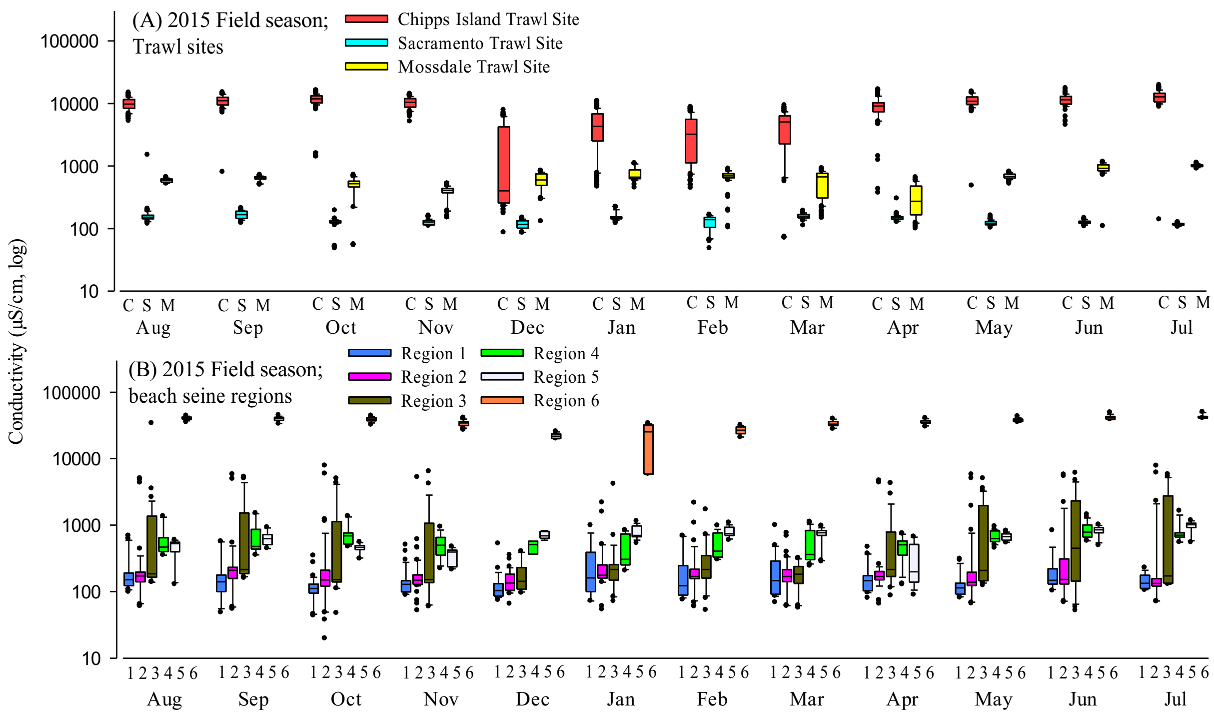


Figure 15. Conductivity data collected by month during sampling at the (A) Chipps Island (C), Sacramento (S), and Mossdale (M) trawl sites and within the (B) Lower Sacramento River (Region 1), North Delta (Region 2), Central Delta (Region 3), South Delta (Region 4), Lower San Joaquin River (Region 5), and San Francisco and San Pablo Bay (Region 6) seine regions during the 2015 field season. The boxes represent the 25th and 75th percentiles, the line within the box represents the median, the whiskers represent the 10th and 90th percentiles, and points represent outliers. The y-axis is presented on a common log scale.

Fish Assemblage

A total of 519,813 fishes, representing 82 species, was collected within samples (beach seines and trawls) used for assemblage analyses during the 2014 and 2015 field seasons (does not include marked or unidentified fish; Tables A.3 and A.4). Sixty-three percent (n=328,642) of the fishes were observed during the 2014 field season. Approximately 77% (n=256,256) and 86% (n=166,020) of the fishes captured during the 2014 and 2015 field seasons, respectively, were identified as species not native to the San Francisco Estuary. Of the 79 species observed, from the 2014 field season the most abundant species were the Inland Silverside *Menidia beryllina*, juvenile Chinook *Oncorhynchus tshawytscha*, Red Shiner *Cyprinella lutrensis*, Threadfin Shad *Dorosoma petenense*, and American Shad *Alosa sapidissima*, comprising 89% of the total annual catch. For 2015, this changed slightly with dominant species being Inland Silverside, Threadfin Shad, American Shad, Red Shiner, and Sacramento Sucker, comprising 84% of the catch.

In general, anadromous-pelagic-nonnative fishes dominated the catch at the Chipps Island Trawl Site during the 2014 and 2015 field seasons (Figure 16). Within this group, the American Shad was the most common species observed at the Chipps Island Trawl Site, and comprised 63% (n=9,149) and 59% (n=7,462) of the fishes captured during the 2014 and 2015 field seasons, respectively (Tables A.3 and A.4). Anadromous-pelagic-nonnative fishes (e.g., American Shad) dominated the catch at the Chipps Island Trawl Site from January and February, and June to December (Figure 16), with anadromous-pelagic-native fishes (e.g., juvenile Chinook) dominating the catch during most of the months between March and May in 2014, and April 2015. The mean yearly CPUE estimates suggested that anadromous-pelagic-native fishes have declined steadily at the Chipps Island Trawl Site since the 1996 field season (Figure 16C). Relative to 2015, the 2014 field year displayed low seasonal variability in water discharge, and this may explain some of the differences between in-community composition of the catch (measured as CPUE) between the two years. The low flows in 2014 would have favored some nonnative pelagic species and the near absence of juvenile salmon in the catch until March suggests that low flows delayed downriver movement. In contrast, the 2015 field season exhibited higher seasonal variation in flow and showed an earlier (December) and overall more protracted occurrence of juvenile salmon in the trawls.

During the 2014 and 2015 field seasons, the most common species captured at the Sacramento Trawl Site was juvenile Chinook (81%, n=25,213; Tables A.3 and A.4). We observed that these anadromous-pelagic-native fishes were generally captured between February and April in 2014, and were more variable in 2015 with highest CPUE in December, February and April. CPUE peaked in February during both field seasons (Figure 17). Nonnative anadromous and resident pelagic fishes were observed in proportionally lower densities from February to May in 2014, and from February to April in 2015. The notable difference between 2014 and 2015 was the historical high in CPUE of pelagic natives (i.e. juvenile Chinook) and pelagic nonnatives in 2014. Part of this difference may be due to the contrasting seasonal flow regimes between the two years, with the 2014 field year displaying low seasonal variability in water discharge relative to 2015 which would have favored nonnative pelagic species. Moreover, juvenile Chinook from the 2014 field season first occurred in February, whereas they were observed in November 2015, suggesting that higher flow regimes in 2015 initiated earlier downriver migration and a more temporally protracted downriver migration of the population.

The Inland Silverside was overall the most common species observed and comprised 51% (n=268,425) of the fishes captured at the Mossdale Trawl Site and in the Lower Sacramento River, North Delta, Central Delta, South Delta, and Lower San Joaquin River seine regions during the 2014 and 2015 field seasons (Tables A.3 and A.4). As a result, the pelagic-nonnative fishes dominated the observed fish assemblage within the Mossdale Trawl Site and most seine regions throughout both field seasons (Figures 18–20). We observed the majority of fishes at the Mossdale Trawl Site in January and August for 2014, and June and July in 2015 (Figure 18). Pelagic native fishes dominated the observed assemblage in February to April of the 2014 field season when anadromous-pelagic-native fishes (e.g., juvenile Chinook) were present, whereas this was only observed in December 2014 and February in the 2015 field season. In addition to pelagic-nonnative fishes, the mean monthly CPUE estimates suggest that the fish assemblage within the North Delta and Lower Sacramento River seine regions contained considerable densities of anadromous-pelagic-native fishes from February to March and benthic-native fishes (e.g., lamprey and Sacramento Sucker; Tables A.3 and A.4) from April to June (Figure 19). The mean yearly CPUE estimates among beach seine regions and the Mossdale Trawl demonstrated that fish densities for anadromous pelagic native and pelagic non-natives were historically high during the 2014 field season, exceeding levels observed since 2000. Following the 2014 field season, CPUE sharply decreased to levels that were comparable to the decadal low level observed in 2010 (Figures 18 and 20).

Within the San Francisco and San Pablo Bay Seine Region, the Topsmelt *Atherinops affinis* was the most common fish species observed and comprised 61% (n=10,372) of all fishes captured during both the 2014 and 2015 field seasons (Tables A.3 and A.4). The mean monthly CPUE estimates suggest that pelagic-nonnative fishes were observed in higher proportions within and among all field seasons relative to other assemblages groups (Figures 19 and 20). Nearly all fishes observed within this seine region, including Topsmelt, are considered marine fish, presumably due to the higher conductivity within the region (Figures 14 and 15). In general, we cannot discern any temporal patterns from monthly or yearly CPUE estimates in this region for any fish assemblage group due to relatively low catch numbers.

The 2014 field season showed substantively higher CPUE in both pelagic native and non-native species, both from 2015 and from previous years' catch to 2000 (Figures 17-20). For pelagic native species this was largely due to very high CPUE of juvenile Chinook from seine regions 1, 2 and 3 and the Sacramento trawl site between February and April. For pelagic non-native fishes, the overall greater CPUE in the 2014 field was attributed to very high catches of Inland Silversides and Threadfin Shad from the South Delta (Region 5, Mossdale) in both seines and trawls, and Red Shiners from seines. The substantial difference between the two years may be attributed to the difference in their respective flow regimes, where 2014 exhibited a lower annual flow and reduced seasonal variability relative to the 2015 field season. As seen between 2014 and 2015, both the magnitude and timing of seasonal flows across the region would have varying effects on the distribution and abundance of certain species. For example, in 2014 the lack of distinguished peak flow events in the winter months likely influenced the first occurrence of downriver migrating juvenile Chinook, which occurred later in the field season (February) relative to 2015 (December)(Figure 17C). Moreover, reduced flows and retention of juvenile Chinook up river may have caused a greater pulse event once fish started to migrate downstream, which is apparent from the sudden and substantive increase in CPUE of pelagic natives in February and March in 2014 relative to 2015. The high CPUE of both native and non-native pelagics from the 2014 field season may have been attributed to lower river volumes and increased catch efficiencies, and this is evidenced by the fact that CPUE of both native and non-native pelagics showed the greatest differences in CPUE between 2014 and 2015 in beach seines and trawls from the Sacramento River, whereas this difference between years was not observed in the lower Delta where volumes are more tidally influenced.

The overall higher densities of fishes in the 2014 field season correspond to reduced and delayed high peak flows occurring later in the year than in 2015 (around 400 m^3/sec in March of the 2014 field season for Delta Outflow and the discharge at the Sacramento River at Freeport versus 880 m^3/sec in December of 2015; Figures 16–20). The increased discharge observed at the Sacramento Trawl Site in 2015 may also explain the earlier occurrence of anadromous-pelagic-native fishes. In contrast, the increased outflow in February through March may explain the overall increased fish densities captured at Chipps Island in 2014. The later flows in the 2014 field season may have also extended the occurrence of the anadromous-pelagic-native fishes in the beach seines (Figure 19).

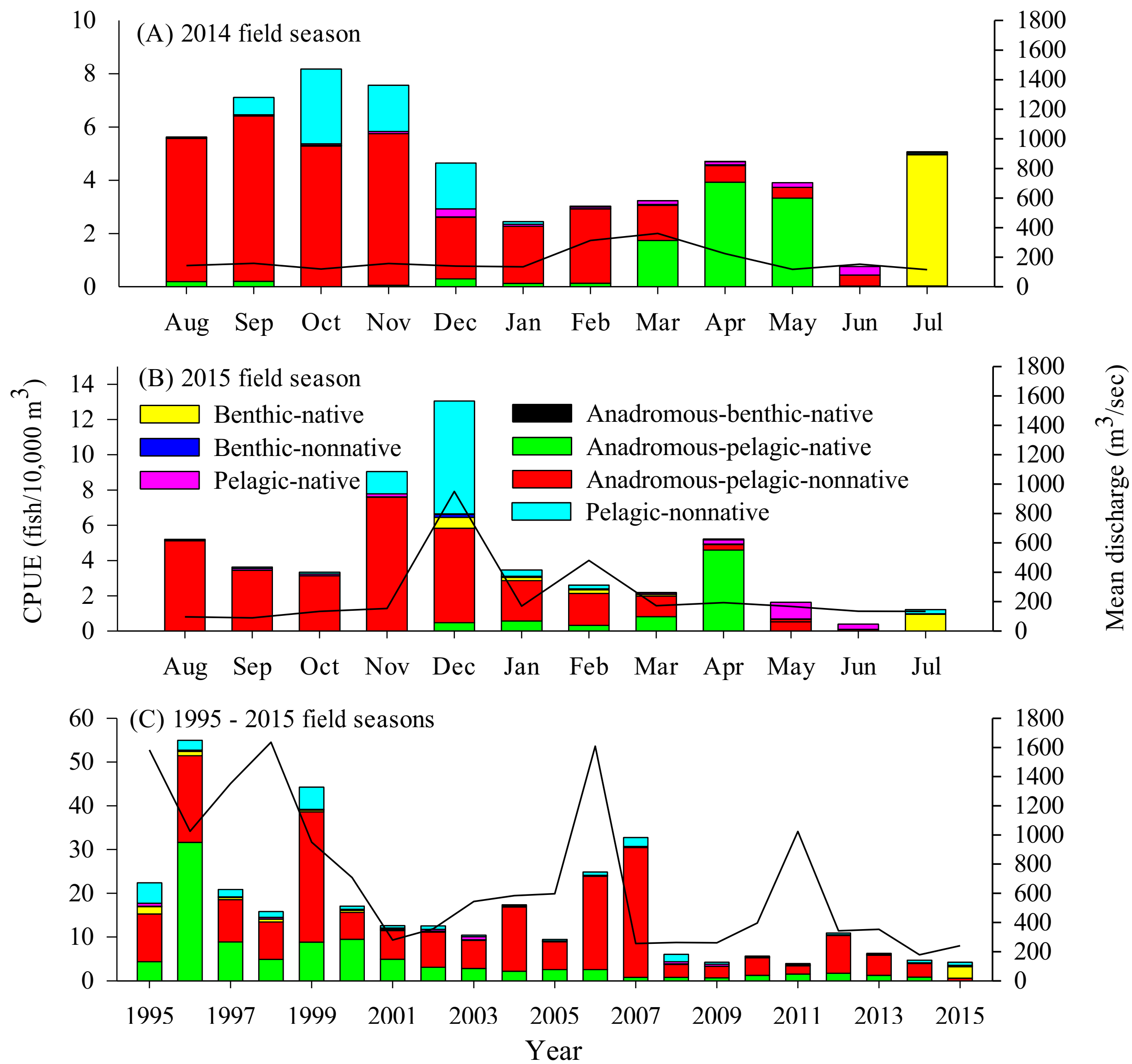


Figure 16. The mean monthly and yearly CPUE (bars) of juvenile fish assemblages captured in MWTRs at the Chipps Island Trawl Site, and the estimated mean monthly and yearly Delta outflow (solid line) during the (A) 2014, (B) 2015, and (C) 1995 through 2015 field seasons.

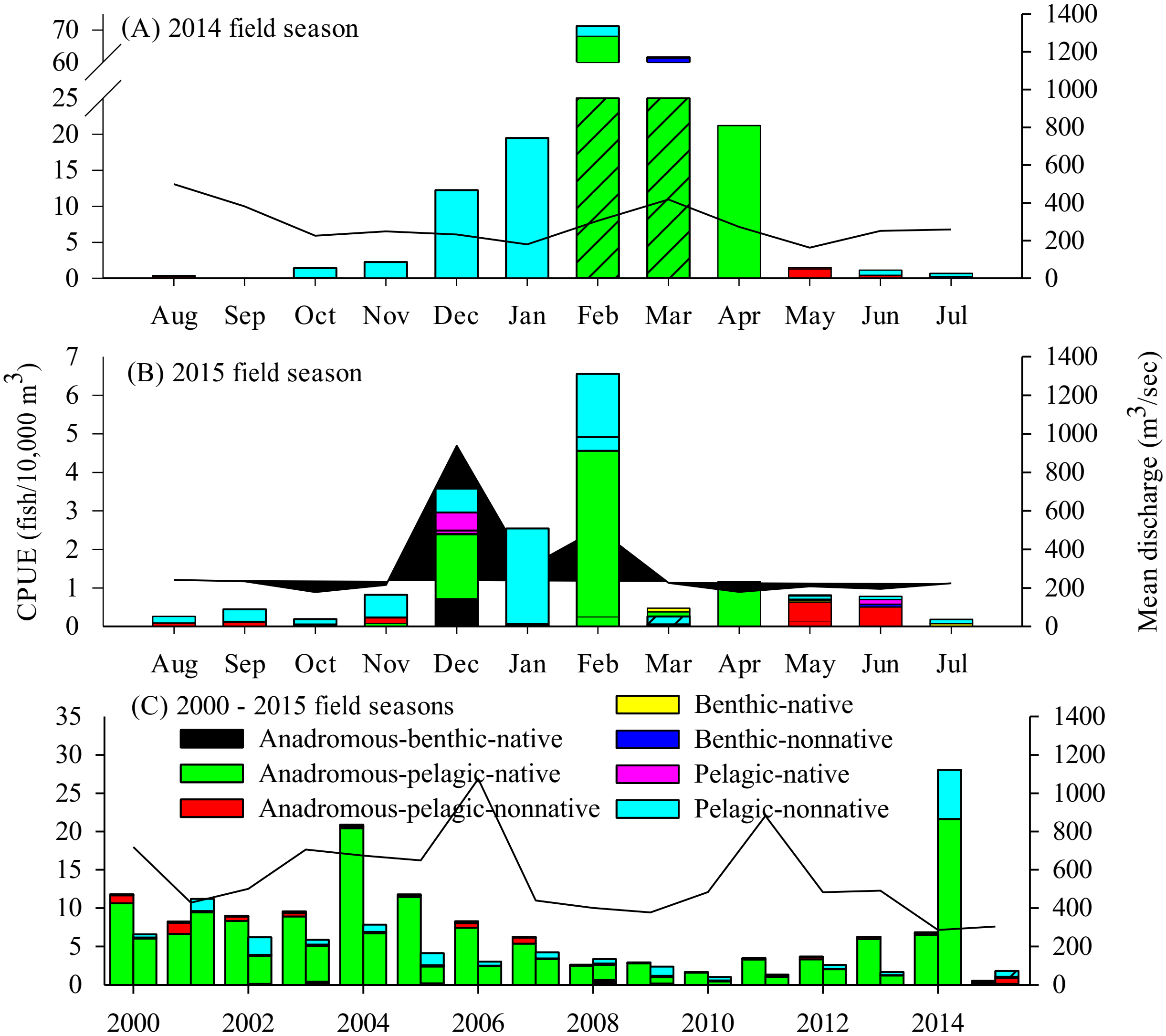


Figure 17. The mean monthly and yearly CPUE of juvenile fish assemblages captured in MWTRs (solid bars) and KDTRs (striped bars) at the Sacramento Trawl Site, and the mean monthly and yearly Sacramento River discharge at Freeport (solid line) during the (A) 2014, (B) 2015, and (C) 2000 through 2015 field seasons.

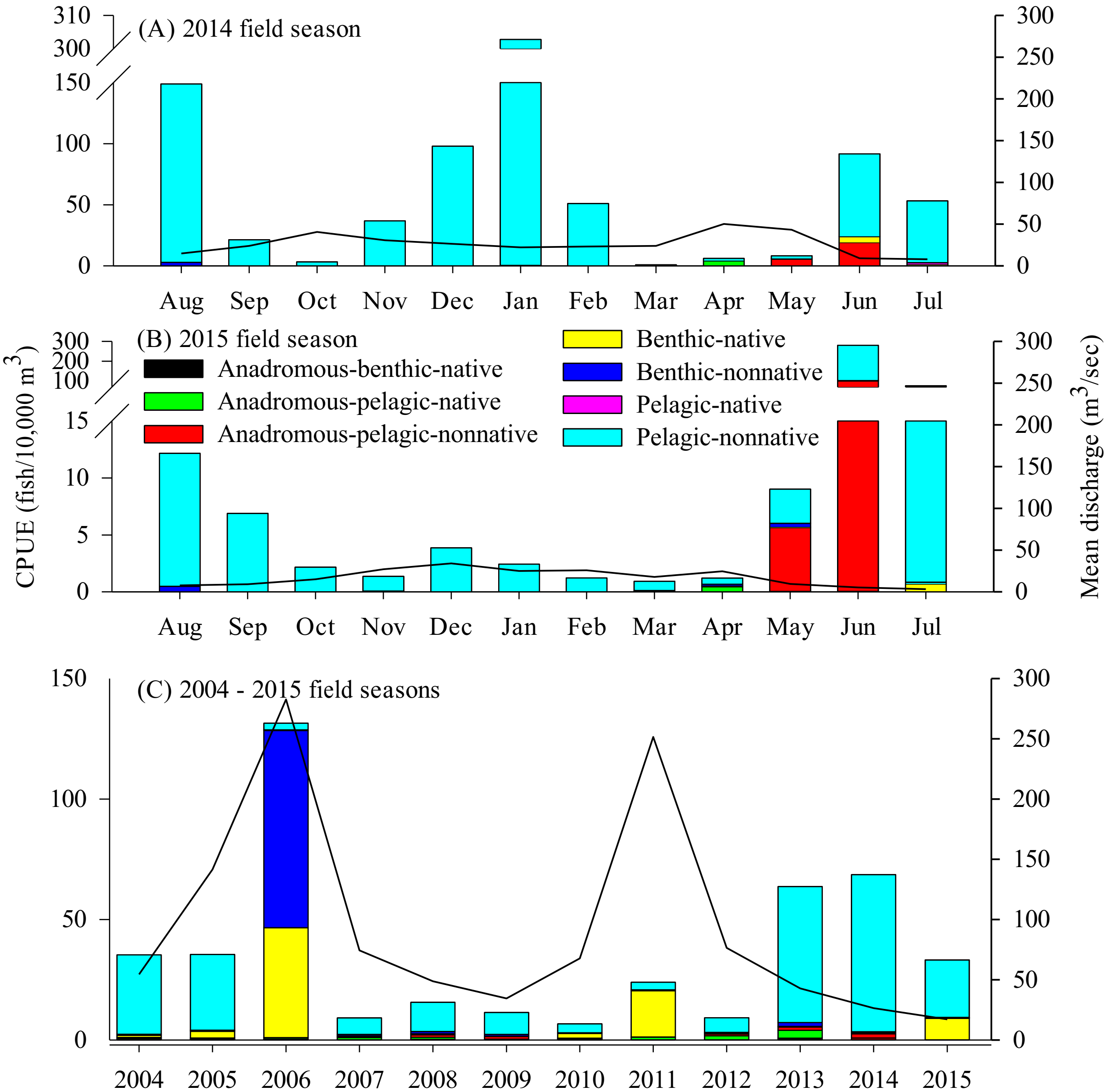


Figure 18. The mean monthly and yearly CPUE (bars) of juvenile fish assemblages captured in KDTRs at the Mossdale Trawl Site, and the mean monthly and yearly San Joaquin River discharge at Vernalis (solid line) during the (A) 2014, (B) 2015, and (C) 2004 through 2015 field seasons.

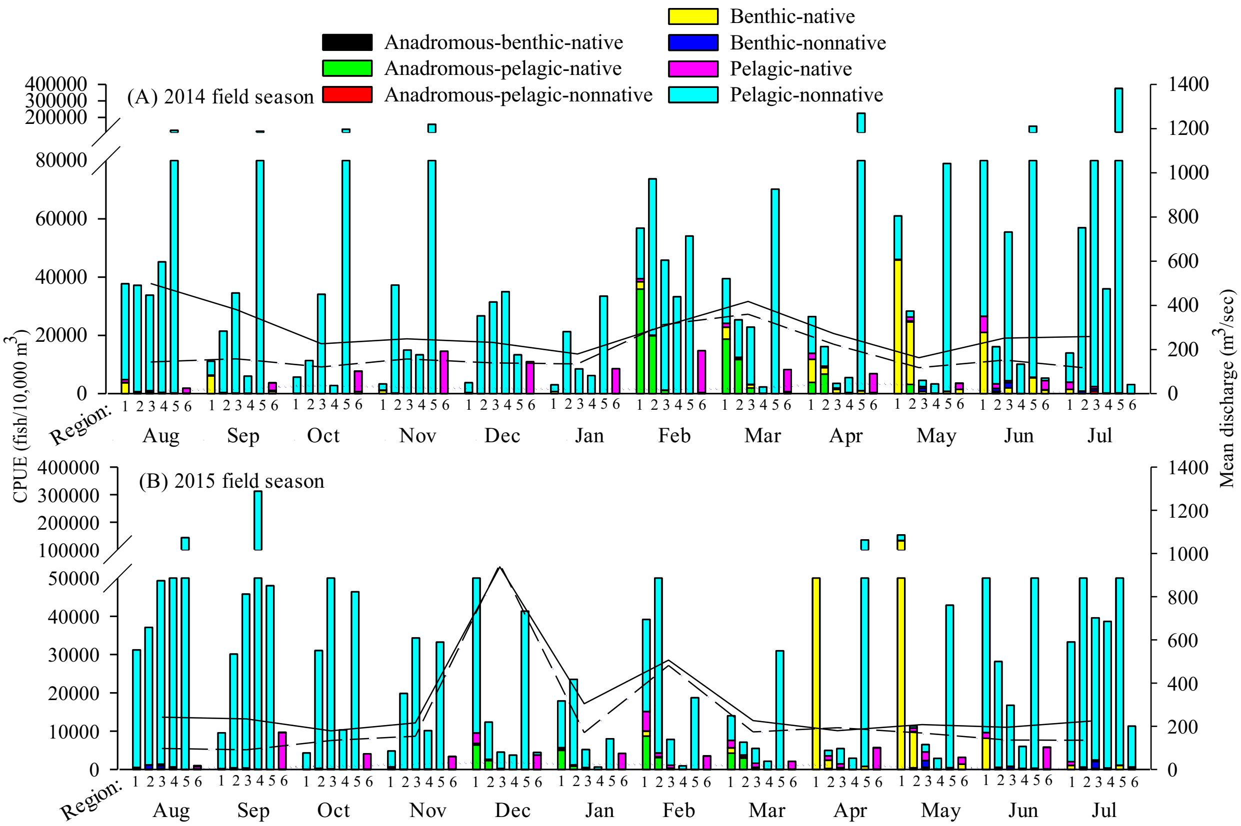


Figure 19. The mean monthly CPUE (bars) of juvenile fish assemblages captured within the Lower Sacramento River (1), North Delta (2), Central Delta (3), South Delta (4), Lower San Joaquin River (5), and San Francisco and San Pablo Bay (6) beach seine regions, and the estimated mean monthly and yearly Delta outflow (dashed line), Sacramento River discharge at Freeport (solid line), and San Joaquin River discharge at Vernalis (dotted line) during the (A) 2014 and (B) 2015 field seasons.

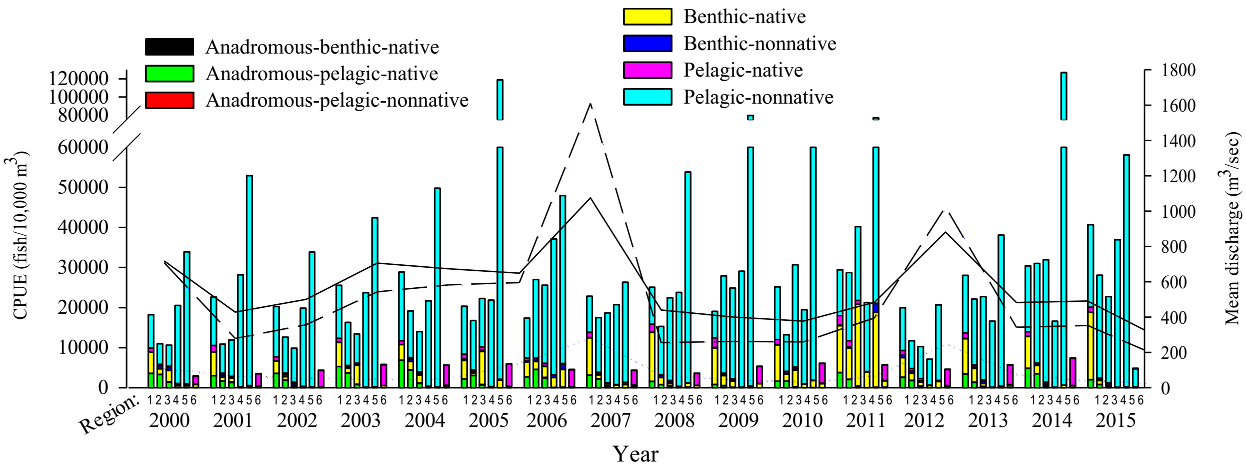


Figure 20. The mean yearly CPUE (bars) of juvenile fish assemblages captured within the Lower Sacramento River (1), North Delta (2), Central Delta (3), South Delta (4), Lower San Joaquin River (5), and San Francisco and San Pablo Bay (6) beach seine regions, and the estimated mean monthly and yearly Delta outflow (dashed line), Sacramento River discharge at Freeport (solid line), and San Joaquin River discharge at Vernalis (dotted line) during the 2000 through 2015 field seasons.

Juvenile Chinook Salmon

We captured 50,646 and 5,399 juvenile Chinook during the 2014 and 2015 field seasons, respectively (Tables A.3 and A.4). During the 2014 field season, 49,490 individuals were unmarked, of which 0.37% (n=181) were identified as winter-run sized, 94.66% (n=46,845) as fall-run sized, 4.96% (n=2,457) as spring-run sized, and 0.01% (n=7) as late fall-run sized using the length at date criteria; a total of 157 individuals were not raced (Table A.3). Of the 1066 marked (i.e., clipped adipose fin) juvenile Chinook recovered during 2014, 98% (n=1052) contained a readable CWT (Table A.20). During the 2015 field season, 4,578 individuals were unmarked, of which 2.56% (n=117) were identified as winter-run sized, 58.56% (n=2,681) as fall-run sized, 38.16% (n=1,747) as spring-run sized, and 0.72% (n=33) as late fall-run sized Chinook (Table A.4). Of the 726 marked juvenile Chinook recovered during 2015, 96% (n=700) contained a readable CWT (Table A.21).

We recovered a total of 31 and 174 marked juvenile winter-run Chinook containing a CWT during the 2014 and 2015 field seasons, respectively, within the Sacramento Trawl Site, and the Chipps Island Trawl Site. All recovered CWT winter-run Chinook had been released by the Livingston Stone National Fish Hatchery, which released 193,264 (190,905 marked and with a CWT) and 609,311 (590,623 marked and with a CWT) juvenile winter-run Chinook in the

Central Valley during the 2014 and 2015 field seasons, respectively (PSMFC 2017). The number of marked and tagged fish reported in parentheses comes from the hatchery and accounts for tag loss before release.

We recovered a total of 325 and 47 marked juvenile spring-run Chinook tagged with CWTs during the 2014 and 2015 field seasons, respectively, within the Lower Sacramento River, North Delta, and Central Delta seine regions, and the Sacramento, Chipps Island, and Mossdale Trawl Sites (Tables A.20 and A.21). All recovered CWT spring-run Chinook had been released by the Feather River Fish Hatchery, which released 2,296,788 (2,275,716 marked and with a CWT) and 1,763,479 (1,745,811 marked and with a CWT) juvenile spring-run Chinook in the Central Valley and the Suisun and San Pablo Bays during the 2014 and 2015 field seasons (PSMFC 2017).

We recovered a total of 549 and 464 marked juvenile fall-run Chinook containing a CWT during the 2014 and 2015 field seasons, respectively, within the Lower Sacramento River, North Delta, Central Delta, and San Francisco-San Pablo Bay seine regions, the Sacramento, Chipps Island, and Mossdale Trawl Sites (Tables A.20 and A.21). In the 2014 field season, 28,279,571 (7,671,718 marked and with a CWT) hatchery reared juvenile fall-run Chinook were released into the Central Valley (48.5%) and the San Francisco area bays (51.5%) in the combined release efforts of the Coleman National Fish Hatchery, Feather River Fish Hatchery, Mokelumne River Fish Hatchery, Nimbus Fish Hatchery, and Merced River Fish Facility (PSMFC 2017). In the 2015 field season, 26,080,867 (6,593,909 marked and with a CWT) hatchery reared juvenile fall-run Chinook were released into the Central Valley (65.7%) or the San Francisco area bays (34.3%) in the combined release efforts of the Coleman National Fish Hatchery, Feather River Fish Hatchery, Mokelumne River Fish Hatchery, Nimbus Fish Hatchery, and Merced River Fish Facility (PSMFC 2017).

