BIOLOGICAL ASSESSMENT OF POTENTIAL EFFECTS ON LISTED FISHES FROM THE WEST FALSE RIVER SALINITY BARRIER PROJECT

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Acronyms and Abbreviations

APN	Assessor Parcel Number
ARB	Air Resources Board
BA	Biological Assessment
BAAQMD	Bay Area Air Quality Management District
Basin Plan	Water Quality Control Plan
BMP	best management practice
BO	biological opinion
BRT	Biological Review Team
Cal Boating	California Department of Parks and Recreation Division of Boating and Waterways
CalOES	Governor's Office of Emergency Services
CDEC	California Data Exchange Center
CDFG	California Department of Fish and Game
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
cm	centimeters
CMP	Carl Moyer Program
CPT	cone penetrometer test
CVP/SWP	Central Valley Project/State Water Project
CVTRT	Central Valley Technical Review Team
CWT	coded-wire tag
1μPa2-s	1 micropascal squared per second
DCC	Delta Cross Channel
Delta	Sacramento-San Joaquin River Delta
DO	dissolved oxygen
DOSS	Delta Operations for Salmonids and Sturgeon
DPS	distinct population segment
DWR	Department of Water Resources
EC	electrical conductivity
EDB	Emergency Drought Barrier
EFH	essential fish habitat
ESA	Endangered Species Act
ESU	evolutionary significant unit
FMP	Fishery Management Plans
FRFH	Feather River Fish Hatchery
ft/s	feet per second
GCID	Glenn Colusa Irrigation District
HAZMAT	hazardous materials
HMMP	Hazardous Materials Management Program
HU	Hydrologic Unit
IEP	Interagency Ecological Program for the San Francisco Estuary
ITP	Incidental Take Permit

JPE	Juvenile Production Estimate
JPI	Juvenile Production Index
kg	kilogram
km	kilometers
LMA	Local Maintaining Agency
LSNFH	Livingston Stone National Fish Hatchery
LSZ	low salinity zone
LWD	large woody debris
mg	milligrams
mg/L	milligrams per liter
mm	millimeter
NAS	National Academy of Sciences
NAVD 88	North American Vertical Datum of 1988
NDOI	Delta Outflow Index
NMFS	National Marine Fisheries Service
NO_X	oxides of nitrogen
O_2	oxygen
OMR	Old and Middle River flows
PAH	poly aromatic hydrocarbon
PCE	primary constituent elements
PFMC	Pacific Fishery Management Council
ppt	parts per thousand
psu	practical salinity units
RBDD	Red Bluff Diversion Dam
Reclamation	Bureau of Reclamation
RMS	root mean square
RST	rotary screw trap
SEL	sound exposure level
SFBAAB	San Francisco Bay Area Air Basin
SKT	Spring Kodiak Trawl
SL	Standard Length
SMAQMD	Sacramento Metropolitan Air Quality Management District
SRA	shaded riverine aquatic
SWG	Smelt working group
SWRCB	State Water Resources Control Board
TBP	Temporary Barriers Project
TL	total body length
TUCP	Temporary Urgency Change Petition
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
WFRSB	West False River Salinity Barrier
YOY	young of the year
μPa	micropascal

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Biological Assessment Of Potential Effects On Listed Fishes From The West False River Salinity Barrier Project

Introduction

Faced with potentially insufficient water supplies to repel salinity in the Sacramento-San Joaquin River Delta (Delta), the California Department of Water Resources (DWR) installed a project similar to the currently proposed project, the Emergency Drought Barrier (EDB) across West False River, in May-July 2015. Installation of the EDB was authorized under Executive Order B-29-15 (April 1, 2015 Directive to Streamline Government Response) and environmental authorizations from the U.S. Army Corps of Engineers (USACE) (SPK-2014-00187), State Water Resources Control Board (SWRCB) (Clean Water Act Section 401 Water Quality Certification), and California Department of Fish and Wildlife (CDFW) (2081-2014-026-03 and 1600-2014-0111-R3). Per the USACE Clean Water Act 404 emergency authorization, the EDB will be removed entirely in fall 2015.

The proposed West False River Salinity Barrier Project (WFRSB or Project) seeks to protect the quality of water for users that rely on Delta water. Keeping saltwater out of the central Delta is a priority, as a large portion of the state's freshwater supplies travels through this part of the Delta. As shown with the EDB, a salinity barrier helps prevent saltwater contamination of water supplies used by people who live in the Delta and in Contra Costa, Alameda, and Santa Clara counties, as well as the 25 million people who rely on the Delta-based federal and state water projects for at least some of their supplies.

The WFRSB consists of the following items:

- installing embankment rock (i.e., temporary salinity barrier) and abutments (king piles, sheet piles, and whalers) as early as April 1, 2016; and
- removing the embankment rock and abutments by November 30, 2016.

The WFRSB would only be constructed if DWR, in co-operation with other State and federal agencies, determines that a drought has reduced water storage in the State Water Project (SWP) to critical levels, such that projected Delta outflow could not control increased salinity in the Delta, thereby worsening water quality and threatening the drinking and irrigation water supply. Operation of the salinity barrier as part of overall Central Valley Project (CVP) and SWP operations would occur through existing rules and regulations under relevant federal and state regulatory agencies.

This document is a Biological Assessment (BA) that assesses the effects of the proposed project on federally listed fish species (some of which are also state listed). The document is divided into the following main sections:

- Introduction;
- Consultation History;
- Purpose and Scope of this Biological Assessment;
- Project Description;
- Action Area;
- Life Histories;
- Critical Habitat;
- Environmental Baseline;
- Effects Assessment;
- Cumulative Effects;
- Conclusions;
- References;
- Appendices.

The Effects Assessment of this BA includes Construction and Removal Effects and Operations Effects, in addition to Effects on Critical Habitat and Effects on Essential Fish Habitat. Note that the Operations Effects section includes effects related to the proposed WFRSB operations, limited to the presence of the WFRSB and its effects in the Action Area near the barrier (e.g., in terms of changing hydrodynamics, turbidity, and providing structure for predatory fishes). It is reasonable to assume that operation of the proposed WFRSB would be done within the broader framework of drought contingency planning through multi-agency collaboration between DWR, the US Bureau of Reclamation (Reclamation), SWRCB, the National Marine Fisheries Service (NMFS), the US Fish and Wildlife Service (USFWS), and CDFW, as occurred in 2015; as such, it is anticipated that an analysis of the broad proposed WFRSBoperational effects on listed fishes would be provided by DWR and Reclamation as part of a Temporary Urgency Change Petiton (TUCP) which would be filed with the SWRCB (see Murillo and Cowin 2015 for an example from 2015). In 2015, USFWS, NMFS, and DFW confirmed that the effects of the TUCP modifications were consistent with the USFWS (2008) and NMFS (2009) SWP/CVP biological opinions, and associated DFW consistency determinations. The proposed WFRSBwould be installed and operated in order to meet water quality and outflow objectives described in D-1641.

In 2015, D-1641 was temporarily modified through a TUCP filed with the SWRCB on May 21, 2015, and subsequent Order issued on July 3, 2015, by the SWRCB Executive Director. The USFWS, NMFS, and CDFW provided consultation on the TUCP and water operations were consistent with their findings. It is reasonable to assume that similar processes would occur in the future when the proposed WFRSBcould be implemented.

A number of different sources were used in preparing this document. The primary source of information is the Biological Assessment Of Potential Effects On Listed Fishes From The West False River Emergency Drought Barrier Project (ICF International 2015), which was the after-the-fact evaluation of the 2015 EDB implementation. The 2015 evaluation of the effects of the implementation of the EDB included biological, noise, and water quality monitoring information collected during project construction, as well as additional data collected by DWR (e.g., flow/velocity surveys near the barrier). Publicly available fish monitoring data were used to assess the overlap of species with the proposed WFRSB construction, operations, and removal. Because it is anticipated that the future implementation of the WFRSB would be similar to the 2015 implementation of the EDB, the 2015 after-the-fact evaluation contains the most relevant information in the present BA. As noted in the BA for the 2015 EDB, the similarity of a number of aspects of the proposed project to the South Delta Temporary Barriers Project (TBP) allowed some of the information found in this document to be adapted from the most recent TBP consultation materials, i.e., Biological Assessments by DWR (2012a,b) and BOs by NMFS (2013) and USFWS (2014a). In addition, useful information was obtained from the recent BOs by NMFS (2014) and USFWS (2014b) on the 2014 Georgiana Slough Floating Fish Guidance Structure Study.

Consultation History

The consultation history for the proposed WFRSB and the 2015 EDB includes the following:

- Coordination meetings: Beginning March 5, 2014, representatives from NMFS and USFWS attended EDB coordination meetings hosted by DWR, which also included representatives from Reclamation, U.S. Army Corps of Engineers (USACE), SWRCB, CDFW, and the AECOM-led consulting team (the meetings generally were held weekly until May 2014 and subsequently were held approximately monthly).

- A first draft BA dated March 17, 2014, was provided to NMFS and USFWS; comments were received.

- A second draft BA dated March 25, 2014, was submitted to USACE as part of EDB permit application initiation.

- A third BA dated April 10, 2014, was submitted to USACE as part of EDB permit application. This and the preceding drafts were focused on implementation of the EDB from spring to fall 2014.

- A fourth BA dated May 2, 2014, was submitted to USACE as part of the EDB permit application. This draft focused on implementation of the EDB from summer to fall 2014.

- On July 17, 2014, DWR requested that the original March 2014 permit application and associated consultations with USFWS and NMFS be rescinded; DWR noted that it intended to continue to coordinate with USACE and other regulatory agencies to obtain a programmatic/long-term permit for the EDB.

- A fifth draft BA dated November 18, 2014, was provided to NMFS and USFWS, and an overview of its contents was provided during a coordination meeting hosted by DWR on November 19. This draft included programmatic approach, reflecting a revision of the project description such that the EDB could be installed up to three times over a 10-year permit period. Comments on the draft BA were received at the coordination meeting.

- Following various coordination meetings, a BA dated January 28, 2015, was submitted to USACE as part of the EDB permit application, covering a 10-year programmatic period.

- Because of USACE and USFWS/NMFS concerns regarding the decision-making process related to installation of the EDB expressed during various communications and agency coordination meetings, a single-year BA for 2015 EDB, dated April 1, 2015, was prepared and submitted. This BA also included a change in two of the proposed barrier locations.

- In response to agency requests to limit the proposed action to only one barrier, a BA dated April 13, 2015 was prepared and used by USACE to initiate consultation with USFWS and NMFS.

- A letter dated April 20, 2015 was submitted to USACE requesting Emergency Procedures be used to secure permits for the EDB in order to begin in-water work by May 7, 2015.

- A BA dated April 29, 2015 was prepared to respond to agency comments on the previous version and provide several updates to the project description; this BA was submitted to USFWS and NMFS on April 29, 2015 when USACE requested Emergency Consultation on a single barrier at West False River.

- On May 1, 2015 NMFS and USFWS provided conservation recommendations to USACE, including implementation of conservation measures identified in the April 29 BA, as well as removal of the abutments that had been proposed to be left in place. NMFS and USFWS requested that formal consultation be initiated as soon as practicable after the emergency is under control.

- On July 10, 2015, a Biological Assessment was submitted to NMFS and USFWS to provide an after-the-fact assessment of the effects of the emergency implementation of the EDB on federally-listed and state-listed fish species, critical habitat, and essential fish habitat (EFH).

DWR's proposal to implement a future barrier project has been discussed at several points during the ongoing agency consultation. This BA has been prepared to address proposed future implementation of a barrier project at the West False River location in 2016.

Purpose and Scope of this Biological Assessment

This BA is intended to satisfy the Section 7 consultation requirements of the federal Endangered Species Act (ESA) for species managed by USFWS and NMFS, specifically in order to provide an assessment of the effects of the implementation of the proposed WFRSB. This BA also includes information for consultation regarding EFH under the Magnuson-Stevens Fishery Conservation and Management Act. As such, this BA describes the potential effects on federally-listed and state-listed fish species, critical habitat, and EFH that may result, from the implementation of the proposed West False River salinity barrier.

The following species and habitats are addressed in this BA, based on the potential for occurrence in the action area.

- Central Valley spring-run Chinook salmon (*Oncorhynchus tshawytscha*).
- Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*).
- Central Valley steelhead (*Oncorhynchus mykiss*).

- North American green sturgeon (*Acipenser medirostris*), southern distinct population segment (DPS).
- Delta smelt (*Hypomesus transpacificus*).
- Central Valley spring-run Chinook salmon designated critical habitat.
- Central Valley steelhead designated critical habitat.
- Sacramento River winter-run Chinook salmon designated critical habitat.
- North American green sturgeon designated critical habitat.
- Delta smelt designated critical habitat.
- Starry flounder (*Platichthys stellatus*) EFH.
- Northern anchovy (*Engraulis mordax*) EFH.
- Chinook salmon EFH.

The listed species analyzed in this BA are protected under the ESA and/or CESA, and their listing status is presented in Table 1.

Table 1. Listed Fish Species Addressed in this Biological Assessment

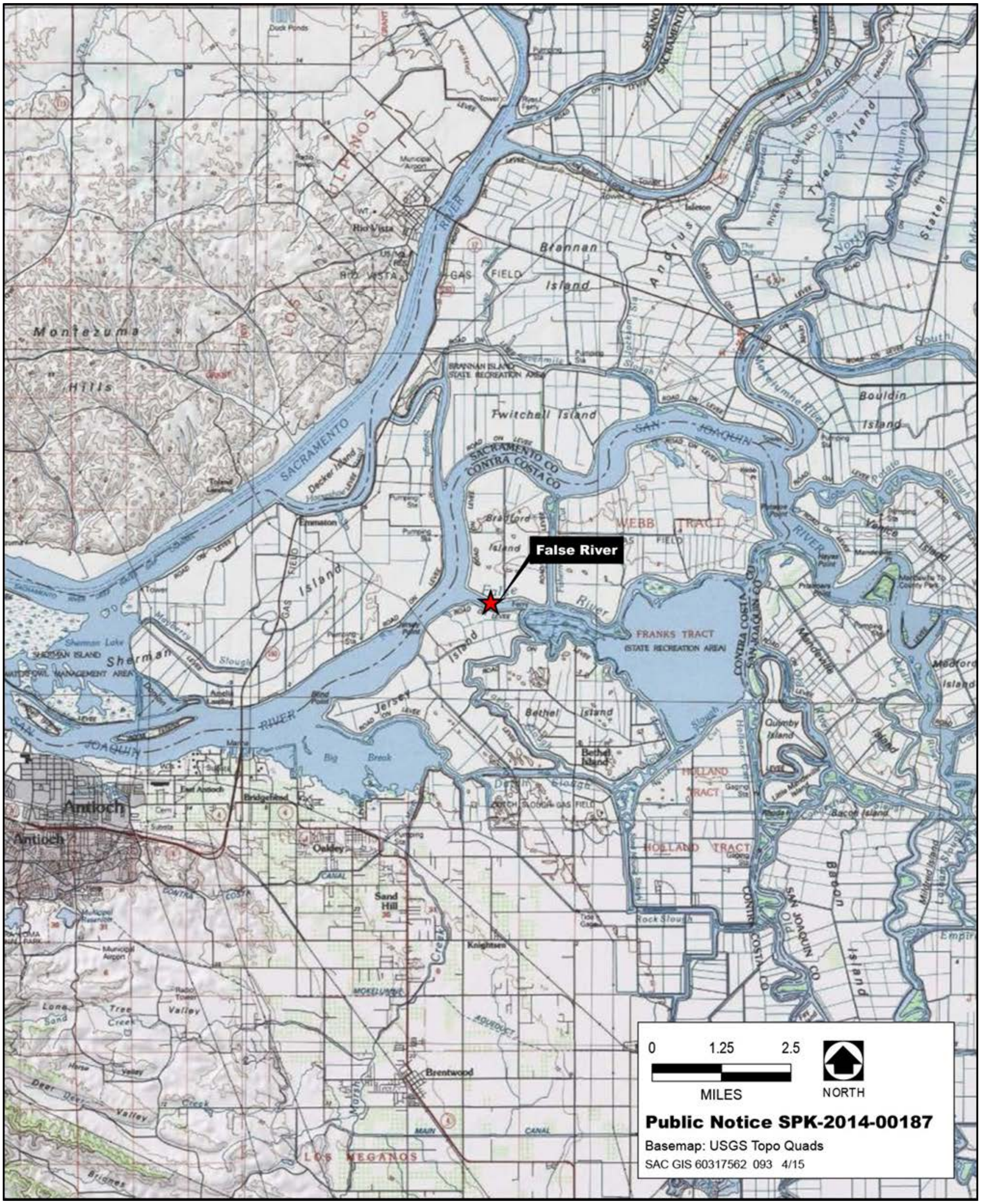
Species	Status*
Central Valley spring-run Chinook salmon	FT, ST
Sacramento River winter-run Chinook salmon	FE, SE
Central Valley steelhead	FT
North American green sturgeon (southern DPS)	FT
Delta smelt	FT, SE

DPS = distinct population segment.
* Status definitions:
FE = listed as endangered under the federal Endangered Species Act.
FT = listed as threatened under the federal Endangered Species Act.
SE = listed as endangered under the California Endangered Species Act.
ST = listed as threatened under the California Endangered Species Act.

Project Description

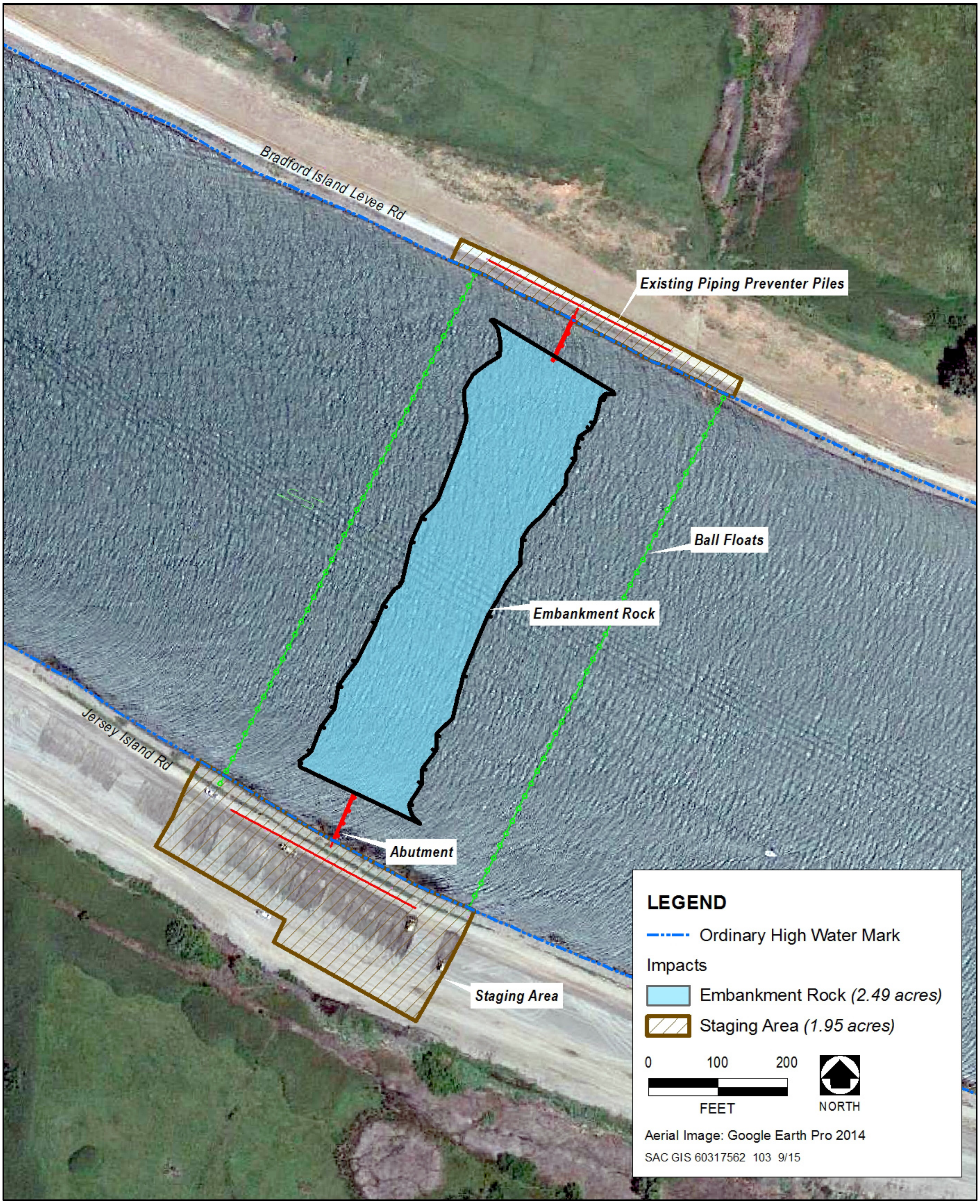
Project Location

DWR would install the WFRSB on almost the identical EDB footprint (**Figure 1** and **Figure 2**). The project site is located on West False River approximately 0.4 mile east of its confluence with the San Joaquin River, between Jersey and Bradford islands in Contra Costa County, and is approximately 4.8 miles northeast of Oakley. The banks of the project site are existing rock-lined levees. The project site would be approximately 4.44 acres, including 2.49 acres of aquatic fill and 1.95 acres on the levee and levee setback for staging. Photographs of the project site during and after installation of the EDB are provided in **Figure 3**.



Source: DWR 2015, AECOM 2015

Figure 1. Location of Proposed Salinity Barrier



Source: DWR 2015, AECOM 2015

Figure 2. Aerial View of the Project Site

Photo 1: Partially constructed barrier and eastern edge of Jersey Island staging area during EDB installation (May 28 2015).

Photo 2: Completed barrier, looking south from Bradford Island to Jersey Island (June 17, 2015).

Figure 3. Photographs of the Project Site

Barrier Installation and Operation

Design

The WFRSB would consist of the following structures:

- Barrier Abutments: Eight (or four pairs) 36-inch-diameter king piles extending out from each levee into the West False River channel for a total length of approximately 75 feet.

- Seventy (or 35 pairs) sheet piles totaling approximately 160 wall feet (including approximately 5 feet on either side that would be in the levee). DWR would attach horizontal whalers to the piles for strength and stability.

- Buoy Line Anchors: Four 12-inch steel pipe piles.

The barrier would be approximately 800 feet long and up to 200 feet wide at the base (in water) and 12 feet wide at the top (above water). The WFRSB would be trapezoid-shaped with a wide base tapering up to a 12-foot-wide top width set perpendicular to the channel alignment. The top of the WFRSB would be at an elevation of 7 feet above sea level across the entire crest. As shown in Figure 2, the WFRSB would consist of approximately 74,000 cubic yards (2.49 acres) of crushed embankment rock (approximately 18 inches or smaller) connected to barrier abutments to be installed on Bradford and Jersey islands. The barrier abutments provide levee stability by reducing barrier loading (weight) on the levees which sit atop peat soils.

Schedule

Construction activities, including mobilization, would begin no sooner than April 1, 2016. Similar to the installation of the EDB in 2015, placement of embankment rock would occur on a 24-hour basis for approximately 45 working days. Most likely, however, placement of embankment rock will not be entirely continuous in a 24-hour period due to the effect the tides have on barge navigation. The construction crew size for installation is assumed to be a maximum of 21 people.

Construction Methodology

The construction methodology will be similar to that used on the EDB. First, DWR would mobilize equipment, establish a staging area adjacent to Jersey Island Road (i.e., left bank), and install silt and exclusion fencing on land along the construction boundaries. Next, material would be transported to the site on barges and trucks. A list of construction equipment anticipated to be used for installation of the abutments and rock barrier is provided in **Table 2**.

Table 2. Construction Equipment Anticipated to be Used for Barrier Installation

Type of Equipment	Number	Type of Equipment	Number	Type of Equipment	Number
Derrick barge	2	Crane barge	3	Scow/material barge	6
Work boat	4	Steel skiff	3	Boston whaler	2
Crew boat	1	Survey boat	1	Tug	2
Grader	1	Off-road fork lift	2	Power generator	2
Compactor	1	Mini excavator	1	Light plants	10
Water truck	1	Backhoe	1	Off-road forklift	1
Manlift	1	Pickup trucks	2	Vibratory pile driver	2

Source: DWR 2015

Following mobilization, DWR would use barge-mounted pile drivers to install the abutments (king piles, river sheet piles, and whaler system). The king piles would be installed on and perpendicular to the islands and a bubble curtain may be deployed to attenuate in-water noise. In a similar manner, sheet piles and whaler systems would be installed on and perpendicular to the islands. To expedite construction, DWR would work concurrently on both sides of the river. DWR would conduct in-water noise monitoring during in-water pile driving.

Concurrent with abutment installation, DWR would begin placing embankment rock into West False River with a dump scow. Embankment rock would be shipped on barges from either an approved quarry or DWR's Rio Vista stockpile. In a uniform manner to prevent levee scour, rock would be dumped near the levees and then into the center of the river. Because of fluctuations in water level and the increased streambed elevation, DWR would only be able to use the dump scow for a limited duration. With barge-mounted cranes using clam-shelled and dragline buckets, DWR would shape the rock into a trapezoid and fill the center of the barrier.

Following installation, DWR would demobilize from the site, conduct minor regrading activities, and place soil stabilization on upland disturbance areas.

Fish Movement and Navigation

The WFRSB would not be designed to allow fish passage. Fish movement can occur through the adjacent San Joaquin River and through other channels, including Fisherman's Cut, East False River, and Dutch Slough during the West False River closure.

Vessel traffic would be blocked at the WFRSB, but alternative routes are available via the Stockton Deep Water Ship Channel in the San Joaquin River between Antioch and eastern Delta locations, or via Fisherman's Cut or East False River to South Delta destinations. DWR would install signs on each side of the barrier, float lines with orange ball floats across the width of the channel to deter boaters from approaching the barrier, and solar-powered warning buoys with flashing lights on the barrier crest to prevent accidents during nighttime hours. DWR would also post signs at upstream and downstream entrances to the waterway or other key locations, informing boaters of the restricted access. Navigation signage would comply with requirements set forth by the U.S. Aids to Navigation

System and the California Waterway Marker System, as appropriate. DWR would coordinate with the U.S. Coast Guard District 11 and California Division of Boating and Waterways regarding safe vessel passage procedures. DWR or the contractor would post a Notice to Mariners, which would include information on the duration of channel closure, and provide copies to marinas throughout the Delta.

Operations and Maintenance

There are no operational features associated with either the WFRSB or abutments. Given the temporary nature of the WFRSB, maintenance would be minimal apart from maintenance of navigational aids (e.g., signage, float lines, lights, warning buoys); however, DWR would regularly inspect the WFRSB during operation and inform the permitting agencies (CDFW, USFWS, and NMFS) if any major maintenance activities are required.

Barrier Removal

Schedule

The embankment rock would be removed no later than November 30, 2016. Late November coincides with the start of the rainy season when freshwater runoff typically occurs and flood risk increases. Initial ground disturbance activities, such as mobilization and installation of silt and exclusion fencing, would occur in September to inhibit giant garter snake from entering the construction work area. Given the volume of embankment rock, DWR anticipates excavation would occur continuously (i.e., 24 hours per day, 7 days per week) for up to 90 days. The construction crew size for removal is assumed to be a maximum of 21 people.

General Construction Methodology

The methodology described herein is general. Although removal activities would primarily be situated in-water, work would also occur from the levee embankments.

First, DWR would mobilize construction equipment and crew. A list of construction equipment anticipated to be used for removal of the abutments and rock barrier is provided in **Table 3**. DWR would utilize multiple barges with excavators, cranes, and work boats that would be transported on water to the barrier site. In-water work would occur on both sides of the barrier (e.g., barge-mounted cranes operating upstream and downstream).