We recovered a total of 147 and 15 marked juvenile late fall-run Chinook containing a CWT during the 2014 and 2015 field seasons, respectively, within the Lower Sacramento River and North Delta seine regions, the Sacramento Trawl Site, and the Chipps Island Trawl Site (Tables A.20 and A.21). All recovered CWT late fall-run Chinook were released by the Coleman National Fish Hatchery, which released 984,977 (960,075 marked) and 1,094,719 (1,056,322 marked) juvenile late fall-run Chinook in the Central Valley during the 2014 and 2015 field seasons (PSMFC 2017). Nearly all of the juvenile Chinook captured using beach seines since the 2000 field season were estimated to be of natural origin using equations 1 and 2 (see “Estimate of Hatchery and Natural Origin Juvenile Chinook Salmon” section; 93.5% natural origin, 1.4% hatchery origin, 5.0% unknown origin). While hatcheries typically release smolt-sized fish and few fry (PSMFC 2017), both fry- and smolt-sized Chinook were observed in the beach seines (see “Fork Length Distributions” section).

Winter-Run Distribution and Relative Abundance

Nearly 100% of all juvenile winter-run Chinook produced by the Livingston Stone National Fish Hatchery have been released marked and containing a CWT since production began in 1995 (PSMFC 2017). We estimated that natural origin juvenile winter-run sized Chinook were captured in relatively low numbers at the Chipps Island Trawl Site, the Sacramento Trawl Site, and in the Lower Sacramento River, North Delta, Central Delta, and South Delta seine regions during the 2014 and 2015 field seasons (Figures 21–24). Although genetic analyses have determined that the river LDC is fairly accurate for winter-run Chinook designation, it should be noted that significant numbers of individuals from other races are included within the winter-run criteria (Pyper et al. 2013), thus the abundance is significantly over-estimated using the river LDC.

Consistent with the 2012 and 2013 field seasons (Barnard et al. 2015), in both 2014 and 2015 winter-run sized juvenile Chinook were generally captured from November through April at the Sacramento Trawl Site and December through April at the Chipps Island Trawl Site (Figures 21 and 22). The CPUE at the Sacramento Trawl Site peaked in February into March during the 2014 and 2015 field seasons. Conversely, the CPUE at the Chipps Island Trawl Site peaked during March in 2014, and February during the 2015 field season. There was no discernible trend with respect to a time-lag in peak CPUE at the Sacramento Trawl Site and the Chipps Island Trawl Site during both years. The Sacramento River discharge, on average, showed a gradual increase from January and peaking in March of the 2014 field season, whereas the 2015 field season showed higher flow variability and higher peak flows in December and February. The influence of flow regimes between 2014 and 2015 can be seen in the strong difference in timing of winter-run juvenile Chinook capture, with the 2015 field year showing a more protracted distribution from November to April at Sacramento and December to April in Chipps, whereas 2014 showed occurrences in February and March at Sacramento, and February to April at Chipps (Figures 21 and 22). The mean yearly CPUE at the Sacramento Trawl Site has increased considerably since the record low observed during the 2011 field season (Figure 22), and mean yearly CPUE at the Chipps Island Trawl Site increased in 2014 and nearly doubled in the 2015 field season (Figure 21).

Estimated natural origin winter-run sized Chinook were captured using beach seines in February and March during the 2014 field season, whereas their occurrence in 2015 was more seasonally protracted to the months of November, December, February and March (Figure 23). We did not observe any marked winter run in the beach seines during the 2014 field season. In 2015, the mean monthly CPUE of natural origin winter-run juveniles peaked in the Lower Sacramento River and North Delta seine regions in December compared to February during the 2014 field season (Figure 23). Conversely, the monthly CPUE in the Central Delta and South Delta seine regions peaked either in February (2015) or March (2014). The mean yearly CPUE estimates suggested that natural origin juvenile winter-run Chinook were consistently observed in higher densities within the Lower Sacramento River Seine Region relative to other seine regions since the 2000 field season (Figure 24).

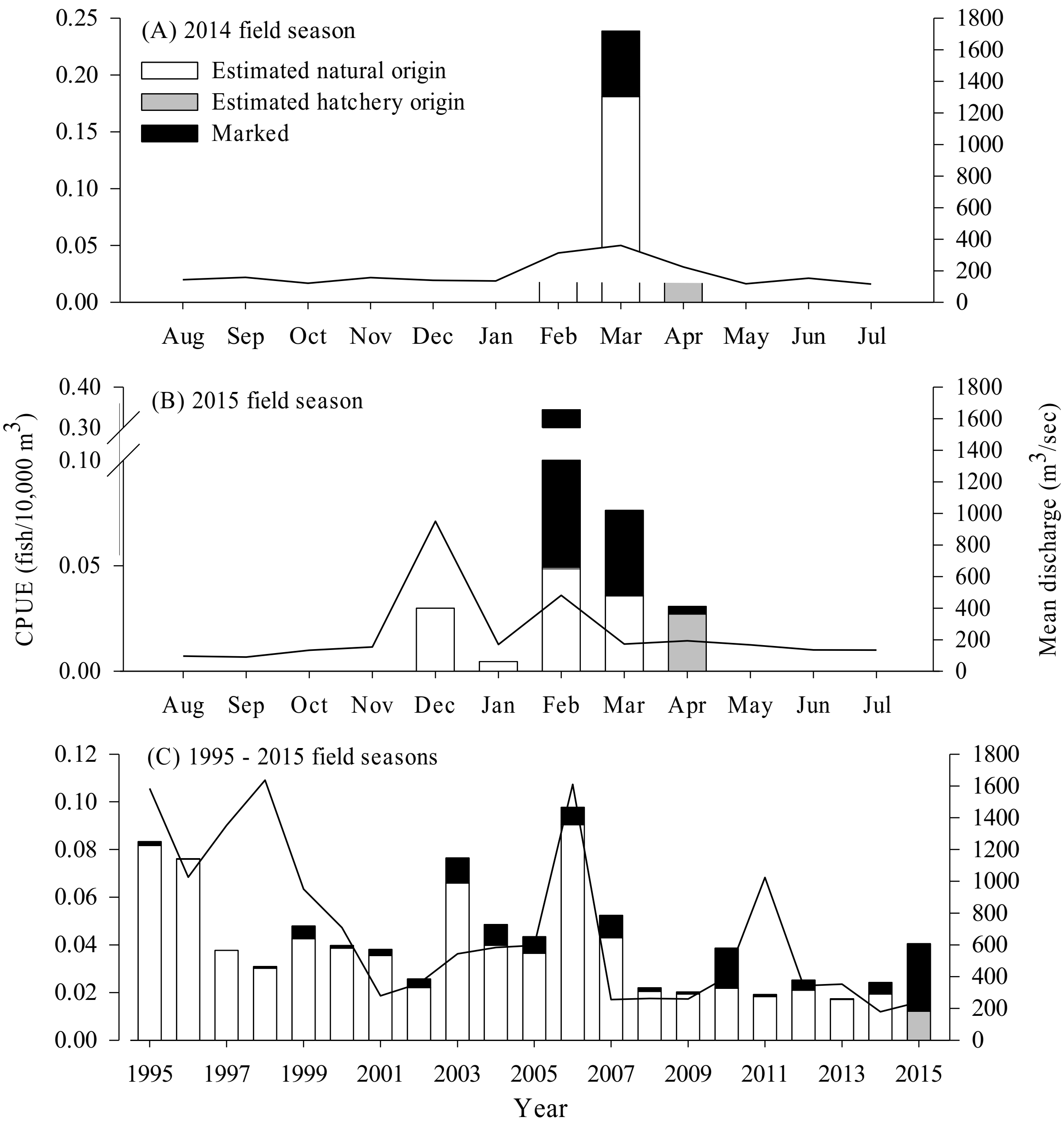


Figure 21. The mean monthly and yearly CPUE (bars) of juvenile hatchery winter-run and winter-run sized Chinook Salmon captured in MWTRs at the Chipps Island Trawl Site, and the estimated mean monthly and yearly Delta outflow (solid line) during the (A) 2014, (B) 2015, and (C) 1995 through 2015 field seasons.

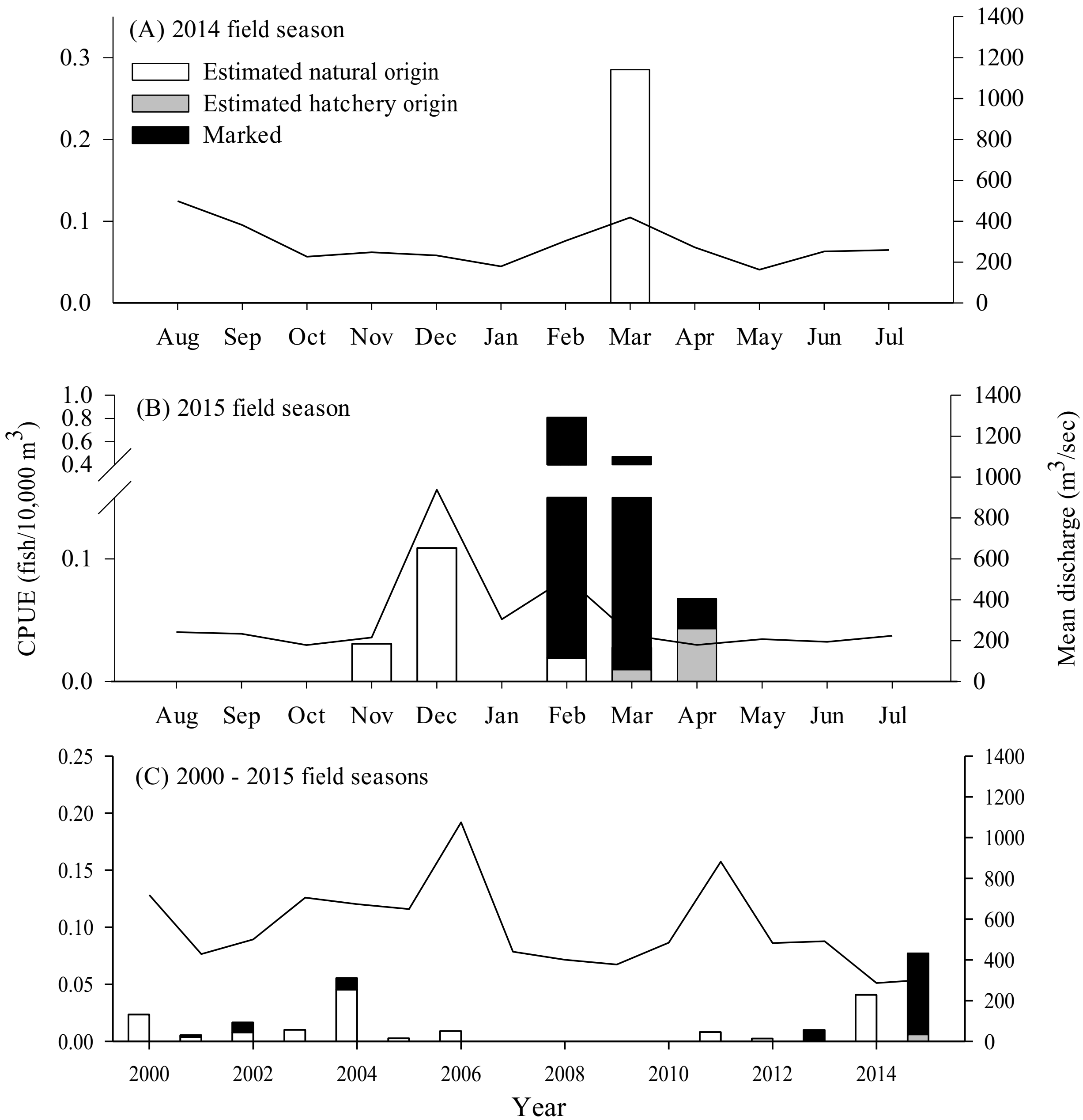


Figure 22. The mean monthly and yearly CPUE of juvenile hatchery winter-run and winter-run sized Chinook Salmon captured in MWTRs (solid bars) and KDTRs (striped bars) at the Sacramento Trawl Site, and the mean monthly and yearly Sacramento River discharge at Freeport (solid line) during the (A) 2014, (B) 2015, and (C) 2000 through 2015 field seasons.

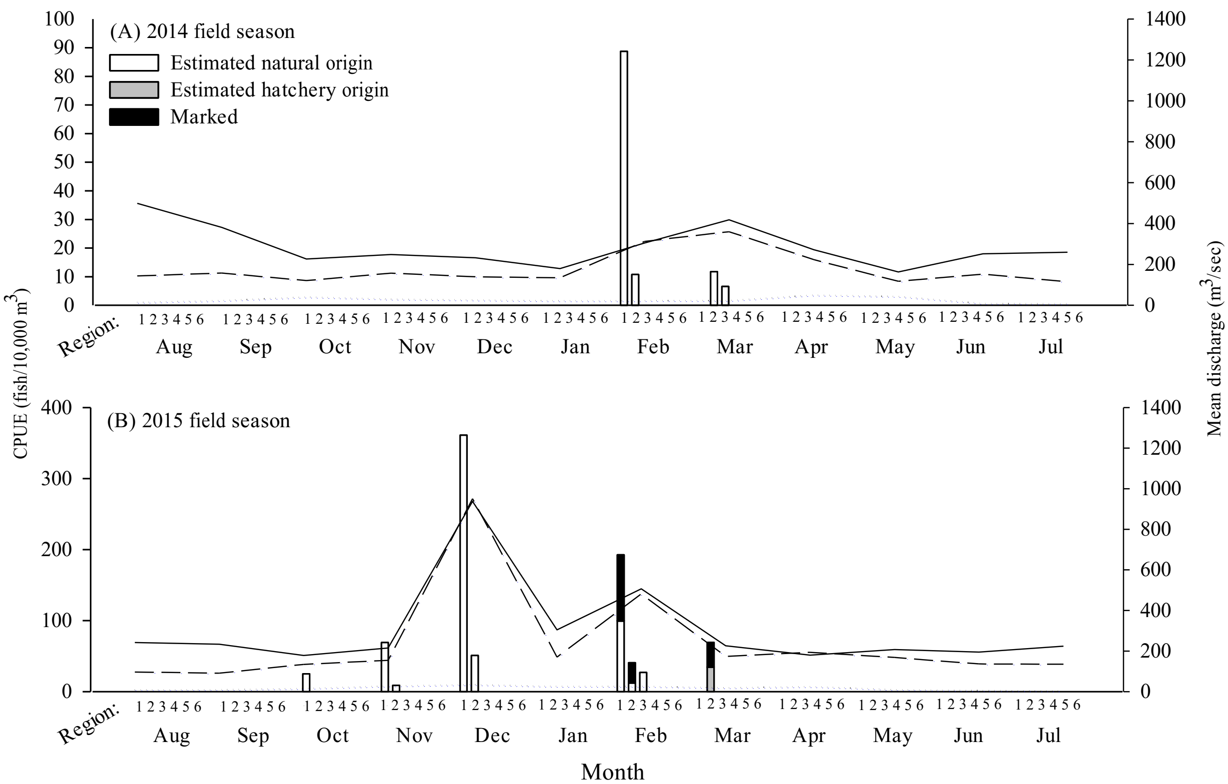


Figure 23. The mean monthly CPUE (bars) of hatchery and juvenile winter-run sized Chinook Salmon captured within the Lower Sacramento River (1), North Delta (2), Central Delta (3), South Delta (4), Lower San Joaquin River (5), and San Francisco and San Pablo Bay (6) beach seine regions, and the estimated mean monthly and yearly Delta outflow (dashed line), Sacramento River discharge at Freeport (solid line), and San Joaquin River discharge at Vernalis (dotted line) during the (A) 2014 and (B) 2015 field seasons.

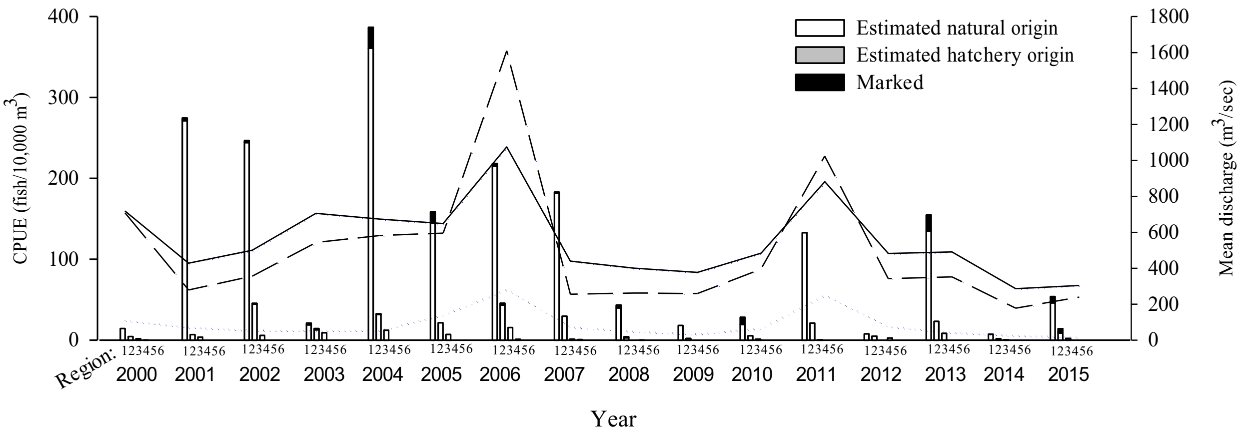


Figure 24. The mean yearly CPUE (bars) of juvenile hatchery winter run and winter-run sized Chinook captured within the Lower Sacramento River (1), North Delta (2), Central Delta (3), South Delta (4), Lower San Joaquin River (5), and San Francisco and San Pablo Bay (6) beach seine regions, and the estimated mean monthly and yearly Delta outflow (dashed line), Sacramento River discharge at Freeport (solid line), and San Joaquin River discharge at Vernalis (dotted line) during the 2000 through 2015 field seasons.

Fall-, Late Fall-, and Spring-Run Distribution and Relative Abundance

We captured juvenile fall-, late fall-, or spring-run sized Chinook in nearly all seine regions and trawl sites during the 2014 and 2015 field seasons (Tables A.3 and A.4). Until the 2000 field season, hatchery fish were often released in groups within the watershed that did not have any marked individuals containing a CWT (Kevin Niemela, USFWS, personal communication; PSMFC 2017). As a result, we were unable to determine the origin of large numbers of fish captured at the Chipps Island and Sacramento trawl sites prior to the 2000 field season.

At the Chipps Island Trawl Site, juvenile fall-, late fall-, or spring-run sized Chinook were captured between February and May in 2014, and between December and May in the 2015 field season (Figure 25). Individuals were captured from February through June at the Sacramento Trawl Site in the 2014 field season whereas the occurrence of juvenile Chinook in the 2015 field season commenced as early as November and continued into May. This difference between years may be attributed to the difference in timing and magnitude of peak flow events, where 2015 showed overall lower discharge but more pronounced peak flow events between the months of November to June relative to 2014 (Figure 26). We observed a greater proportion of hatchery fish (estimated and marked) relative to natural origin fish during the 2015 season at Chipps Island, whereas the Sacramento trawl site generally showed higher proportions of estimated natural origin fish. In the 2014 field season fish of natural origin dominated at both trawl sites.

The majority of fish captured at the Mossdale Trawl Site that occurred between March and June were considered to be natural origin due to few hatchery releases occurring in the San Joaquin Basin (PSMFC 2017; Figure 27). At all the trawl sites, the peak-mean monthly CPUE representing natural origin individuals occurred from January through May for 2014, and from February through April for the 2015 field season. The mean yearly CPUE at the Chipps Island Trawl Site has declined annually since the 2011 field season, however the 2014 CPUE was nearly equal to the historical averages (Figures 25 and 28). This assumes that catch efficiency at Chipps Island did not vary between variable flow years of 2011 (a high flow year) and 2012 to 2015 (low flow years; Table A.19). The mean yearly CPUE at the Sacramento trawl site in 2014 was a historic high from 2000, which was subsequently followed by historically low CPUE in 2015 (Figure 26). From the Mossdale Trawl Site, CPUE in the 2014 field season had decreased over three-fold from the 2013 field year, and CPUE further dropped from 2014 to historically low numbers from 2004 (Figures 26 and 27). Although these races are grouped for consistency within this report, all juvenile Chinook captured at Mossdale are assumed to be fall-run.

Estimated natural origin juvenile fall-, late fall-, or spring-run Chinook were generally captured using beach seines between February and May during the 2014, and November and April 2015 field seasons (Figure 29). We observed few marked fish during both field seasons. The mean monthly CPUE of natural origin fall-, late fall-, or spring-run Chinook peaked in the Lower Sacramento River and North Delta seine regions during February and March in 2014, and December to March in 2015. The mean yearly CPUE estimates suggested that natural origin juvenile fall-, late fall-, or spring-run Chinook were consistently observed in higher densities within the Lower Sacramento River and North Delta seine regions, and to a lesser extent the Central Delta seine regions, relative to other seine regions since the 2000 field season (Figure 30).

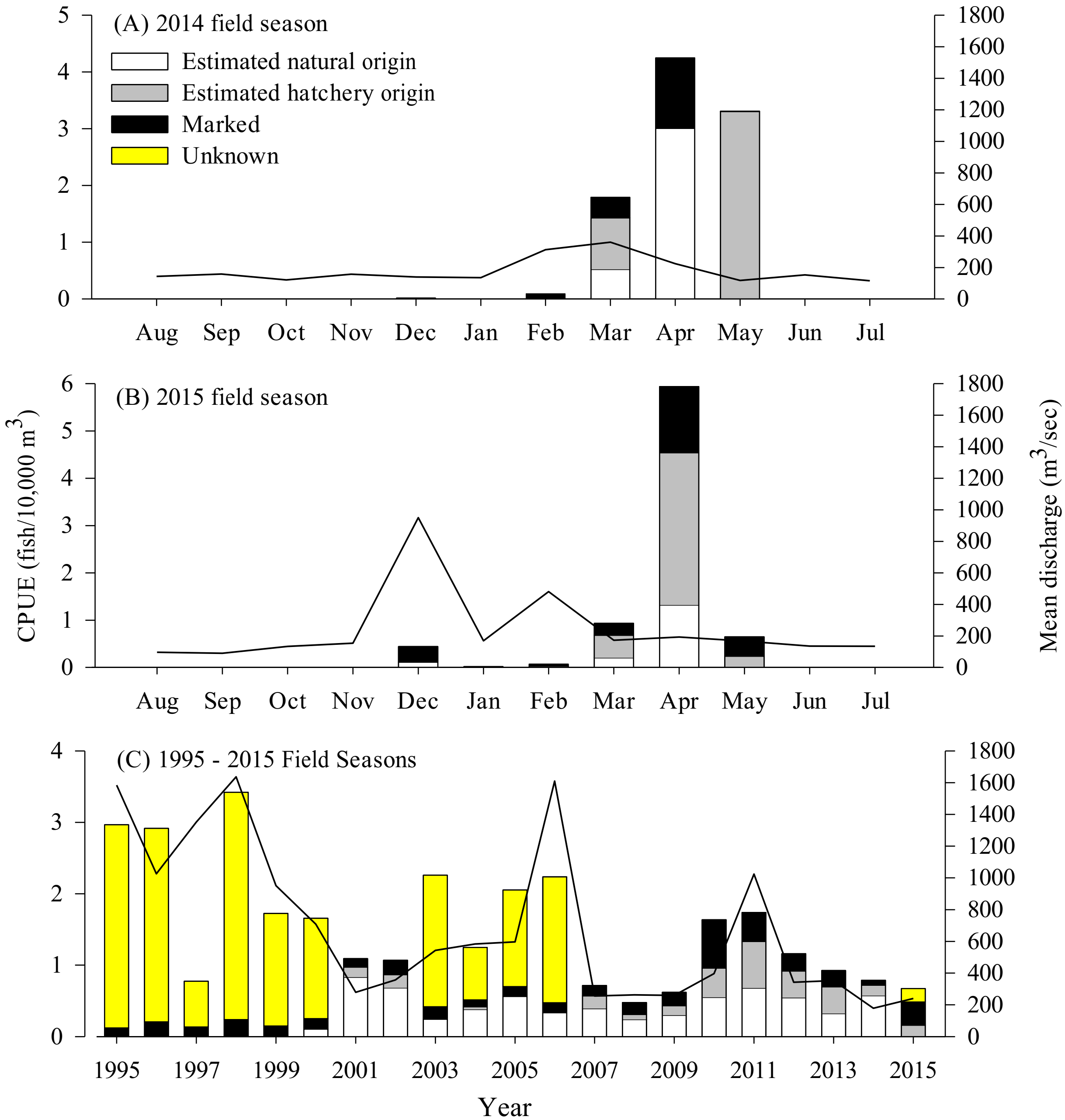


Figure 25. The mean monthly and yearly CPUE (bars) of juvenile fall-, late fall-, and spring-run Chinook Salmon captured in MWTRs at the Chipps Island Trawl Site, and the estimated mean monthly and yearly Delta outflow (solid line) during the **(A)** 2014, **(B)** 2015, and **(C)** 1995 through 2015 field seasons.

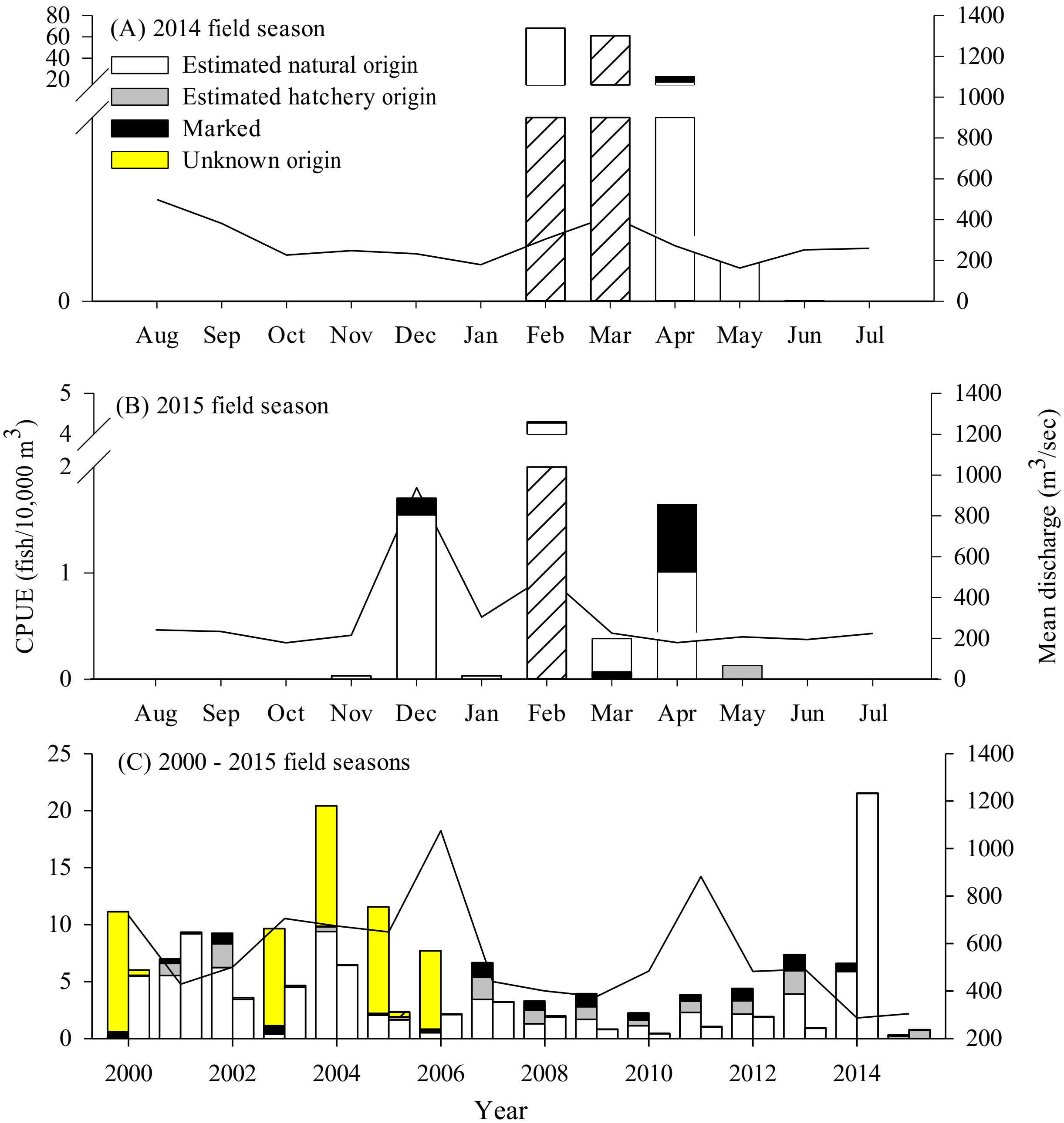


Figure 26.The mean monthly and yearly CPUE (bars) of juvenile fall-, late fall-, and spring-run Chinook Salmon captured in MWTRs (solid bars) and KDTRs (striped bars) at the Sacramento Trawl Site, and the mean monthly and yearly Sacramento River discharge at Freeport (solid line) during the (A) 2014, (B) 2015, and (C) 2000 through 2015 field seasons.

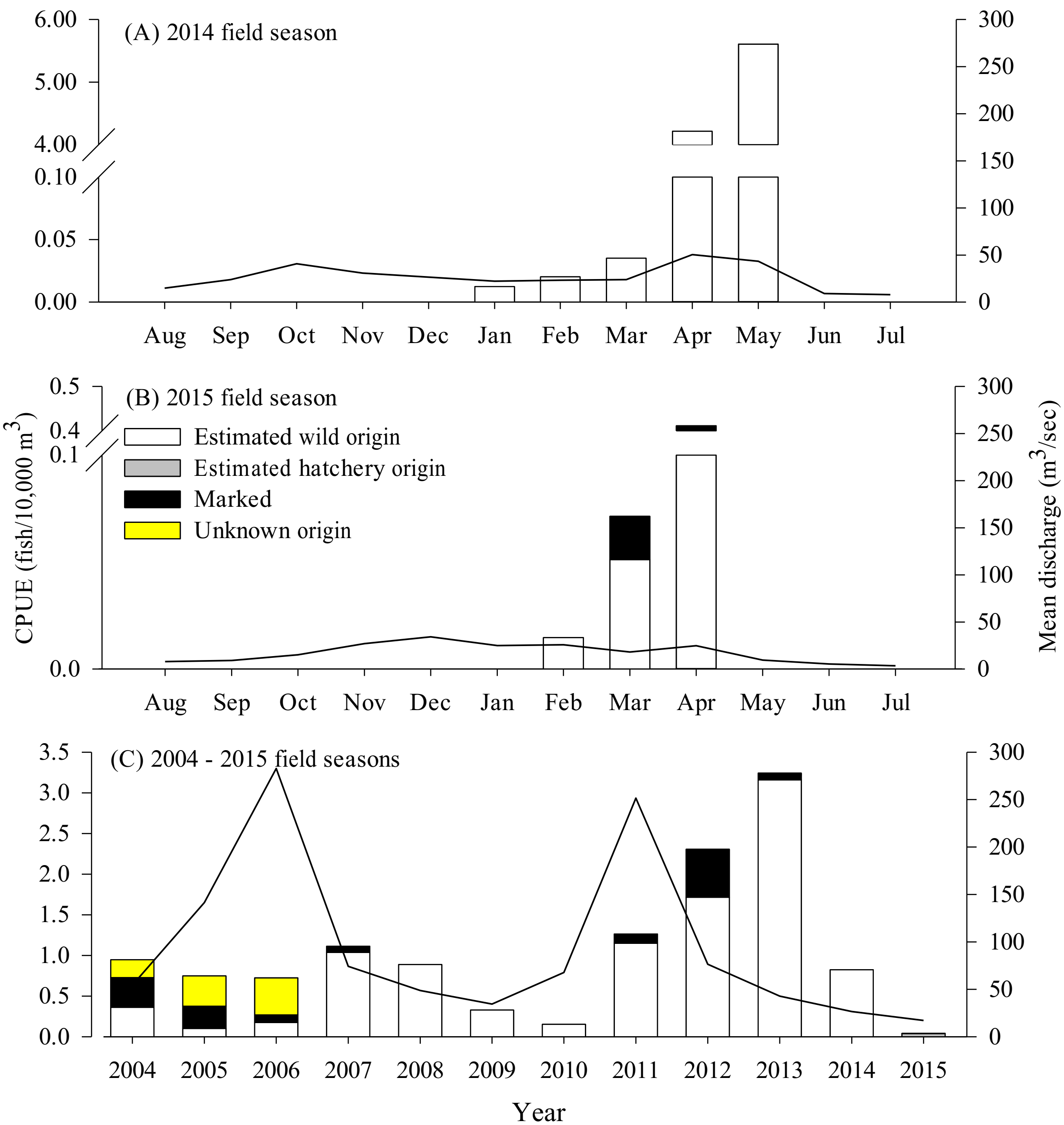


Figure 27. The mean monthly and yearly CPUE (bars) of juvenile fall-, late fall-, and spring-run sized Chinook Salmon captured in KDTRs at the Mossdale Trawl Site, and the mean monthly and yearly San Joaquin River discharge at Vernalis (solid line) during the (A) 2014, (B) 2015, and (C) 2004 through 2015 field seasons. Juvenile Chinook Salmon captured at Mossdale are assumed to be fall-run only.