Table 3. Construction Equipment Anticipated to be Used for Barrier Removal

Type of Equipment	Maximum Number	Type of Equipment	Maximum Number	Type of Equipment	Maximum Number
Tug/barge	8	Excavator	3	Front-end loader	2
Long-reach excavator	3	Dump truck	4	Grader	1
Work boat	2	Dozer	1		

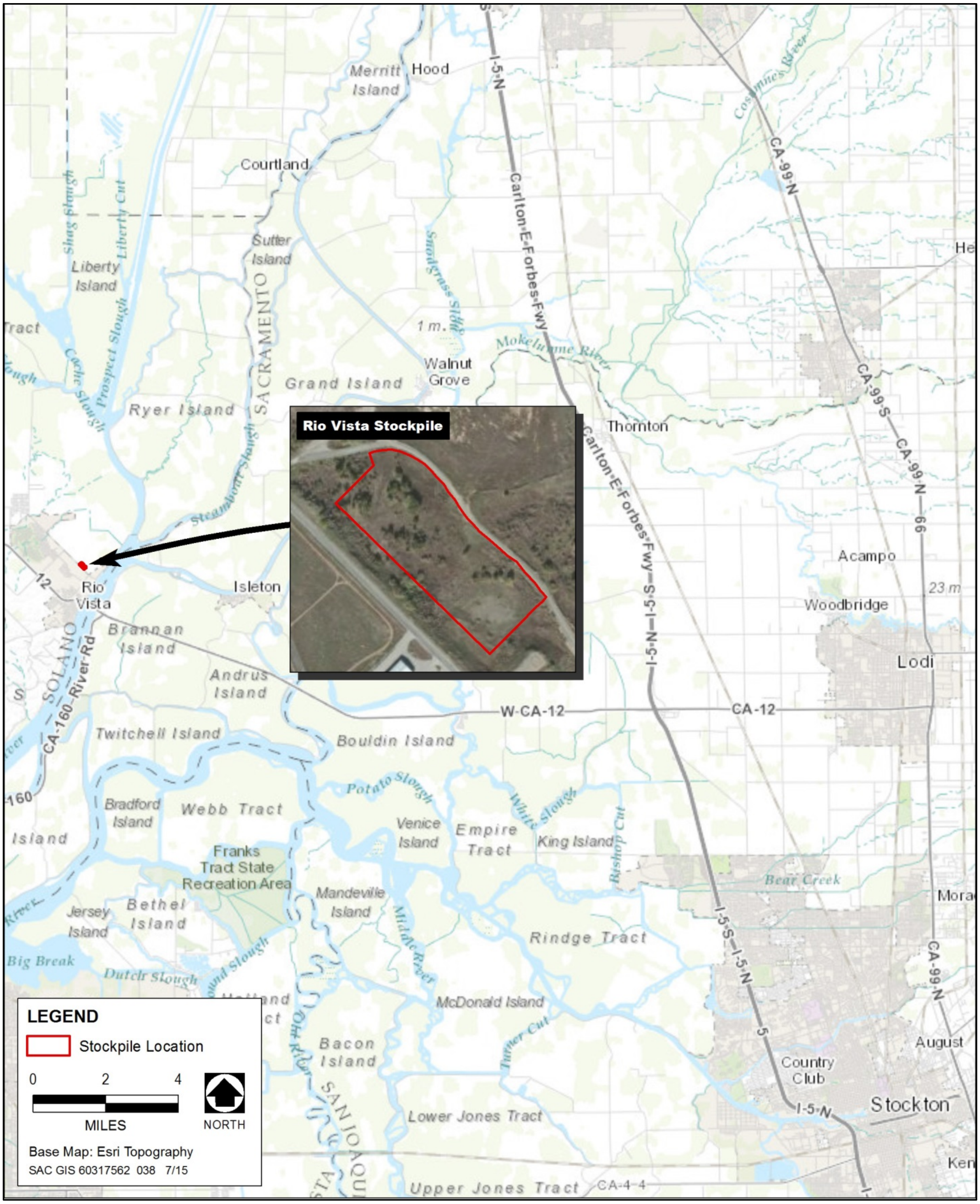
Source: DWR 2015

Next, DWR would strategically place the barges adjacent to the barrier in order to excavate the rock. Barge-mounted cranes with clam-shell or dragline buckets and/or excavators would excavate the rock and place it on another barge. To prevent levee scour, rock removal would begin at the center of the channel and work toward the levees. Excavation would occur from the top of the barrier down to approximate pre-project streambed contours. DWR would restore the levee geometry to ensure compliance with any local maintaining agency or USACE requirements. DWR would conduct bathymetric surveys during, and immediately after barrier removal to confirm reestablishment of pre-project streambed contours.

DWR would transport the rock on a barge from the project site to the off-loading site, where it would be transferred onto dump trucks using conveyors, excavators, and loaders and then hauled to DWR's Rio Vista stockpile location (outside of waters of the United States), which is depicted in **Figure 4**. DWR upgraded the stockpile site in summer 2015 as part of the DWR Delta Flood Emergency Facilities Improvement Project. Alternatively, the rock may be retained by the contractor and stored/used in accordance with their own separate permits and approvals.

Upon removal of the rock barrier, DWR would then remove the abutments, buoy piles, buoys, and signs. Divers would remove the abutments and buoy piles by cutting the structures below the original riverbed grade. Because the buoys and signs are anchored by concrete blocks, DWR would completely remove these structures by barge-mounted cranes. The contractor would be required to retain or properly dispose of these materials.

After the barrier is completely removed, the staging areas would be restored to approximate pre-project conditions and hydroseeded as appropriate. Any levee access roads that are damaged as a result of construction equipment or truck use would be restored to pre-construction conditions or better after construction is completed.



Source: DWR, adapted by AECOM 2015

Figure 4. Stockpile Location

Action Area

The Action Area is defined as all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR § 402.02). The Action Area, for the purposes of this BA covering listed fish species, includes the waters of the legal Delta and the lands associated with the barrier footprint. Whereas the near-field effects of the proposed WFRSB are very limited in extent (i.e., the footprints of the barrier and its environs), the far-field effects of the WFRSB potentially are broad because of the barrier's influence on hydrodynamics; hence, the Action Area is large in extent.

Life Histories

Chinook Salmon

The following account is adapted from the NMFS (2014) BO on the Georgiana Slough Floating Fish Guidance Structure Study, with updates to reflect the most recent population status information.

General Life History

Chinook salmon exhibit two generalized freshwater life history types (Healey 1991). "Stream- type" Chinook salmon, enter freshwater months before spawning and reside in freshwater for a year or more following emergence, whereas "ocean-type" Chinook salmon spawn soon after entering freshwater and migrate to the ocean as fry or parr within their first year. Spring-run Chinook salmon can exhibit a stream-type life history. Adults enter freshwater in the spring, hold over summer, spawn in the fall, and some of the juveniles may spend a year or more in freshwater before emigrating. The remaining fraction of the juvenile spring-run population may also emigrate to the ocean as young-of-the-year in spring. Winter-run Chinook salmon are somewhat anomalous in that they have characteristics of both stream- and ocean-type races (Healey 1991). Adults enter freshwater in winter or early spring, and delay spawning until spring or early summer (stream-type). However, juvenile winter-run Chinook salmon migrate to sea after only 4 to 7 months of river life (ocean-type). Adequate instream flows and cool water temperatures are more critical for the survival of Chinook salmon exhibiting a stream-type life history due to over summering by adults and/or juveniles.

Chinook salmon typically mature between 2 and 6 years of age (Myers et al. 1998). Freshwater entry and spawning timing generally are thought to be related to local water temperature and flow regimes. Runs are designated on the basis of adult migration timing; however, distinct runs also differ in the degree of maturation at the time of river entry, thermal regime and flow characteristics of their spawning site, and the actual time of spawning (Myers et al. 1998). Both spring-run and winter-run Chinook salmon tend to enter freshwater as fish with sexually immature gonads, migrate far upriver, and delay spawning for weeks or months. For comparison, fall-run Chinook salmon enter freshwater at an advanced stage of sexual maturity with ripe gonads, move rapidly to their spawning areas on the main stem or lower tributaries of the rivers, and spawn within a few days or weeks of freshwater entry (Healey 1991).

During their upstream migration, adult Chinook salmon require stream flows sufficient to provide olfactory and other orientation cues used to locate their natal streams. Adequate stream flows are necessary to allow adult passage to upstream holding habitat. The preferred temperature range for upstream migration is 38°F to 56°F (Bell 1991, CDFG 1998). Boles (1988) recommends water temperatures below 65°F for adult Chinook salmon migration, and Lindley et al. (2004) report that adult migration is blocked when temperatures reach 70°F, and that fish can become stressed as temperatures approach 70°F. Reclamation reports that spring-run Chinook salmon holding in upper watershed locations prefer water temperatures below 60°F; although salmon can tolerate temperatures up to 65°F before they experience an increased susceptibility to disease (Williams 2006).

Information on the migration rates of Chinook salmon in freshwater is scant and primarily comes from the Columbia River basin where information regarding migration behavior is needed to assess the effects of dams on travel times and passage (Matter et al. 2003). Keefer et al. (2004) found migration rates of Chinook salmon ranging from approximately 10 kilometers (km) per day to greater than 35 km per day and to be primarily correlated with date, and secondarily with discharge, year, and reach, in the Columbia River basin. Matter et al. (2003) documented migration rates of adult Chinook salmon ranging from 29 to 32 km per day in the Snake River. Adult Chinook salmon inserted with sonic tags and tracked throughout the Delta and lower Sacramento and San Joaquin rivers were observed exhibiting substantial upstream and downstream movement in a random fashion while migrating upstream over the course of several days (CALFED Science Program 2001). Adult salmonids migrating upstream are assumed to make greater use of pool and mid-channel habitat than channel margins (Stillwater Sciences 2004), particularly larger salmon such as Chinook salmon, as described by Hughes (2004). Adults are thought to exhibit crepuscular behavior during their upstream migrations; meaning that they primarily are active during twilight hours. Recent hydroacoustic monitoring showed peak upstream movement of adult Central Valley spring-run Chinook salmon in lower Mill Creek, a tributary to the Sacramento River, occurring in the 4-hour period before sunrise and again after sunset.

Spawning Chinook salmon require clean, loose gravel in swift, relatively shallow riffles or along the margins of deeper runs, and suitable water temperatures, depths, and velocities for redd construction and adequate oxygenation of incubating eggs. Chinook salmon spawning typically occurs in gravel beds that are located at the tails of holding pools (USFWS 1995). The range of water depths and velocities in spawning beds that Chinook salmon find acceptable is very broad. The upper preferred water temperature for spawning Chinook salmon is 55°F to 57°F (Chambers 1956, Smith 1973, Bjornn and Reiser 1991, Snider 2001).

Incubating eggs are vulnerable to adverse effects from floods, siltation, desiccation, disease, predation, poor gravel percolation, and poor water quality. Studies of Chinook salmon egg survival to hatching conducted by Shelton (1995) indicated 87 percent of fry emerged successfully from large gravel with adequate subgravel water circulation. The optimal water temperature for egg incubation ranges from 41°F to 56°F (44°F to 54°F [Rich 1997], 46°F to 56°F [NMFS 1997 Winter-run Chinook salmon Recovery Plan], and 41°F to 55.4°F [Moyle 2002]). A significant reduction in egg viability occurs at water temperatures above 57.5°F and total embryo mortality can occur at temperatures above 62°F (NMFS 1997). Alderdice and Velsen (1978) found that the upper and lower temperatures resulting in 50 percent pre-hatch mortality were 61°F and 37°F, respectively, when the incubation temperature was held constant. As water temperatures increase, the rate of embryo malformations also increases, as well as the susceptibility to fungus and bacterial infestations. The length of development for Chinook salmon embryos is dependent on the ambient water temperature surrounding the egg pocket in the redd. Colder water necessitates longer development times as metabolic processes are slowed. Within the appropriate water temperature range for embryo incubation, embryos hatch in 40 to 60 days, and the alevins (yolk-sac fry) remain in the gravel for an additional 4 to 6 weeks before emerging from the gravel.

During the 4- to 6-week period when alevins remain in the gravel, they utilize their yolk-sac to nourish their bodies. As their yolk-sac is depleted, fry begin to emerge from the gravel to begin exogenous feeding in their natal stream. The post-emergent fry disperse to the margins of their natal stream, seeking out shallow waters with slower currents, finer sediments, and bank cover such as overhanging and submerged vegetation, root wads, and fallen woody debris, and begin feeding on zooplankton, small insects, and small aquatic invertebrates. As they switch from endogenous nourishment to exogenous feeding, the fry's yolk-sac is reabsorbed, and the belly suture closes over the former location of the yolk-sac (button-up fry). Fry typically range from 25 millimeters (mm) to 40 mm during this stage. Some fry may take up residence in their natal stream for several weeks to a year or more, while others are displaced downstream by the stream's current. Once started downstream, fry may continue downstream to the estuary and rear, or may take up residence in river reaches farther downstream for a period of time ranging from weeks to a year (Healey 1991). Fry then seek nearshore habitats containing beneficial aspects such as riparian vegetation and associated substrates important for providing aquatic and terrestrial invertebrates, predator avoidance, and slower velocities for resting (NMFS 1996). The benefits of shallow water habitats for salmonid rearing also have recently been realized as shallow water habitat has been found to be more productive than the main river channels, supporting higher growth rates, partially due to higher prey consumption rates, as well as favorable environmental temperatures (Sommer et al. 2001).

When juvenile Chinook salmon reach a length of 50 mm to 57 mm, they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures. In the mainstems of larger rivers, juveniles tend to migrate along the channel margins and avoid the elevated water velocities found in the thalweg of the channel. When the channel of the river is greater than 9 feet to 10 feet in depth, juvenile salmon tend to inhabit the surface waters (Healey 1982). Migrational cues, such as increasing turbidity from runoff, increased flows, changes in day length, or intraspecific competition from other fish in their natal streams may spur outmigration of juveniles when they have reached the appropriate stage of maturation (Kjelson et al. 1982, Brandes and McLain 2001).

As fish begin their emigration, they are displaced by the river's current downstream of their natal reaches. Similar to adult movement, juvenile salmonid downstream movement is crepuscular. Documents and data provided to NMFS in support of ESA section 10 research permit applications depicts that the daily migration of juveniles passing Red Bluff Diversion Dam (RBDD) is highest in the four-hour period prior to sunrise (Martin et al. 2001). Juvenile Chinook salmon migration rates vary considerably, presumably dependent on the physiological stage of the juvenile and ambient hydrologic conditions. Kjelson et al. (1982) found fry Chinook salmon to travel as fast as 30 km per day in the Sacramento River and Sommer et al. (2001) found rates ranging from approximately 0.5 miles up to more than 6 miles per day in the Yolo Bypass. As Chinook salmon begin the smoltification stage, they prefer to rear further downstream where ambient salinity is up to 1.5 to 2.5 parts per thousand (Healey 1980, Levy and Northcote 1982).

Fry and parr may rear within riverine or estuarine habitats of the Sacramento River, the Delta, and their tributaries. In addition, Central Valley spring-run Chinook salmon juveniles have been observed rearing in the lower reaches of non-natal tributaries and intermittent streams in the Sacramento Valley during the winter months (Maslin et al. 1997, Snider 2001). Within the Delta, juvenile Chinook salmon forage in shallow areas with protective cover, such as intertidal and subtidal mudflats, marshes, channels, and sloughs (McDonald 1960, Dunford 1975). Cladocerans, copepods, amphipods, and larvae of diptera, as well as small arachnids and ants are common prey items (Kjelson et al. 1982, Sommer et al. 2001, MacFarlane and Norton 2002). Shallow water habitats are more productive than the main river channels, supporting higher growth rates, partially due to higher prey consumption rates, as well as favorable environmental temperatures (Sommer et al. 2001). Optimal water temperatures for the growth of juvenile Chinook salmon in the Delta are between 54°F to 57°F (Brett 1952). In Suisun and San Pablo Bays water temperatures can reach 54°F by February in a typical year. Other portions of the Delta (i.e., south Delta and central Delta) can reach 70°F by February in a dry year. However, cooler temperatures are usually the norm until after the spring runoff has ended.

Within the estuarine habitat, juvenile Chinook salmon movements are dictated by the tidal cycles, following the rising tide into shallow water habitats from the deeper main channels, and returning to the main channels when the tide recedes (Levy and Northcote 1982, Levings 1982, Levings et al. 1986, Healey 1991). As juvenile Chinook salmon increase in length, they tend to school in the surface waters of the main and secondary channels and sloughs, following the tides into shallow water habitats to feed (Allen and Hassler 1986). In Suisun Marsh, Moyle et al. (1989) reported that Chinook salmon fry tend to remain close to the banks and vegetation, near protective cover, and in dead-end tidal channels. Kjelson et al. (1982) reported that juvenile Chinook salmon demonstrated a diel migration pattern, orienting themselves to nearshore cover and structure during the day, but moving into more open, offshore waters at night. The fish also distributed themselves vertically in relation to ambient light. During the night, juveniles were distributed randomly in the water column, but would school up during the day into the upper 3 meters of the water column. Available data indicates that juvenile Chinook salmon use Suisun Marsh extensively both as a migratory pathway and rearing area as they move downstream to the Pacific Ocean. Juvenile Chinook salmon were found to spend about 40 days migrating through the Delta to the mouth of San Francisco Bay and grew little in length or weight until they reached the Gulf of the Farallones (MacFarlane and Norton 2002). Based on the mainly ocean- type life history observed (i.e., fall-run Chinook salmon) MacFarlane and Norton (2002) concluded that unlike other salmonid populations in the Pacific Northwest, Central Valley Chinook salmon show little estuarine dependence and may benefit from expedited ocean entry.

Sacramento River Winter-run Chinook Salmon

The distribution of winter-run Chinook salmon spawning and rearing historically was limited to the upper Sacramento River and its tributaries, where spring-fed streams provided cold water throughout the summer, allowing for spawning, egg incubation, and rearing during the mid-summer period (Slater 1963, Yoshiyama et al. 1998). The headwaters of the McCloud, Pit, and Little Sacramento rivers, and Hat and Battle creeks, historically provided clean, loose gravel; cold, well-oxygenated water; and optimal stream flow in riffle habitats for spawning and incubation. These areas also provided the cold, productive waters necessary for egg and fry development and survival, and juvenile rearing over the summer. The construction of Shasta Dam in 1943 blocked access to all of these waters except Battle Creek, which has its own impediments to upstream migration (i.e., the fish weir at the Coleman National Fish Hatchery and other small hydroelectric facilities situated upstream of the weir) (Moyle et al. 1989, NMFS 1997, 1998a,b). Approximately 299 miles of tributary spawning habitat in the upper Sacramento River is now inaccessible to winter-run Chinook salmon. Yoshiyama et al. (2001) estimated that in 1938, the Upper Sacramento had a “potential spawning capacity” of 14,303 redds. Most components of the winter-run Chinook salmon life history (e.g., spawning, incubation, freshwater rearing) have been compromised by the habitat blockage in the upper Sacramento River.

Adult winter-run Chinook salmon enter San Francisco Bay from November through June (Hallock and Fisher 1985) and migrate past the RBDD from mid-December through early August (NMFS 1997). The majority of the run passes RBDD from January through May, with the peak passage occurring in mid-March (Hallock and Fisher 1985). The timing of migration may vary somewhat due to changes in river flows, dam operations, and water year type (see Table 4; Yoshiyama et al. 1998, Moyle 2002). Spawning occurs primarily from mid-April to mid-August, with the peak activity occurring in May and June in the Sacramento River reach between Keswick Dam and RBDD (Vogel and Marine 1991). The majority of Sacramento River winter-run Chinook salmon spawners are 3 years old.

Sacramento River winter-run Chinook salmon fry begin to emerge from the gravel in late June to early July and continue through October (Fisher 1994). Emigration of juvenile Sacramento River winter-run Chinook salmon past RBDD may begin as early as mid-July, typically peaks in September, and can continue through March in dry years (Vogel and Marine 1991, NMFS 1997). Juvenile Sacramento River winter-run Chinook salmon occur in the Delta primarily from November through early May based on data collected from trawls in the Sacramento River at West Sacramento (River Mile 57; USFWS 2001a,b). The timing of migration may vary somewhat due to changes in river flows, dam operations, and water year type. Winter-run Chinook salmon juveniles remain in the Delta until they reach a fork length of approximately 118 mm and are from 5 to 10 months of age, and then begin emigrating to the ocean as early as November and continue through May (Fisher 1994, Myers et al. 1998).

Table 4. The temporal occurrence of adult (a) and juvenile (b) Sacramento River winter-run Chinook salmon in the Sacramento River. Darker shades indicate months of greatest relative abundance.

a) Adult migration

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sac. River basin[a]	Medium	Medium	High	Medium	Medium	Medium	Medium					Medium
Sac. River[b]	Medium	Medium	Medium	Medium	Medium	Medium					Medium	Medium

b) Juvenile migration

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sac. River @ Red Bluff[c]	Low	Low	Low				Low / Medium	Medium	Medium	Medium	Medium	Medium
Sac. River @ Red Bluff[b]	Low	Low	Low				Low	Medium	Medium	Medium	Medium	Medium
Sac. River @ KL[d]	Medium	Medium	Medium	Low	Low			Low	Low	Low	High	High
Lower Sac. River (seine)[e]	High	High	Medium	Low	Low					Low	Medium	High
West Sac. River (trawl)[e]	Medium	Medium	High	Medium	Low						Low	Medium

KL = Knights Landing

Relative Abundance: (black) = High; (dark grey) = Medium; (light grey) = Low

Sources : [a]Yoshiyama et al. (1998); Moyle (2002); [b]Myers et al. (1998) ; Vogel and Marine(1991); [c]Martin et al. (2001); [d]Snider and Titus (2000); [e]USFWS (2001a, 2001b)

Historical Sacramento River winter-run Chinook salmon population estimates, which included males and females, were as high as approximately 100,000 fish in the 1960s, but declined to under 200 fish in the 1990s (Good et al. 2005). Population estimates in 2003 (8,218), 2004 (7,869), 2005 (15,839) and 2006 (17,296) showed a recent increase in the population size (CDFG GrandTab, April 2013) and a 4-year average of 12,306 (Table 5). The 2006 run was the highest since the 1994 listing. Abundance measures over the last decade suggest that the abundance was initially increasing (Good et al. 2005). However, escapement estimates for 2007-2011, showed a precipitous decline in escapement numbers based on red counts and carcass counts. Estimates place the adult escapement numbers for 2007 at 2,541 fish, 2,830 fish for 2008, and 4,537 fish for 2009, 1,596 fish for 2010, 827 fish for 2011, 2,674 fish for 2012, 6,123 fish for 2013, and 3015 for 2014 (Table 5).

Two current methods are utilized to estimate the juvenile production of Sacramento River winter-run Chinook salmon: the Juvenile Production Estimate (JPE) method, and the Juvenile Production Index (JPI) method (Gaines and Poytress 2004). Gaines and Poytress (2004) estimated the average juvenile population of Sacramento River winter-run Chinook salmon exiting the upper Sacramento River at RBDD to be 3,707,916 juveniles per year using the JPI method between the years 1995 and 2003 (excluding 2000 and 2001). Using the JPE method, they estimated an average of 3,857,036 juveniles exiting the upper Sacramento River at RBDD between the years of 1996 and 2003. Averaging these two estimates yields an estimated overall average population size of 3,782,476.

Table 5. Sacramento River Winter-run Chinook Salmon Adult Population Estimates, Cohort Replacement Rates, and Juvenile Production Estimates, 1986-2013

Year	Population Estimatea	5-Year Moving Average of Population Estimate	Cohort Replacement Rateb	5-Year Moving Average of Cohort Replacement Rate	NMFS –Calculated Juvenile Production Estimate (JPE)c
1986	2,596				
1987	2,185				
1988	2,878				
1989	696		0.27		
1990	430	1,757	0.20		
1991	211	1,280	0.07		40,100
1992	1,240	1,091	1.78		273,100
1993	387	593	0.90	0.64	90,500
1994	186	491	0.88	0.77	74,500
1995	1,297	664	1.05	0.94	338,107
1996	1,337	889	3.45	1.61	165,069
1997	880	817	4.73	2.20	138,316
1998	2,992	1,338	2.31	2.48	454,792
1999	3,288	1,959	2.46	2.80	289,724
2000	1,352	1,970	1.54	2.90	370,221
2001	8,224	3,347	2.75	2.76	1,864,802
2002	7,441	4,659	2.26	2.26	2,136,747
2003	8,218	5,705	6.08	3.02	1,896,649
2004	7,869	6,621	0.96	2.72	881,719
2005	15,839	9,518	2.13	2.84	3,831,286
2006	17,296	11,333	2.10	2.71	3,739,050
2007	2,541	10,353	0.32	2.32	589,900
2008	2,830	9,275	0.18	1.14	617,783
2009	4,537	8,609	0.26	1.00	1,179,650
2010	1,596	5,760	0.63	0.70	332,012
2011	827	2,466	0.29	0.34	162,051
2012	2,674	2,493	0.59	0.39	532,809
2013	6,123	3,151	3.84	1.12	1,196,387
2014	3,015	2,847	3.65	1.80	124,521
median	2,596	2,493	1.29	2.00	412,507
mean[d]	3,827	3,959	1.76	1.79	888,325
Last 10[e]	5,728	6,580	1.40	1.43	1,230,545
Last 6[f]	3,129	4,221	1.54	0.89	587,905
Last 3[g]	3,937	2,830	2.69	1.10	617,906

Notes:

[a] Population estimates were based on RBDD counts until 2001. Starting in 2001, population estimates were based on carcass surveys.

[b] The majority of winter-run spawners are 3 years old. Therefore, the Cohort Replacement Rate (CRR) was calculated using spawning population of a given year, divided by the spawning population 3 years prior.

[c] JPEs were derived from NMFS calculations utilizing RBDD winter-run counts through 2001, and carcass counts thereafter for deriving adult escapement numbers.

[d] Average of 1986 through 2014

Year	Population Estimatea	5-Year Moving Average of Population Estimate	Cohort Replacement Rateb	5-Year Moving Average of Cohort Replacement Rate	NMFS –Calculated Juvenile Production Estimate (JPE)c

[e] Average of last 10 years of data and derived calculations (2005 to 2014)

[f] Average of last 6 years of data and derived calculations (2009 to 2015)

[g] Average of last 3 years of data and derived calculations (2012 to 2014)

Source: Adult data from California Department of Fish and Wildlife GrandTab 2014.04.22 (Available: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=84381&inline=1, accessed February 4, 2015); 2014 JPE data from 2014 NMFS letter to Reclamation estimating the JPE (Available: http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/Operations,%20Criteria%20and%20Plan/nmfs__winter-run_broodyear_2013_jpe_letter_-_february_21__2014.pdf, accessed February 4, 2015; 2015 adult and JPE data from 2015 NMFS letter to Reclamation estimating the JPE (Available: http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/20150116_nmfs_winter-run_juvenile_production_estimate_nr.pdf, accessed March 27, 2015)

Based on the RBDD counts, the population has been growing rapidly since the 1990s with positive short-term trends (excluding the 2007-2011 escapement numbers). An age-structured density-independent model of spawning escapement by Botsford and Brittnacker (1998 as referenced in Good et al. 2005) assessing the viability of Sacramento River winter-run Chinook salmon found the species was certain to fall below the quasi-extinction threshold of 3 consecutive spawning runs with fewer than 50 females (Good et al. 2005). Lindley and Mohr (2003) assessed the viability of the population using a Bayesian model based on spawning escapement that allowed for density dependence and a change in population growth rate in response to conservation measures found a biologically significant expected quasi-extinction probability of 28 percent. Although the status of the Sacramento River winter-run Chinook salmon population had been improving until as recently as 2006, there is only one population, and it depends on cold-water releases from Shasta Dam, which could be vulnerable to a prolonged drought (Good et al. 2005). Recent population trends have indicated that the status of the winter-run Chinook salmon population may be changing as reflected in the diminished abundance during recent years, prior to greater numbers after 2011. The 2014 (2013 brood year) JPE estimated over 1.1 million fish entered the Delta, which is similar to 2009 but generally less than the JPE values seen in the last decade. The 2015 (brood year 2014) JPE is considerably lower (124,521) than the 2014 JPE, reflecting challenging upstream conditions during the continuing drought. The two most recent years of adult escapement estimates (2013 and 2014) had several times the number of returning adults compared to the recent low in 2011 (827 winter-run Chinook salmon).