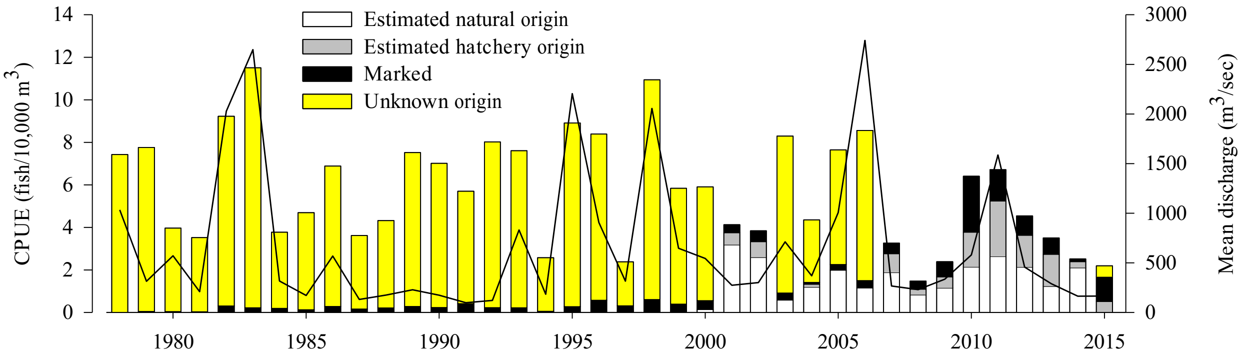


Figure 28. Mean yearly CPUE (bars) of juvenile fall-, late fall-, and spring-run sized Chinook Salmon captured in MWTRs at the Chipps Island Trawl Site, and the estimated mean monthly and yearly Delta outflow (solid line) during April–June of the 1978–2015 field seasons.

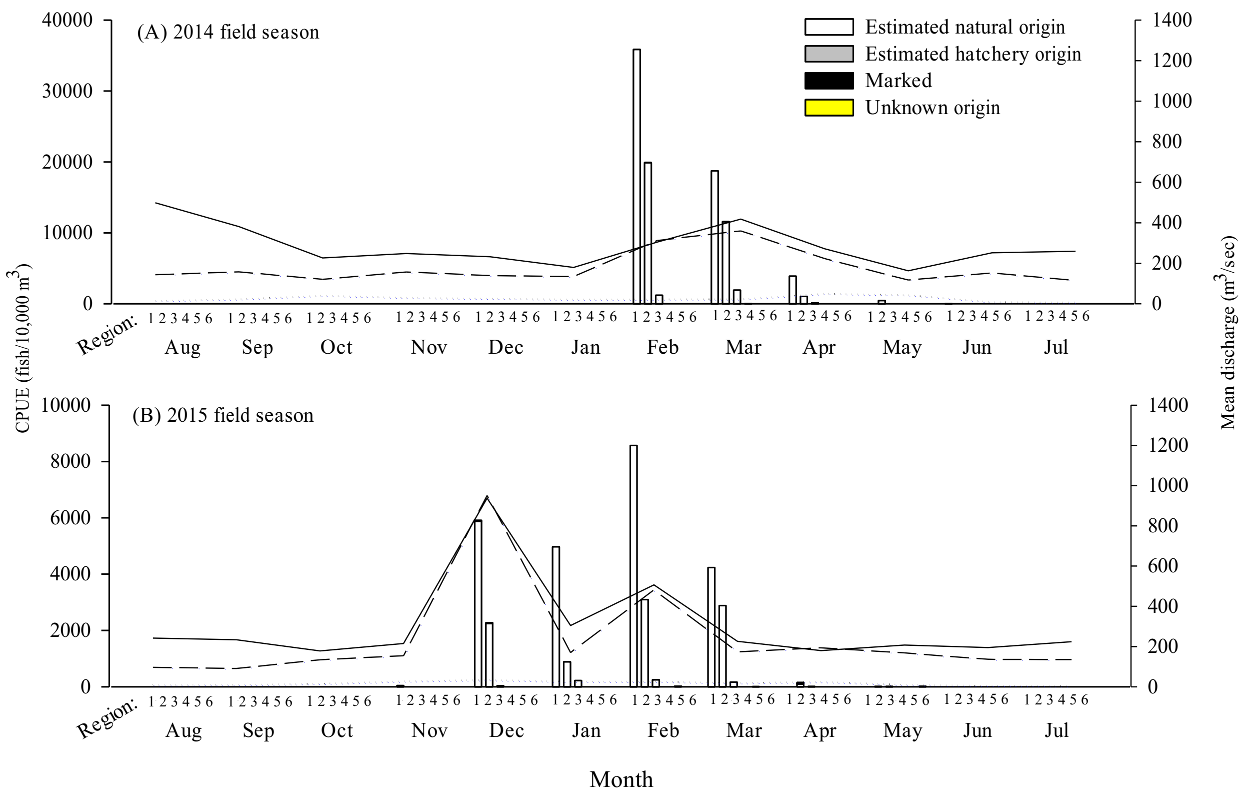


Figure 29. The mean monthly CPUE (bars) of juvenile fall-, late fall-, and spring-run sized Chinook Salmon captured within the Lower Sacramento River (1), North Delta (2), Central Delta (3), South Delta (4), Lower San Joaquin River (5), and San Francisco and San Pablo Bay (6) beach seine regions, and the estimated mean monthly and yearly Delta outflow (dashed line), Sacramento River discharge at Freeport (solid line), and San Joaquin River discharge at Vernalis (dotted line) during the (A) 2014 and (B) 2015 field seasons.

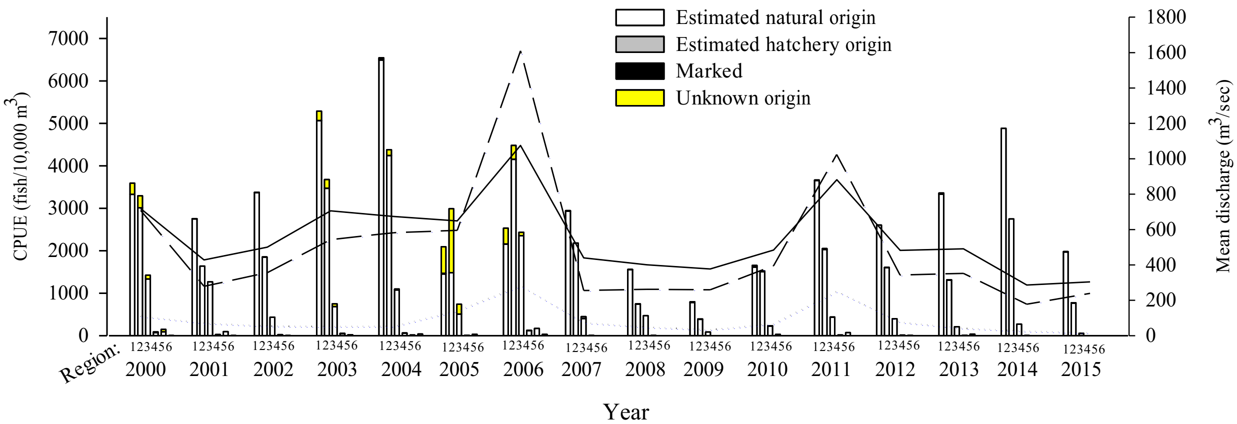


Figure 30. The mean yearly CPUE (bars) of juvenile fall-, late fall-, and spring-run sized Chinook Salmon captured within the Lower Sacramento River (1), North Delta (2), Central Delta (3), South Delta (4), Lower San Joaquin River (5), and San Francisco and San Pablo Bay (6) beach seine regions, and the estimated mean monthly and yearly Delta outflow (dashed line), Sacramento River discharge at Freeport (solid line), and San Joaquin River discharge at Vernalis (dotted line) during the 2000 through 2015 field seasons.

Absolute Abundance

Among the 130 release groups used to estimate the $\overline{TRR}$ at the Chipps Island Trawl Site, 12,655,350 fish were marked with a CWT (PSMFC 2017). Release groups ranged in size from 22,911 to 717,966 individuals. The $\overline{TRR}$ at the Chipps Island Trawl Site was estimated to be 0.48% ± 0.08% (mean ± 95% CI), using CWT recoveries from 1989 to 2015. The duration of recoveries of CWT fish within a release group spanned, on average, 10.1 days.

We used 42 release groups to estimate the $\overline{TRR}$ of the MWTR at the Sacramento Trawl Site. Within these release groups, 2,398,810 fish were marked with a CWT. Release groups ranged in size from 34,480 to 104,516 individuals. The duration of recoveries of CWT fish within a release group spanned, on average, 10.8 days. Two of the release groups did not have any individuals captured at the site. The $\overline{TRR}$ of the Sacramento MWTR was estimated to be 0.82% ± 0.35%, using CWT releases from 1988 to 2009. We used 5 release groups to estimate the $\overline{TRR}$ of the KDTR at the Sacramento Trawl Site, where a total of 300,960 fish were marked with a CWT (PSMFC 2015). Release groups ranged in size from 48,987 to 69,490 individuals. The duration of recoveries of CWT fish within a release group spanned, on average, 4.9 days. The $\overline{TRR}$ of the KDTR was estimated to be 0.74% ± 0.87% between 1996 and 2006.

There were 53 release groups used to estimate the $\overline{TRR}$ at the Mossdale Trawl Site. Among these release groups, 438,529 individuals were marked either with stain dye (Steve Tsao, CDFW, personal communication) or an adipose fin clip and contained a CWT (PSMFC 2017). Release groups ranged in size from 1,195 to 74,411 individuals. The $\overline{TRR}$ was estimated to be 2.88% ± 3.00%, using CWT and stain dye releases from 1997 to 2015. The duration of recoveries of marked fish within a release group spanned, on average, 1 day. Six of the release groups did not have any recoveries. While the $\overline{TRR}$ rate for the CWT groups (0.64% ± 0.83%) at Mossdale was comparable with the estimate for the Chipps Island and Sacramento trawl sites (0.48% ± 0.08% and 0.82% ± 0.35%, respectively; see above), the $\overline{TRR}$ of the stain dye groups were considerably higher (6.52% ± 4.93%). The increased recoveries may be due to unintentional targeting of marked fish or a time effect. In general, CWT releases at Mossdale occurred at random relative to sampling at the Mossdale Trawl Site, whereas spray dye fish were released at the beginning of a sample day (SJRGA 2009).

The $\overline{TRR}$ had a negative lower 95% confidence limit for both the Sacramento Trawl Site (KDTR) and the Mossdale Trawl Site, which is due to relatively small sample sizes coupled with considerable variation among samples. Because a negative or zero value of $\overline{TRR}$ results in an absolute abundance of infinity, and the lower $\overline{TRR}$ confidence limit was used to estimate the upper absolute abundance confidence limit, we assigned the lower $\overline{TRR}$ confidence limit as 0.10% in order to provide absolute abundance confidence limits. This value was chosen based on a conservative comparison to the lower $\overline{TRR}$ confidence limits at the Chipps Island and Sacramento (MWTR) trawl sites (0.40% and 0.47%, respectively; see above). We highly recommend further investigation of the efficiency of each of the trawls to obtain more precise and accurate absolute abundance estimates that can be used to inform future management decisions within the San Francisco Estuary and its watershed.

We estimated, on average, a total of 172,753 (83% natural origin, 16% marked) and 260,630 (17% natural origin, 82% marked) juvenile winter-run sized Chinook immigrating into the Delta at the Sacramento Trawl Site during the 2014 and 2015 field seasons, respectively (Figure 31). However, a total of 243,554 (80% natural origin, 20% marked) and 367,238 (31% natural origin, 69% marked) juvenile winter-run sized Chinook were estimated to emigrate from the Delta at Chipps Island during the 2014 and 2015 field seasons, respectively (Figure 32). Since we estimated that more winter-run sized Chinook exited the Delta than entered the Delta in 2014 and 2015, no reproduction of winter-run Chinook can occur in the Delta, and no hatchery releases of winter-run Chinook were made downstream of the Sacramento Trawl Site; from our data we believe that either the absolute abundance of winter-run Chinook at Chipps Island is over-estimated or the absolute abundance at the Sacramento Trawl Site is under-estimated. It might be more likely that the absolute abundance at Chipps Island is over-estimated, since the river LDC has been shown to over-estimate a higher number of genetic winter-run at Chipps Island than at the Sacramento Trawl Site (Dekar et al. 2013). Regardless, it is apparent that the abundance of winter-run sized Chinook at Chipps Island is highly variable and has declined considerably since the 1990s (Figure 32).

The mean yearly absolute abundance of all juvenile fall-, late fall-, and spring-run sized Chinook immigrating into the Delta at Sacramento was estimated to be 38,409,509 and 1,580,919 individuals during the 2014 and 2015 field seasons, respectively (Figures 33 and 34). We estimated, on average, a total of 37,946,318 (98.2% natural origin, 1.1% hatchery origin, 0.5% marked) and 1,555,565 (92.3% natural origin, 0.02% hatchery origin, 7.6% marked) juveniles at the Sacramento Trawl Site during the 2014 and 2015 field seasons (Figure 33). Additionally, 463,191(100% natural origin) and 25,354 (96.4% natural origin, 3.5 marked) juveniles were estimated at the Mossdale Trawl Site during the 2014 and 2015 field seasons (Figure 34). At the Chipps Island Trawl Site, we estimated a total of 9,770,455 (71.9.5% natural origin, 19.3% hatchery origin, 8.7% marked) and 7,430,738 (23.7% natural origin, 50.6% hatchery origin, 25.6% marked) juveniles emigrating from the Delta during the 2014 and 2015 field seasons (Figure 35).

The absolute abundance estimates for juvenile Chinook presented in this report likely contain bias from several sources, in addition to potentially inaccurate race designations caused by the application of the LDC. Firstly, we assumed that unmarked individuals were never recaptured. However, nine CWT individuals in 2014 and five CWT individuals in 2015 that were released downstream of Chipps Island (San Pablo Bay) were captured by the Chipps Island MWTR (Tables A.20 and A.21). This points to the possibility of recapturing fish multiple times at one location, a violation of our assumption. Therefore, our abundance estimates may be over-estimated to an unknown degree. Secondly, we may have under-estimated the absolute abundance of juvenile Chinook at each of the trawl sites due to the possible size selectivity of the MWTR's and KDTR's cod end design and mesh. Thirdly, we assumed that juvenile Chinook were equally distributed in time, which is unlikely due to diel migratory patterns. Several studies have shown primarily nocturnal migratory behavior in juvenile Chinook (Gaines and Martin 2002; Williams 2006 and references therein), while some studies in the Delta have provided evidence for diurnal migration of juvenile Chinook during the spring (Buchanan 2015; Wilder and Ingram 2006). While Bradford and Higgins (2001) mostly observed nocturnal activity, additional observations of a variety of diel activity patterns in the Bridge River of British Columbia led them to conclude that diel activity is caused by individual fish responding to fine-scale habitat attributes and is difficult to generalize. Given that the DJFMP only samples during the day, any diel activity patterns of juvenile Chinook could produce an unknown effect on the estimate of absolute abundance at all sampling locations. More investigation is needed to understand the effect of diel migratory patterns of juvenile Chinook on catch efficiency.

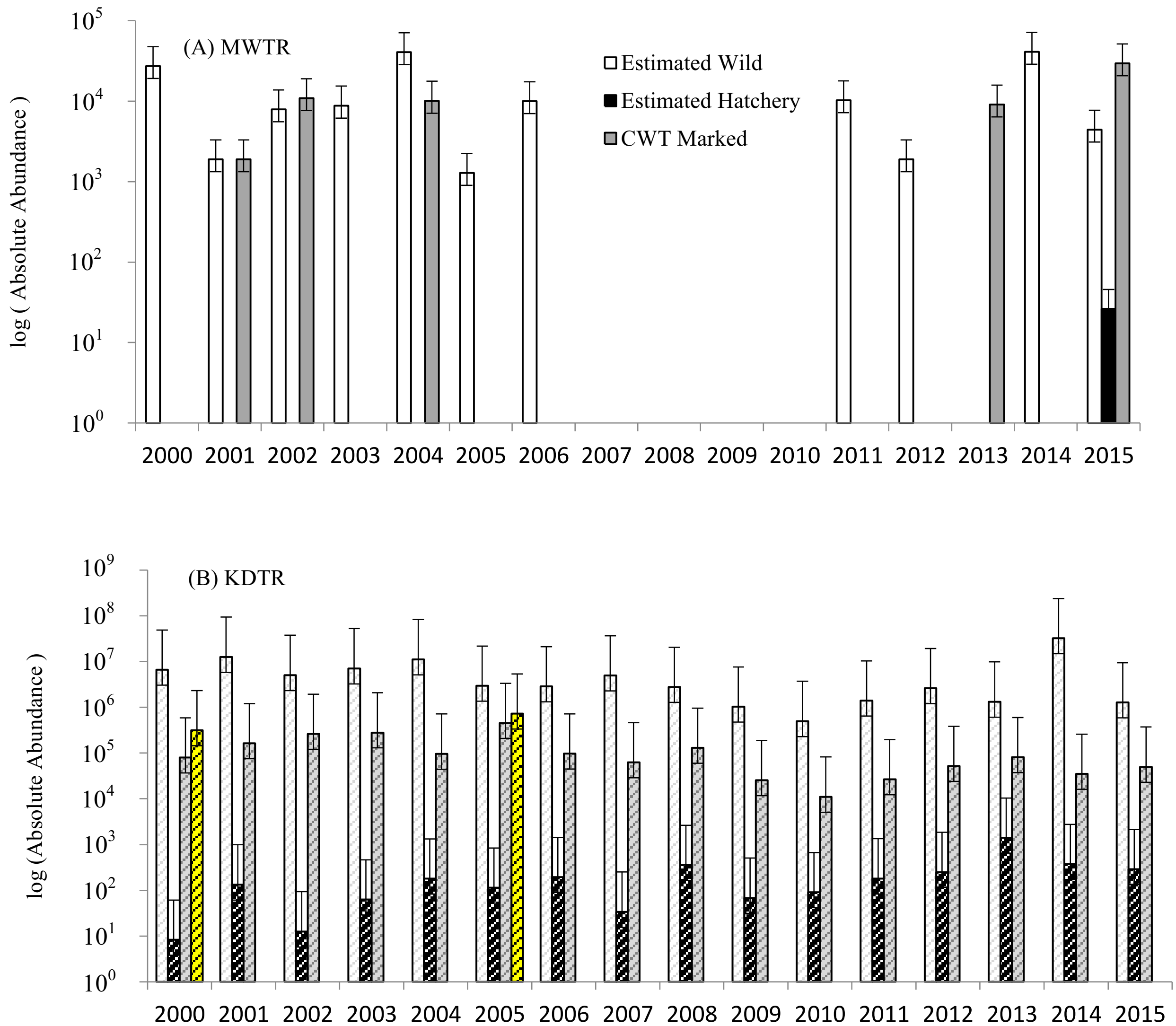


Figure 31. Mean absolute abundance estimates and their 95% confidence intervals for juvenile winter-run sized Chinook Salmon at the Sacramento Trawl Site when (A) MWTRs (solid bars) and (B) KDTRs (striped bars) were used during the 2000–2015 field seasons. The y-axis is presented on a common log scale.

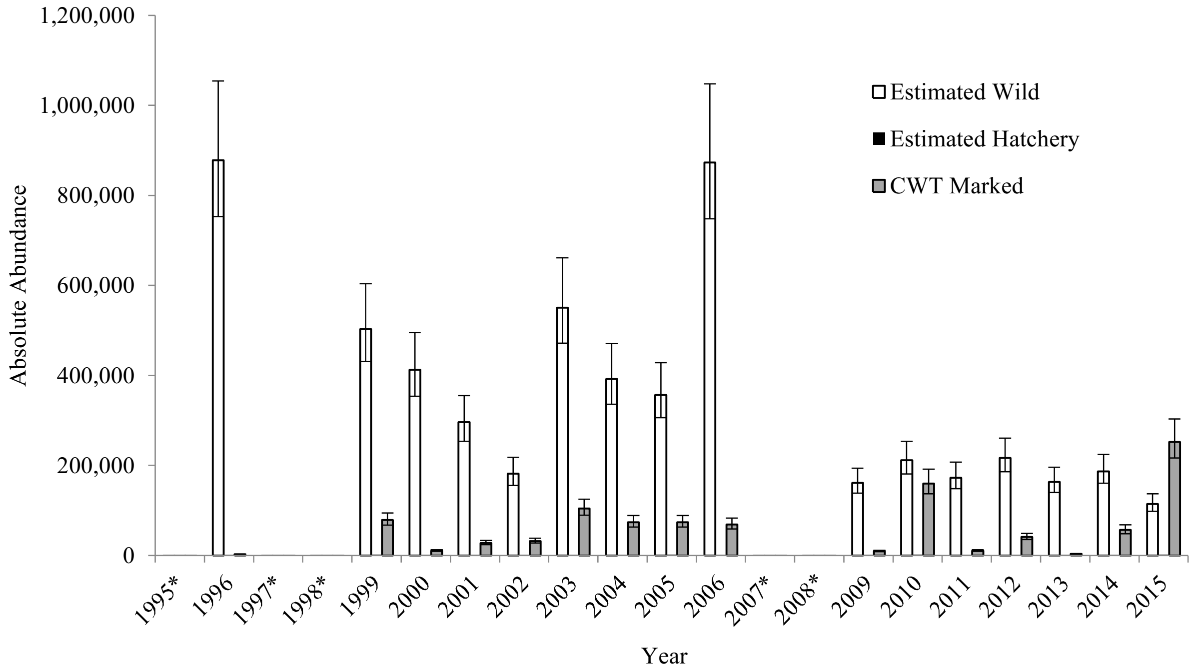


Figure 32. Mean absolute abundance estimates and their 95% confidence intervals for juvenile winter-run Chinook Salmon at the Chipps Island Trawl Site during the 1995–2015 field seasons. Years with asterisks indicate that 1 or 2 months of that field season were not sampled, which may bias the low annual estimate.

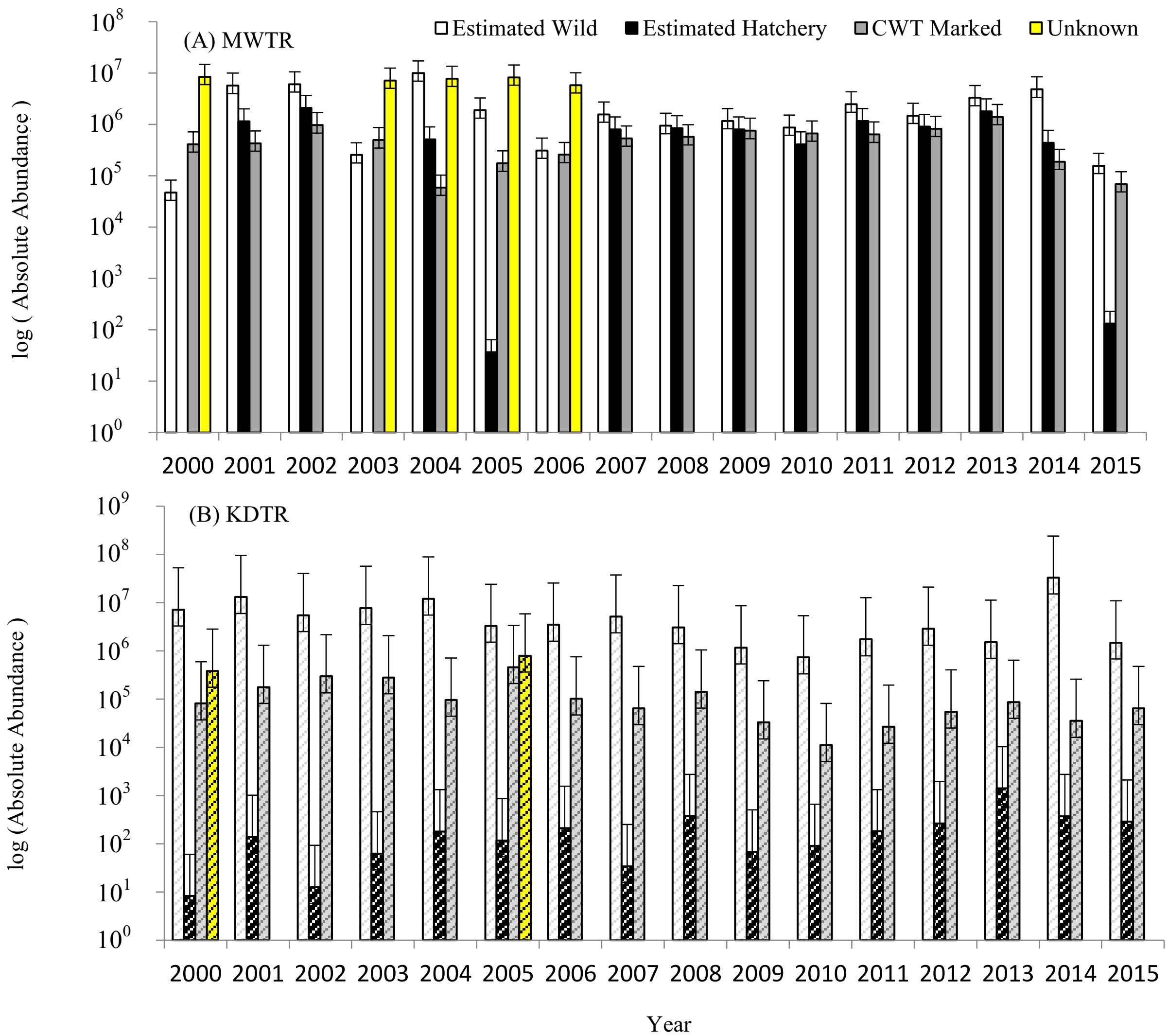


Figure 33. Mean absolute abundance estimates and their 95% confidence intervals for juvenile fall-, late fall-, and spring-run Chinook Salmon at the Sacramento Trawl Site when (A) MWTRs (solid bars) and (B) KDTRs (striped bars) were used during the 2000–2015 field seasons. The y-axis is presented on a common log scale.

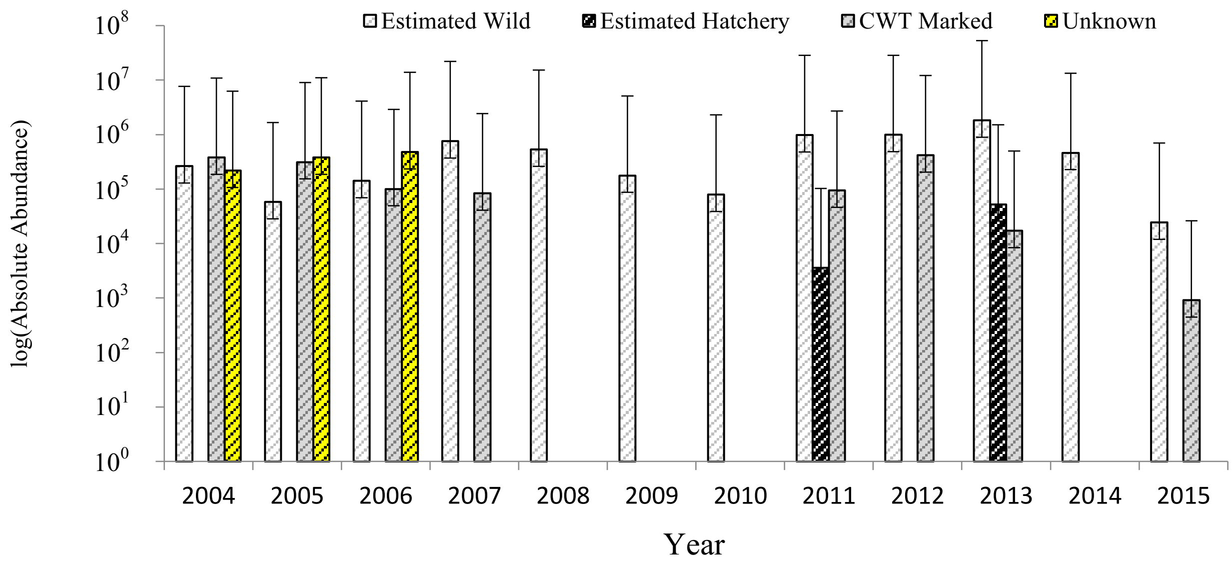
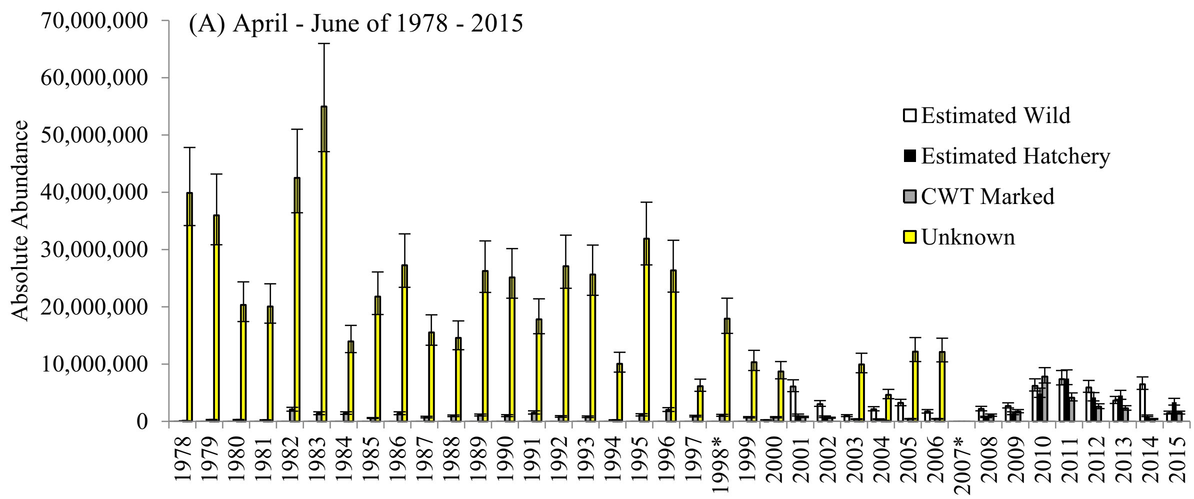


Figure 34. Mean absolute abundance estimates and their 95% confidence intervals for juvenile fall-, late fall-, and spring-run Chinook Salmon at the Mossdale Trawl Site during the 2004–2015 field seasons. The y-axis is presented on a common log scale. Juvenile Chinook Salmon captured at Mossdale are assumed to be fall-run only.