In 2007, Lindley et al. (2007) determined that the Sacramento River winter-run Chinook salmon population that spawns below Keswick Dam is at a moderate extinction risk according to population viability analysis (PVA), and at a low risk according to other criteria (i.e., population size, population decline, and the risk of wide ranging catastrophe). However, concerns of genetic introgression with hatchery populations are increasing. Hatchery-origin winter-run Chinook salmon from Livingston Stone National Fish Hatchery (LSNFH) have made up more than 5 percent of the natural spawning run in recent years and in 2005, it exceeded 18 percent of the natural run. If the proportion of hatchery origin fish from the LSNFH exceeded 15 percent in 2006-2007, Lindley et al. (2007) recommended reclassifying the winter-run Chinook population extinction risk as moderate, rather than low, based on the impacts of the hatchery fish over multiple generations of spawners. However, since 2005, the percentage of hatchery fish recovered at the LSNFH has been consistently below 15 percent.

Furthermore, Lindley et al. (2007) did not include the recent declines in adult escapement abundance which may modify the conclusion reached in 2007. The recent status review of the Sacramento River winter-run Chinook salmon evolutionary significant unit (ESU) in August 2011 (NMFS 2011a) did assess this recent decline and found that the winter-run Chinook salmon population was still at an elevated risk of extinction. Its current status did not warrant a change from its listing as endangered.

Lindley et al. (2007) also states that the winter-run Chinook salmon population fails the "representation and redundancy rule" because it has only one population, and that population spawns outside of the ecoregion in which it evolved. In order to satisfy the "representation and redundancy rule," at least two populations of winter-run Chinook salmon would have to be re-established in the basalt- and porous-lava region of its origin. An ESU represented by only one spawning population at moderate risk of extinction is at a high risk of extinction over an extended period of time (Lindley et al. 2007).

Viable Salmonid Population Summary for Sacramento River Winter-run Chinook Salmon

Abundance: During the first part of this decade, redd and carcass surveys as well as fish counts, suggested that the abundance of winter-run Chinook salmon was increasing since its listing. However, the depressed abundance estimates from 2007-2011 are contrary to this earlier trend and may represent a combination of a new cycle of poor ocean productivity (Lindley et al. 2009) and recent drought conditions in the Central Valley. The most recent three years have indicated a slight upwards trend in the population abundance for winter-run, when ocean conditions have been more positive for salmonid populations. The current annual and five-year averaged cohort replacement rates (CRR) are both well above 1.0. The annual CRR has been above 1.0 for the past two years and indicates that the winter-run population recommenced replacing itself following three brood years (2010-2012) when it did not (Table 5).

Productivity: ESU productivity has been positive over the short term, and adult escapement and juvenile production had been increasing annually (Good et al. 2005) until recently (2006). However, since 2006, there has been declining escapement estimates for the years 2007 through 2011, with a moderate positive increase in adult escapement for 2012-2013 over the low seen in 2011 (827 fish), followed by a roughly 50% decrease in 2014 (3,015 fish) compared to 2013 (6,123 fish; Table 5). The long-term trend for the ESU remains negative, as it consists of only one population that is subject to possible impacts from environmental and artificial conditions. The most recent CRR estimates suggest an increase in productivity for the last two returning cohorts, returning in 2013 and 2014.

Spatial Structure: The greatest risk factor for winter-run Chinook salmon lies with their spatial structure (Good et al. 2005). The remnant population cannot access historical winter-run Chinook salmon habitat and must be artificially maintained in the Sacramento River by a regulated, finite cold-water pool behind Shasta Dam. Winter-run Chinook salmon require cold water temperatures in summer that simulate their upper Sacramento River basin habitat, and they are more likely to be exposed to the impacts of drought in a lower basin environment, as occurred in 2014. Battle Creek remains the most feasible opportunity for the ESU to expand its spatial structure, which currently is limited to the upper 25-mile reach of the main stem Sacramento River below Keswick Dam. Based on Reasonable and Prudent Alternative actions described in the CVP/SWP BO, passage of winter-run Chinook salmon above Keswick and Shasta Dams is being considered as one of the actions. This would reintroduce winter-run Chinook salmon into regions they had historically occupied and significantly benefit the spatial structure of the ESU.

Diversity: The second highest risk factor for the Sacramento River winter-run Chinook salmon ESU has been the detrimental effects on its diversity. The present winter-run Chinook salmon population has resulted from the introgression of several stocks that occurred when Shasta Dam blocked access to the upper watershed. A second genetic bottleneck occurred with the construction of Keswick Dam; and there may have been several others within the recent past (Good et al. 2005). Concerns of genetic introgression with hatchery populations are also increasing. Hatchery-origin winter-run Chinook salmon from LSNFH have made up more than 5 percent of the natural spawning run in recent years and in 2005, it exceeded 18 percent of the natural run. The average over the last 10 years (approximately 3 generations) has been 8 percent, still below the low-risk threshold for hatchery influence. Since 2005, the percentage of hatchery fish in the river was consistently below 15 percent until the recent drought years of 2014 and 2015; a greater percentage of adults were collected and spawned at LSNFH in 2014-2015 because of concerns over in-river survival being threatened by relatively high water temperature.

Central Valley Spring-Run Chinook Salmon

Historically the spring-run Chinook salmon were the second most abundant salmon run in the Central Valley (CDFG 1998) (see Table 6). These fish occupied the upper and middle reaches (1,000 to 6,000 feet) of the San Joaquin, American, Yuba, Feather, Sacramento, McCloud and Pit rivers, with smaller populations in most tributaries with sufficient habitat for over-summering adults (Stone 1874, Rutter 1904, Clark 1929). The Central Valley Technical Review Team (CVTRT) estimated that historically there were 18 or 19 independent populations of Central Valley spring-run Chinook salmon, along with a number of dependent populations and four diversity groups (Lindley et al. 2004). Of these 18 populations, only three extant populations currently exist (Mill, Deer, and Butte creeks on the upper Sacramento River) and they represent only the northern Sierra Diversity group. All populations in the Basalt and Porous Lava Group and the Southern Sierra Nevada Group have been extirpated.

Table 6. Central Valley Spring-run Chinook salmon population estimates with corresponding cohort replacement rates for years since 1986.

Year	Sacramento River Basin Escapement Run Size[a]	FRFH Population	Tributary Populations	5-Year Moving Average of Tributary Population Estimate	Trib CRR[b]	5-Year Moving Average of Trib CRR	5-Year Moving Average of Basin Population Estimate	Basin CRR	5-Year Moving Average of Basin CRR

Year	Sacramento River Basin Escapement Run Size[a]	FRFH Population	Tributary Populations	5-Year Moving Average of Tributary Population Estimate	Trib CRR[b]	5-Year Moving Average of Trib CRR	5-Year Moving Average of Basin Population Estimate	Basin CRR	5-Year Moving Average of Basin CRR
1986	25,696	1,433	24,263						
1987	13,888	1,213	12,675						
1988	18,933	6,833	12,100						
1989	12,163	5,078	7,085		0.29			0.47	
1990	7,683	1,893	5,790	12,383	0.46		15,673	0.55	
1991	5,926	4,303	1,623	7,855	0.13		11,719	0.31	
1992	3,044	1,497	1,547	5,629	0.22		9,550	0.25	
1993	6,076	4,672	1,404	3,490	0.24	0.27	6,978	0.79	0.48
1994	6,187	3,641	2,546	2,582	1.57	0.52	5,783	1.04	0.59
1995	15,238	5,414	9,824	3,389	6.35	1.7	7,294	5.01	1.48
1996	9,083	6,381	2,702	3,605	1.92	2.06	7,926	1.49	1.72
1997	5,193	3,653	1,540	3,603	0.6	2.14	8,355	0.84	1.84
1998	31,649	6,746	24,903	8,303	2.53	2.6	13,470	2.08	2.09
1999	10,100	3,731	6,369	9,068	2.36	2.75	14,253	1.11	2.11
2000	9,244	3,657	5,587	8,220	3.63	2.21	13,054	1.78	1.46
2001	26,663	4,135	22,528	12,185	0.9	2.01	16,570	0.84	1.33
2002	25,043	4,189	20,854	16,048	3.27	2.54	20,540	2.48	1.66
2003	30,697	8,662	22,035	15,475	3.94	2.82	20,349	3.32	1.91
2004	17,150	4,212	12,938	16,788	0.57	2.47	21,759	0.64	1.81
2005	23,093	1,774	21,319	19,935	1.02	1.94	24,529	0.92	1.64
2006	12,906	2,181	10,725	17,574	0.49	1.86	21,778	0.42	1.56
2007	11,144	1,916	9,228	15,249	0.71	1.35	18,998	0.65	1.19
2008	13,387	1,460	11,927	13,227	0.56	0.67	15,536	0.58	0.64
2009	4,505	989	3,516	11,343	0.33	0.62	13,007	0.35	0.58
2010	4,623	1,661	2,962	7,672	0.32	0.48	9,313	0.41	0.48
2011	7,408	1,969	5,439	6,614	0.46	0.48	8,213	0.55	0.51
2012	22,249	3,738	18,511	8,471	5.26	1.39	10,434	4.94	1.37
2013	23,697	4,294	19,403	9,966	6.55	2.58	12,496	5.13	2.28
2014	9,901	2,776	7,125	10,688	1.31	2.78	13,576	1.34	2.47
Median	12,163	3,657	9,228	9,068	0.81	1.98	13,054	0.84	1.52
Average[c]	14,227	3,590	10,637	9,974	1.77	1.74	13,646	1.47	1.42
Last 10[d]	13,291	2,276	11,016	12,074	1.70	1.42	14,788	1.53	1.27
Last 6[e]	12,064	2,571	9,493	9,126	2.37	1.39	11,173	2.12	1.28
Last 3[f]	18,616	3,603	15,013	9,708	4.37	2.25	12,169	3.80	2.04

Notes:

[a] NMFS included both the escapement numbers from the FRFH and the Sacramento River and its tributaries in this table. Sacramento River Basin run size is the sum of the escapement numbers from the FRFH and the tributaries.

[b] Abbreviations: CRR = Cohort Replacement Rate, Trib = tributary

[c] Grand average for years 1986 to 2014

[d] Average over last 10 years of data and derived calculations (2005 to 2014)

Year	Sacramento River Basin Escapement Run Size[a]	FRFH Population	Tributary Populations	5-Year Moving Average of Tributary Population Estimate	Trib CRR[b]	5-Year Moving Average of Trib CRR	5-Year Moving Average of Basin Population Estimate	Basin CRR	5-Year Moving Average of Basin CRR

[e] Average over last 6 years of data and derived calculations (2009 to 2014)

[f] Average over last 3 years of data and derived calculations (2012 to 2014)

Data are from NMFS (2014, and references therein) and DFW GrandTab 2015.04.15 California Central Valley Chinook Population Database Report (Available: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=98234. Accessed: June 26, 2015).

The Central Valley drainage as a whole is estimated to have supported spring-run Chinook salmon runs as large as 600,000 fish between the late 1880s and 1940s (CDFG 1998, Fisher 1994). Before the construction of Friant Dam, nearly 50,000 adults were counted in the San Joaquin River alone (Skinner 1958, Fry 1961). Construction of other low elevation dams in the foothills of the Sierras on the American, Mokelumne, Stanislaus, Tuolumne, and Merced rivers extirpated Central Valley spring-run Chinook salmon from these watersheds. Naturally-spawning populations of Central Valley spring-run Chinook salmon currently are restricted to accessible reaches of the upper Sacramento River, Antelope Creek, Battle Creek, Beegum Creek, Big Chico Creek, Butte Creek, Clear Creek, Deer Creek, Feather River, Mill Creek, and Yuba River (CDFG 1998).

Adult Central Valley spring-run Chinook salmon leave the ocean to begin their upstream migration in late January and early February (CDFG 1998) and enter the Sacramento River between March and September, primarily in May and June (Yoshiyama et al. 1998, Moyle 2002) (Table 7). Lindley et al. (2004) indicates adult Central Valley spring-run Chinook salmon enter native tributaries from the Sacramento River primarily between mid-April and mid-June. Typically, spring-run Chinook salmon utilize mid- to high-elevation streams that provide appropriate temperatures and sufficient flow, cover, and pool depth to allow over-summering while conserving energy and allowing their gonadal tissue to mature (Yoshiyama et al. 1998).

Spring-run Chinook salmon spawning occurs between September and October depending on water temperatures. Between 56 and 87 percent of adult spring-run Chinook salmon that enter the Sacramento River basin to spawn are 3 years old (Calkins et al. 1940, Fisher 1994).

Spring-run Chinook salmon fry emerge from the gravel from November to March (Moyle 2002) and the emigration timing is highly variable, as they may migrate downstream as young-of-the- year or as juveniles or yearlings. The modal size of fry migrants at approximately 40 mm between December and April in Mill, Butte, and Deer creeks reflects a prolonged emergence of fry from the gravel (Lindley et al. 2004). Studies in Butte Creek (Ward et al. 2002, 2003, McReynolds et al. 2005) found the majority of Central Valley spring-run Chinook salmon migrants to be fry occurring primarily during December, January, and February; and that these movements appeared to be influenced by flow (Table 7). Small numbers of Central Valley spring-run Chinook salmon remained in Butte Creek to rear and migrated as yearlings later in the spring. Juvenile emigration patterns in Mill and Deer

Table 7. The temporal occurrence of adult (a) and juvenile (b) Central Valley spring-run Chinook salmon in the Sacramento River. Darker shades indicate months of greatest relative abundance

(a) Adult migration												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sac.River basin[a,b]	–, –	–, –	M, M	M, M	H, H	H, H	M, M	M, M	M, M	L, L	–, –	–, –
Sac. River mainstem[c]	–, L	L, L	M, M	M, M	M, M	M, M	M, M	L, L	–, –	–, –	–, –	–, –
Mill Creek[d]	–, –	–, –	L, L	M, H	H, H	H, M	M, L	L, –	–, –	–, –	–, –	–, –
Deer Creek[d]	–, –	–, –	L, L	M, H	H, H	H, M	M, –	–, –	–, –	–, –	–, –	–, –
Butte Creek[d]	–, –	M, M	M, M	M, H	H, H	H, M	L, –	–, –	–, –	–, –	–, –	–, –
(b) Adult Holding	–, –	M, M	M, M	M, H	H, H	H, H	H, H	H, H	H, M	M, L	–, –	–, –
(c) Adult Spawning	–, –	–, –	–, –	–, –	–, –	–, –	–, –	L, M	H, H	M, L	–, –	–, –

(d) Juvenile migration												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sac. River Tribs[e]	M, M	M, M	M, M	–, –	–, –	–, –	–, –	–, –	–, –	M, M	H, H	H, H
Upper Butte Creek[f]	H, H	H, H	M, M	M, M	M, M	L, L	–, –	–, –	–, –	L, L	L, L	H, H
Mill, Deer, Butte Creeks[d]	H, H	H, H	M, M	M, M	M, M	L, L	–, –	–, –	–, –	L, L	L, L	L, L
Sac. River at RBDD[c]	H, H	L, L	L, L	L, L	L, –	–, –	–, –	–, –	–, –	–, –	H, H	H, H
Sac. River at KL[g]	M, M	M, M	H, H	H, H	M, M	–, –	–, –	–, –	–, –	–, –	M, M	H, H

Relative Abundance: H = High; M = Medium; L = Low

Sources: [a]Yoshiyama et al. (1998); [b]Moyle (2002); [c]Myers et al. (1998); [d]Lindley et al. (2004); [e]CDFG (1998); [f]McReynolds et al. (2005); Ward et al. (2002, 2003); [g]Snider and Titus (2000)

creeks are very similar to patterns observed in Butte Creek, with the exception that Mill and Deer creek juveniles typically exhibit a later young-of-the-year migration and an earlier yearling migration (Lindley et al. 2004).

Once juveniles emerge from the gravel they initially seek areas of shallow water and low velocities while they finish absorbing the yolk sac and transition to exogenous feeding (Moyle 2002). Many also will disperse downstream during high-flow events. As is the case in other salmonids, there is a shift in microhabitat use by juveniles to deeper faster water as they grow larger. Microhabitat use can be influenced by the presence of predators which can force fish to select areas of heavy cover and suppress foraging in open areas (Moyle 2002). The emigration period for spring-run Chinook salmon extends from November to early May, with up to 69 percent of the young-of-the-year fish outmigrating through the lower Sacramento River and Delta during this period (CDFG 1998). Peak movement of juvenile Central Valley spring-run Chinook salmon in the Sacramento River at Knights Landing occurs in December, and again in March and April (Table 7). However, juveniles also are observed between November and the end of May (Snider and Titus 2000). Based on the available information, the emigration timing of Central Valley spring-run Chinook salmon appears highly variable (CDFG 1998). Some fish may begin emigrating soon after emergence from the gravel, whereas others over-summer and emigrate as yearlings with the onset of intense fall storms (CDFG 1998).

On the Feather River, significant numbers of spring-run Chinook salmon, as identified by run timing, return to the Feather River Fish Hatchery (FRFH). In 2002, the FRFH reported 4,189 returning spring-run Chinook salmon, which is 22 percent below the 10-year average of 4,727 fish. However, coded-wire tag (CWT) information from these hatchery returns indicates substantial introgression has occurred between fall-run and spring-run Chinook salmon populations within the Feather River system due to previous hatchery practices. Because Chinook salmon have not always been temporally separated in the hatchery, spring-run and fall-run Chinook salmon have been spawned together in the past, thus compromising the genetic integrity of the spring-run Chinook salmon stock in the Feather River. The most recent status review for Central Valley spring-run Chinook salmon (NMFS 2011b) reported that there were subtle differences between the FRFH spring-run Chinook salmon and the fall-run Chinook salmon stocks spawning in that river system (Garza and Pearse 2008) but that there was also a high level of similarity between the two runs, reflecting historic gene flow between them. Currently, the FRFH allows early returning fish that exhibit spring-run run timing behavior to enter the hatchery in spring, where they are tagged and then released back into the river below the hatchery to over-summer. When spawning the spring-run stock, the hatchery only spawns early returning fish with other early returning fish, as indicated by the tags. However, only a limited number of fish can be spawned for hatchery production, the remaining tagged fish remain in the river to spawn naturally. These fish may spawn with either other spring-run Chinook salmon or with fall-run Chinook salmon that have now entered the river system. It also is noted in the review that not all early returning fish exhibiting the spring-run timing characteristics enter the hatchery in spring, and thus a fraction of the run remains "unidentified" in the river and are not enumerated as spring-run in any census of the river. The number of naturally spawning spring-run Chinook salmon in the Feather River has been estimated only periodically since the 1960s, with estimates ranging from 2 fish in 1978 to 2,908 in 1964. However, the genetic integrity of this population is questionable because of the significant temporal and spatial overlap between spawning populations of spring-run and fall-run Chinook salmon (Good et al. 2005). For the reasons discussed previously, the Feather River spring- run Chinook population numbers are not included in the following discussion of ESU abundance.

In addition, monitoring of the Sacramento River main stem during spring-run Chinook salmon spawning timing indicates some spawning occurs in the river. Here, the potential to physically separate spring-run Chinook salmon from fall-run Chinook salmon is complicated by overlapping migration and spawning periods. Significant hybridization with fall-run Chinook salmon has made identification of a spring-run Chinook salmon population in the main stem very difficult to determine, and there is speculation as to whether a true spring-run Chinook salmon population still exists below Keswick Dam. Although the conditions of the physical habitats in the Sacramento River below Keswick Dam are capable of supporting spring-run Chinook salmon, some years have had high water temperatures resulting in substantial levels of egg mortality. Redd surveys conducted in September between 2001 and 2011 have observed an average of 36 salmon redds from Keswick Dam downstream to the RBDD. This is typically when spring-run spawn, however, these redds also could be early spawning fall-run. Therefore, even though physical habitat conditions may be suitable, spring-run Chinook salmon depend on spatial segregation and geographic isolation from fall-run Chinook salmon to maintain genetic diversity. With the onset of fall-run Chinook salmon spawning occurring in the same time and place as potential spring-run Chinook salmon spawning, it is likely to have caused extensive introgression between the populations (CDFG 1998). For these reasons, Sacramento River main stem spring-run Chinook salmon are not included in the following discussion of ESU abundance.

Lindley et al. (2007) indicated that the spring-run population of Chinook salmon in the Central Valley had a low risk of extinction in Butte and Deer creeks, according to their PVA model and the other population viability criteria (i.e., population size, population decline, catastrophic events, and hatchery influence). The Mill Creek population of spring-run Chinook salmon is at moderate extinction risk according to the PVA model, but appears to satisfy the other viability criteria for low-risk status. However, like the winter-run Chinook salmon population, the Central Valley spring-run Chinook salmon population fails to meet the "representation and redundancy rule" (Lindley et al. 2007) since there is only one demonstrably viable population out of the three diversity groups that historically contained them. The spring-run population is only represented by the group that currently occurs in the northern Sierra Nevada. The spring-run Chinook salmon populations that formerly occurred in the basalt and porous-lava region and southern Sierra Nevada region have been extirpated. The northwestern California region contains a few ephemeral populations (e.g., Clear, Cottonwood, and Thomes creeks) of spring-run Chinook salmon that are likely dependent on the northern Sierra populations for their continued existence. Over the long term, these remaining independent populations are considered to be vulnerable to catastrophic events, such as volcanic eruptions from Mount Lassen or large forest fires due to the close proximity of their headwaters to each other. Drought is also considered to pose a significant threat to the viability of the spring-run Chinook salmon populations in these three watersheds due to their close proximity to each other. One large event could eliminate all three populations.

Viable Salmonid Population Summary for Central Valley Spring-run Chinook Salmon

Abundance: Over the first half of the past decade, the Central Valley spring-run Chinook salmon ESU has experienced a trend of increasing abundance in some natural populations, most dramatically in the Butte Creek population (Good et al. 2005). There has been more opportunistic utilization of migration-dependent streams overall. The FRFH spring-run Chinook salmon stock has been included in the ESU based on its genetic linkage to the natural population and the potential development of a conservation strategy for the hatchery program at this facility. In contrast to the first half of the decade, the adult returns through 2010, indicate that population abundance declined sharply from the peaks seen in the 5 years prior (2001 to 2005) for the entire Sacramento River basin; there was increased abundance in 2012-2013, however, before a decrease in 2014 (Table 6). According to the latest species status review (NMFS 2011b), the recent declines in abundance through 2010, place the Mill and Deer creek populations in the high extinction risk category due to the rate of decline, and in the case of Deer Creek, also the level of escapement. However, the estimates of adult escapement increased sharply in 2012 for both Deer and Mill creeks (734 and 768 fish, respectively), moving these populations back to a moderate risk category; data for 2013-2014 were of similar magnitude (Mill Creek: 644 in 2013, 679 in 2014; Deer Creek: 708 in 2013, 830 in

2014; see data included in Attachment A from Murillo and Cowin 2015). Butte Creek has sufficient abundance to retain its low extinction risk classification, but the rate of population decline in the past several years (2005 to 2011) is adequate to classify it as a moderate extinction risk based on this criterion. In 2012, the Butte Creek estimate of adult escapement increased from 4,505 fish to 16,140 fish moving the population's risk assessment back towards a low risk category; however, escapement of 16,783 fish in 2013 was followed by considerably lower escapement in 2014 (4,815; Table 6). During the same period, some tributaries, such as Clear Creek and Battle Creek have shown indications of population gains and are approaching the levels of Mill and Deer Creeks, but the overall abundance numbers are still low compared to Butte Creek. Battle Creek has increased from approximately 200 adults per year (2006 to 2011) to nearly 800 fish in 2012, 608 fish in 2013, and 429 fish in 2014 (see Attachment A of Murillo and Cowin 2015). The recent increases in Battle Creek would qualify this population as being at a moderate risk of extinction based on the escapement estimates for the river. Spring-run Chinook salmon also occur on the Yuba River, with the annual run size generally ranging from a few hundred fish to several thousand fish, and the annual trends closely following the annual abundance trend of the FRFH spring-run Chinook salmon population. There appears to be considerable hatchery influence, as preliminary data from Barnett-Johnson et al. (2011) suggested that in 2009 only 9% of spawners were of Yuba River origin. This is not surprising as the Yuba River is a tributary to the Feather River. The Yuba River spring-run Chinook salmon population satisfies the moderate extinction risk criteria for abundance, but likely falls into the high risk category for hatchery influence. Spring-run Chinook salmon population trends in the Central Valley through 2010 are given in the NMFS 5-year review (NMFS 2011b).

Productivity: The 5-year mean for the tributary populations generally increased from 1994 to 2005, from just under 2,600 to just under 20,000 (Table 6). The 5-year geometric mean increased fairly consistently from 1986 to 2006, indicating increasing productivity over the short-term and was projected to likely continue into the future (Good et al. 2005). However, a decline in the adult escapement in the tributaries saw the 5-year mean decline from 2005's high to just over 6,600 in 2011. The CRR has declined in concert with the population declines, falling from a 5-year mean of 1.02 in 2005 to 0.48 in 2010-2011, before increasing to 1.39 in 2012, 2.58 in 2013, and 2.78 in 2014. As mentioned previously, greater escapement occurred in the tributaries in 2012-2014, with 5-year means of around 8,500 to 10,700 fish (Table 6). The productivity of the "wild" Feather River and Yuba River spring-run populations and contribution to the Central Valley spring-run ESU currently is unknown.

Spatial Structure: Spring-run Chinook salmon presence has been reported more frequently in several upper Central Valley creeks, but the sustainability of these runs is unknown. Butte Creek spring-run Chinook salmon cohorts have recently utilized all currently available habitat in the creek; and it is unknown if individuals have opportunistically migrated to other systems. The spatial structure of the spring-run Chinook salmon ESU has been reduced with the extirpation of all San Joaquin River basin spring-run Chinook salmon populations. In the near future, an experimental population of Central Valley spring-run Chinook salmon will be reintroduced into the San Joaquin River below Friant Dam as part of the San Joaquin River Settlement Agreement. Its long term contribution to the Central Valley spring-run Chinook salmon ESU is uncertain. The populations in Clear Creek and Battle Creek may add to the spatial structure of the Central Valley spring-run population if they can persist by colonizing waterways in the Basalt and Porous Lava and Northwestern California Coastal Range diversity group areas. The most recent returns for Battle Creek indicate that there is reason to believe that this tributary may sustain another population of spring-run and therefore re-colonize the Basalt and Porous Lava eco-region of the Central Valley.

Diversity: The Central Valley spring-run Chinook salmon ESU comprises two genetic complexes. Analysis of natural and hatchery spring-run Chinook salmon stocks in the Central Valley indicates that the Northern Sierra Nevada spring-run Chinook salmon population complex (Mill, Deer, and Butte creeks) retains genetic integrity. The genetic integrity of the Northern Sierra Nevada spring-run Chinook salmon population complex in the Feather River has been somewhat compromised. The Feather River spring-run Chinook salmon have introgressed with the fall-run Chinook salmon, and it appears that the Yuba River population may have been impacted by FRFH fish straying into the Yuba River. The diversity of the spring-run Chinook salmon ESU has been further reduced with the extirpation of the San Joaquin River basin spring-run Chinook salmon populations (Southern Sierra Diversity Group) and the Basalt and Porous Lava Diversity Group independent populations. A few dependent populations persist in the Northwestern California Diversity Group, and their genetic lineage appears to be closely aligned with strays from the Northern Sierra Diversity group.