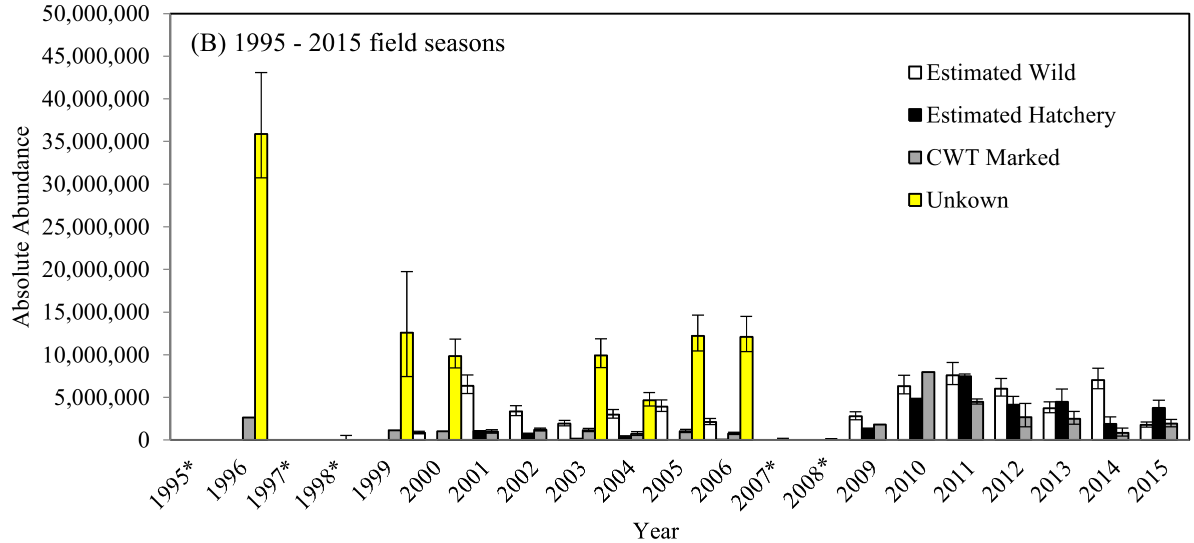


Figure 35. Mean absolute abundance estimates and their 95% confidence intervals for juvenile fall-, late fall-, and spring-run Chinook Salmon at the Chipps Island Trawl Site (A) during April–June during the 1978–2015 field seasons and (B) year-round during the 1995–2015 field seasons. Years with asterisks indicate that 1 or 2 months of that field season were not sampled, which may bias low the annual estimate.

Fork Length Distributions

Unmarked juvenile Chinook varied considerably in size between seine regions and trawl sites during the 2014 and 2015 field seasons (Figures 36–40). At the Chipps trawl site and at Mossdale, juvenile Chinook tended to be larger in 2015 relative to 2014. However, the apparent size difference between years was not observed at Sacramento. The majority of salmon were identified as fry (FL<70 mm; Kjelson et al. 1982) and individuals were slightly larger (1–6 mm FL) within most seine regions and trawl sites during the 2015 field season. The FL distribution of unmarked juvenile Chinook captured during both the 2014 and 2015 field seasons ranged from 37–567 mm using the MWTR at the Chipps Island Trawl Site (Figure 36). At the Mossdale Trawl Site, the FL of fish captured by the KDTR ranged from 34–165 mm (Figure 36). Fish captured by the KDTR and MWTR at the Sacramento Trawl Site ranged from 25–143 mm and 34–300 mm (FL), respectively (Figure 37). For beach seines, the range was 27–142 mm in 2014 and 29–189 mm during the 2015 field season (Figures 38–40). In contrast to beach seine catches, the majority of fishes captured by MWTR trawls in 2014 and 2015 were identified as smolts (FL≥70 mm; Kjelson et al. 1982). However, fishes captured within the KDTR at the Sacramento Trawl Site during both years were generally identified as fry. Our results are largely consistent with the observations made between the 2010 to 2013 field seasons (Speegle et al. 2013, Barnard et al. 2015) and indicate that fry- and smolt-sized individuals occupy both open water mid-channel and near shore littoral habitats.

Although our data and other investigations (e.g., Kjelson et al. 1982) imply that fry may prefer near-shore littoral habitat and that smolts may prefer to occupy open water mid-channel habitat during the day, these patterns could be confounded by the influence of sample bias from variable gear efficiencies (Bayley and Peterson 2001). For example, each trawl site was sampled using varying trawl nets (i.e., Chipps Island=MWTR, Mossdale=KDTR, and Sacramento=KDTR and MWTR), cod-end designs (i.e., Mossdale=live box, Chipps Island=mesh, and Sacramento=mesh and live box), and cod-end mesh sizes (i.e., Chipps Island MWTR=0.8 mm, Mossdale and Sacramento KDTR=0.46 mm, and Sacramento MWTR=0.3 mm), which can greatly affect the gear efficiency for different size classes of fish. Furthermore, the beach seine methods used by the DJFMP are thought to select for smaller individuals based on the fact that larger individuals are more likely able to avoid the gear during sampling. Thus, the DJFMP has completed, and will continue to perform studies on how gear efficiency varies among gear types, methods, and locations.

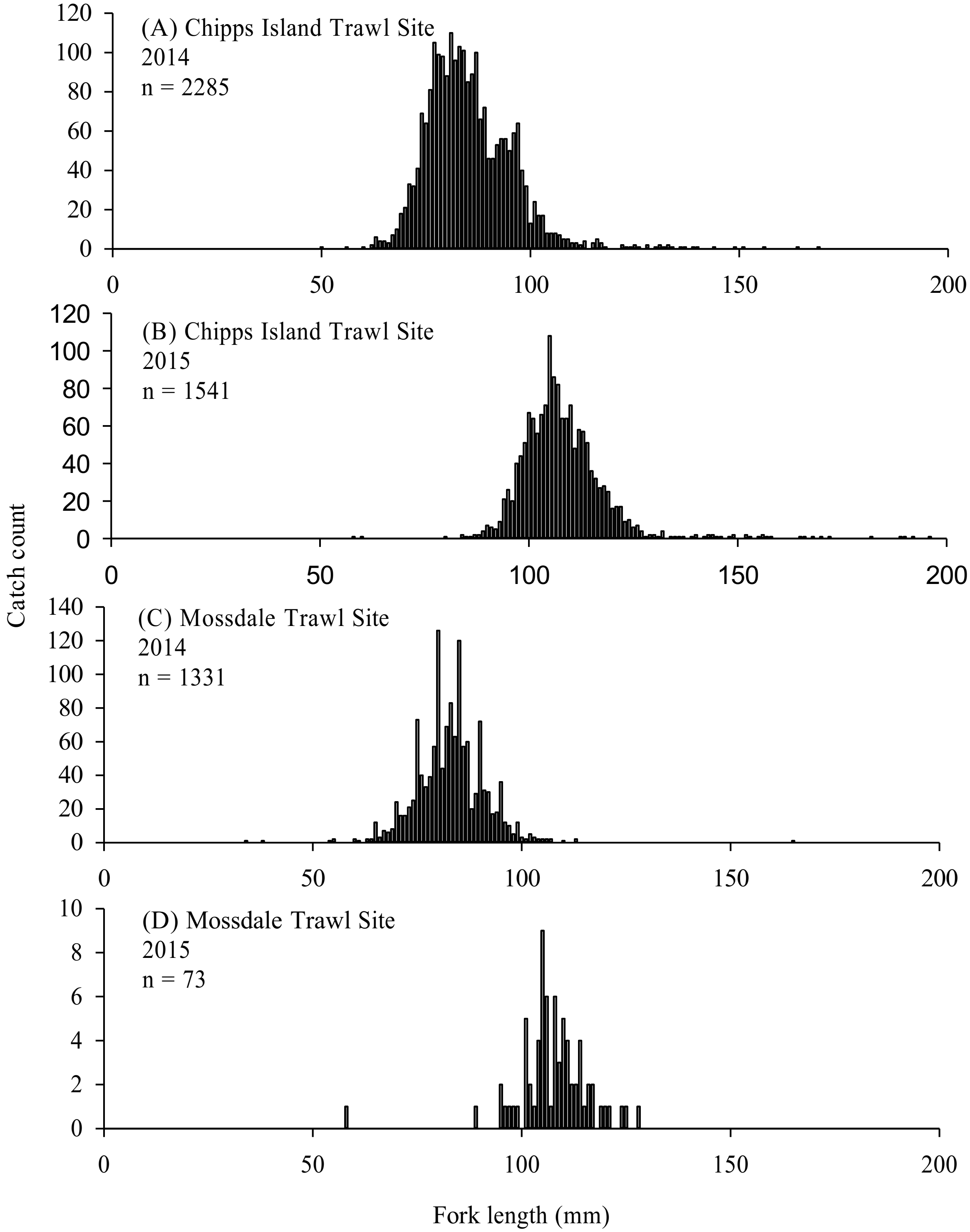


Figure 36. Fork length distributions for juvenile Chinook Salmon captured in MWTRs at the Chipps Island Trawl Site and KDTRs at the Mossdale Trawl Site during the 2014 and 2015 field seasons.

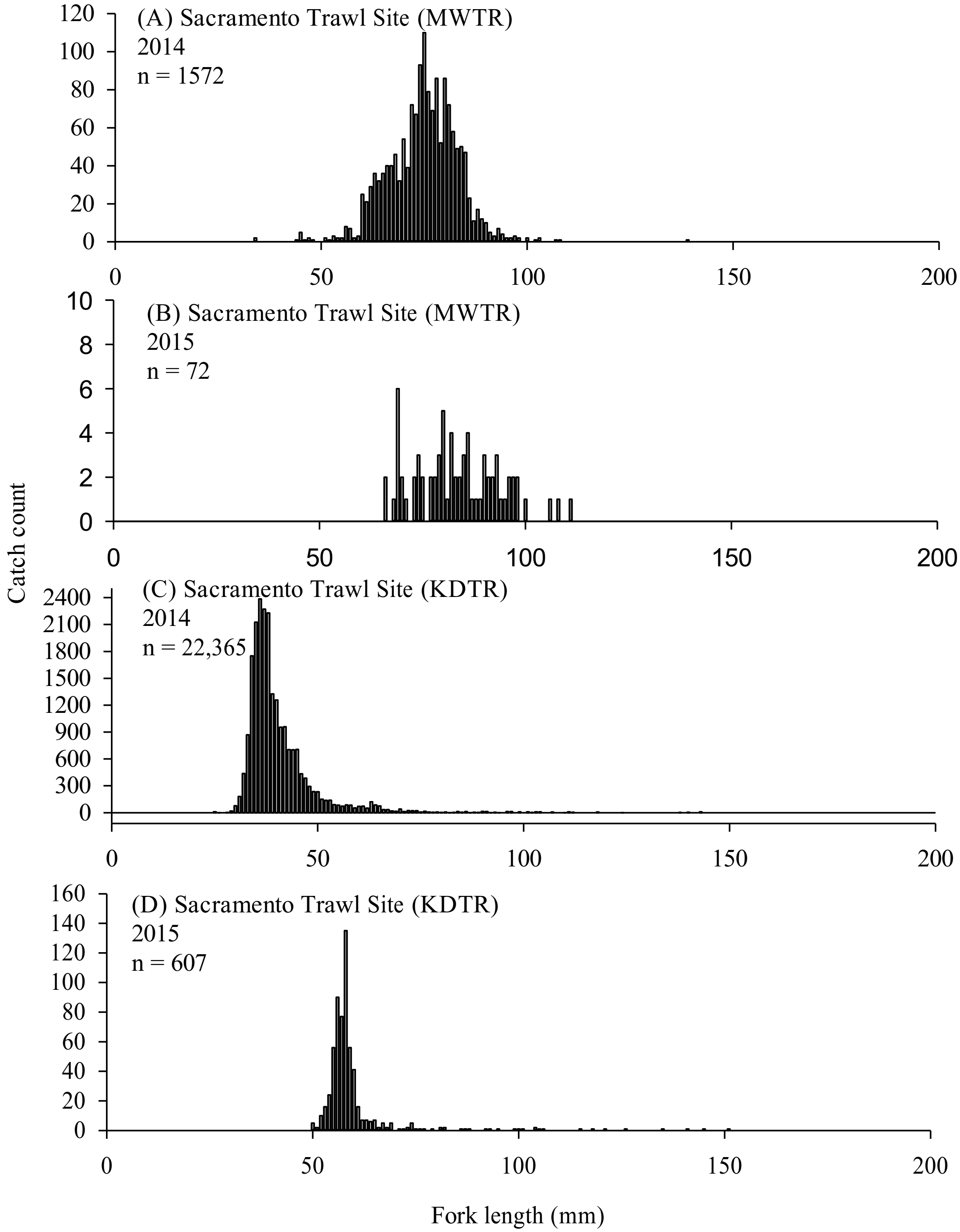


Figure 37. Fork length distributions for unmarked juvenile Chinook Salmon captured in MWTRs and KDTRs at the Sacramento Trawl Site during the 2014 and 2015 field seasons.

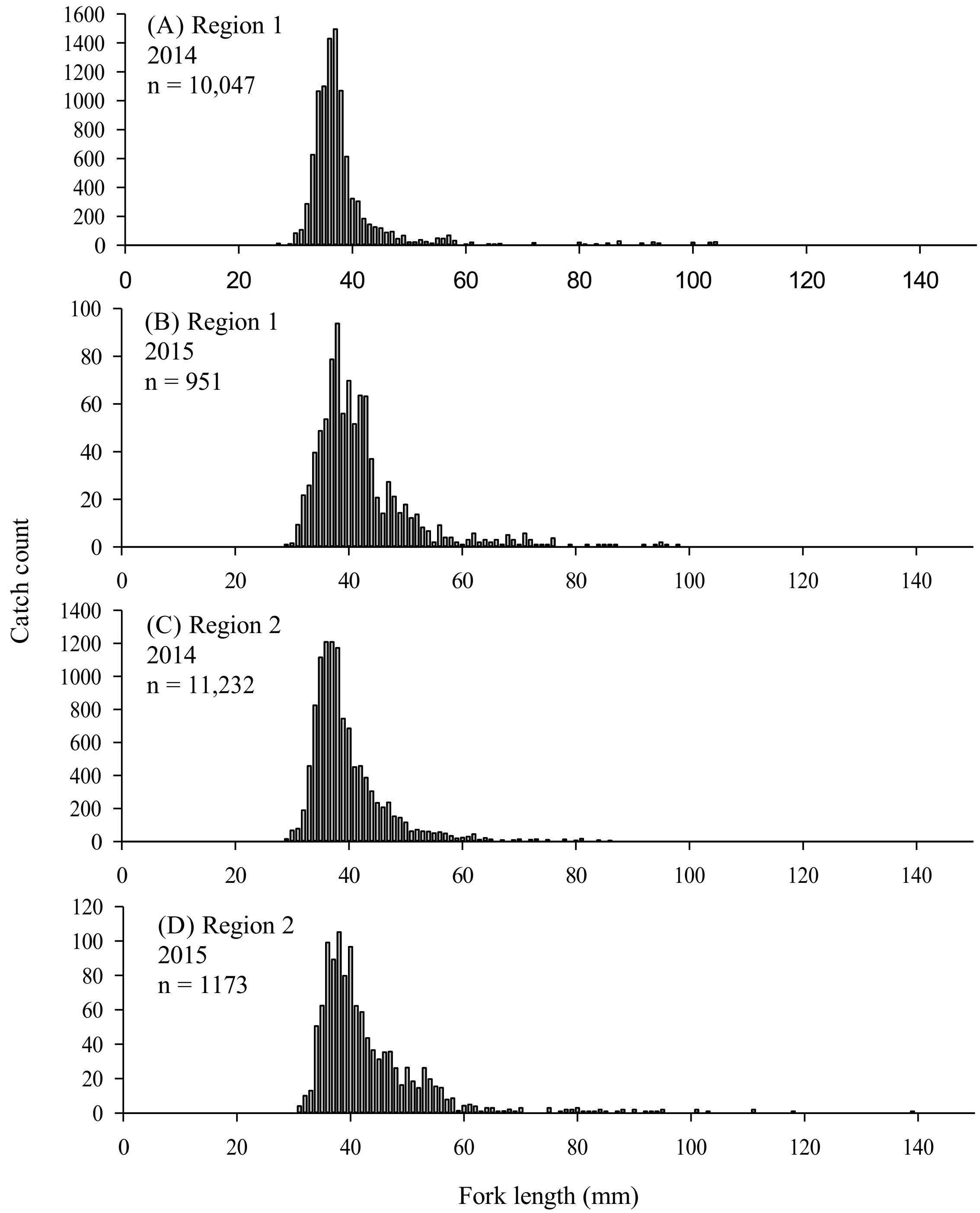


Figure 38. Fork length distributions for unmarked juvenile Chinook Salmon captured in beach seines within the Lower Sacramento River (Region 1) and North Delta (Region 2) beach seine regions during the 2014 and 2015 field seasons.

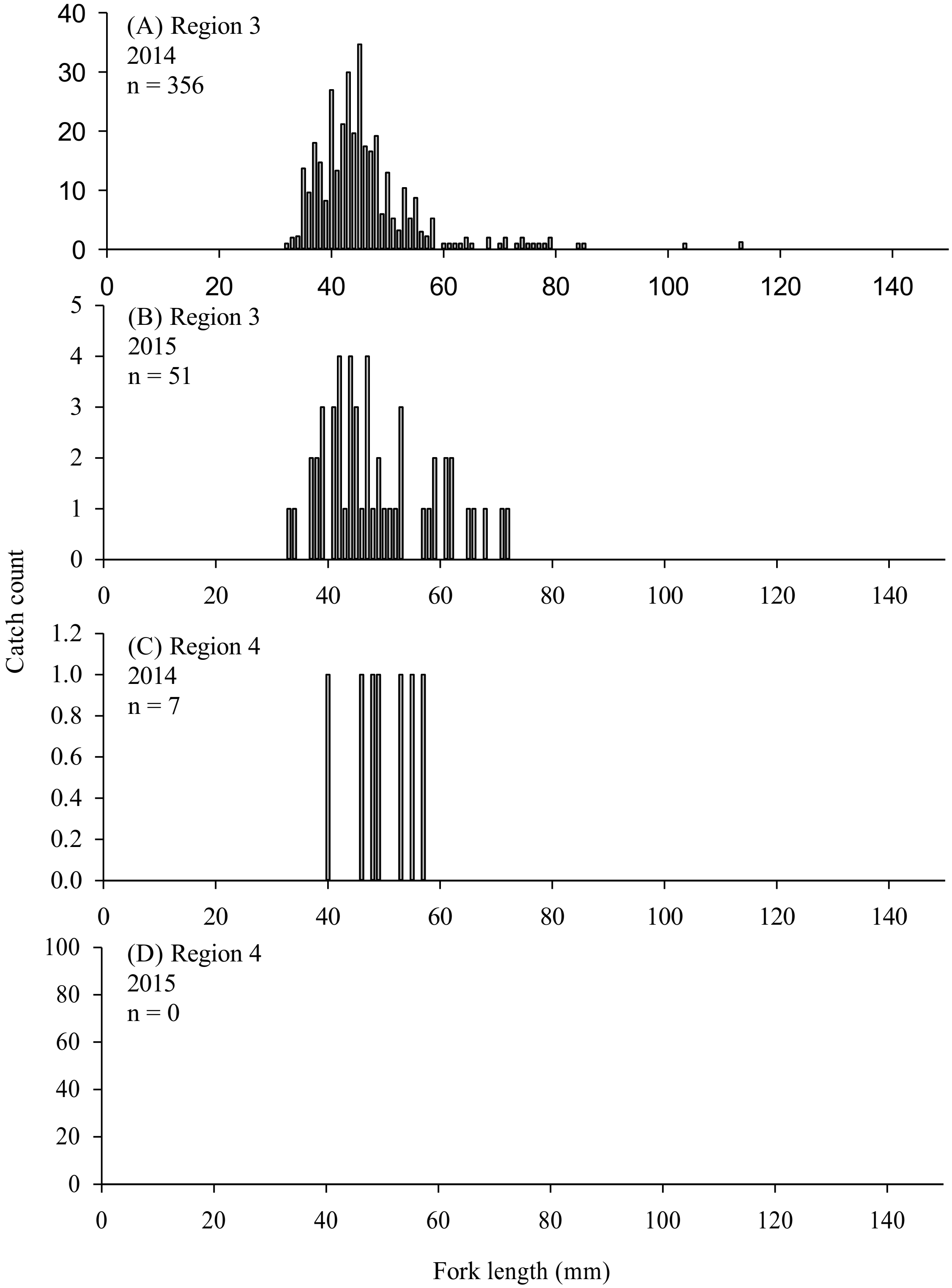


Figure 39. Fork length distributions for unmarked juvenile Chinook Salmon captured in beach seines within the Central Delta (Region 3) and South Delta (Region 4) beach seine regions during the 2014 and 2015 field seasons.

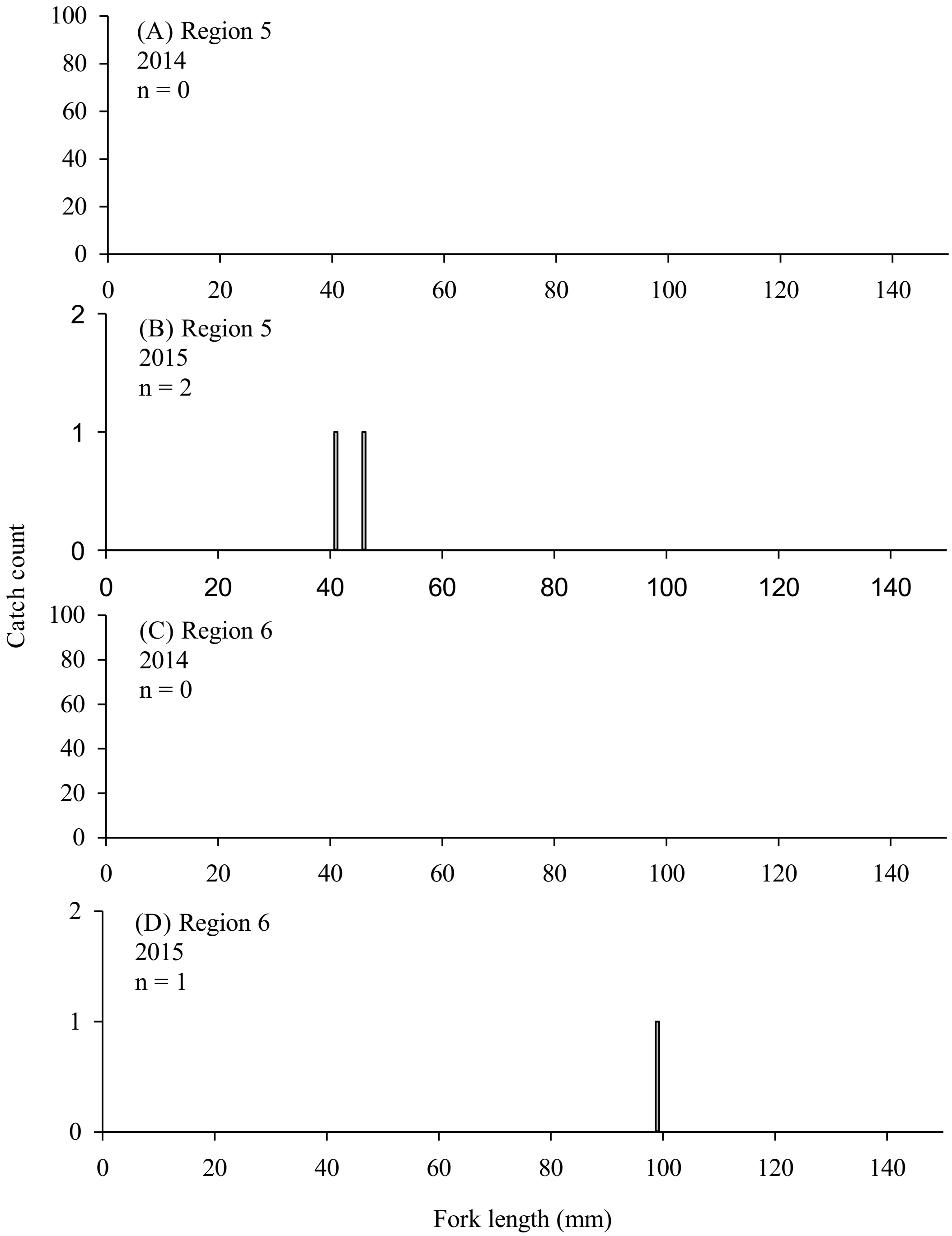


Figure 40. Fork length distributions for unmarked juvenile Chinook Salmon captured in beach seines within the Lower San Joaquin River (Region 5) and San Francisco and San Pablo Bay (Region 6) beach seine regions during the 2014 and 2015 field seasons.

MONITORING FOR DELTA CROSS CHANNEL OPERATIONS

Introduction

The DCC was constructed by the U.S. Bureau of Reclamation (USBR) in 1951 at Walnut Grove, California. The DCC was designed to facilitate the transfer of fresh water from the Sacramento River southwards through the channels of the Mokelumne River system towards the south Delta. Ultimately, water is diverted to the CVP and SWP pumps at Tracy which provide water for agricultural, municipal, and industrial uses within the Central Valley and southern California. The DCC gates enable USBR operators to increase the amount of Sacramento River water for export. Historically, the DCC gates remained open, except during periods of high Sacramento River flow (20,000 to 25,000 cfs at Freeport) when risks of channel scouring or downstream flooding warranted their closure. The USBR currently operates the DCC gates in the open position to (1) improve the transfer of water from the Sacramento River to the CVP and SWP pumping facilities, (2) improve water quality in the southern Delta, and (3) to reduce the amount of Sacramento River flow needed to repel saltwater intrusion into the western Delta.

The operation of the DCC gates alters river flows throughout the Estuary and thereby influences the migration pathways and survival of emigrating juvenile Chinook (Kjelson and Brandes 1989; Kimmerer 2008; Newman and Brandes 2010; Perry et al. 2010). Juvenile salmon of all runs can be diverted into the central Delta when the DCC gates are open. In the central Delta, juvenile Chinook experience lower survival rates than if they stay on the mainstem Sacramento River (Brandes and McLain 2001; Newman and Brandes 2010). The lower survival in the central Delta may be due to water export, high water temperatures, predation and pollution (Moyle, 1994, Kimmerer 2008, Newman and Brandes, 2010). Because ESA-listed species, including spring-run and winter-run Chinook, are affected by DCC operations, the state and federal fishery agencies have called for the closure of the DCC gates to reduce the entry of juvenile salmon into the central Delta.

In 1978, the State Water Resources Control Board (SWRCB) instituted a decision (D-1485) to amend the water right permits of the CDWR and USBR for the SWP and the CVP facilities, respectively (SWRCB 1978). This decision mandated that in addition to reducing direct water diversion at the project pumps and releasing stored or natural water flows, DCC gate operations could be used to ensure adequate river flow for salinity control and to improve water quality for fish and wildlife in the estuarine ecosystem. The 1995 Water Quality Control Plan (WQCP) for the San Francisco Estuary (95-1) included specific guidelines for the operation of the DCC gates for the protection of threatened or endangered fish (SWRCB 1995), which were reaffirmed by the SWRCB in 1999 (D-1641) and the 2006 WQCP for the San Francisco Estuary (SWRCB 2006). Recovery and Biological Opinions for the protection of juvenile winter-run and spring-run Chinook were the basis for the salmon decision processes in controlling DCC gate operations for the protection of ESA-listed species (NMFS 2009b).

Further modifications of DCC gate operations were instituted through the 2009 NMFS RPA, with 2011 amendments (NMFS 2011) that resulted from 2010 independent review panel report (Anderson et al. 2010). The current DCC operation plan (NMFS 2011, Action IV.1.2) mandates that the DCC gates be closed from October through November if fish species of management concern are present. Contingent upon water quality conditions, the DCC gates remain closed from December through January except during experiments approved by NMFS investigating fish migration patterns occurring from December 1 through December 14 (Table 2). The NMFS RPA mandates DCC closures from February 1 to May 20 for a maximum of 14 days between May 21 and June 15 if requested (NMFS 2011).

To facilitate coordination among the fishery resource agencies and project operators, a salmon decision process (refer to NMFS 2011 for the current process, Action IV.1.2) was drafted by NMFS to minimize the impact of the DCC on emigrating salmonids and Green Sturgeon *Acipenser medirostris*. Once the salmon decision process is triggered, depending on the magnitude of the catch and the water quality, recommendations are made to USBR through the Delta Operations for Salmonids and Sturgeon group (DOSS) to close the DCC gates (Table 2). The DOSS group is a technical advisory group made up of NMFS, USFWS, CDWR, CDFW and USBR (NMFS 2011, Action IV.5). The Knights Landing Catch Index (KLCI) and the Sacramento Catch Index (SCI) are the criteria upon which the first action is based for closing the DCC gates. The KLCI is calculated using catch data from the CDFW rotary screw trap located at Knights Landing. The SCI is generated from beach seine and trawl catch data collected by the DJFMP on the Sacramento River.

The catch data are provided to the DOSS group through the Data Assessment Team (DAT) report. The SCI, used alone or in conjunction with the KLCI or increases in the average daily flow rates, may trigger various actions of the Salmon Decision Process (Table 2). In this section of the report, we will discuss how the relative abundance indices of unmarked winter-run sized or older juvenile Chinook occurring near Sacramento informed real-time DCC water operation decisions.

Methods

The SCI was calculated using unmarked juvenile Chinook catch data collected either at the Sacramento Trawl Site or within the Sacramento Area Seine Region (Table 1; Figure 41). In general, the Sacramento Trawl Site was sampled three days per week from October through January during the 2014 and 2015 field seasons. In addition, eight beach seine sites located within the Sacramento Area Seine Region were sampled three days per week from October through December and one day per week in January (Tables A.23 and A.24). The increased sampling frequency of the beach seines during October through December was intended to better detect winter-run sized or older juvenile Chinook migrating near the DCC and inform real-time water diversion decisions (NMFS 2011). The frequency of sampling at the Sacramento Trawl Site did not increase during this period, but each year the Sacramento trawluses a KDTR in place of the MWTR between October and March to sample larger juvenile Chinook. The sampling methodologies and fish processing methods were the same as described earlier within the "Long-Term Monitoring" section. The race of all unmarked juvenile Chinook was categorized using the river LDC developed by Fisher (1992) and modified by Greene (1992).

Table 2. The Salmon Decision Process (NMFS 2011, RPA Action IV.1).