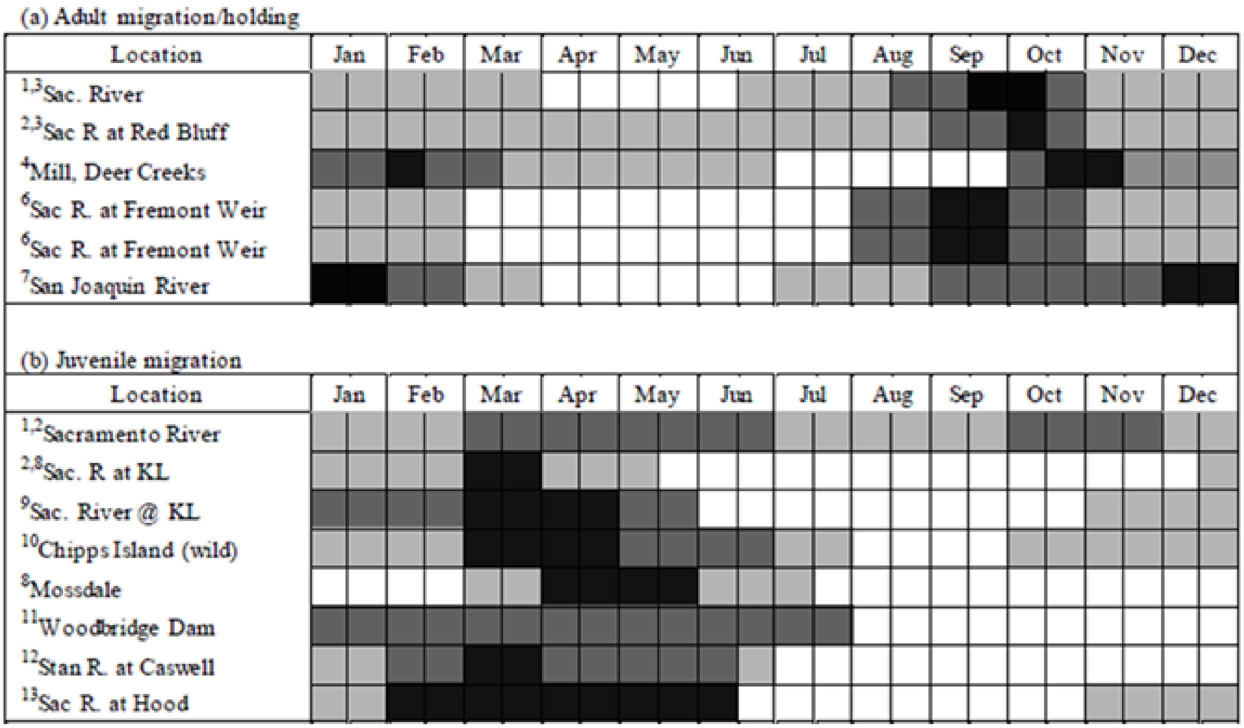
Central Valley Steelhead

The following account is adapted from the NMFS (2014) BO on the Georgiana Slough Floating Fish Guidance Structure Study.

Steelhead can be divided into two life history types, summer-run steelhead and winter-run steelhead, based on their state of sexual maturity at the time of river entry and the duration of their spawning migration, stream-maturing and ocean-maturing. Only winter-run steelhead currently are found in Central Valley rivers and streams (McEwan and Jackson 1996), although there are indications that summer-run steelhead were present in the Sacramento river system prior to the commencement of large-scale dam construction in the 1940s (Interagency Ecological Program [IEP] Steelhead Project Work Team 1999). At present, summer-run steelhead are found only in North Coast drainages, mostly in tributaries of the Eel, Klamath, and Trinity river systems (McEwan and Jackson 1996).

California Central Valley steelhead generally leave the ocean from August through April (Busby et al. 1996), and spawn from December through April with peaks from January through March in small streams and tributaries where cool, well oxygenated water is available year-round (Hallock et al. 1961, McEwan and Jackson 1996; Table 8). Timing of upstream migration is correlated with higher flow events, such as freshets or sand bar breaches at river mouths, and associated lower water temperatures. Unlike Pacific salmon, steelhead are iteroparous, or capable of spawning more than once before death (Barnhart et al. 1986, Busby et al. 1996). However, it is rare for steelhead to spawn more than twice before dying; most that do so are females (Busby et al. 1996). Iteroparity is more common among southern steelhead populations than northern populations (Busby et al. 1996). Although one-time spawners are the great majority, Shapovalov and Taft (1954) reported that repeat spawners are relatively numerous (17.2 percent) in California streams.

Table 8. The Temporal Occurrence of Adult (A) and Juvenile (B) California Central Valley Steelhead In the Central Valley



Note: Darker shades indicate months of greatest relative abundance.

Sources : [1]Hallock 1961; [2]McEwan 2001; [3]USFWS unpublished data; [4]CDFG1995; [5]Hallock et al. 1957; [6]Bailey 1954; [7]CDFG Steelhead Report Card Data; [8]CDFG unpublished data; [9]Snider and Titus 2000; [10]Nobriga and Cadrett 2001; [11]Jones & Stokes Associates, Inc., 2002; [12]S.P. Cramer and Associates, Inc. 2000 and 2001; [13]Schaffter 1980, 1997.

Spawning occurs during winter and spring months. The length of time it takes for eggs to hatch depends mostly on water temperature. Hatching of steelhead eggs in hatcheries takes about 30 days at 51°F. Fry emerge from the gravel usually about 4 to 6 weeks after hatching, but factors such as redd depth, gravel size, siltation, and temperature can speed or retard this time (Shapovalov and Taft 1954). Newly emerged fry move to the shallow, protected areas associated with the stream margin (McEwan and Jackson 1996) and they soon move to other areas of the stream and establish feeding locations, which they defend (Shapovalov and Taft 1954).

Steelhead rearing during the summer takes place primarily in higher velocity areas in pools, although young-of-year also are abundant in glides and riffles. Productive steelhead habitat is characterized by complexity, primarily in the form of large and small woody debris. Cover is an important habitat component for juvenile steelhead both as velocity refugia and as a means of avoiding predation (Meehan and Bjornn 1991).

Juvenile steelhead emigrate episodically from natal streams during fall, winter, and spring high flows. Emigrating California Central Valley steelhead use the lower reaches of the Sacramento River and the Delta for rearing and as a migration corridor to the ocean. Juvenile California Central Valley steelhead feed mostly on drifting aquatic organisms and terrestrial insects and will also take active bottom invertebrates (Moyle 2002).

Some steelhead may utilize tidal marsh areas, non-tidal freshwater marshes, and other shallow water areas in the Delta as rearing areas for short periods prior to their final emigration to the sea. Hallock et al. (1961) found that juvenile steelhead in the Sacramento River basin migrate downstream during most months of the year, but the peak period of emigration occurred in the spring, with a much smaller peak in the fall. Nobriga and Cadrett (2001) also have verified these temporal findings based on analysis of captures at Chipps Island.

Historic California Central Valley steelhead run sizes are difficult to estimate given the paucity of data, but may have approached 1 to 2 million adults annually (McEwan 2001). By the early 1960s the steelhead run size had declined to about 40,000 adults (McEwan 2001). Over the past 30 years, the naturally-spawned steelhead populations in the upper Sacramento River have declined substantially. Hallock et al. (1961) estimated an average of 20,540 adult steelhead through the 1960s in the Sacramento River, upstream of the Feather River. Steelhead counts at the RBDD declined from an average of 11,187 for the period of 1967 to 1977, to an average of approximately 2,000 through the early 1990s, with an estimated total annual run size for the entire Sacramento-San Joaquin system, based on RBDD counts, to be no more than 10,000 adults (McEwan and Jackson 1996, McEwan 2001). Steelhead escapement surveys at RBDD ended in 1993 due to changes in dam operations.

Nobriga and Cadrett (2001) compared CWT and untagged (wild) steelhead smolt catch ratios at Chipps Island trawl from 1998 through 2001 to estimate that about 100,000 to 300,000 steelhead juveniles are produced naturally each year in the Central Valley. In the Updated Status Review of West Coast Salmon and Steelhead (Good et al. 2005), the Biological Review Team (BRT) made the following conclusion based on the Chipps Island data:

> "If we make the fairly generous assumptions (in the sense of generating large estimates of spawners) that average fecundity is 5,000 eggs per female, 1 percent of eggs survive to reach Chipps Island, and 181,000 smolts are produced (the 1998-2000 average), about 3,628 female steelhead spawn naturally in the entire Central Valley. This can be compared with McEwan's (2001) estimate of 1 million to 2 million spawners before 1850, and 40,000 spawners in the 1960s".

Existing wild steelhead stocks in the Central Valley are mostly confined to the upper Sacramento River and its tributaries, including Antelope, Deer, and Mill creeks and the Yuba River. Populations may exist in Big Chico and Butte creeks and a few wild steelhead are produced in the American and Feather rivers (McEwan and Jackson 1996). Snorkel surveys (1999 to 2002) indicate that steelhead are present in Clear Creek (J. Newton, USFWS, pers. comm. 2002, as reported in Good et al. 2005). Because of the large resident *O. mykiss* population in Clear Creek, steelhead spawner abundance has not been estimated.

Until recently, California Central Valley steelhead were thought to be extirpated from the San Joaquin River system. Recent monitoring has detected small self-sustaining populations of steelhead in the Stanislaus, Mokelumne, and Calaveras rivers, and other streams previously thought to be devoid of steelhead (McEwan 2001). On the Stanislaus River, steelhead smolts have been captured in rotary screw traps at Caswell State Park and Oakdale each year since 1995 (S.P. Cramer and Associates Inc. 2000, 2001). Zimmerman et al. (2008) has documented California Central Valley steelhead in the Stanislaus, Tuolumne and Merced rivers based on otolith microchemistry.

It is possible that naturally-spawning populations exist in many other streams but are undetected due to lack of monitoring programs (IEP Steelhead Project Work Team 1999). Incidental catches and observations of steelhead juveniles also have occurred on the Tuolumne and Merced rivers during fall-run Chinook salmon monitoring activities, indicating that steelhead are widespread, throughout accessible streams and rivers in the Central Valley (Good et al. 2005). CDFG staff have prepared catch summaries for juvenile migrant California Central Valley steelhead on the San Joaquin River near Mossdale which represents migrants from the Stanislaus, Tuolumne, and Merced rivers. Based on trawl recoveries at Mossdale between 1988 and 2002, as well as rotary screw trap efforts in all three tributaries, CDFG staff stated that it is "clear from this data that rainbow trout do occur in all the tributaries as migrants and that the vast majority of them occur on the Stanislaus River" (Marston 2004). The documented returns on the order of single fish in these tributaries suggest that existing populations of California Central Valley steelhead on the Tuolumne, Merced, and lower San Joaquin rivers are severely depressed.

Recent assessments of the status of California Central Valley steelhead have indicated that the population was in danger of extinction. Lindley et al. (2006) indicated that prior population census estimates completed in the 1990s found the California Central Valley steelhead spawning population above RBDD had a fairly strong negative population growth rate and small population size. Good et al. (2005) indicated the decline was continuing as evidenced by new information (Chipps Island trawl data). California Central Valley steelhead populations generally show a continuing decline, an overall low abundance, and fluctuating return rates. The future of California Central Valley steelhead is uncertain due to limited data concerning their status. However, Lindley et al. (2007), citing evidence presented by Yoshiyama et al. (1996); McEwan (2001); and Lindley et al. (2006), concluded that there is sufficient evidence to suggest that the DPS is at moderate to high risk of extinction.

The most recent status review of the California Central Valley steelhead DPS (NMFS 2011c) found that the status of the population appears to have worsened since the 2005 status review (Good et al. 2005), when it was considered to be in danger of extinction. Analysis of data from the Chipps Island monitoring program indicates that natural steelhead production has continued to decline and that hatchery origin fish represent an increasing fraction of the juvenile production in the Central Valley. Since 1998, all hatchery produced steelhead in the Central Valley have been adipose fin clipped (ad-clipped). Since that time, the trawl data indicates that the proportion of ad-clip steelhead juveniles captured in the Chipps Island monitoring trawls has increased relative to wild juveniles, indicating a decline in natural production of juvenile steelhead. In recent years, the proportion of hatchery produced juvenile steelhead in the catch has exceeded 90 percent and in 2010 was 95 percent of the catch. Because hatchery releases have been fairly consistent through the years, this data suggests that the natural production of steelhead has been declining in the Central Valley.

Salvage of juvenile steelhead at the CVP and SWP fish collection facilities have also shown a shift towards reduced natural production. The annual salvage of juvenile steelhead at the two facilities in the south Delta has fluctuated since 1993. In the past decade, there has been a marked decline in the total number of salvaged juvenile steelhead, with the salvage of hatchery produced steelhead showing the larger decline at the facilities in absolute numbers of fish salvaged. However, the percentage of wild fish to hatchery produced fish has also declined during the past decade. Thus, while the total number of salvaged hatchery produced fish has declined, naturally produced steelhead have also declined at a consistently higher rate than hatchery produced fish, thereby consistently reducing the ratio of wild to hatchery produced steelhead in the salvage data.

In contrast to the data from Chipps Island and the CVP and SWP fish collection facilities, some populations of wild California Central Valley steelhead appear to be improving (Clear Creek) while others (Battle Creek) appear to be better able to tolerate the recent poor ocean conditions and dry hydrology in the Central Valley compared to hatchery produced fish (NMFS 2011c). Since 2003, fish returning to the Coleman National Fish Hatchery have been identified as wild (adipose fin intact) or hatchery produced (ad-clipped). Returns of wild fish to the hatchery have remained fairly steady at 200-300 fish per year, but represent a small fraction of the overall hatchery returns. Numbers of hatchery origin fish returning to the hatchery have fluctuated much more widely; ranging from 624 to 2,968 fish per year. The returns of wild fish remained steady, even during the recent poor ocean conditions and the 3-year drought in the Central Valley, while hatchery produced fish showed a decline in the numbers returning to the hatchery (NMFS 2011c). Furthermore, the continuing widespread distribution of wild steelhead throughout most of the watersheds in the Central Valley provides the spatial distribution necessary for the DPS to survive and avoid localized catastrophes. However, these populations are frequently very small, and lack the resiliency to persist for protracted periods if subjected to additional stressors, particularly widespread stressors such as climate change.

Viable Salmonid Population Summary for California Central Valley Steelhead

Abundance: All indications are that the naturally produced California Central Valley steelhead population has continued to decrease in abundance and in the proportion of naturally spawned fish to hatchery produced fish over the past 25 years (Good et al. 2005, NMFS 2011c); the long-term abundance trend remains negative. There has been little comprehensive steelhead population monitoring, despite 100 percent marking of hatchery steelhead since 1998. Efforts are underway to improve this deficiency, and a long-term adult escapement monitoring plan is being considered (NMFS 2011c). Hatchery production and returns are dominant over natural fish and include significant numbers of non-DPS-origin Eel River steelhead stock. Continued decline in the ratio between wild juvenile steelhead to hatchery juvenile steelhead in fish monitoring efforts indicates that the wild population abundance is declining. Hatchery releases (100 percent adipose fin clipped fish since 1998) have remained relatively constant over the past decade, yet the proportion of ad-clipped fish to wild adipose fin bearing fish has steadily increased over the past several years.