Time	Trigger	Action
Oct 1–Nov 30	Water quality criteria met, Knights Landing Catch Index (KLCI) and/or Sacramento Catch Index (SCI) > 3 and ≤ 5	Close Delta Cross Channel (DCC) gates for 3 days within 24 hours
	Water quality criteria met, KLCI and/or SCI > 5	Close DCC gates until index < 3
	Water quality criteria not met, KLCI and/or SCI > 3	DOSS elevates decision to NMFS & Water Operations Management Team (WOMT)
Dec 1–Dec 14	Water quality criteria are met	DCC gates closed, may be opened for Delta Action 8
	Water quality criteria not met, and KLCI and/or SCI < 3	Open DCC gates until water quality criteria met
	Water quality criteria not met, and KLCI and/or SCI > 3	DOSS elevates decision to NMFS & WOMT
Dec 15–Jan 31	No triggers needed	DCC gates closed
	NMFS-approved experiments conducted	DCC gates may be opened for 5 days
Feb 1–May 20	D-1641 mandatory gate closure	DCC gates closed per water quality criteria
May 21–Jun 15	D-1641 gate operations criteria	DCC gates closed for 14 days, if NMFS warrants

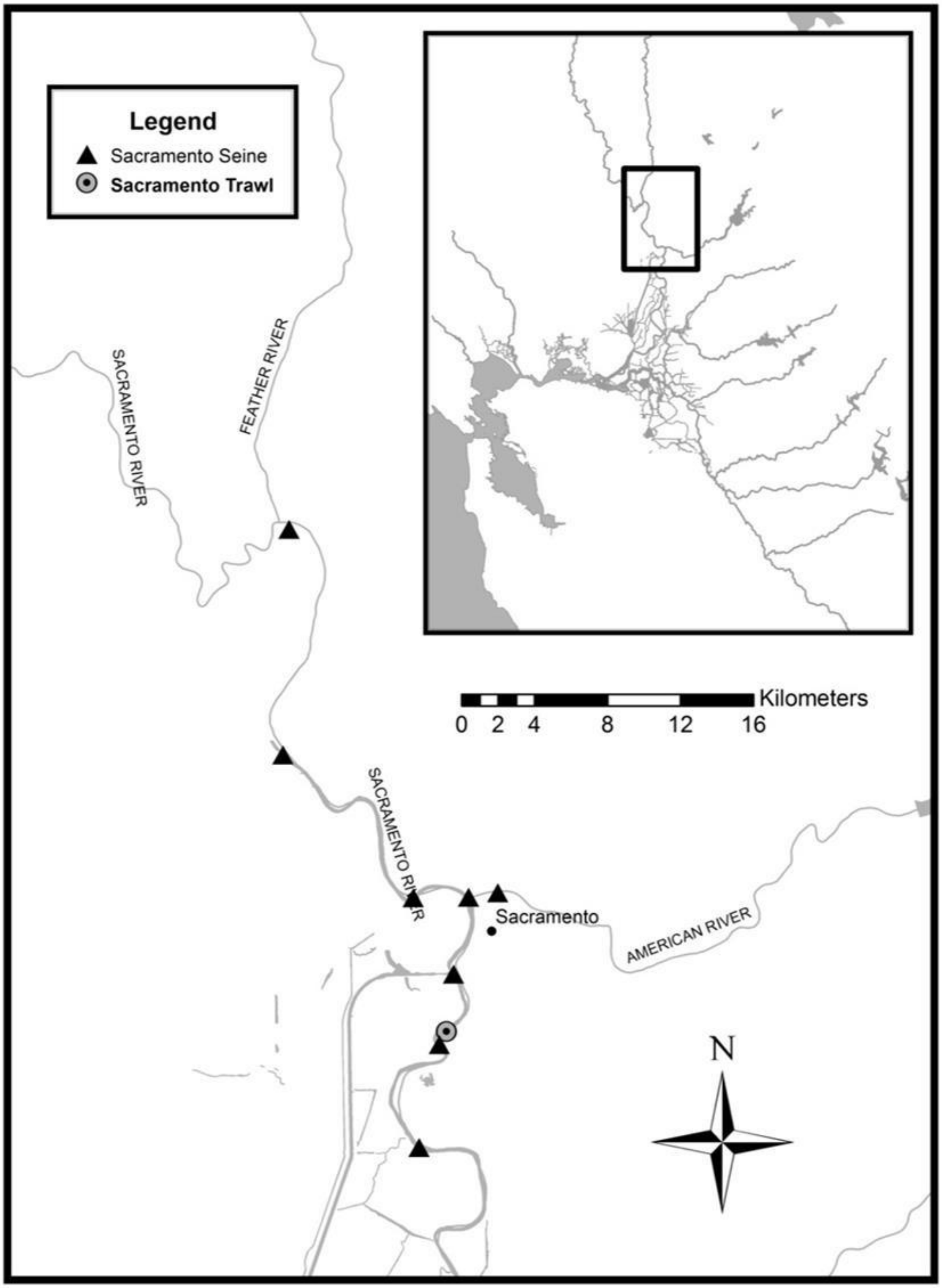


Figure 41. Sampling sites used to trigger Delta Cross Channel closures sampled during the 2014 and 2015 field season within the lower Sacramento River.

The SCI represents the number of winter-run size or larger juvenile Chinook captured within a day at the Sacramento Trawl Site or within the Sacramento Area Seine Region standardized to one day of effort and is calculated as:

$$SCI_{dG} = \frac{\sum Catch_{dG}}{Samples_{dG}} \cdot SE_G \qquad (8)$$

where d indexes a sample day, G indexes gear type (i.e., seine or trawl), $Catch_{dG}$ represents the number of winter-run sized or larger juvenile Chinook Sample captured using gear type G during sample day d, $Samples_{dG}$ represents the number of seine hauls or trawl tows completed during sample day d using gear type G, and SE_G represents the standard number of samples completed using gear type G during a typical sample day (SE_{seine}=8 and SE_{trawl}=10). All samples regardless of their condition (e.g., good, poor, etc.) were used for SCI estimates for each sample day.

Results and Discussion

Unmarked winter-run sized or larger juvenile Chinook were first detected within the Sacramento Area Beach Seine Region near the DCC water diversion gates during November 2014 for the 2015 field season (Figure 42); none were observed in the 2014 field season (August 1, 2013 to July 31, 2014). The DJFMP Sacramento Catch Index did not trigger any DCC operations in the 2014 field season. However, the Sacramento Trawl SCI or the Sacramento Beach Seine SCI exceeded the threshold of the salmon decision process on 8 sampling dates during the 2015 field season (Table 3; Figure 42). This either triggered or maintained the closure of the DCC gates in conjunction with the KLCI and water quality indices on 8 occasions (DCC operational logs and final DOSS notes; Barbara Byrne, NOAA, personal communication).

Table 3. Salmon Decision Process trigger events (Sacramento Catch Index=SCI, Knights Landing Catch Index=KLCI) by sample day and gear type (beach seine or trawl) during the 2014 and 2015 field seasons.

Sample date	SCI (seine)	SCI (trawl)	Action IV.1.2
11/05/2014		2.00	
11/07/2014			
11/10/2014			
11/12/2014			
11/14/2014	2.29		
11/17/2014			
11/19/2014	1.14		
11/20/2014	1.14		
11/24/2014			
11/26/2014			
11/28/2014		2.00	
12/01/2014	1.00		
12/03/2014	4.57	2.00	SCI index triggered a recommendation to close gate for 7 days
12/05/2014	9.14	4.00	SCI indices triggered a recommendation to close gate for 7 days
12/08/2014	5.00	18.00	SCI indices triggered a recommendation to close gate for 7 days
12/09/2014		8.00	SCI index triggered a recommendation to close gate for 7 days
12/10/2014	4.57		SCI index triggered a recommendation to close gate for 7 days
12/12/2014	8.00		SCI index triggered a recommendation to close gate for 7 days
12/15/2014			
12/16/2014		2.00	
12/17/2014	5.71		SCI index triggered a recommendation to close gate for 7 days
12/19/2014	8.00		SCI index triggered a recommendation to close gate for 7 days
12/22/2014	7.00	2.00	SCI index triggered a recommendation to close gate for 7 days
12/24/2014	9.14		SCI index triggered a recommendation to close gate for 7 days
12/29/2014			
12/31/2014			
01/02/2015	1.14		
01/05/2015			
01/07/2015			
01/09/2015			
01/12/2015			
01/14/2015			
01/16/2015			
01/20/2015			
01/21/2015			
01/23/2015			
01/26/2015			
01/27/2015	1.14		

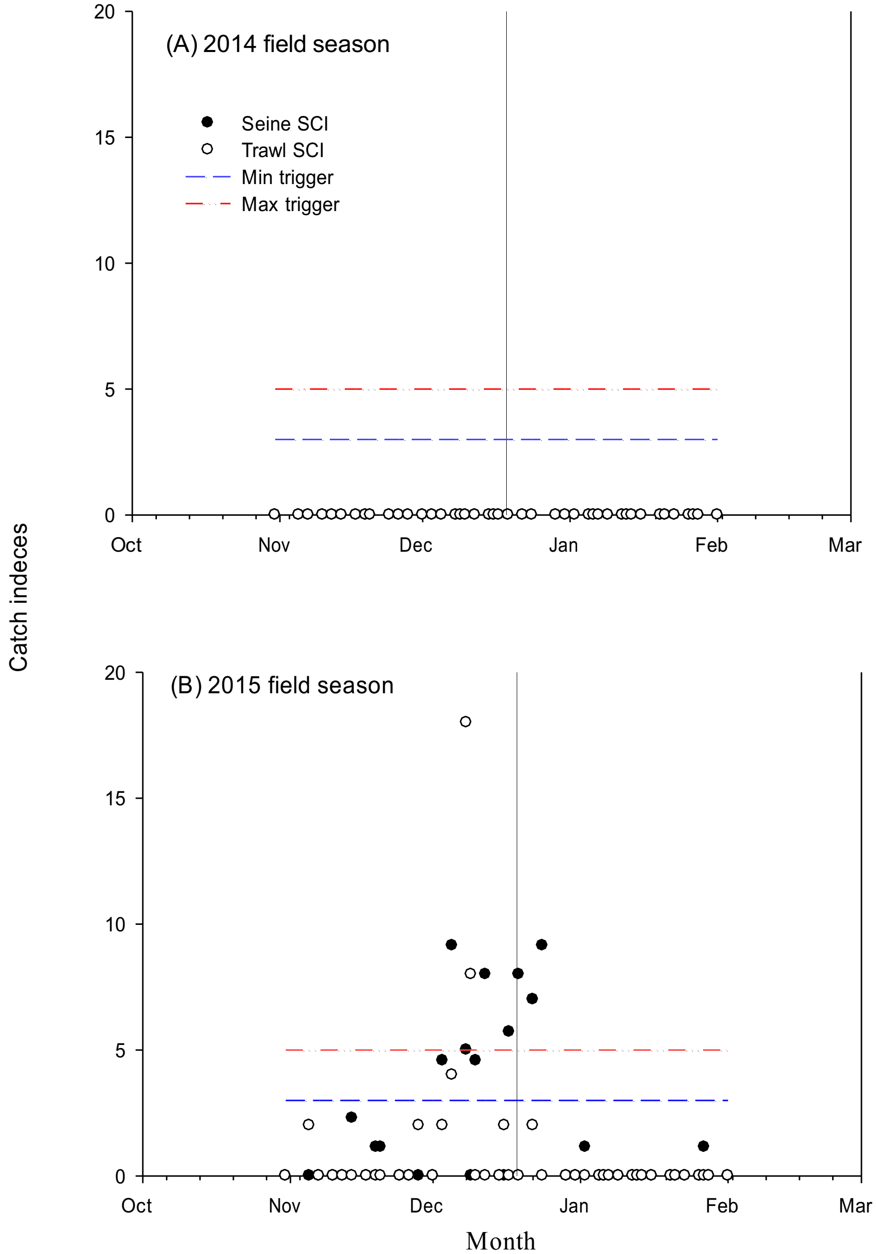


Figure 42. Sacramento Catch Index (SCI) estimates generated by the catch of winter-run size or larger juvenile Chinook Salmon in the Sacramento Trawl Site and within the Sacramento Area Beach Seine Region during the (A) 2014 and (B) 2015 field seasons and the minimum (blue dashed line) and maximum (red dashed line) SCI values required to trigger recommendations to close the Delta Cross Channel gates.

LIBERTY ISLAND BEACH SEINE

Introduction

The Delta Juvenile Fish Monitoring Program (DJFMP) conducted field efforts at Liberty Island from March 2010 through February 2013 under the BREACH III agreement with the California Department of Fish and Wildlife, and this has since been integrated within DJFMP's regular beach seine monitoring across the Delta. The DJFMP sampling at Liberty Island provides baseline data that can serve as a reference site for future restoration efforts at Liberty Island and other north Delta sites in conjunction with the EcoStore (formerly Bay Delta Conservation Plan) and the Fish and Wildlife Service Operational Criteria and Plan Biological Opinion, respectively. The BREACH III study was intended to provide information regarding how abiotic and biotic factors control vegetation colonization and expansion and subsequent responses by higher trophic levels. Considering the uncertainty of biological responses to restoration efforts (Brown 2003; Grimaldo et al. 2012), the sampling at Liberty Island provides important information regarding the design and implementation of restoration projects, particularly within an adaptive management framework. Therefore, it is critical to understand habitat factors that influence the abundance and occupancy of fishes over broad spatial and temporal scales. The objectives of the Liberty Island monitoring program were to (1) document the temporal and spatial distribution of native and non-native fishes and (2) evaluate the occupancy of Delta Smelt, Longfin Smelt, Sacramento Splittail, and juvenile Chinook Salmon.

Methods

We used beach seines (15 m × 1.2 m with 3 mm delta square mesh) to determine the distribution and relative abundance of juvenile and small adult fishes within shallow and unobstructed near-shore habitats of Liberty Island from October 2013 to September 2015. Beach seining and water quality methods followed those already established by the DJFMP and described in the "Methods" section. In general, we identified all fishes captured to species that were greater than 25 mm in fork length (FL). We sampled a total of 21 fixed sites each month (10 - 11 sites per trip, two trips per month) distributed among four quadrants within Liberty Island (Figure 43). Ten sites were selected from locations previously sampled during a pilot study conducted from 2002-2005 in the southern quadrants of Liberty Island (Hansen et al. 2005). In 2010, eleven new sites were selected in the northern quadrants of Liberty Island to maximize spatial coverage. Liberty Island was broken up into four quadrants based on habitat types and exposure. The southern quadrants of Liberty Island are tidally influenced however they remain inundated at low tide. The southeast quadrant of Liberty Island is susceptible to the effects of wind and wave erosion, whereas the southwest quadrant is more protected from those effects and tends to have more submerged aquatic vegetation (SAV). The northern quadrants of Liberty Island are heavily influenced by tide and are mostly characterized by exposed mudflats at low tide with a few channels and areas of inundation less than a meter. The northern quadrants have immense stands of emergent vegetation as well as large areas of SAV. Erosion due to wind and wave processes is limited to the southeast corner of the northeast quadrant of Liberty Island.

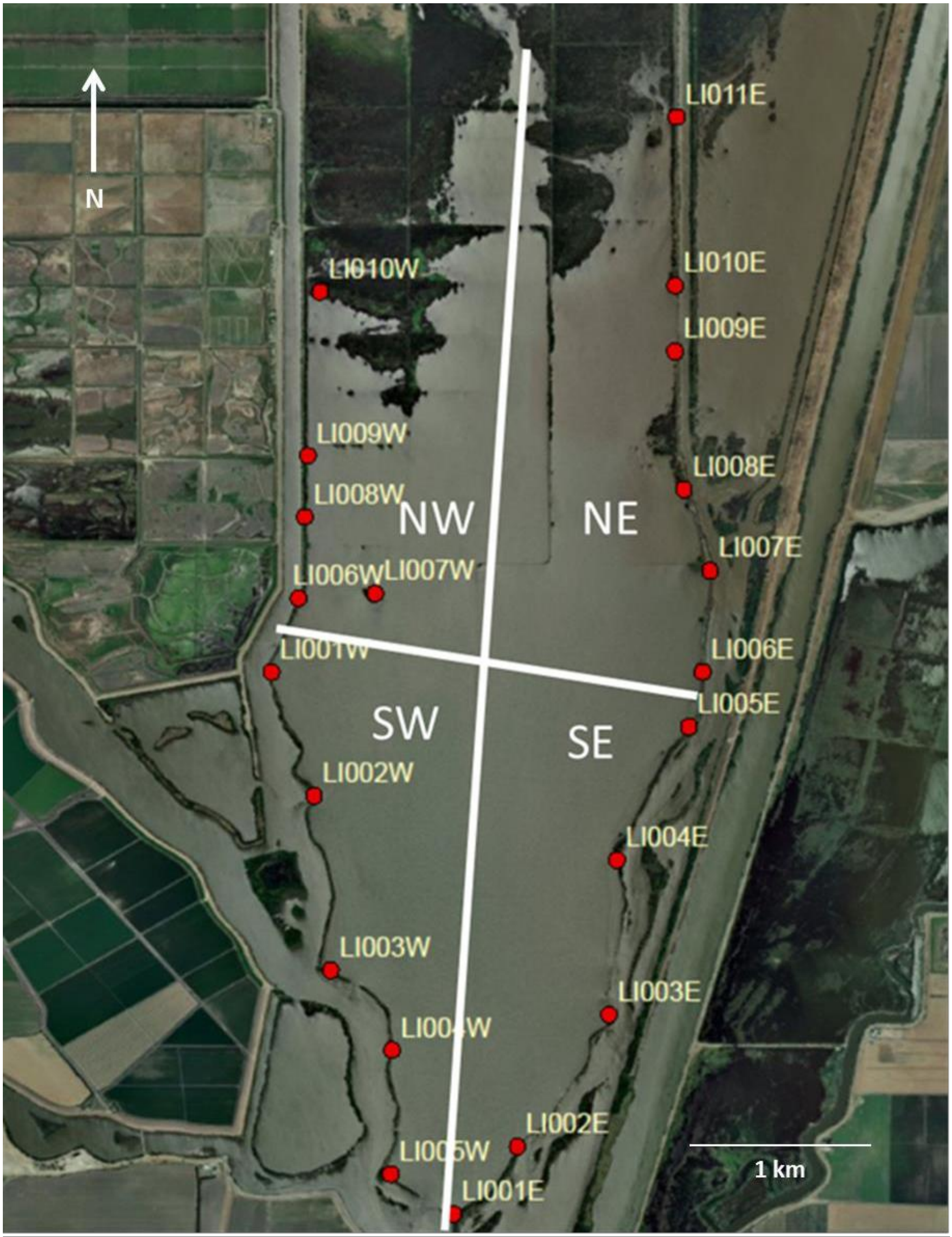


Figure 43. Beach seine sites within sampling quadrants at Liberty Island from 2014 and 2015 field seasons (Appendix B).

Results and Discussion

Water Quality

We collected 1,354 water quality samples during the 2014 and 2015 field seasons in the Liberty Island seine region: 342 water temperature, 336 conductivity, 336 dissolved oxygen, and 340 turbidity samples. The intra-annual variability in water temperature was consistent among Liberty Island seine sites during the 2014 and 2015 field seasons and similar to the variability observed in the other seine regions and trawl sites (Figure 44). Water temperature ranged from 4.4 to 27.7°C among Liberty Island seine sites during the 2014 field season and 5.4 to 26.0°C during the 2015 field season.

We observed dissolved oxygen values ranging from 2.0 to 17.1 mg/L among Liberty Island seine sites during the 2014 field season and 6.5 to 14.2 mg/L among sites during the 2015 field season (Figure 45). In general, dissolved oxygen was slightly higher during the winter season and lower during the summer season for all Liberty Island seine sites during both field seasons. January 2014 had the greatest range of dissolved oxygen levels. The most variation in the 2015 sampling season occurred in March. Similar to the other seine regions and trawl sites, upper and lower extremes tended to occur January/February through June.

Turbidity samples ranged from 6.1 to 1,000 NTU and 0.4 to 417 NTU during the 2014 and 2015 field seasons, respectively (Figure 46). With the exception of several anomalously high turbidity values in May of the 2014 field season, highest mean turbidity values occurred within the months of February, March and July, whereas for 2015 highest values were in December and February, with both years coinciding with peak flow events. Overall, temporal trends in turbidity were similar to those observed from other seine regions and trawl sites across the Delta.

Conductivity ranged from 118.2 to 478 µS/cm and from 23.7 to 645 µS/cm during the 2014 and 2015 field seasons, respectively (Figure 47). For the 2014 field season, highest mean conductivity occurred from the months of February to April, whereas in 2015 this was more protracted with similarly high values between the months of January to April. Overall, the range of conductivity values observed from the Liberty Island region was most similar to the ranges observed at the Sacramento and Mossdale trawl sites and the Lower Sacramento and North Delta seine regions.

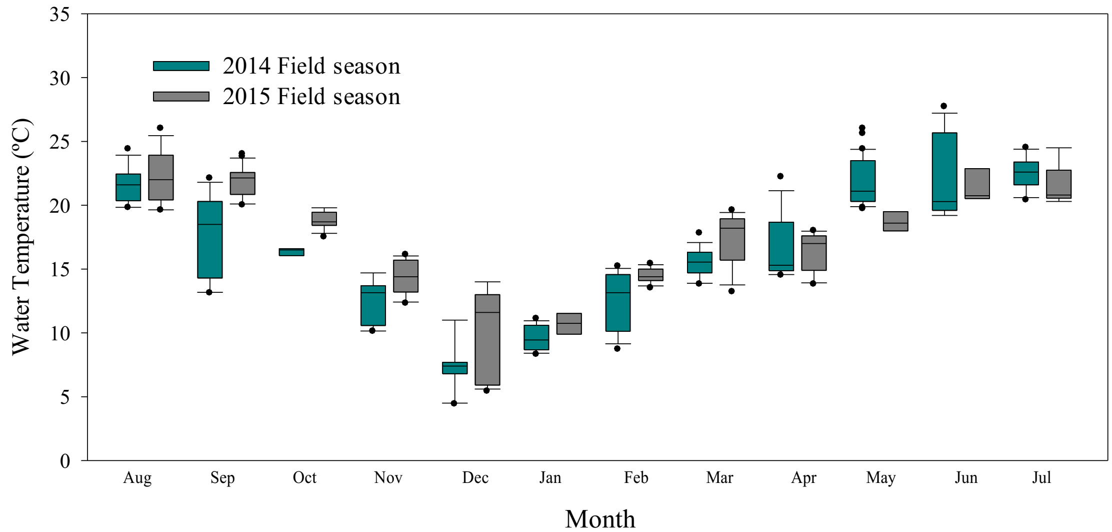


Figure 44. Water temperature data collected by month during sampling at the Liberty Island seine region during the 2014 and 2015 field seasons. The boxes represent the 25th and 75th percentiles, the line within the box represents the median, the whiskers represent the 10th and 90th percentiles, and points represent outliers.

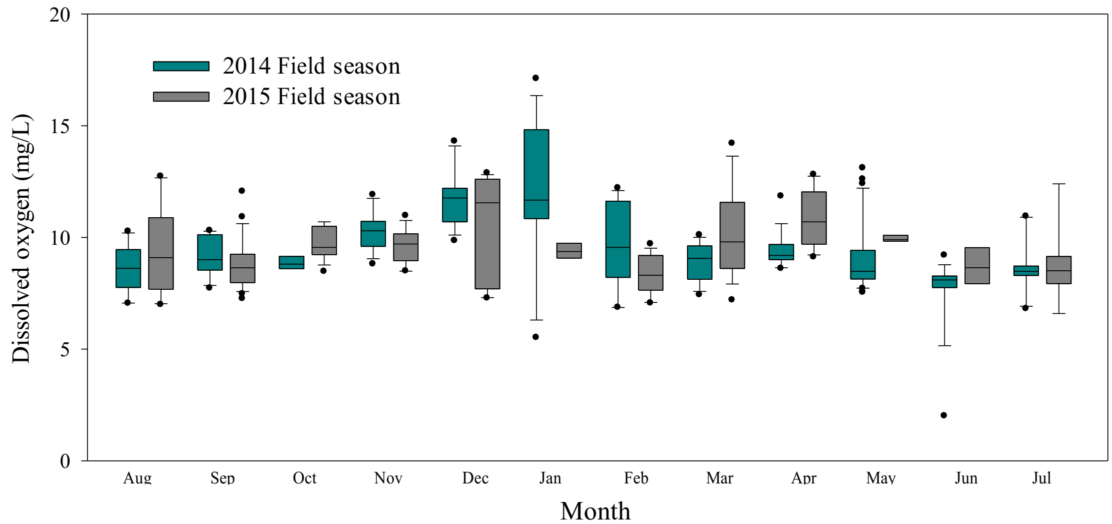


Figure 45. Dissolved oxygen data collected by month during sampling at the Liberty Island seine region during the 2014 and 2015 field seasons. The boxes represent the 25th and 75th percentiles, the line within the box represents the median, the whiskers represent the 10th and 90th percentiles, and points represent outliers.

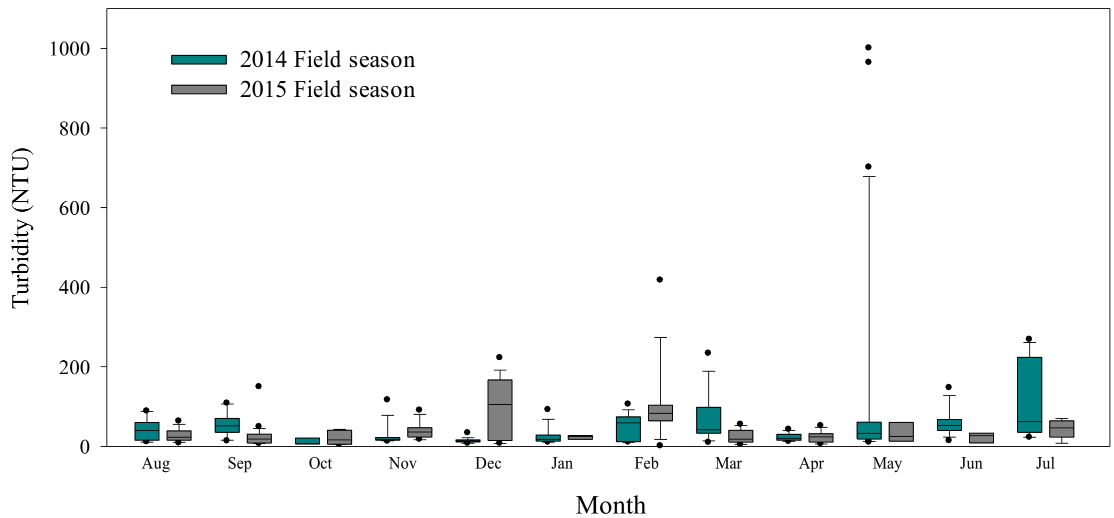


Figure 46. Turbidity data collected by month during sampling at the Liberty Island seine region during the 2014 and 2015 field seasons. The boxes represent the 25th and 75th percentiles, the line within the box represents the median, the whiskers represent the 10th and 90th percentiles, and points represent outliers.

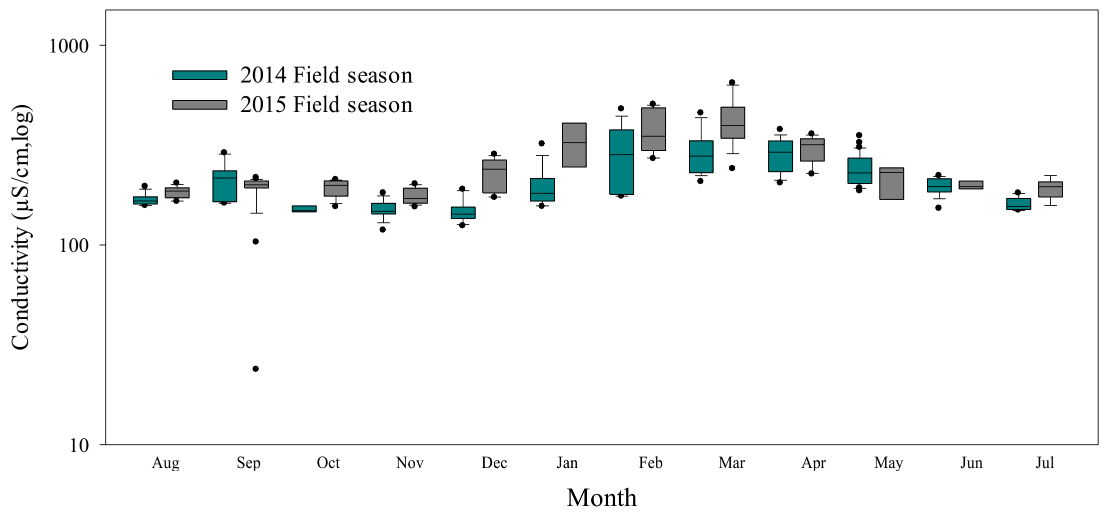


Figure 47. Conductivity data collected by month during sampling at the Liberty Island seine region during the 2014 and 2015 field seasons. The boxes represent the 25th and 75th percentiles, the line within the box represents the median, the whiskers represent the 10th and 90th percentiles, and points represent outliers. The y-axis is presented on a common log scale.

Fish Assemblage

From the 2014 and 2015 field seasons a total of 28,896 fishes representing 29 species were collected by beach seine sampling within the Liberty Island seine region (this does not include marked or unidentified fish; Tables B.2 and B.3). Proportionally, from both years 58% (n=16,697) of the fishes were observed during the 2014 field season. Species not native to the San Francisco Estuary accounted for approximately 97% (n=16,133) and 99.5% (n=12,138) of the total catch during the 2014 and 2015 field seasons, respectively. During the 2014 field season, the most abundant species were the Inland Silverside *Menidia beryllina*, juvenile Chinook Salmon *Oncorhynchus tshawytscha*, and Yellowfin Goby *Acanthogobius flavimanus*, comprising 96% of the total annual catch. For 2015, this changed slightly with dominant species being Inland Silverside, Threadfin Shad *Dorosoma patenense*, and Striped Bass *Morone saxatilis*, comprising 96% of the catch.

Pelagic-nonnative fishes dominated catches in the Liberty Island region during both the 2014 and 2015 field seasons (Figure 48). Within pelagic-nonnative fishes, the Inland Silverside was the most common species observed, comprising 91.7% (n=15,312) and 91.4% (n=11,144) of total catches during 2014 and 2015, respectively (Tables B.2 and B.3). The Inland Silverside was also the most common species observed at the Mossdale Trawl Site and in the Lower Sacramento River, North Delta, Central Delta, South Delta, and Lower San Joaquin River seine regions during the 2014 and 2015 field seasons (Tables A.3 and A.4). Within the Liberty Island region, the percentage of catch by month in both 2014 and 2015 was dominated by pelagic-nonnative fishes, which often exceeded 90% of the total. Some exceptions to this were in March 2014, when 38% of the catch was anadromous-pelagic-native (i.e. juvenile Chinook) and in May 2014 when 34.6% of catch was composed of benthic-nonnative fishes (i.e. predominantly Yellowfin Goby). The mean yearly CPUE estimates for 2014 and 2015 indicated that pelagic-nonnative fishes increased in the Liberty Island region compared to previous sampling years (2003-2005 and 2010-2013; Figure 49). The increased dominance of pelagic-nonnative fishes was also reflected in the mean yearly CPUE estimates at the Mossdale trawl site, especially in 2014.

The mean yearly CPUE for juvenile Chinook in 2014 was more than an order of magnitude greater than in 2015 (Figures 48 and 49), and also greater than in every other year of sampling in the Liberty Island region (Figure 49). The higher CPUE of anadromous-pelagic-native fishes in 2014 compared to 2015 is consistent with the trends exhibited in 2014 and 2015 from the other seine regions in the North Delta (Figure 20). Most of the difference was driven by CPUE in the months of February and March, also consistent with the trends observed in the other seine regions in the North Delta (Figure 19).

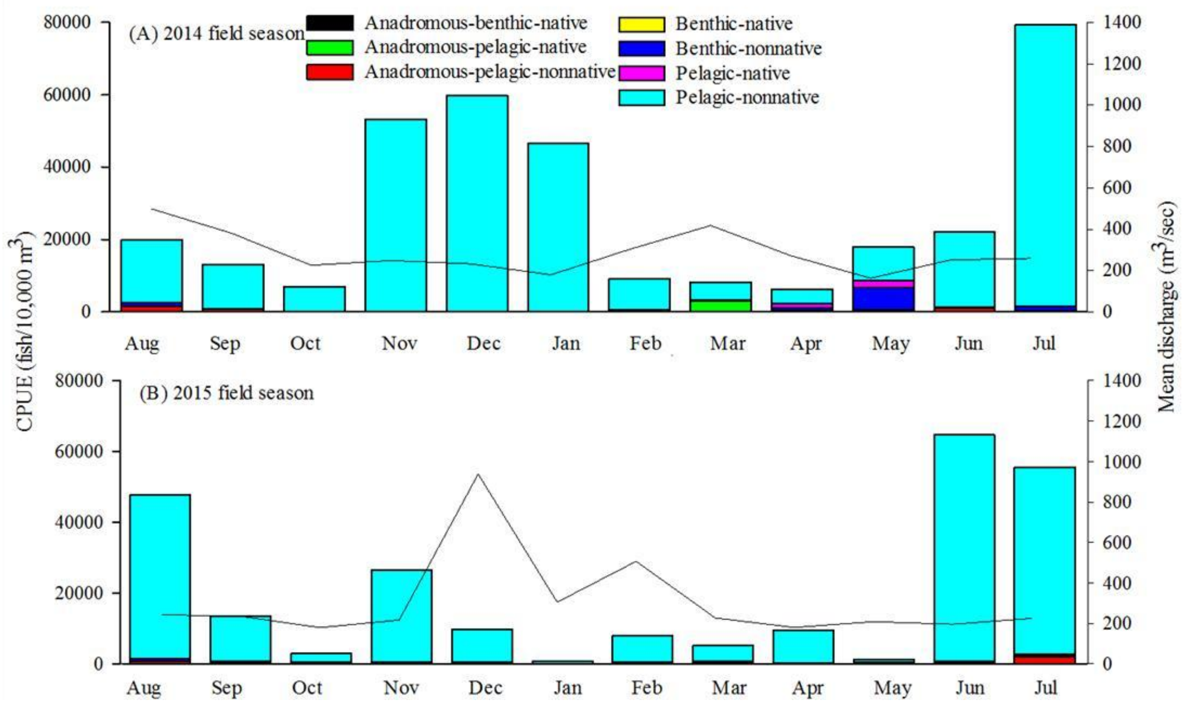


Figure 48. Mean monthly CPUE (bars) of juvenile fish assemblages captured within the Liberty Island seine region, and the estimated mean monthly Sacramento River discharge at Freeport (solid line) during the (A) 2014 and (B) 2015 field seasons.

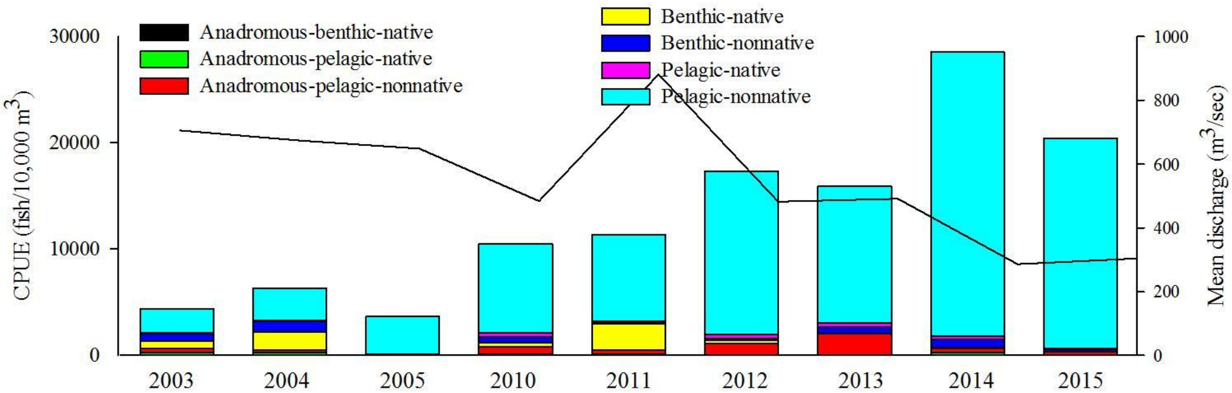


Figure 49. Mean yearly CPUE (bars) of juvenile fish assemblages captured within the Liberty Island seine region, and the estimated mean yearly Sacramento River discharge at Freeport (solid line), during the 2003 through 2005 and 2010 through 2015 field seasons.

<u>Juvenile Chinook Salmon</u>

We captured 431 and 11 juvenile Chinook Salmon during the 2014 and 2015 field seasons, respectively (Tables B.2 and B.3). During the 2014 field season one individual was categorized as winter-run sized, 426 (99%) were fall-run sized, and four were spring-run sized (Table B.2) based on the LDC. In 2015, all juvenile Chinook captured in the Liberty Island region were fall-run sized (n=11; Table B.3). No marked juvenile Chinook were collected during either 2014 or 2015 (Table B.4). Since sampling began in 2003 in the Liberty Island seine region, a total of 13 marked juvenile Chinook have been recovered (seven in 2003, one in 2004, one in 2010, three in 2011, and one in 2012; Table B.4).

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APPENDIX A

Table A.1. Sites sampled during the 2014 and 2015 field seasons categorized by gear (beach seine or trawl) and region. Station codes refer to body of water (first 2 letters; AR=American River, DS=Disappointment Slough, GS=Georgiana Slough, LP=Little Potato Slough, MK=Mokelumne River, MR=Middle River, MS=Mayberry Slough, OR=Old River, SA=San Francisco Bay, SB=Suisun Bay, SF=South Fork of Mokelumne River, SJ=San Joaquin River, SP=San Pablo Bay, SR=Sacramento River, SS=Steamboat Slough, TM=Three Mile Slough, WD=Werner Dredger Cut, or XC=Delta Cross Channel), river mile (3 digits), and location within site (last letter; N=north, S=south, W=west, E=east, or M=mid channel). For example, Colusa State Park is on the Sacramento River (SR) at river mile 144 on the west bank (W).

Site code	Site name	County	Coordinates (UTM)			First year sampled annually
			Zone	Northing	Easting	
Region 1: Lower Sacramento River Seine						
SR144W	Colusa State Park	Colusa	10 S	4341652	585032	1981
SR138E	Ward's Landing	Colusa	10 S	4338873	591787	1981
SR130E	South Meridian	Sutter	10 S	4329625	594819	1981
SR094E	Reels Beach	Sutter	10 S	4301235	610500	1981
SR090W	Knights Landing	Yolo	10 S	4295506	610842	1981
SR080E[a]	Verona[a]	Sutter	10 S	4293731	620049	1981
SR071E[a]	Elkhorn[a]	Sacramento	10 S	4281359	619626	1981
SR119E	Tisdale	Sutter	10S	4320172	601969	2012
Region 2: North Delta Seine						
SR060E[b]	Discovery Park[b]	Sacramento	10 S	4273503	629820	1976
AM001S[b]	American River[b]	Sacramento	10 S	4273377	630121	1976
SR049E[b]	Garcia Bend[b]	Sacramento	10 S	4259863	627056	1976
SR043W	Clarksburg	Yolo	10 S	4249352	629186	1976
SS011N	Steamboat Slough	Sacramento	10 S	4240586	624600	1992
SR024E	Koket	Sacramento	10 S	4233475	626473	1976
SR017E	Isleton	Sacramento	10 S	4224781	621633	1976
SR014W	Rio Vista	Solano	10 S	4227355	617119	1976
SR012W	Sandy Beach	Solano	10 S	4222029	614333	2007
MS001N	Sherman Island	Sacramento	10 S	4212733	606513	1976
Region 3: Central Delta Seine						
SJ005N	Eddo's	Sacramento	10 S	4212249	614110	1976
SJ001S	Antioch Dunes	Contra Costa	10 S	4208157	606855	1979
XC001N	Delta Cross Channel	Sacramento	10 S	4234115	630930	1976
GS010E	Georgiana Slough	Sacramento	10 S	4231900	628914	1976
MK004W	B&W Marina	Sacramento	10 S	4220909	624418	1979

Table A.1. Continued

Site code	Site name	County	Coordinates (UTM) Zone	Northing	Easting	First year sampled annually
SF014E	Wimpy's	San Joaquin	10 S	4232068	632064	1976
TM001N	Brannan Island	Sacramento	10 S	4219577	615378	1976
DS002S	King's Island	San Joaquin	10 S	4213457	635248	1979
LP003E	Terminous	San Joaquin	10 S	4219075	631488	1979
Region 4: South Delta Seine						
SJ051E	Dos Reis	San Joaquin	10 S	4188374	648601	1994
SJ041N	Dad's Point	San Joaquin	10 S	4202181	645287	1979
SJ032S	Lost Isle	San Joaquin	10 S	4206624	636393	1993
SJ026S	Medford Island	San Joaquin	10 S	4212589	630739	2002
OR023E	Union Island	San Joaquin	10 S	4187462	627498	1997
OR019E	Old River	San Joaquin	10 S	4193094	625167	1993
OR014W	Cruiser Haven	Contra Costa	10 S	4198087	626927	1993
OR003W	Frank's Tract	Contra Costa	10 S	4210312	624458	1993
MR010W	Woodward Island	San Joaquin	10 S	4198130	629336	1979
WD002W	Veale Tract	Contra Costa	10 S	4201793	622619	1993
Region 5: Lower San Joaquin River Seine						
SJ083W[c]	N. of Tuolumne River[c]	Stanislaus	10 S	4164462	660960	1994
SJ077E[c]	Route 132[c]	Stanislaus	10 S	4167222	656395	1994
SJ074W[c]	Sturgeon Bend[c]	San Joaquin	10 S	4170903	654784	1994
SJ068W[c]	Durham Site[c]	San Joaquin	10 S	4173594	652327	1994
SJ063W[c]	Big Beach[c]	San Joaquin	10 S	4176666	650093	1994
SJ058W[d]	Weatherbee[d]	San Joaquin	10 S	4181923	649451	1994
SJ056E[d]	Mossdale[d]	San Joaquin	10 S	4183536	649043	1994
SJ079E[e]	San Luis Refuge[e]	Stanislaus	10 S	4166449	657914	2008
SJ076W[e]	N. of Route 132[e]	Stanislaus	10 S	4168198	656679	2008
SJ074A[e]	Sturgeon Bend Alternate[e]	San Joaquin	10 S	4170228	654634	2008
Region 6: San Francisco and San Pablo Bay Seine						
SA007E	Berkeley Frontage Rd	Alameda	10 S	4189562	561459	1997
SP001W	China Camp	Marin	10 S	4206179	546771	1997
SA009E	Keller Beach	Contra Costa	10 S	4196872	553964	1998
SP000W	McNear's Beach	Marin	10 S	4205405	547852	1997
SA008W	Paradise Beach	Marin	10 S	4194678	546872	1997
SP003E	Point Pinole East	Contra Costa	10 S	4206789	556219	1998

Table A.1. Continued.

Site code	Site name	County	Coordinates (UTM) Zone	Northing	Easting	First year sampled annually
SA010W	San Quentin Beach	Marin	10 S	4199230	544068	1997
SA004W	Tiburon Beach	Marin	10 S	4193885	544413	1997
SA001M	Treasure Island	San Francisco	10 S	4185026	555671	1997
Region 7: Sacramento Area Seine						
SR062E	Sand Cove	Sacramento	10 S	4273283	626860	1994
SR057E	Miller Park	Sacramento	10 S	4269001	629279	1994
SR055E	Sherwood Harbor	Sacramento	10 S	4265358	628190	1994
Trawls						
SR055M	Sacramento	Sacramento	10 S	4265084	628299	1988
SJ054M	Mossdale	San Joaquin	10 S	4182898	649315	1996
SB055M,N,S	Chipps Island	Contra Costa	10 S	4211218	595531	1976

[a] Site was included within both Region 1 and Region 7 from Oct 1 to Jan 31.
[b] Site was included within both Region 2 and Region 7 from Oct 1 to Jan 31.
[c] Site was sampled when San Joaquin River discharge was > $51 m^3/s$ during the 2000–2012 field seasons, and year-round during the 2013 field season.
[d] Site was sampled throughout the field season during 2000–2013.
[e] Site was sampled when San Joaquin River discharge was ≤ $51 m^3/s$ during the 2000–2012 field seasons.

Table A.2. Fish species, common names, and assemblage groups. Fish species are listed in phylogenetic order.

Common name	Genus	Species	Assemblage group
River Lamprey	*Lampetra*	*ayresii*	Anadromous-benthic-native
Western Brook Lamprey	*Lampetra*	*richardsoni*	Benthic-native
Pacific Lamprey	*Lampetra*	*tridentatus*	Anadromous-benthic-native
Spiny Dogfish	*Squalus*	*acanthias*	Benthic-native
Gray Smoothhound	*Mustelus*	*californicus*	Benthic-native
Brown Smoothhound	*Mustelus*	*henlei*	Benthic-native
Leopard Shark	*Triakis*	*semifasciata*	Benthic-native
Pacific Electric Ray	*Torpedo*	*californica*	Benthic-native
Thornback Ray	*Platyrhinoidis*	*triseriata*	Benthic-native
Big Skate	*Raja*	*binoculata*	Benthic-native
Bat Ray	*Myliobatis*	*californica*	Benthic-native
Green Sturgeon	*Acipenser*	*medirostris*	Anadromous-benthic-native
White Sturgeon	*Acipenser*	*transmontanus*	Anadromous-benthic-native
American Eel	*Anguilla*	*rostrata*	Benthic-nonnative
Northern Anchovy	*Engraulis*	*mordax*	Pelagic-native
American Shad	*Alosa*	*sapidissima*	Anadromous-pelagic-nonnative
Pacific Herring	*Clupea*	*pallasii*	Pelagic-native
Threadfin Shad	*Dorosoma*	*petenense*	Pelagic-nonnative
Pacific Sardine	*Sardinops*	*sagax*	Pelagic-native
Goldfish	*Carassius*	*auratus*	Pelagic-nonnative
Red Shiner	*Cyprinella*	*lutrensis*	Pelagic-nonnative
Common Carp	*Cyprinus*	*carpio*	Benthic-nonnative
Tui Chub	*Gila*	*bicolor*	Pelagic-native
California Roach	*Hesperoleucus*	*symmetricus*	Pelagic-native
Hitch	*Lavinia*	*exilicauda*	Pelagic-native
Hardhead	*Mylopharodon*	*conocephalus*	Pelagic-native
Golden Shiner	*Notemigonus*	*crysoleucas*	Pelagic-nonnative

Table A.2. Continued.

Common name	Genus	Species	Assemblage group
Sacramento Blackfish	*Orthodon*	*microlepidotus*	Pelagic-native
Rosyface Shiner	*Notropis*	*rubellus*	Pelagic-nonnative
Fathead Minnow	*Pimephales*	*promelas*	Pelagic-nonnative
Sacramento Splittail	*Pogonichthys*	*macrolepidotus*	Benthic-native
Sacramento Pikeminnow	*Ptychocheilus*	*grandis*	Pelagic-native
Speckled Dace	*Rhinichthys*	*osculus*	Pelagic-native
Sacramento Sucker	*Catostomus*	*occidentalis*	Benthic-native
White Catfish	*Ameiurus*	*catus*	Benthic-nonnative
Black Bullhead	*Ameiurus*	*melas*	Benthic-nonnative
Yellow Bullhead	*Ameiurus*	*natalis*	Benthic-nonnative
Brown Bullhead	*Ameiurus*	*nebulosus*	Benthic-nonnative
Blue Catfish	*Ictalurus*	*furcatus*	Benthic-nonnative
Channel Catfish	*Ictalurus*	*punctatus*	Benthic-nonnative
Northern Pike	*Esox*	*lucius*	Pelagic-nonnative
Whitebait Smelt	*Allosmerus*	*elongatus*	Pelagic-native
Wakasagi	*Hypomesus*	*nipponensis*	Pelagic-nonnative
Surf Smelt	*Hypomesus*	*pretiosus*	Pelagic-native
Delta Smelt	*Hypomesus*	*transpacificus*	Anadromous-pelagic-native
Night Smelt	*Spirinchus*	*starksi*	Pelagic-native
Longfin Smelt	*Spirinchus*	*thaleichthys*	Anadromous-pelagic-native
Pink Salmon	*Oncorhynchus*	*gorbuscha*	Anadromous-pelagic-nonnative
Coho Salmon	*Oncorhynchus*	*kisutch*	Anadromous-pelagic-native
Kokanee (lacustrine Sockeye Salmon)	*Oncorhynchus*	*nerka*	Pelagic-nonnative
Steelhead	*Oncorhynchus*	*mykiss*	Anadromous-pelagic-native
Chinook Salmon	*Oncorhynchus*	*tshawytscha*	Anadromous-pelagic-native
Brown Trout	*Salmo*	*trutta*	Anadromous-pelagic-nonnative

Table A.2. Continued.

Common name	Genus	Species	Assemblage group
Plainfin Midshipman	*Porichthys*	*notatus*	Benthic-native
Pacific Tomcod	*Microgadus*	*proximus*	Pelagic-native
Striped Mullet	*Mugil*	*cephalus*	Pelagic-native
Topsmelt	*Atherinops*	*affinis*	Pelagic-native
Jacksmelt	*Atherinopsis*	*californiensis*	Pelagic-native
Inland Silverside	*Menidia*	*beryllina*	Pelagic-nonnative
Rainwater Killifish	*Lucania*	*parva*	Pelagic-nonnative
Western Mosquitofish	*Gambusia*	*affinis*	Pelagic-nonnative
Threespine Stickleback	*Gasterosteus*	*aculeatus*	Anadromous-pelagic-native
Bay Pipefish	*Syngnathus*	*leptorhynchus*	Pelagic-native
Brown Rockfish	*Sebastes*	*auriculatus*	Benthic-native
Lingcod	*Ophiodon*	*elongatus*	Benthic-native
Prickly Sculpin	*Cottus*	*asper*	Benthic-native
Riffle Sculpin	*Cottus*	*gulosus*	Benthic-native
Pacific Staghorn Sculpin	*Leptocottus*	*armatus*	Benthic-native
Tidepool Sculpin	*Oligocottus*	*maculosus*	Benthic-native
Saddleback Sculpin	*Oligocottus*	*rimensis*	Benthic-native
Cabezon	*Scorpaenichthys*	*marmoratus*	Benthic-native
White Bass	*Morone*	*chrysops*	Pelagic-nonnative
Striped Bass	*Morone*	*saxatilis*	Anadromous-pelagic-nonnative
Sacramento Perch	*Archoplites*	*interruptus*	Pelagic-native
Green Sunfish	*Lepomis*	*cyanellus*	Pelagic-nonnative
Pumpkinseed	*Lepomis*	*gibbosus*	Pelagic-nonnative
Warmouth	*Lepomis*	*gulosus*	Pelagic-nonnative
Bluegill	*Lepomis*	*macrochirus*	Pelagic-nonnative
Redear Sunfish	*Lepomis*	*microlophus*	Pelagic-nonnative
Smallmouth Bass	*Micropterus*	*dolomieu*	Pelagic-nonnative
Spotted Bass	*Micropterus*	*punctulatus*	Pelagic-nonnative

Table A.2. Continued.

Common name	Genus	Species	Assemblage group
Redeye Bass	*Micropterus*	*coosae*	Pelagic-nonnative
Largemouth Bass	*Micropterus*	*salmoides*	Pelagic-nonnative
White Crappie	*Pomoxis*	*annularis*	Pelagic-nonnative
Black Crappie	*Pomoxis*	*nigromaculatus*	Pelagic-nonnative
Yellow Perch	*Perca*	*flavescens*	Pelagic-nonnative
Bigscale Logperch	*Percina*	*macrolepida*	Pelagic-nonnative
Pacific Pompano	*Peprilus*	*simillimus*	Pelagic-native
White Croaker	*Genyonemus*	*lineatus*	Pelagic-native
Barred Surfperch	*Amphistichus*	*argenteus*	Pelagic-native
Calico Surfperch	*Amphistichus*	*koelzi*	Pelagic-native
Redtail Surfperch	*Amphistichus*	*rhodoterus*	Pelagic-native
Kelp Perch	*Brachyistius*	*frenatus*	Pelagic-native
Shiner Perch	*Cymatogaster*	*aggregata*	Pelagic-native
Black Perch	*Embiotoca*	*jacksoni*	Pelagic-native
Striped Seaperch	*Embiotoca*	*lateralis*	Pelagic-native
Spotfin Surfperch	*Hyperprosopon*	*anale*	Pelagic-native
Walleye Surfperch	*Hyperprosopon*	*argenteum*	Pelagic-native
Silver Surfperch	*Hyperprosopon*	*ellipticum*	Pelagic-native
Tule Perch	*Hysterocarpus*	*traskii*	Pelagic-native
Dwarf Surfperch	*Micrometrus*	*minimus*	Pelagic-native
White Seaperch	*Phanerodon*	*furcatus*	Pelagic-native
Rubberlip Seaperch	*Rhacochilus*	*toxotes*	Pelagic-native
Pile Perch	*Rhacochilus*	*vacca*	Pelagic-native
Penpoint Gunnel	*Apodichthys*	*flavidus*	Benthic-native
Saddleback Gunnel	*Pholis*	*ornata*	Benthic-native
Red Gunnel	*Pholis*	*schultzi*	Benthic-native
Wolf-Eel	*Anarrhichthys*	*ocellatus*	Benthic-native
Striped Kelpfish	*Gibbonsia*	*metzi*	Pelagic-native

Table A.2. Continued.

Common name	Genus	Species	Assemblage group
Crevice Kelpfish	*Gibbonsia*	*montereyensis*	Pelagic-native
Giant Kelpfish	*Heterostichus*	*rostratus*	Pelagic-native
Yellowfin Goby	*Acanthogobius*	*flavimanus*	Benthic-nonnative
Arrow Goby	*Clevelandia*	*ios*	Benthic-native
Tidewater Goby	*Eucyclogobius*	*newberryi*	Benthic-native
Longjaw Mudsucker	*Gillichthys*	*mirabilis*	Benthic-native
Cheekspot Goby	*Ilypnus*	*gilberti*	Benthic-native
Bay Goby	*Lepidogobius*	*lepidus*	Benthic-native
Shokihaze Goby	*Tridentiger*	*barbatus*	Benthic-nonnative
Shimofuri Goby	*Tridentiger*	*bifasciatus*	Benthic-nonnative
Chameleon Goby	*Tridentiger*	*trigonocephalus*	Benthic-nonnative
Pacific Sanddab	*Citharichthys*	*sordidus*	Benthic-native
Speckled Sanddab	*Citharichthys*	*stigmaeus*	Benthic-native
Bigmouth Sole	*Hippoglossina*	*stomata*	Benthic-nonnative
California Halibut	*Paralichthys*	*californicus*	Benthic-native
Pacific Halibut	*Hippoglossus*	*stenolepis*	Benthic-native
California Tonguefish	*Symphurus*	*Atricauda*	Benthic-native
Butter Sole	*Isopsetta*	*isolepis*	Benthic-native
Rock Sole	*Lepidopsetta*	*bilineata*	Benthic-native
English Sole	*Parophrys*	*vetulus*	Benthic-native
Starry Flounder	*Platichthys*	*stellatus*	Benthic-native
Diamond Turbot	*Pleuronichthys*	*guttulatus*	Benthic-native
Sand Sole	*Psettichthys*	*melanostictus*	Benthic-native

Table A.3. Total of individuals observed in samples used to assess the fish assemblage structure during the 2014 field season. Counts are grouped by species and trawl site or seine region. Fish species are listed in phylogenetic order. Beach seine regions represent sites as assigned in Table A.1.

Fish species	Trawl site			Beach seine region					
	Sacramento	Mossdale	Chipps Island	1	2	3	4	5	6
River Lamprey *Lampetra ayresii*	1	0	0	0	0	0	0	0	0
Pacific Lamprey *Lampetra tridentatus*	3	1	1	0	0	0	0	0	0
Lamprey unknown *Lampetra* spp.	1	0	0	2	1	0	0	0	0
Leopard Shark *Triakis semifasciata*	0	0	0	0	0	0	0	0	2
Thornback Ray *Platyrhinoidis triseriata*	0	0	0	0	0	0	0	0	2
Northern Anchovy *Engraulis mordax*	0	0	95	0	0	0	0	0	2780
American Shad *Alosa sapidissima*	73	1415	9149	1	25	11	3	0	2
Pacific Herring *Clupea pallasii*	0	0	152	0	0	0	0	0	143
Threadfin Shad *Dorosoma petenense*	351	10682	1747	792	584	2633	606	1031	1
Goldfish *Carassius auratus*	1	0	0	0	0	1	0	0	0
Red Shiner *Cyprinella lutrensis*	0	92	0	1226	41	1	67	41745	0
Common Carp *Cyprinus carpio*	3	5	1	30	0	4	1	5	0
Hitch *Lavinia exilicauda*	0	0	0	14	28	27	0	0	0
Hardhead *Mylopharodon conocephalus*	0	0	0	13	1	1	0	0	0
Golden Shiner *Notemigonus crysoleucas*	11	53	5	335	47	59	85	28	0
Fathead Minnow *Pimephales promelas*	2	0	0	1267	10	1	0	19	0
Sacramento Splittail *Pogonichthys macrolepidotus*	1	471	28	711	534	81	0	188	0
Sacramento Pikeminnow *Ptychocheilus grandis*	4	5	0	744	164	14	3	13	0
Sacramento Sucker *Catostomus occidentalis*	0	2	0	4814	2839	11	4	283	0

Table A.3. Continued.

Fish species	Trawl site: Sacramento	Trawl site: Mossdale	Trawl site: Chipps Island	Beach seine region: 1	2	3	4	5	6
White Catfish *Ameiurus catus*	4	57	1	0	1	0	2	0	0
Black Bullhead *Ameiurus melas*	0	0	0	0	4	3	0	0	0
Brown Bullhead *Ameiurus nebulosus*	0	0	0	1	9	2	2	0	0
Channel Catfish *Ictalurus punctatus*	2	271	0	10	1	0	0	3	0
Wakasagi *Hypomesus nipponensis*	12	0	7	0	1	0	0	0	0
Surf Smelt *Hypomesus pretiosus*	0	0	5	0	0	0	0	0	0
Delta Smelt *Hypomesus transpacificus*	21	0	203	0	81	1	0	0	0
Longfin Smelt *Spirinchus thaleichthys*	0	0	111	0	0	0	0	0	0
Steelhead *Oncorhynchus mykiss*	273	11	80	18	11	2	0	0	0
Unmarked Steelhead	9	6	14	0	0	0	0	0	0
Marked Steelhead	264	0	66	18	11	2	0	0	0
Acoustic Tag Steelhead	0	5	0	0	0	0	0	0	0
Juvenile Chinook Salmon *Oncorhynchus tshawytscha*	24369	1503	2810	10356	11238	363	7	0	0
Unmarked winter-run	71	1	72	29	7	1	0	0	0
Unmarked fall-run	23112	1040	886	10285	11171	344	7	0	0
Unmarked spring-run	753	290	1311	39	53	11	0	0	0
Unmarked late fall-run	0	0	5	1	1	0	0	0	0
Unmarked not raced	0	157	0	0	0	0	0	0	0
Marked w/ CWT	432	12	535	2	6	7	0	0	0
Acoustic Tag	1	3	1	0	0	0	0	0	0
Plainfin Midshipman *Porichthys notatus*	0	0	0	0	0	0	0	0	1
Topsmelt *Atherinops affinis*	0	0	128	0	0	0	0	0	6168

Table A.3. Continued.

Fish species	Trawl site			Beach seine region					
	Sacramento	Mossdale	Chipps Island	1	2	3	4	5	6
Inland Silverside *Menidia beryllina*	4078	49612	6	6962	36497	15172	23229	34391	2
Rainwater Killifish *Lucania parva*	0	0	0	1	126	89	243	0	41
Western Mosquitofish *Gambusia affinis*	0	1	0	248	924	256	301	1347	0
Threespine Stickleback *Gasterosteus aculeatus*	0	0	9	0	361	12	0	0	26
Bay Pipefish *Syngnathus leptorhynchus*	0	0	0	0	0	0	0	0	101
Prickly Sculpin *Cottus asper*	0	0	0	2	25	65	47	2	0
Pacific Staghorn Sculpin *Leptocottus armatus*	0	0	3	0	46	92	0	0	206
Tidepool Sculpin *Oligocottus maculosus*	0	0	0	0	0	0	0	0	1
Cabezon *Scorpaenichthys marmoratus*	0	0	0	0	0	0	0	0	2
Striped Bass *Morone saxatilis*	1	679	409	0	57	133	68	34	4
Green Sunfish *Lepomis cyanellus*	0	0	0	2	1	0	1	0	0
Pumpkinseed *Lepomis gibbosus*	0	0	0	0	0	0	0	0	1
Warmouth *Lepomis gulosus*	0	0	0	0	0	0	2	0	0
Bluegill *Lepomis macrochirus*	9	1846	1	42	68	150	297	299	0
Redear Sunfish *Lepomis microlophus*	0	95	0	99	22	447	599	57	0
Smallmouth Bass *Micropterus dolomieu*	0	0	0	10	50	4	0	0	0
Spotted Bass *Micropterus punctulatus*	1	3	0	120	129	17	3	28	0
Largemouth Bass *Micropterus salmoides*	1	5	1	213	83	396	396	69	0
White Crappie *Pomoxis annularis*	0	2	1	2	0	0	0	0	0
Black Crappie *Pomoxis nigromaculatus*	2	1	0	78	5	1	0	6	0
Bigscale Logperch *Percina macrolepida*	0	0	0	312	48	84	39	3	0

Table A.3. Continued.

Fish species	Trawl site: Sacramento	Trawl site: Mossdale	Trawl site: Chipps Island	Beach seine region: 1	2	3	4	5	6
White Croaker *Genyonemus lineatus*	0	0	0	0	0	0	0	0	8
Barred Surfperch *Amphistichus argenteus*	0	0	0	0	0	0	0	0	132
Shiner Perch *Cymatogaster aggregata*	0	0	1	0	0	0	0	0	50
Black Perch *Embiotoca jacksoni*	0	0	0	0	0	0	0	0	3
Walleye Surfperch *Hyperprosopon argenteum*	0	0	0	0	0	0	0	0	75
Tule Perch *Hysterocarpus traskii*	5	1	7	20	183	148	7	0	0
Dwarf Surfperch *Micrometrus minimus*	0	0	0	0	0	0	0	0	179
Rubberlip Seaperch Rhacochilus toxotes	0	0	0	0	0	0	0	0	1
Crevice Kelpfish *Gibbonsia montereyensis*	0	0	0	0	0	0	0	0	1
Yellowfin Goby *Acanthogobius flavimanus*	0	2	3	0	150	119	3	0	10
Arrow Goby *Clevelandia ios*	0	0	0	0	0	0	0	0	41
Cheekspot Goby *Llypnus gilberti*	0	5	0	0	0	0	0	0	6
Bay Goby *Lepidogobius Lepidus*	0	0	0	0	0	0	0	0	1
Shokihaze Goby *Tridentiger barbatus*	0	0	0	0	0	0	0	0	1
Shimofuri Goby *Tridentiger bifasciatus*	0	11	8	0	55	93	73	0	22
California Halibut *Paralichthys californicus*	0	0	0	0	0	0	0	0	7
English Sole *Parophrys vetulus*	0	0	0	0	0	0	0	0	59
Starry Flounder *Platichthys stellatus*	0	0	1	0	0	0	0	0	0
Diamond Turbot *Pleuronichthys guttulatus*	0	0	0	0	0	0	0	0	14
Sand Sole *Psettichthys melanostictus*	0	0	0	0	0	0	0	0	7
California Tonguefish Symphurus atricauda	0	0	0	0	0	0	0	0	4
Unidentified fish	0	0	0	0	1	0	0	0	0

Table A.4. Total of individuals observed in samples used to assess the fish assemblage structure during the 2015 field season. Counts are grouped by species and trawl site or seine region. Fish species are listed in phylogenetic order. Beach seine regions represent sites as assigned in Table A.1.

Fish species	Trawl site			Beach seine region					
	Sacramento	Mossdale	Chipps Island	1	2	3	4	5	6
River Lamprey *Lampetra ayresii*	6	0	0	0	0	0	0	0	0
Pacific Lamprey *Lampetra tridentatus*	102	4	0	0	0	0	0	0	0
Lamprey unknown *Lampetra* spp.	96	0	0	0	13	1	0	0	0
Northern Anchovy *Engraulis mordax*	0	0	341	0	0	0	0	0	1841
American Shad *Alosa sapidissima*	75	8136	7462	1	29	6	5	0	13
Pacific Herring *Clupea pallasii*	0	0	164	0	0	0	0	0	12
Threadfin Shad *Dorosoma petenense*	235	18116	1577	927	433	1481	3186	500	0
Goldfish *Carassius auratus*	1	0	0	4	0	0	0	0	0
Red Shiner *Cyprinella lutrensis*	0	16	0	1230	39	4	58	12139	0
Common Carp *Cyprinus carpio*	11	0	0	9	0	0	0	2	0
California Roach *Hesperoleucus symmetricus*	0	0	0	1	0	0	0	0	0
Hitch *Lavinia exilicauda*	0	0	1	10	7	43	0	0	0
Hardhead *Mylopharodon conocephalus*	0	0	0	26	1	0	0	0	0
Golden Shiner *Notemigonus crysoleucas*	1	12	1	38	29	158	117	42	0
Fathead Minnow *Pimephales promelas*	0	0	0	210	8	0	0	0	0
Sacramento Splittail *Pogonichthys macrolepidotus*	7	196	246	595	691	75	0	13	0
Sacramento Pikeminnow *Ptychocheilus grandis*	83	0	2	993	407	175	34	0	0
Sacramento Sucker *Catostomus occidentalis*	1	1	0	7768	918	5	0	92	0
White Catfish *Ameiurus catus*	3	57	0	0	3	0	0	0	0

Table A.4. Continued.

Fish species	Trawl site: Sacramento	Trawl site: Mossdale	Trawl site: Chipps Island	Beach seine region: 1	2	3	4	5	6
Black Bullhead *Ameiurus melus*	0	0	0	0	2	1	0	0	0
Brown Bullhead *Ameiurus nebulosus*	1	1	0	0	0	0	0	0	0
Channel Catfish *Ictalurus punctatus*	0	55	0	1	0	0	0	0	0
Wakasagi *Hypomesus nipponensis*	2	0	0	1	1	0	0	0	0
Delta Smelt *Hypomesus transpacificus*	0	0	12	0	39	0	0	0	0
Longfin Smelt *Spirinchus thaleichthys*	0	0	245	0	1	0	0	0	0
Steelhead *Oncorhynchus mykiss*	11	25	81	1	4	1	0	0	0
Unmarked Steelhead	1	17	3	0	0	0	0	0	0
Marked Steelhead	10	0	78	1	4	1	0	0	0
Acoustic Tag	0	8	0	0	0	0	0	0	0
Juvenile Chinook Salmon *Oncorhynchus tshawytscha*	844	78	2175	1057	1188	53	0	2	2
Unmarked winter-run	20	0	35	42	19	1	0	0	0
Unmarked fall-run	601	5	371	768	894	40	0	2	0
Unmarked spring-run	66	68	1108	237	257	10	0	0	1
Unmarked late fall-run	5	0	22	3	3	0	0	0	0
Spray dyed	0	3	0	0	0	0	0	0	0
Marked w/ CWT	152	2	639	7	15	2	0	0	1
Plainfin Midshipman *Porichthys notatus*	0	0	1	0	0	0	0	0	0
Striped Mullet *Mugil cephalus*	0	0	0	0	0	1	0	0	5
Topsmelt *Atherinops affinis*	0	0	12	0	0	0	0	0	4204
Jacksmelt *Atherinopsis californiensis*	0	0	17	0	0	0	0	0	11
Inland Silverside *Menidia beryllina*	320	4467	0	8076	30232	9800	33960	11566	55

Table A.4. Continued.

Fish species	Trawl site			Beach seine region					
	Sacramento	Mossdale	Chipps Island	1	2	3	4	5	6
Rainwater Killifish *Lucania parva*	0	0	0	0	439	53	118	0	20
Western Mosquitofish *Gambusia affinis*	1	0	0	306	508	89	125	271	0
Threespine Stickleback *Gasterosteus aculeatus*	3	0	7	10	17	5	0	0	8
Bay Pipefish *Syngnathus leptorhynchus*	0	0	0	0	0	0	0	0	49
Prickly Sculpin *Cottus asper*	0	0	0	3	7	9	6	0	0
Pacific Staghorn Sculpin *Leptocottus armatus*	0	0	0	0	0	3	0	0	48
Cabezon *Scorpaenichthys marmoratus*	0	0	0	0	0	0	0	0	1
Striped Bass *Morone saxatilis*	5	887	906	0	128	85	81	37	4
Green Sunfish *Lepomis cyanellus*	0	1	0	3	1	0	1	0	0
Warmouth *Lepomis gulosus*	1	0	0	0	0	1	0	0	0
Bluegill *Lepomis macrochirus*	32	1270	12	63	49	245	370	806	0
Redear Sunfish *Lepomis microlophus*	11	223	1	21	52	613	717	145	0
Smallmouth Bass *Micropterus dolomieu*	0	1	0	49	27	5	0	3	0
Redeye Bass *Micropterus coosae*	0	1	0	0	0	0	0	0	0
Spotted Bass *Micropterus punctulatus*	0	8	0	244	82	16	17	21	0
Largemouth Bass *Micropterus salmoides*	10	17	3	139	73	294	206	79	0
White Crappie *Pomoxis annularis*	0	0	0	8	0	0	0	0	0
Black Crappie *Pomoxis nigromaculatus*	3	3	1	6	2	0	1	2	0
Bigscale Logperch *Percina macrolepida*	0	1	0	291	13	64	16	0	0
White Croaker *Genyonemus lineatus*	0	0	0	0	0	0	0	0	1
Barred Surfperch *Amphistichus argenteus*	0	0	0	0	0	0	0	0	118
Calico Surfperch *Amphistichus koelzi*	0	0	0	0	0	0	0	0	1

Table A.4. Continued.

Fish species	Trawl site			Beach seine region					
	Sacramento	Mossdale	Chipps Island	1	2	3	4	5	6
Shiner Perch *Cymatogaster aggregata*	0	0	0	0	0	0	0	0	8
Black Perch *Embiotoca jacksoni*	0	0	0	0	0	0	0	0	3
Walleye Surfperch *Hyperprosopon argenteum*	0	0	0	0	0	0	0	0	144
Tule Perch *Hysterocarpus traskii*	11	0	4	22	176	154	10	0	0
Dwarf Surfperch *Micrometrus minimus*	0	0	0	0	0	0	0	0	63
White Seaperch *Phanerodon furcatus*	0	0	0	0	0	0	0	0	1
Crevice Kelpfish *Gibbonsia montereyensis*	0	0	0	0	0	0	0	0	2
English Sole Parophrys vetulus	0	0	0	0	0	0	0	0	4
Starry Flounder Platichthys stellatus	0	0	6	0	9	10	0	0	6
Diamond Turbot Pleuronichthys guttulatus	0	0	0	0	0	0	0	0	11
Sand Sole Psettichthys melanostictus	0	0	0	0	0	0	0	0	7
California Tonguefish Symphurus atricauda	0	0	1	0	0	0	0	0	0
Unidentified fish	0	5	0	0	0	0	0	0	1

Table A.5. Number of sample days and average number, standard deviation, and range of trawls per sample day for trawl sites within sample weeks during the 2014 field season.

	Chipps Island (SB018M,N,S)			Mossdale (SJ054M)			Sacramento (SR055M)		
Sample week	Sample days	Average trawls per sample day (SD)	Range	Sample days	Average trawls per sample day (SD)	Range	Sample days	Average trawls per sample day (SD)	Range
7/28/2013	1	10 (0)	10	1	10 (0)	10	1	10 (0)	10
8/4/2013	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
8/11/2013	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
8/18/2013	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
8/25/2013	3	10 (0)	10	3	10 (0)	10	3	8.67 (2.31)	6-10
9/1/2013	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
9/8/2013	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
9/15/2013	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
9/22/2013	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
9/29/2013	1	10 (0)	10	1	10 (0)	10	1	10 (0)	10
10/13/2013	1	10 (0)	10	1	10 (0)	10	1	10 (0)	10
10/20/2013	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
10/27/2013	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
11/3/2013	3	10 (0)	10	3	7 (5.20)	1-10	3	10 (0)	10
11/10/2013	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
11/17/2013	2	10 (0)	10	3	10 (0)	10	3	10 (0)	10
11/24/2013	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
12/1/2013	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
12/8/2013	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
12/15/2013	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
12/22/2013	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
12/29/2013	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
1/5/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
1/12/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
1/19/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
1/26/2014	3	7.33 (4.62)	2-10	3	10 (0)	10	3	10 (0)	10
2/2/2014	3	10 (0)	10	3	9 (1.73)	7-10	6	10 (0)	10
2/9/2014	3	10 (0)	10	2	10 (0)	10	7	10 (0)	10
2/16/2014	3	10 (0)	10	2	10 (0)	10	7	10 (0)	10
2/23/2014	3	10 (0)	10	3	10 (0)	10	5	10 (0)	10
3/2/2014	3	9.67 (0.58)	9-10	3	10 (0)	10	3	10 (0)	10
3/9/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
3/16/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
3/23/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10

Table A.5. Continued.

Sample week	Chipps Island (SB018M,N,S) Sample days	Average trawls per sample day (SD)	Range	Mossdale (SJ054M) Sample days	Average trawls per sample day (SD)	Range	Sacramento (SR055M) Sample days	Average trawls per sample day (SD)	Range
3/30/2014	3	10 (0)	10	5	10 (0)	10	3	10 (0)	10
4/6/2014	3	10 (0)	10	5	10.8 (1.79)	10-14	3	10 (0)	10
4/13/2014	3	10 (0)	10	5	10 (0)	10	3	10 (0)	10
4/20/2014	3	10 (0)	10	5	10 (0)	10	3	10 (0)	10
4/27/2014	3	10 (0)	10	5	10 (0)	10	3	10 (0)	10
5/4/2014	2	10 (0)	10	5	10 (0)	10	2	10 (0)	10
5/11/2014	2	10 (0)	10	5	10 (0)	10	2	10 (0)	10
5/18/2014	2	10 (0)	10	5	10 (0)	10	2	10 (0)	10
5/25/2014	2	10 (0)	10	4	10 (0)	10	2	10 (0)	10
6/1/2014	2	10 (0)	10	3	10 (0)	10	2	10 (0)	10
6/8/2014	2	10 (0)	10	3	10 (0)	10	2	10 (0)	10
6/15/2014	2	10 (0)	10	3	10 (0)	10	2	10 (0)	10
6/22/2014	2	10 (0)	10	3	10 (0)	10	2	10 (0)	10
6/29/2014	3	9 (1.73)	7-10	3	10 (0)	10	3	10 (0)	10
7/6/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
7/13/2014	3	9.33 (1.15)	8-10	3	10 (0)	10	3	10 (0)	10
7/20/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
7/27/2014	2	10 (0)	10	2	10.5 (0.71)	10-11	2	10 (0)	10

Table A.6. Number of sample days and average number, standard deviation, and range of trawls per sample day for trawl sites within sample weeks during the 2015 field season.

	Chipps Island (SB018M,N,S)			Mossdale (SJ054M)			Sacramento (SR055M)		
Sample week	Sample days	Average trawls per sample day (SD)	Range	Sample days	Average trawls per sample day (SD)	Range	Sample days	Average trawls per sample day (SD)	Range
7/27/2014	1	10 (0)	10	1	10 (0)	10	1	10 (0)	10
8/3/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
8/10/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
8/17/2014	3	10 (0)	10	3	10 (0)	10	3	10.33 (0.58)	10-11
8/24/2014	3	10 (0)	10	2	10 (0)	10	3	10 (0)	10
8/31/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
9/7/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
9/14/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
9/21/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
9/28/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
10/5/2014	3	10 (0)	10	3	10 (0)	10	3	9 (1.73)	7-10
10/12/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
10/19/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
10/26/2014	3	10 (0)	10	2	10 (0)	10	3	10 (0)	10
11/2/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
11/9/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
11/16/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
11/23/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
11/30/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
12/7/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
12/14/2014	2	10 (0)	10	3	10 (0)	10	3	10 (0)	10
12/21/2014	2	10 (0)	10	2	10 (0)	10	2	10 (0)	10
12/28/2014	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
1/4/2015	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
1/11/2015	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
1/18/2015	3	7 (5.20)	1-10	3	10 (0)	10	3	10 (0)	10
1/25/2015	3	10 (0)	10	3	9.33 (1.15)	8-10	3	10 (0)	10
2/1/2015	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
2/8/2015	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
2/15/2015	3	10 (0)	10	2	10 (0)	10	3	10 (0)	10
2/22/2015	3	8.33 (2.89)	5-10	3	10 (0)	10	3	10 (0)	10
3/1/2015	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
3/8/2015	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
3/15/2015	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
3/22/2015	3	8.67 (2.31)	6-10	3	10 (0)	10	3	10 (0)	10

Table A.6. Continued.

	Chipps Island (SB018M,N,S)			Mossdale (SJ054M)			Sacramento (SR055M)		
Sample week	Sample days	Average trawls per sample day (SD)	Range	Sample days	Average trawls per sample day (SD)	Range	Sample days	Average trawls per sample day (SD)	Range
3/29/2015	3	10 (0)	10	5	10 (0)	10	3	10 (0)	10
4/5/2015	3	10 (0)	10	5	10 (0)	10	3	10 (0)	10
4/12/2015	3	10 (0)	10	5	10 (0)	10	3	10 (0)	10
4/19/2015	3	10 (0)	10	5	10 (0)	10	3	10 (0)	10
4/26/2015	3	10 (0)	10	5	10 (0)	10	4	9.75 (0.5)	9-10
5/3/2015	2	10 (0)	10	5	10 (0)	10	2	10 (0)	10
5/10/2015	2	10 (0)	10	4	10 (0)	10	6	10 (0)	10
5/17/2015	2	10 (0)	10	4	10 (0)	10	2	10 (0)	10
5/24/2015	2	10 (0)	10	4	10 (0)	10	2	10 (0)	10
5/31/2015	2	10 (0)	10	3	10 (0)	10	2	10 (0)	10
6/7/2015	2	10 (0)	10	3	10 (0)	10	2	10 (0)	10
6/14/2015	2	10 (0)	10	3	10 (0)	10	2	10 (0)	10
6/21/2015	2	10 (0)	10	3	10 (0)	10	2	9 (1.41)	8-10
6/28/2015	3	10 (0)	10	3	10 (0)	10	2	10 (0)	10
7/5/2015	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
7/12/2015	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
7/19/2015	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10
7/26/2015	3	10 (0)	10	3	10 (0)	10	3	10 (0)	10

Table A.7. Beach seine sites where fish samples were collected at least once within a sample week in the Lower Sacramento River Seine Region during the 2014 field season.

Sample	Station code							
week	SR071E	SR080E	SR090W	SR094E	SR119E	SR130E	SR138E	SR144W
7/28/2013	X		X	X	X		X	X
8/4/2013	X	X	X	X	X	X	X	X
8/11/2013	X	X	X	X	X	X	X	X
8/18/2013	X	X	X	X	X		X	X
8/25/2013	X	X	X	X	X	X	X	
9/1/2013	X	X	X	X	X	X		
9/8/2013	X	X	X	X	X		X	
9/15/2013	X	X	X	X	X	X	X	
9/22/2013	X	X	X	X	X	X	X	
10/13/2013	X	X						
10/20/2013	X	X	X	X	X	X	X	
10/27/2013	X	X	X	X	X	X	X	
11/3/2013	X	X	X	X	X	X	X	
11/10/2013	X	X	X	X	X	X	X	
11/17/2013	X	X	X		X	X		
11/24/2013	X	X	X		X	X		
12/1/2013	X	X	X	X	X			
12/8/2013	X	X	X	X	X	X		
12/15/2013	X	X	X	X	X			
12/22/2013	X	X	X		X	X		
12/29/2013	X	X	X	X	X	X		
1/5/2014	X	X	X	X	X	X		
1/12/2014	X	X	X	X	X			
1/19/2014		X	X	X	X	X		
1/26/2014	X	X			X			
2/2/2014	X	X	X		X			
2/9/2014	X	X	X		X	X	X	
2/16/2014	X	X	X	X	X	X	X	
2/23/2014	X	X	X	X	X	X		
3/2/2014	X	X	X		X		X	X
3/9/2014	X	X	X		X		X	X
3/16/2014	X	X	X		X		X	
3/23/2014	X	X	X	X	X	X		
3/30/2014	X	X	X		X		X	X
4/6/2014	X	X	X		X	X	X	
4/13/2014	X	X	X	X	X	X		
4/20/2014	X	X	X		X			
4/27/2014	X	X	X			X		

Table A.7. Continued.

Sample week	Station code							
	SR071E	SR080E	SR090W	SR094E	SR119E	SR130E	SR138E	SR144W
5/4/2014		X	X		X	X		
5/11/2014		X	X	X	X	X		
5/18/2014		X		X	X	X		
5/25/2014		X	X	X	X	X		
6/1/2014	X	X	X	X	X		X	
6/8/2014		X	X	X	X	X		
6/15/2014	X	X	X	X	X			
6/22/2014		X	X	X	X		X	
6/29/2014		X	X	X	X		X	
7/6/2014	X	X	X	X	X	X	X	
7/13/2014	X	X	X	X	X		X	
7/20/2014	X	X	X	X	X		X	
7/27/2014	X	X	X	X	X		X	

Table A.8. Beach seine sites where fish samples were collected at least once within a sample week in the Lower Sacramento River Seine Region during the 2015 field season.

Sample	Station code							
week	SR071E	SR080E	SR090W	SR094E	SR119E	SR130E	SR138E	SR144W
8/3/2014	X	X	X	X	X		X	
8/10/2014	X	X	X	X	X		X	
8/17/2014	X	X	X	X	X		X	
8/24/2014	X	X	X	X	X			
8/31/2014	X	X	X	X	X		X	
9/7/2014	X	X	X	X	X			
9/14/2014	X	X	X	X	X			
9/21/2014	X	X	X	X	X			
9/28/2014	X	X	X	X	X		X	
10/5/2014	X	X	X		X			
10/12/2014	X	X	X	X	X	X		
10/19/2014	X	X	X	X	X		X	
10/26/2014	X	X	X	X	X			
11/2/2014	X	X	X	X	X		X	
11/9/2014	X	X	X	X	X		X	
11/16/2014	X	X	X	X	X			
11/23/2014	X	X	X	X	X	X	X	
11/30/2014	X	X	X	X	X		X	
12/7/2014	X	X						
12/14/2014	X	X	X				X	X
12/21/2014	X	X					X	
12/28/2014	X	X	X					
1/4/2015	X	X	X		X			
1/11/2015	X	X	X		X		X	
1/18/2015	X	X	X	X	X		X	
1/25/2015	X	X	X		X			
2/1/2015	X	X	X		X	X		
2/8/2015	X	X					X	X
2/15/2015		X	X	X	X			
2/22/2015	X	X	X		X		X	
3/1/2015	X	X	X	X	X		X	
3/8/2015	X	X	X		X			
3/15/2015	X	X	X		X			
3/22/2015	X	X	X	X	X			
3/29/2015	X	X	X		X	X	X	
4/5/2015	X	X	X				X	
4/12/2015	X	X	X			X	X	
4/19/2015	X	X	X		X	X	X	

Table A.8. Continued.

Sample week	Station code							
	SR071E	SR080E	SR090W	SR094E	SR119E	SR130E	SR138E	SR144W
4/26/2015	X	X	X	X	X	X		
5/3/2015	X	X	X	X	X	X		
5/10/2015	X	X	X		X	X		
5/17/2015	X	X	X		X	X		
5/24/2015	X	X			X	X		
5/31/2015	X	X	X		X	X		
6/7/2015	X		X		X			
6/14/2015	X	X	X	X	X	X		
6/21/2015		X	X		X	X	X	
6/28/2015	X	X	X	X	X	X		
7/5/2015		X	X		X	X		
7/12/2015	X	X	X	X	X	X		
7/19/2015		X	X	X	X	X		
7/26/2015		X	X		X	X		

Table A.9. Beach seine sites where fish samples were collected at least once within a sample week in the North Delta Seine Region during the 2014 field season.

Sample	Station code										
week	AM001S	MS001A	MS001N	SR012W	SR014W	SR017E	SR024E	SR043W	SR049E	SR060E	SS011N
8/4/2013	X		X		X	X	X	X	X	X	X
8/11/2013	X		X	X	X	X	X	X	X	X	X
8/18/2013	X		X	X	X	X	X		X	X	X
8/25/2013	X		X	X	X	X	X		X	X	X
9/1/2013	X			X	X	X	X	X	X	X	X
9/8/2013	X		X	X	X	X	X	X	X	X	X
9/15/2013	X		X	X	X	X	X	X	X	X	X
9/22/2013	X		X	X	X	X	X	X	X	X	X
10/13/2013	X								X	X	
10/20/2013	X			X	X	X	X	X	X	X	X
10/27/2013	X		X	X	X	X		X	X	X	X
11/3/2013	X		X	X		X	X	X	X	X	X
11/10/2013	X		X	X	X	X	X	X	X	X	X
11/17/2013	X		X	X	X	X	X	X	X	X	X
11/24/2013	X		X	X	X	X	X	X	X	X	
12/1/2013	X		X	X	X		X	X	X	X	X
12/8/2013	X		X	X	X	X	X	X	X	X	X
12/15/2013	X		X	X	X		X	X	X	X	X
12/22/2013	X		X	X	X	X	X	X	X	X	X
12/29/2013	X		X	X	X	X	X	X	X	X	X
1/5/2014	X		X	X	X	X	X	X	X	X	X
1/12/2014	X		X	X	X	X	X	X	X	X	X
1/19/2014	X		X	X	X	X	X	X	X	X	X
1/26/2014	X					X	X	X	X	X	X
2/2/2014	X		X	X	X	X	X	X	X	X	X
2/9/2014	X		X	X	X	X	X	X	X	X	X
2/16/2014	X			X	X	X	X	X	X	X	X
2/23/2014	X		X	X	X	X	X	X	X	X	X
3/2/2014	X			X	X	X	X	X	X	X	X
3/9/2014	X		X		X	X	X	X	X	X	X
3/16/2014	X	X		X	X	X	X	X	X	X	X
3/23/2014	X		X	X	X	X	X	X	X	X	
3/30/2014	X			X	X			X	X	X	X
4/6/2014	X		X		X	X	X	X	X	X	X
4/13/2014	X			X	X	X	X	X	X	X	X
4/20/2014	X		X	X	X	X	X	X	X	X	X
4/27/2014	X		X	X	X	X	X	X	X	X	
5/4/2014	X		X	X	X	X	X	X	X	X	X
5/11/2014	X			X	X	X		X	X	X	
5/18/2014	X		X	X	X	X	X	X	X	X	X
5/25/2014	X			X	X		X	X	X	X	X
6/1/2014	X		X		X	X		X	X	X	X
6/8/2014				X	X		X	X	X	X	X
6/15/2014	X		X	X	X	X	X	X	X	X	X
6/22/2014	X			X	X	X		X	X	X	X
6/29/2014	X		X	X	X	X	X	X	X	X	X
7/6/2014	X		X		X	X	X	X	X	X	X
7/13/2014	X		X	X	X	X	X	X	X	X	X
7/20/2014	X		X	X	X	X	X	X	X	X	
7/27/2014					X						

Table A.10. Beach seine sites where fish samples were collected at least once within a sample week in the North Delta Seine Region during the 2015 field season.

Sample	Station code										
week	AM001S	MS001A	MS001N	SR012W	SR014W	SR017E	SR024E	SR043W	SR049E	SR060E	SS011N
7/27/2014	X					X	X	X	X	X	
8/3/2014	X		X	X	X	X	X	X		X	X
8/10/2014	X			X	X	X		X	X	X	X
8/17/2014	X		X	X	X	X		X	X	X	
8/24/2014	X			X	X	X	X	X	X	X	X
8/31/2014	X		X	X	X	X	X	X	X	X	
9/7/2014	X			X	X	X	X	X	X	X	X
9/14/2014	X		X	X	X	X	X	X	X	X	X
9/21/2014	X			X		X			X	X	X
9/28/2014	X		X	X		X	X	X	X	X	X
10/5/2014	X		X	X	X	X	X	X	X	X	X
10/12/2014	X			X			X	X	X	X	X
10/19/2014	X		X	X		X		X	X	X	X
10/26/2014	X		X	X			X	X	X	X	X
11/2/2014	X			X			X	X	X	X	X
11/9/2014	X					X	X	X	X	X	X
11/16/2014	X		X	X		X	X	X	X	X	X
11/23/2014	X		X	X		X	X	X	X	X	X
11/30/2014	X		X	X		X	X	X	X	X	X
12/7/2014	X					X	X	X	X	X	X
12/14/2014						X	X		X	X	X
12/21/2014				X		X	X	X	X	X	
12/28/2014	X				X	X	X	X		X	
1/4/2015	X		X	X		X	X	X		X	X
1/11/2015			X	X		X	X			X	X
1/18/2015	X		X	X	X	X	X	X		X	X
1/25/2015			X			X	X	X	X	X	X
2/1/2015	X		X		X	X	X	X	X	X	X
2/8/2015	X		X			X	X	X	X	X	X
2/15/2015	X				X	X	X	X	X		X
2/22/2015	X		X			X	X	X	X	X	X
3/1/2015	X		X		X	X	X	X	X	X	X
3/8/2015	X			X		X	X	X	X	X	X
3/15/2015	X			X	X	X	X	X	X	X	X
3/22/2015	X			X	X	X	X		X	X	X
3/29/2015	X			X	X	X		X	X	X	X
4/5/2015	X			X	X	X	X	X	X	X	X
4/12/2015	X				X	X	X	X	X	X	X
4/19/2015	X		X			X	X	X	X	X	X
4/26/2015	X		X	X	X	X	X	X	X	X	X
5/3/2015	X		X	X				X	X	X	X
5/10/2015	X		X	X	X	X	X	X	X	X	X
5/17/2015				X		X	X	X	X	X	
5/24/2015	X			X	X		X	X	X	X	X
5/31/2015	X			X				X	X	X	X
6/7/2015	X		X	X			X	X	X	X	X
6/14/2015	X			X	X	X		X	X	X	X
6/21/2015	X		X	X		X	X	X	X	X	X
6/28/2015	X			X	X			X	X	X	X
7/5/2015	X		X	X		X	X	X	X	X	X
7/12/2015	X			X	X	X		X	X	X	X
7/19/2015	X		X			X	X		X	X	X
7/26/2015	X			X		X		X	X	X	X

Table A.11. Beach seine sites where fish samples were collected at least once within a sample week in the Central Delta Seine Region during the 2014 field season.

Sample	Station code								
week	DS002S	GS010E	LP003E	MK004W	SF014E	SJ001S	SJ005N	TM001N	XC001N
8/4/2013	X	X	X	X	X	X	X		
8/11/2013		X	X	X	X	X	X	X	X
8/18/2013	X	X	X	X	X	X	X		
8/25/2013	X	X	X	X	X	X	X		X
9/1/2013	X	X	X	X	X	X	X	X	X
9/8/2013		X	X	X	X	X	X		X
9/15/2013		X	X	X	X	X	X	X	X
9/22/2013		X	X	X	X	X	X		X
10/20/2013		X	X	X	X	X	X		X
10/27/2013	X		X	X	X	X	X		X
11/3/2013		X	X	X	X	X	X		X
11/10/2013	X	X	X	X	X		X		X
11/17/2013	X	X	X	X	X	X	X	X	
11/24/2013	X	X	X	X	X	X	X		X
12/1/2013		X	X	X	X		X		X
12/8/2013	X	X	X	X	X		X	X	
12/15/2013	X	X	X	X	X		X		X
12/22/2013	X	X	X	X	X	X	X		
12/29/2013	X	X	X	X	X	X	X	X	X
1/5/2014	X	X	X	X	X	X	X		
1/12/2014	X	X	X	X	X	X	X	X	X
1/19/2014	X	X	X	X	X	X	X		X
1/26/2014		X			X				X
2/2/2014		X	X	X	X	X	X		
2/9/2014	X	X	X	X	X		X	X	X
2/16/2014	X	X	X	X	X	X	X	X	X
2/23/2014	X	X	X	X	X		X		X
3/2/2014	X		X	X	X	X	X	X	
3/9/2014	X	X	X	X	X	X	X	X	X
3/16/2014	X	X		X	X	X	X	X	X
3/23/2014	X		X	X	X		X		X
3/30/2014	X	X	X	X	X	X	X	X	X
4/6/2014	X	X	X	X	X	X	X	X	X
4/13/2014	X	X	X	X	X	X	X	X	
4/20/2014	X			X	X		X		
4/27/2014	X	X		X	X	X	X	X	
5/4/2014	X	X	X	X	X	X	X	X	X
5/11/2014	X	X	X	X	X	X	X		X
5/18/2014	X	X	X	X	X	X	X		
5/25/2014	X	X		X	X	X	X		
6/1/2014	X	X	X	X	X	X	X		
6/8/2014	X			X	X		X		
6/15/2014	X		X	X	X	X	X		
6/22/2014	X	X	X	X	X	X	X		
6/29/2014	X	X	X	X	X	X	X		
7/6/2014	X	X	X	X	X	X	X		X
7/13/2014	X		X	X	X	X	X	X	
7/20/2014	X	X	X	X	X	X	X		X
7/27/2014	X			X		X	X		

Table A.12. Beach seine sites where fish samples were collected at least once within a sample week in the Central Delta Seine Region during the 2015 field season.

Sample	Station code								
week	DS002S	GS010E	LP003E	MK004W	SF014E	SJ001S	SJ005N	TM001N	XC001N
7/27/2014		X			X				
8/3/2014	X	X	X	X	X	X	X		X
8/10/2014	X		X	X	X	X	X		
8/17/2014	X		X	X	X	X	X		X
8/24/2014	X	X		X	X	X	X		
8/31/2014	X	X	X	X	X		X	X	X
9/7/2014	X	X		X	X	X	X		
9/14/2014	X	X		X		X	X		
9/21/2014	X	X		X	X	X	X		X
9/28/2014		X		X	X	X	X		
10/5/2014		X		X	X	X	X		
10/12/2014		X		X	X		X		X
10/19/2014		X		X	X	X	X		
10/26/2014		X		X	X	X	X		
11/2/2014	X	X		X	X	X	X		
11/9/2014	X	X		X	X	X	X		
11/16/2014	X	X		X	X		X	X	X
11/23/2014	X	X			X		X	X	
11/30/2014	X	X			X		X		
12/7/2014		X			X				
12/14/2014	X				X				
12/21/2014	X			X	X	X			
12/28/2014	X	X		X	X		X		X
1/4/2015	X			X	X	X	X		
1/11/2015	X	X	X	X	X	X	X	X	X
1/18/2015	X		X	X	X				
1/25/2015	X	X	X		X	X			X
2/1/2015		X		X	X		X	X	X
2/8/2015	X	X		X	X	X	X		
2/15/2015	X			X	X	X	X	X	
2/22/2015	X	X	X	X	X		X		
3/1/2015	X	X	X	X	X	X	X	X	X
3/8/2015	X	X		X	X	X	X	X	
3/15/2015	X			X	X	X	X	X	X
3/22/2015	X	X		X	X	X	X	X	X
3/29/2015	X	X		X	X	X	X	X	X
4/5/2015	X	X	X	X	X	X	X		
4/12/2015	X	X	X	X	X		X		X
4/19/2015	X	X		X	X	X	X		
4/26/2015	X	X	X	X	X	X	X	X	X
5/3/2015	X			X	X	X	X		
5/10/2015	X	X	X	X	X	X	X		
5/17/2015	X	X		X	X	X	X		
5/24/2015	X	X	X	X	X	X	X		X
5/31/2015	X	X		X	X	X	X	X	
6/7/2015	X		X	X	X	X	X		
6/14/2015	X		X	X	X	X	X	X	
6/21/2015	X			X	X	X	X		X

Table A. 12. Continued.

Sample week	Station code								
	DS002S	GS010E	LP003E	MK004W	SF014E	SJ001S	SJ005N	TM001N	XC001N
6/28/2015	X			X	X	X	X	X	
7/5/2015	X	X		X	X	X	X		
7/12/2015	X	X		X	X	X			X
7/19/2015	X			X		X	X		
7/26/2015	X			X	X	X	X		X

Table A.13. Beach seine sites where fish samples were collected at least once within a sample week in the South Delta Seine Region during the 2014 field season.

Sample	Station code									
week	MR010W	OR003W	OR014W	OR019E	OR023E	SJ026S	SJ032S	SJ041N	SJ051E	WD002W
7/28/2013	X	X	X	X		X	X	X	X	X
8/4/2013	X		X	X	X	X	X	X	X	X
8/11/2013	X		X			X	X	X	X	X
8/18/2013	X		X			X			X	
8/25/2013	X		X	X		X	X	X	X	X
9/1/2013	X	X		X	X	X	X	X	X	X
9/8/2013	X	X				X	X			X
9/15/2013	X	X		X	X	X	X	X		X
9/22/2013	X						X	X		
10/20/2013	X						X	X	X	
10/27/2013	X	X		X	X	X	X	X		X
11/3/2013	X	X	X							
11/10/2013		X				X	X	X		X
11/17/2013	X						X	X		X
11/24/2013		X					X	X		X
12/1/2013	X						X	X	X	
12/8/2013							X	X	X	X
12/15/2013	X	X	X	X	X		X	X	X	X
12/22/2013							X	X	X	
12/29/2013	X	X	X	X		X	X	X		X
1/5/2014							X	X	X	
1/12/2014	X	X		X		X	X	X	X	X
1/19/2014							X	X	X	
1/26/2014	X	X	X			X	X	X	X	X
2/2/2014	X						X	X	X	
2/9/2014	X	X			X	X	X	X	X	X
2/16/2014	X		X			X	X	X	X	X
2/23/2014		X	X			X	X	X	X	X
3/2/2014	X						X		X	
3/9/2014	X	X	X	X	X	X	X	X	X	X
3/16/2014						X	X	X	X	
3/23/2014	X	X	X	X	X	X	X	X	X	
3/30/2014	X		X	X		X	X		X	X
4/6/2014	X	X	X	X		X	X	X	X	X
4/13/2014	X	X	X	X	X	X	X	X	X	X
4/20/2014	X		X			X	X	X	X	
4/27/2014	X	X				X	X	X	X	
5/4/2014	X		X			X	X	X		

Table A.13. Continued.

Sample week	Station code									
	MR010W	OR003W	OR014W	OR019E	OR023E	SJ026S	SJ032S	SJ041N	SJ051E	WD002W
5/11/2014	X	X	X	X	X	X	X	X	X	
5/18/2014	X	X	X		X	X	X	X	X	
5/25/2014	X		X		X	X	X		X	
6/1/2014						X	X	X	X	
6/8/2014	X		X		X	X	X		X	
6/15/2014	X		X			X	X	X	X	X
6/22/2014	X	X				X	X	X	X	
6/29/2014	X								X	
7/6/2014	X		X		X	X	X	X		X
7/13/2014						X	X	X	X	
7/20/2014		X				X	X	X		
7/27/2014	X					X	X		X	

Table A.14. Beach seine sites where fish samples were collected at least once within a sample week in the South Delta Seine Region during the 2015 field season.

Sample	Station code									
week	MR010W	OR003W	OR014W	OR019E	OR023E	SJ026S	SJ032S	SJ041N	SJ051E	WD002W
8/3/2014		X	X			X	X	X		
8/10/2014	X					X			X	
8/17/2014	X	X			X	X	X	X		
8/24/2014	X					X	X			
9/7/2014	X									
9/14/2014	X				X	X	X	X		
9/21/2014	X									
9/28/2014	X							X		X
10/5/2014	X				X		X			
10/12/2014	X	X					X	X		
10/19/2014	X	X			X		X	X		
10/26/2014	X							X		
11/2/2014	X	X			X		X	X	X	X
11/9/2014										
11/16/2014		X						X	X	
11/23/2014	X							X		
11/30/2014						X			X	
12/7/2014	X									
12/14/2014	X					X	X		X	
12/21/2014				X						
12/28/2014								X		
1/4/2015	X								X	
1/11/2015								X		
1/18/2015	X			X		X	X	X		
1/25/2015	X						X	X	X	
2/1/2015		X	X	X			X		X	
2/8/2015							X		X	
2/15/2015	X		X	X			X	X	X	
2/22/2015					X		X	X	X	
3/1/2015	X	X					X	X	X	
3/8/2015	X								X	
3/15/2015	X	X	X	X	X	X	X	X	X	X
3/22/2015	X							X	X	
3/29/2015	X	X	X	X	X	X	X	X	X	
4/5/2015	X					X	X		X	
4/12/2015	X		X	X	X	X	X	X	X	
4/19/2015										
4/26/2015	X	X	X	X	X	X	X	X	X	

Table A.14. Continued.

Sample	Station code									
week	MR010W	OR003W	OR014W	OR019E	OR023E	SJ026S	SJ032S	SJ041N	SJ051E	WD002W
5/3/2015	X								X	
5/10/2015	X	X	X		X	X	X	X	X	
5/17/2015	X								X	
5/24/2015	X	X		X		X	X		X	
5/31/2015	X		X	X	X	X			X	
6/7/2015	X					X	X	X	X	
6/14/2015	X								X	
6/21/2015		X	X	X		X	X	X	X	
6/28/2015	X		X	X		X		X	X	X
7/5/2015	X					X	X	X		
7/12/2015	X								X	
7/19/2015	X		X	X		X	X	X		
7/26/2015	X	X	X	X	X	X			X	

Table A.15. Beach seine sites where fish samples were collected at least once within a sample week in the Lower San Joaquin River Seine Region during the 2014 field season.

Sample	Station code							
week	SJ056E	SJ058W	SJ063W	SJ068W	SJ074W	SJ076W	SJ077E	SJ083W
7/28/2013	X	X	X	X	X	X		
8/4/2013	X	X	X		X		X	
8/11/2013	X	X	X		X		X	
8/18/2013	X	X	X		X		X	
8/25/2013	X	X	X		X		X	
9/1/2013		X	X		X		X	
9/8/2013			X		X		X	
9/15/2013			X		X		X	
9/22/2013		X	X	X	X			X
10/20/2013	X	X	X	X	X		X	X
10/27/2013	X	X	X	X	X			X
11/3/2013	X	X	X	X	X		X	X
11/10/2013	X	X	X	X	X		X	X
11/17/2013	X	X	X	X	X		X	X
11/24/2013	X	X	X	X	X		X	X
12/1/2013	X	X	X	X	X		X	X
12/8/2013	X	X	X	X	X		X	X
12/15/2013	X	X	X	X	X		X	X
12/22/2013	X	X	X	X	X		X	X
1/5/2014	X	X	X		X		X	
1/12/2014	X	X	X		X		X	
1/19/2014	X	X	X		X		X	
1/26/2014	X	X	X	X	X		X	X
2/2/2014	X	X	X	X	X		X	X
2/9/2014	X	X	X	X	X		X	X
2/16/2014	X	X	X	X	X		X	X
2/23/2014	X	X	X		X		X	
3/2/2014	X	X	X	X	X		X	X
3/9/2014	X	X	X		X		X	X
3/16/2014	X	X	X		X		X	
3/23/2014	X	X	X		X		X	
3/30/2014	X	X	X		X		X	X
4/6/2014	X	X	X		X		X	X
4/13/2014	X	X					X	X
4/20/2014	X	X	X	X			X	X
4/27/2014	X	X	X	X				X
5/4/2014	X	X	X	X			X	X
5/11/2014	X	X	X	X	X		X	

Table A.15. Continued.

Sample	Station code							
week	SJ056E	SJ058W	SJ063W	SJ068W	SJ074W	SJ076W	SJ077E	SJ083W
5/18/2014	X	X	X		X		X	
5/25/2014	X	X	X		X		X	
6/1/2014	X	X	X		X		X	
6/8/2014	X	X	X		X		X	
6/15/2014	X	X	X		X		X	
6/22/2014	X	X	X		X		X	
6/29/2014	X	X	X		X		X	
7/13/2014	X	X	X		X		X	
7/27/2014	X	X	X		X		X	

Table A.16. Beach seine sites where fish samples were collected at least once within a sample week in the Lower San Joaquin River Region during the 2015 field season.

Sample	Station code							
week	SJ056E	SJ058W	SJ063W	SJ068W	SJ074W	SJ076W	SJ077E	SJ083W
8/10/2014	X	X	X		X		X	
8/24/2014	X	X	X		X		X	
9/7/2014	X	X	X		X		X	
9/21/2014	X	X	X		X		X	
10/5/2014	X	X	X		X		X	
10/19/2014	X	X	X		X		X	
11/2/2014	X	X	X	X	X			
11/16/2014	X	X	X		X		X	
11/30/2014	X	X	X	X	X			
12/14/2014	X	X	X	X	X			
12/28/2014	X	X	X	X	X			
1/4/2015	X	X	X	X	X			
1/11/2015	X	X	X	X	X			
1/18/2015					X			
1/25/2015	X	X	X	X	X			
2/1/2015	X	X	X	X	X			
2/8/2015	X	X	X	X	X			
2/15/2015	X	X	X		X			
2/22/2015	X	X	X	X	X			
3/1/2015	X	X	X		X		X	
3/8/2015	X	X	X		X		X	
3/15/2015	X	X	X		X		X	
3/22/2015	X	X	X		X	X		
3/29/2015	X	X	X		X		X	
4/5/2015	X	X	X		X			
4/12/2015	X	X	X		X		X	
4/19/2015	X	X	X		X		X	
4/26/2015	X	X	X		X		X	
5/3/2015	X	X	X				X	
5/10/2015	X	X	X					
5/17/2015	X	X	X				X	
5/24/2015	X	X	X		X		X	
5/31/2015	X	X	X		X		X	
6/7/2015	X	X	X		X		X	
6/14/2015	X	X	X		X		X	
6/21/2015	X	X	X		X		X	
6/28/2015		X	X		X		X	
7/12/2015	X	X	X		X		X	
7/26/2015	X	X	X		X		X	

Table A.17. Beach seine sites where fish samples were collected at least once within a sample week in the San Francisco and San Pablo Bays Region during the 2014 field season.

Sample	Station code								
week	SA001M	SA004W	SA007E	SA008W	SA009E	SA010W	SP000W	SP001W	SP003E
7/28/2013		X		X		X	X	X	
8/4/2013	X		X		X				
8/11/2013		X		X		X	X	X	
8/18/2013	X		X		X				
8/25/2013				X		X	X	X	
9/1/2013	X		X		X				
9/8/2013		X		X			X	X	
9/15/2013	X		X		X				
9/22/2013				X		X	X	X	
10/20/2013		X				X		X	
10/27/2013	X		X		X				X
11/3/2013		X		X		X	X	X	
11/10/2013	X		X		X				X
11/17/2013		X		X		X	X	X	
11/24/2013	X		X		X				X
12/1/2013		X		X		X	X	X	
12/8/2013	X		X		X				X
12/15/2013		X				X	X	X	
12/22/2013	X		X		X				X
12/29/2013		X		X		X	X	X	
1/5/2014	X		X		X				X
1/12/2014		X				X	X	X	
1/19/2014	X		X		X				X
1/26/2014		X		X		X	X	X	
2/2/2014	X		X		X				X
2/9/2014		X		X		X	X	X	
2/16/2014	X		X		X				
2/23/2014		X				X	X	X	
3/2/2014	X		X		X				X
3/9/2014		X		X			X	X	
3/16/2014	X		X		X				
3/23/2014		X		X		X	X	X	
3/30/2014	X		X		X				
4/6/2014				X		X	X	X	
4/13/2014	X		X		X				
4/20/2014				X		X	X	X	
4/27/2014	X		X		X				
5/4/2014				X		X	X	X	

Table A.17. Continued.

Sample week	Station code SA001M	SA004W	SA007E	SA008W	SA009E	SA010W	SP000W	SP001W	SP003E
5/11/2014	X		X		X				
5/18/2014		X				X	X	X	
5/25/2014	X		X		X				
6/1/2014				X		X		X	
6/8/2014	X		X		X				
6/15/2014				X		X	X	X	
6/22/2014	X		X		X				X
6/29/2014						X	X	X	
7/6/2014	X		X		X				X
7/13/2014				X		X			
7/20/2014	X		X		X				X
7/27/2014				X		X			

Table A.18. Beach seine sites where fish samples were collected at least once within a sample week in the San Francisco and San Pablo Bays Region during the 2015 field season.

Sample	Station code								
week	SA001M	SA004W	SA007E	SA008W	SA009E	SA010W	SP000W	SP001W	SP003E
8/3/2014	X		X		X				X
8/10/2014				X		X			
8/17/2014	X		X		X				X
8/24/2014		X		X			X		
8/31/2014			X		X				X
9/7/2014		X		X		X	X		
9/14/2014	X		X		X				X
9/21/2014		X		X		X	X	X	
9/28/2014			X		X				X
10/5/2014		X		X		X	X	X	
10/12/2014			X		X				X
10/19/2014		X		X		X	X	X	
10/26/2014			X		X				X
11/2/2014		X		X		X	X	X	
11/9/2014			X		X				X
11/16/2014		X		X		X	X	X	
11/23/2014			X		X				X
11/30/2014		X		X		X	X	X	
12/14/2014		X		X		X	X	X	
12/21/2014			X		X				
12/28/2014		X		X		X	X	X	
1/4/2015			X		X				
1/11/2015				X		X	X		
1/18/2015			X		X				X
1/25/2015		X		X		X	X	X	
2/1/2015			X		X				X
2/8/2015				X		X	X	X	
2/15/2015			X		X				X
2/22/2015				X		X			
3/1/2015			X		X				X
3/8/2015				X		X	X		
3/15/2015			X		X				X
3/22/2015				X		X			
3/29/2015			X		X				
4/5/2015				X		X			
4/12/2015	X		X		X				X
4/19/2015						X		X	
4/26/2015	X		X		X				X

Table A.18. Continued.

Sample week	Station code SA001M	SA004W	SA007E	SA008W	SA009E	SA010W	SP000W	SP001W	SP003E
5/3/2015				X		X			
5/10/2015	X		X		X				X
5/17/2015				X		X			
5/24/2015			X		X				X
5/31/2015		X		X		X	X	X	
6/7/2015	X		X		X				X
6/14/2015				X		X			
6/21/2015	X		X		X				X
6/28/2015		X		X			X	X	
7/5/2015	X		X		X				X
7/12/2015		X					X	X	
7/19/2015	X		X		X				X
7/26/2015		X					X		

Table A.19. Water year types for the Sacramento and San Joaquin River basins from 1978 to 2015 (CDWR 2016). Water year types were classified as wet (W), above normal (AN), below normal (BN), dry (D), and critically dry (C).

Water year	Water year type	
	Sacramento River	San Joaquin River
1978	AN	W
1979	BN	AN
1980	AN	W
1981	D	D
1982	W	W
1983	W	W
1984	W	AN
1985	D	D
1986	W	W
1987	D	C
1988	C	C
1989	D	C
1990	C	C
1991	C	C
1992	C	C
1993	AN	W
1994	C	C
1995	W	W
1996	W	W
1997	W	W
1998	W	W
1999	W	AN
2000	AN	AN
2001	D	D
2002	D	D
2003	AN	BN
2004	BN	D
2005	AN	W
2006	W	W
2007	D	C
2008	C	C
2009	D	BN
2010	BN	AN
2011	W	W
2012	BN	D

Table A.19. Continued.

Water year	Water year type	
	Sacramento River	San Joaquin River
2013	D	C
2014	C	C
2015	C	C

Table A.20. Recoveries of all coded wire tagged juvenile winter-, fall-, late fall-, and spring-run Chinook Salmon by the DJFMP and fish facilities during the 2014 field season by release location and hatchery of origin. The hatcheries of origin included the Coleman National Fish Hatchery (ColemNFH), Livingston Stone National Fish Hatchery (LivinNFH), Feather River Fish Hatchery (FeathFH), Mokelumne River Fish Hatchery (MokeFH), San Joaquin River Conservation Hatchery (SanJoaqFH), and Merced River Fish Facility (MercFF; PSMFC 2017).

	Recovery location									
Release location (hatchery of origin)	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Sacramento Trawl Site	Mossdale Trawl Site	Chipps Island Trawl Site	**DJFMP total**
Winter-run										
Caldwell Park (LivinNFH)	0	0	0	0	0	0	13	0	18	**31**
Fall-run										
Battle Creek (ColemNFH)	0	0	0	0	0	0	89	0	66	**155**
Sac. R. at Rio Vista (ColemNFH)	0	2	0	0	0	0	0	0	157	**159**
Sac. R. at Rio Vista (FeathFH)	0	1	0	0	0	0	0	0	12	**13**
Wickland Oil Net Pen (FeathFH)	0	0	0	0	0	0	0	0	8	**8**
Yolo Bypass (FeathFH)	0	0	0	0	0	0	0	0	1	**1**
San Joaq. R. Jersey Pt. (MercFH)	0	0	6	0	0	0	0	0	71	**77**
San Joaq. Shrm. Is. Net Pen (MokeFH)	0	0	0	0	0	0	0	0	129	**129**
San Joaq. R. Friant Net (SanJoaqFH)	0	0	0	0	0	0	0	1	0	**1**
San Joaq. R. Ab. Merced (SanJoaqFH)	0	0	0	0	0	0	0	6	0	**6**
Late fall-run										
Battle Creek (ColemNFH)	3	9	0	0	0	0	47	0	88	**147**
Spring-run										
Feather at Gridley (FeathFH)	2	12	2	0	0	0	90	0	112	**1**
Feather Boyds pump ramp (FeathFH)	0	0	0	0	0	0	294	0	27	**321**
Mare Is. Net Pen (FeathFH)	0	0	0	0	0	0	0	0	1	**1**
San Joaq. R. at Merced (FeathFH)	0	0	0	0	0	0	0	2	0	**2**
Unknown	0	0	1	0	0	0	3	3	7	**14**

Table A.21. Recoveries of all coded wire tagged juvenile winter-, fall-, late fall-, and spring-run Chinook Salmon by the DJFMP during the 2015 field season by release location and hatchery of origin. The hatcheries of origin included the Coleman National Fish Hatchery (ColemNFH), Livingston Stone National Fish Hatchery (LivinNFH), Feather River Fish Hatchery (FeathFH), Mokelumne River Fish Hatchery (MokeFH), Nimbus Fish Hatchery (NimbFH), and Merced River Fish Facility (MercFF; PSMFC 2017).

	Recovery location									
Release location (hatchery of origin)	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Sacramento Trawl Site	Mossdale Trawl Site	Chipps Island Trawl Site	**DJFMP total**
Winter-run										
Caldwell Park (LivinNFH)	4	4	0	0	0	0	86	0	80	**174**
Fall-run										
Sac. R. at Rio Vista (ColemNFH)	0	2	0	0	0	0	0	0	271	**273**
Mare Is. Net Pen (FeathFH)	0	0	0	0	0	1	0	0	3	**4**
San Joaq R. Jersey Pt (MercFH)	0	0	0	0	0	0	0	0	36	**36**
San Joaq Shrm. Is. Net Pen (MokeFH)	0	0	0	0	0	0	0	0	149	**149**
Wickland Oil Net Pen (NimbFH)	0	0	0	0	0	0	0	0	2	**2**
Late fall-run										
Battle Creek (ColemNFH)	0	0	0	0	0	0	2	0	13	**15**
Spring-run										
Feather at Gridley (FeathFH)	0	2	0	0	0	0	28	0	0	**30**
Feather Boyds pump ramp (FeathFH)	0	1	0	0	0	0	13	0	1	**15**
San Joaq. R. Ab. Merced (FeathFH)	0	0	0	0	0	0	0	2	0	**2**
Unknown	1	0	0	0	0	0	7	0	18	**26**

Table A.22. Total adult Chinook Salmon escapement estimates by race for the Sacramento and San Joaquin River basins from 1978 to 2015 (CDFW 2016).

Year	Winter-run	Fall-run	Late fall-run	Spring-run
1978	25,012	156,962	12,479	8,126
1979	2,364	227,646	10,284	3,116
1980	1,156	172,137	9,093	12,464
1981	22,797	260,259	6,718	22,105
1982	1,281	230,706	6,899	27,890
1983	1,831	205,290	15,089	7,958
1984	2,763	262,907	10,388	9,599
1985	5,407	356,304	10,180	15,221
1986	2,596	297,820	8,301	25,696
1987	2,185	301,583	16,571	13,888
1988	2,878	268,436	13,218	18,933
1989	696	182,350	12,872	12,163
1990	430	87,853	8,078	7,683
1991	211	132,455	8,263	5,926
1992	1,240	110,413	10,131	3,044
1993	387	165,423	1,267	6,076
1994	186	220,667	889	6,187
1995	1,297	330,168	489	15,238
1996	1,337	351,551	1,385	9,083
1997	880	402,797	4,578	5,193
1998	2,992	246,026	42,419	31,649
1999	3,288	414,259	15,758	10,100
2000	1,352	485,681	12,883	9,244
2001	8,224	624,631	21,813	26,663
2002	7,441	872,669	40,406	25,043
2003	8,218	590,992	8,882	30,697
2004	7,869	386,848	14,150	17,150
2005	15,839	437,693	16,282	23,093
2006	17,296	292,954	15,089	12,906
2007	2,541	97,168	18,843	11,144
2008	2,830	71,291	10,372	13,387
2009 [a]	4,537	53,129	10,196	4,429
2010 [a]	1,596	163,189	9,986	4,623
2011 [a]	827	227,598	8,448	7,774
2012 [a]	2,671	340,819	5,986	22,426
2013 [a]	6,084	447,621	9,004	23,696

Table A.22. Continued.

Year	Winter-run	Fall-run	Late fall-run	Spring-run
2014 [a]	3,015	256,220	13,050	9,901
2015 [a]	3,440	152,663	9,347	5,635

[a] indicates years containing preliminary data

Table A.23. The number of juvenile fish samples collected (i.e., number of days samples were collected) at seine sites by sample week in the Sacramento Area Beach Seine Region during the 2014 field season.

Sample week	Station code							
	AM001S	SR049E	SR055E	SR057E	SR060E	SR062E	SR071E	SR080E
10/13/2013	1	1	1	1	1	1	1	1
10/20/2013	1	3	3	3	3	3	3	3
10/27/2013	1	3	3	3	3	3	3	3
11/3/2013	1	3	3	3	3	3	3	3
11/10/2013	1	3	3	3	3	3	3	3
11/17/2013	1	3	3	3	3	3	3	3
11/24/2013	1	3	3	3	3	3	3	3
12/1/2013	1	3	3	3	3	3	3	3
12/8/2013	1	3	3	3	3	3	3	3
12/15/2013	1	3	3	3	3	3	3	3
12/22/2013	1	3	3	3	3	3	3	3
12/29/2013	1	3	3	3	3	3	3	3
1/5/2014	1	3	3	3	3	3	3	3
1/12/2014	1	3	3	3	3	3	3	3
1/19/2014	1	3	3	3	3	3	3	3
1/26/2014	1	3	3	3	3	3	3	3

Table A.24. The number of juvenile fish samples collected (i.e., number of days samples were collected) at seine sites by sample week in the Sacramento Area Beach Seine Region during the 2015 field season.

Sample	Station code							
week	AM001S	SR049E	SR055E	SR057E	SR060E	SR062E	SR071E	SR080E
10/5/2014	1	3	3	3	3	3	3	3
10/12/2014	1	3	3	3	3	3	3	3
10/19/2014	1	3	3	3	3	3	3	3
10/26/2014	1	3	3	3	3	3	3	3
11/2/2014	1	3	3	3	3	3	3	3
11/9/2014	1	3	3	3	3	3	3	3
11/16/2014	1	3	3	3	3	3	3	3
11/23/2014	1	3	3	3	3	3	3	3
11/30/2014	1	3	3	3	3	3	3	3
12/7/2014	1	3	3	3	3	3	3	3
12/14/2014	0	2	2	2	2	2	2	2
12/21/2014	1	2	2	2	2	2	2	2
12/28/2014	1	3	3	3	3	3	3	3
1/4/2015	1	2	2	2	2	2	2	2
1/11/2015	0	1	1	1	1	1	1	1
1/18/2015	1	1	1	1	1	1	1	1
1/25/2015	0	1	1	1	1	1	1	1

APPENDIX B

Table B.1. Sites sampled during the 2014 and 2015 field seasons in the Liberty Island region. Station codes refer to body of water (first 2 letters; LI = Liberty Island), river mile (3 digits), and location within site (last letter; W=west, E=east).

			Coordinates (UTM)			
Site code	Site name	County	Zone	Northing	Easting	First Year Sampled Annually
LI001E	Liberty Island	Solano	10 S	4233484	615314	2003
LI001W	Liberty Island	Solano	10 S	4237405	614211	2003
LI002E	Liberty Island	Solano	10 S	4233976	615669	2003
LI002W	Liberty Island	Solano	10 S	4236504	614473	2003
LI003E	Liberty Island	Solano	10 S	4234947	616186	2003
LI003W	Liberty Island	Solano	10 S	4235240	614589	2003
LI004E	Liberty Island	Solano	10 S	4236068	616215	2003
LI004W	Liberty Island	Solano	10 S	4234667	614948	2003
LI005E	Liberty Island	Solano	10 S	4237032	616606	2003
LI005W	Liberty Island	Solano	10 S	4233771	614947	2003
LI006E	Liberty Island	Solano	10 S	4237439	616681	2010
LI006W	Liberty Island	Solano	10 S	4237938	614369	2010
LI007E	Liberty Island	Solano	10 S	4238168	616711	2010
LI007W	Liberty Island	Solano	10 S	4237974	614799	2010
LI008E	Liberty Island	Solano	10 S	4238755	616557	2010
LI008W	Liberty Island	Solano	10 S	4238529	614390	2010
LI009E	Liberty Island	Solano	10 S	4239755	616494	2010
LI009W	Liberty Island	Solano	10 S	4238968	614405	2010
LI010E	Liberty Island	Solano	10 S	4240225	616485	2010
LI010W	Liberty Island	Solano	10 S	4240155	614452	2010
LI011E	Liberty Island	Solano	10 S	4241450	616478	2010

Table B.2. Total of individuals observed in samples used to assess the fish assemblage structure during the 2014 field season. Counts are grouped by species. Fish species are listed in phylogenetic order.

Fish species	Liberty Island
American Shad *Alosa sapidissima*	69
Threadfin Shad *Dorosoma petenense*	97
Common Carp *Cyprinus carpio*	3
Fathead Minnow *Pimephales promelas*	7
Splittail *Pogonichthys macrolepidotus*	3
Sacramento Pikeminnow *Ptychocheilus grandis*	6
Sacramento Sucker *Catostomus occidentalis*	6
White Catfish *Ameiurus catus*	6
Channel Catfish *Ictalurus punctatus*	1
Delta Smelt *Hypomesus transpacificus*	6
Chinook Salmon *Oncorhynchus tshawytscha*	431
Unmarked winter-run	1
Unmarked fall-run	426
Unmarked spring-run	4
Inland Silverside *Menidia beryllina*	15312
Rainwater Killifish *Lucania parva*	1
Western Mosquitofish *Gambusia affinis*	6
Prickly Sculpin *Cottus asper*	22
Pacific Staghorn sculpin *Leptocottus armatus*	2
Striped Bass *Morone saxatilis*	218
Bluegill *Lepomis macrochirus*	1
Redear Sunfish *Lepomis microlophus*	3
Spotted Bass *Micropterus punctulatus*	2
Largemouth Bass *Micropterus salmoides*	21
Bigscale Logperch *Percina macrolepida*	21
Tule Perch *Hysterocarpus traskii*	88
Yellowfin Goby *Acanthogobius flavimanus*	310
Shimofuri Goby *Tridentiger bifasciatus*	55

Table B.3. Total of individuals observed in samples used to assess the fish assemblage structure during the 2015 field season. Counts are grouped by species. Fish species are listed in phylogenetic order.

Fish species	Liberty Island
American Shad Alosa sapidissima	45
Threadfin Shad *Dorosoma petenense*	451
Common Carp *Cyprinus carpio*	6
Golden Shiner *Notemigonus crysoleucas*	5
Splittail *Pogonichthys macrolepidotus*	10
Sacramento Pikeminnow *Ptychocheilus grandis*	29
Sacramento Sucker *Catostomus occidentalis*	5
Wakasagi *Hypomesus nipponensis*	1
Delta Smelt *Hypomesus transpacificus*	2
Chinook Salmon *Oncorhynchus tshawytscha*	11
Unmarked fall-run	11
Inland Silverside *Menidia beryllina*	11144
Rainwater Killifish *Lucania parva*	1
Western Mosquitofish *Gambusia affinis*	53
Prickly Sculpin *Cottus asper*	2
Striped Bass *Morone saxatilis*	153
Bluegill *Lepomis macrochirus*	15
Redear Sunfish *Lepomis microlophus*	32
Smallmouth Bass *Micropterus dolomieu*	1
Largemouth Bass *Micropterus salmoides*	33
Black Crappie *Pomoxis nigromaculatus*	1
Bigscale Logperch *Percina macrolepida*	77
Tule Perch *Hysterocarpus traskii*	2
Yellowfin Goby *Acanthogobius flavimanus*	34
Shimofuri Goby *Tridentiger bifasciatus*	86

Table B.4. Recoveries of coded wire tagged juvenile Chinook Salmon by the DJFMP in the Liberty Island seine region from 2003 to 2015 by release location and hatchery of origin. The hatcheries of origin included the Coleman National Fish Hatchery (ColemNFH), Feather River Fish Hatchery (FeathFH), and Nimbus Fish Hatchery (NimbFH) (MercFF; PSMFC 2014).

Field Season	Release location (hatchery of origin)	Race	Number of individuals recovered
2003	Sac. R at Vierra's Resort (FeatFH)	Fall-run	1
	Sac. R at Elkhorn Boat Ramp (FeatFH)	Fall-run	1
	Sac. R at West Sacramento (FeatFH)	Fall-run	3
	Feather at Live Oak (FeatFH)	Fall-run	1
	Unknown	Unknon	1
2004	Yolo Bypass (FeatFH)	Fall-run	1
2005	no recoveries		0
2010	Coleman NFH (ColemNFH)	Late fall-run	1
2011	Coleman NFH (ColemNFH)	Late fall-run	1
	Sac. R at Discovery Park (NimbFH)	Fall-run	2
2012	Coleman NFH (ColemNFH)	Late fall-run	1
2013	no recoveries		0
2014	no recoveries		0
2015	no recoveries		0

Table B.5. Seine sites where fish samples were collected at least once within a sample week in the Liberty Island Seine Region during the 2014 field season.

	Station code																		
Sample week	LI001E	LI001W	LI002E	LI002W	LI003E	LI003W	LI004E	LI004W	LI005E	LI005W	LI006E	LI006W	LI007E	LI007W	LI008E	LI008W	LI009E	LI009W	LI010E
8/11/2013	X				X	X	X		X	X									
8/25/2013												X	X	X	X	X	X		X
9/8/2013	X				X		X		X	X									
9/22/2013											X	X	X		X	X			X
10/20/2013	X					X	X		X	X									
11/3/2013													X		X				
11/10/2013											X	X	X	X		X	X		
11/24/2013	X					X	X	X	X	X									
12/1/2013												X				X			
12/8/2013											X		X		X				X
12/15/2013	X	X	X	X	X	X	X		X	X									
12/29/2013											X		X				X		X
1/12/2014	X	X	X	X	X	X	X		X	X									
1/26/2014												X	X		X	X	X		
2/2/2014	X				X	X	X		X	X									
2/16/2014											X	X	X	X	X	X	X		X
3/2/2014	X	X	X	X	X	X	X	X	X	X									
3/16/2014											X	X	X	X	X	X	X		X
3/30/2014	X	X	X	X	X	X	X	X	X	X									
4/13/2014												X		X		X	X	X	X
4/27/2014	X	X	X	X	X	X	X	X	X	X	X		X		X				
5/11/2014											X	X	X	X		X	X		X
5/25/2014	X	X		X	X	X	X	X	X	X					X				
6/8/2014			X									X	X	X	X	X	X	X	X
6/22/2014	X																		
6/29/2014												X		X	X	X	X		X
7/6/2014	X				X	X	X	X	X	X									
7/20/2014												X			X	X	X		

Table B.6. Seine sites where fish samples were collected at least once within a sample week in the Liberty Island Seine Region during the 2015 field season.

	Station code																		
Sample week	LI001E	LI001W	LI002E	LI002W	LI003E	LI003W	LI004E	LI004W	LI005E	LI005W	LI006E	LI006W	LI007E	LI007W	LI008E	LI008W	LI009E	LI009W	LI010E
8/10/2014	X	X			X	X	X		X	X									
8/24/2014											X	X	X	X		X	X		X
8/31/2014	X	X		X	X	X	X	X	X	X									
9/14/2014												X	X	X	X	X	X		
9/28/2014	X	X	X	X		X	X	X	X	X									
10/12/2014											X	X	X	X	X	X	X		X
10/26/2014	X	X	X	X		X				X									
11/9/2014												X	X	X	X	X	X		X
11/23/2014	X	X	X	X	X	X	X	X											
11/30/2014												X	X	X	X	X			X
12/14/2014	X			X		X	X	X		X									
12/28/2014											X	X	X	X	X	X			X
1/11/2015	X									X									
1/25/2015											X	X	X		X	X	X		
2/8/2015											X	X	X	X	X	X	X		X
2/15/2015	X	X	X		X		X	X		X									
3/1/2015												X	X	X			X	X	X
3/15/2015	X	X			X	X	X												
3/29/2015											X	X	X	X	X		X		
4/5/2015												X	X	X	X		X		X
4/12/2015	X				X		X		X	X									
5/10/2015											X	X	X		X				
5/24/2015	X	X								X									
6/14/2015												X			X		X		X
6/21/2015	X	X					X			X									
7/5/2015											X		X	X	X		X	X	
7/19/2015	X						X			X									