Productivity: An estimated 100,000 to 300,000 natural juvenile steelhead are estimated to leave the Central Valley annually, based on rough calculations from sporadic catches in trawl gear (Good et al.

2005). Concurrently, 1,000,000 in-DPS hatchery steelhead smolts and another 500,000 out-of-DPS hatchery steelhead smolts are released annually in the Central Valley. The estimated ratio of non-clipped to clipped steelhead has decreased from 0.3 to less than 0.1, with a net decrease to one-third of wild female spawners from 1998 to 2000 (Good et al. 2005). Recent data from the Chipps Island fish monitoring trawls indicates that in recent years over 90 percent of captured steelhead smolts have been of hatchery origin. In 2010, the data indicated hatchery fish made up 95 percent of the catch (NMFS 2011c).

Spatial Structure: Steelhead appear to be well-distributed where found throughout the Central Valley (Good et al. 2005, NMFS 2011c). Until recently, there was very little documented evidence of steelhead due to the lack of monitoring efforts. Since 2000, steelhead have been confirmed in the Stanislaus, Tuolumne, Merced, and Calaveras rivers (Zimmerman et al. 2009, NMFS 2011c). The efforts to provide passage of salmonids over impassable dams may increase the spatial diversity of California Central Valley steelhead populations if the passage programs are implemented for steelhead.

Diversity: Analysis of natural and hatchery steelhead stocks in the Central Valley reveal genetic structure remaining in the DPS (Nielsen et al. 2003). There appears to be a great amount of gene flow among upper Sacramento River basin stocks, due to the post-dam, lower basin distribution of steelhead and management of stocks. Recent reductions in natural population sizes have created genetic bottlenecks in several California Central Valley steelhead stocks (Good et al. 2005; Nielsen et al. 2003). The out-of-basin steelhead stocks of the Nimbus and Mokelumne River hatcheries are currently not included in the California Central Valley steelhead DPS. However, recent work (Garza and Pearse 2008) has identified introgression of stray domestic rainbow trout genes with steelhead, which may be occurring either during egg taking practices in hatcheries or in-river spawning between domesticated strains of rainbow trout and steelhead. Garza and Pearse (2008) also found that all below dam steelhead populations in the Central Valley were genetically closely related and that these populations had a high level of genetic similarity to populations of steelhead in the Klamath and Eel river basins. This genetic data suggests that the progeny of out-of-basin steelhead reared in the Nimbus and Mokelumne river hatcheries have become widely introgressed with natural steelhead populations throughout the anadromous sections of rivers and streams in the Central Valley, including the tail-water sections below impassable dams. This suggests the potential for the loss of local genetic diversity and population structure over time in these waters. Their work also indicates that in contrast to the similarity of the steelhead genetics below dams in the Central Valley, the ancestral genetic structure is still relatively intact above the impassable barriers. This would indicate that extra precautions should be included in restoration plans before above dam access is provided to the steelhead from the below dam populations in order to maintain genetic heritage and structure in the above dam steelhead populations.

Southern Distinct Population Segment of Green Sturgeon

The following account is adapted from the NMFS (2014) BO on the Georgiana Slough Floating Fish Guidance Structure Study.

In North America, spawning populations of green sturgeon are currently found in only three river systems: the Sacramento and Klamath rivers in California and the Rogue River in southern Oregon. Green sturgeon are known to range from Baja California to the Bering Sea along the North American continental shelf. Data from commercial trawl fisheries and tagging studies indicate that the green sturgeon occupy waters within the 110 meter contour (Erickson and Hightower 2007, Huff et al. 2011, Lindley et al., 2008, 2011). During the late summer and early fall, sub-adults and non-spawning adult green sturgeon frequently can be found aggregating in estuaries along the Pacific Coast (Emmett et al. 1991, Moser and Lindley 2007, Huff et al. 2011).

Particularly large concentrations of green sturgeon from both the northern and southern populations occur in the Columbia River estuary, Willapa Bay, Grays Harbor, and Winchester Bay, with smaller aggregations in Humboldt Bay, Tillamook Bay, Nehalem Bay, and San Francisco and San Pablo bays (Emmett et al 1991, Moyle et al. 1992, Beamesderfer et al. 2007, Lindley et al. 2008, 2011). Lindley et al. (2008, 2011) reported that green sturgeon make seasonal migratory movements along the west coast of North America, overwintering north of Vancouver Island, British Columbia, and south of Cape Spencer, Alaska. Individual fish from the Southern DPS of North American green sturgeon have been detected in these seasonal aggregations. Lindley (2006) presented preliminary results of large-scale green sturgeon migration studies, and verified past population structure delineations based on genetic work and found frequent large-scale migrations of green sturgeon along the Pacific Coast. This work was further expanded by recent tagging studies of green sturgeon conducted by Erickson and Hightower (2007) and Lindley et al. (2008, 2011). To date, the data indicate that North American green sturgeon are migrating considerable distances up the Pacific Coast into other estuaries, particularly the Columbia River estuary. This information also agrees with the results of previous green sturgeon tagging studies (CDFG 2002), where CDFG tagged a total of 233 green sturgeon in the San Pablo Bay estuary between 1954 and 2001. A total of 17 tagged fish were recovered: 3 in the Sacramento-San Joaquin Estuary, 2 in the Pacific Ocean off of California, and 12 from commercial fisheries off of the Oregon and Washington coasts. Eight of the 12 recoveries were in the Columbia River estuary (CDFG 2002).

The Southern DPS of North American green sturgeon includes all green sturgeon populations south of the Eel River, with the only known spawning population being in the Sacramento River basin (fertilized green sturgeon eggs were recovered in the Feather River in 2011). Green sturgeon life history can be broken down into four main stages: eggs and larvae, juveniles, sub-adults, and sexually mature adults. Sexually mature adults are those fish that have fully developed gonads and are capable of spawning. Female green sturgeon are typically 13 to 27 years old when sexually mature and have a total body length (TL) ranging between 145 and 205 centimeters (cm) at sexual maturity (Nakamoto et al. 1995, Van Eenennaam et al. 2006). Male green sturgeon become sexually mature at a younger age and smaller size than females. Typically, male green sturgeon reach sexual maturity between 8 and 18 years of age and have a TL ranging between 120 cm to 185 cm (Nakamoto et al. 1995, Van Eenennaam et al. 2006). The variation in the size and age of fish upon reaching sexual maturity is a reflection of their growth and nutritional history, genetics, and the environmental conditions they were exposed to during their early growth years. Adult green sturgeon are believed to feed primarily upon benthic invertebrates such as clams, mysid shrimp, grass shrimp, and amphipods (Radtke 1966). Adult sturgeon caught in Washington State waters were found to have fed on Pacific sand lance (*Ammodytes hexapterus*) and callianassid shrimp (Moyle et al. 1992). It is unknown what forage species are consumed by adults in the Sacramento River upstream of the Delta.

Adult green sturgeon are gonochoristic (sex genetically fixed), oviparous, and iteroparous. They are believed to spawn every 2 to 5 years, with most spawning occurring at 3- to 4-year intervals (Beamesderfer et al. 2007, Brown 2007, Poytress et al., 2012). Upon maturation of their gonadal tissue, but prior to ovulation or spermiation, the sexually mature fish enter freshwater and migrate upriver to their spawning grounds. The remainder of the adult's life is generally spent in the ocean or near-shore environment (bays and estuaries) without venturing upriver into freshwater. Younger females may not spawn the first time they undergo oogenesis and subsequently they reabsorb their gametes without spawning. Adult female green sturgeon produce between 60,000 and 140,000 eggs, depending on body size, with a mean egg diameter of 4.3 mm (Moyle et al. 1992, Van Eenennaam et al. 2001). They have the largest egg size of any sturgeon, and the volume of yolk ensures an ample supply of energy for the developing embryo. The outside of the eggs are adhesive, and are more dense than those of white sturgeon (*Acipenser transmontanus*) (Kynard et al. 2005, Van Eenennaam et al. 2009).

Kelly et al. (2007) indicated that green sturgeon enter the San Francisco estuary during the spring and remain until autumn (Table 9). The authors studied the movement of adults in the San Francisco estuary and found them to make significant long-distance movements with distinct directionality. The movements were not found to be related to salinity, current, or temperature, and Kelly et al. (2007) surmised that they are related to resource availability and foraging behavior. Adults begin their upstream spawning migrations into freshwater in late February with spawning occurring between March and July (CDFG 2002, Heublein 2006, Heublein et al. 2009, Vogel 2008) with peaks in spawning activity influenced by factors including water flow and temperature (Heublein et al. 2009, Poytress et al. 2011). Peak spawning is believed to occur between April and June. Spawning primarily occurs in cool sections of the upper mainstem Sacramento River in deep pools containing clean gravel or cobble substrate (Poytress et al. 2011). Females broadcast spawn their eggs over this substrate, while the male releases its milt (sperm) into the water column. Fertilization occurs externally in the water column and the fertilized eggs sink into the interstices of the substrate where they develop further (Kynard et al. 2005, Heublein et al. 2009). Known historic and current spawning occurs in the Sacramento River (Adams et al. 2002, Beamesderfer et al. 2004, Adams et al. 2007). Currently, Keswick and Shasta dams on the mainstem of the Sacramento River block passage to the upper river. Based on egg surveys (Poytress et al. 2009; Poytress et al. 2010-2012) and telemetry studies (Heublein et al. 2009, Thomas et al. 2013), Southern DPS of North American green sturgeon are known to spawn in several locations in the mainstem Sacramento River below Keswick Dam, both upstream and downstream of the RBDD as was noted in Brown (2007). Behavioral observations in Thomas et al. (2013) suggest that males may fertilize the eggs of multiple females.

Although no historical accounts exist for identified green sturgeon spawning occurring above the current dam sites, suitable spawning habitat existed and the geographic extent of spawning has been reduced due to the impassable barriers constructed on the river.

Table 9. The temporal occurrence of (a) adult, (b) larval (c) juvenile and (d) sub-adult coastal migrant Southern DPS of North American green sturgeon. Locations emphasize the Central Valley of California

(a) Adult-sexually mature (≥145 – 205 cm TL for females and ≥ 120 – 185 cm TL old for males)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upper Sac. River[a,b,c,i]	Low	Low	Medium	Medium/High	High	High/Medium	Medium	Medium	Medium	Low	Low	Low
SF Bay Estuary[d,h,i]	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low	Low

(b) Larval and juvenile (≤10 months old)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RBDD, Sac River[e]					Medium	High	High	Medium				
GCID, Sac River[e]					Medium	High	High	Medium	Low	Low		

(c) Older Juvenile (> 10 months old and ≤3 years old)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
South Delta*[f]	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Sac-SJ Delta[f]	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Sac-SJ Delta[e]				Medium	Medium	Medium	Medium	Medium	Medium	Medium		
Suisun Bay[e]	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium

(d) Sub-Adult/non-sexually mature (approx. 75 cm to 145 cm for females and 75 to 120 cm for males)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pacific Coast[c,g]	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium

Relative Abundance: ■ = High ■ = Medium □ = Low

Note:Darker shades indicate months of greatest relative abundance.

* Fish Facility salvage operations

Sources: [a]USFWS (2002); [b]Moyle et al. (1992); [c]Adams et al. (2002) and NMFS (2005); [d]Kelly et al. (2007); [e]CDFG (2002); [f]IEP Relational Database, fall midwater trawl green sturgeon captures from 1969 to 2003; [g]Nakamoto et al. (1995); [h]Heublein (2006); [i]CDFG Draft Sturgeon Report Card (2007)

Spawning on the Feather River is suspected to have occurred in the past due to the continued presence of adult green sturgeon in the river below Oroville Dam. This continued presence of adults below the dam suggests that fish are trying to migrate to upstream spawning areas now blocked by the dam, which was constructed in 1968. In 2011, fertilized green sturgeon eggs were recovered during monitoring activities by DWR on the Feather River and several adult green sturgeon were recorded on video congregating below Daguerre Point Dam on the Yuba River. In January 2012, a natural barrier to upstream migration at Shanghai Bend was breached by river flows, thus allowing access to sections of the Feather River above Shanghai Bend over a wider range of flows.

Spawning in the San Joaquin River system has not been recorded historically or observed recently, but alterations of the San Joaquin River and its tributaries (Stanislaus, Tuolumne, and Merced rivers) occurred early in the European settlement of the region. During the latter half of the 1800s, impassable barriers were built on these tributaries where the water courses left the foothills and entered the valley floor. Therefore, these low elevation dams have blocked potentially suitable spawning habitats located further upstream for approximately a century. Additional destruction of riparian and stream channel habitat by industrialized gold dredging further disturbed any valley floor habitat that was still available for sturgeon spawning. Additional impacts to the watershed include the increased loads of selenium entering the system through agricultural practices on the western side of the San Joaquin Valley. Green sturgeon have recently been identified by University of California, Davis researchers as being highly sensitive to selenium levels. Currently, only white sturgeon have been encountered in the San Joaquin River system upstream of the Delta, and adults have been captured by sport anglers as far upstream on the San Joaquin River as Hills Ferry and Mud Slough which are near the confluence of the Merced River with the main stem San Joaquin River (2007 sturgeon report card - CDFG 2008).

Post-spawn fish may hold for several months in the Sacramento River and out-migrate in the fall, or move into and out of the river quickly during the summer months, although the holding behavior is the behavior that is most commonly observed (Heublein et al. 2009). Acoustic tagging studies on the Rogue River (Erickson et al. 2002) have shown that adult green sturgeon will hold for as much as 6 months in deep (> 5 m), low gradient reaches or off channel sloughs or coves of the river during summer months when water temperatures were between 15°C and 23°C. When ambient temperatures in the river dropped in autumn and early winter (<10°C) and flows increased, fish moved downstream and into the ocean. Erickson et al. (2002) surmised that this holding in deep pools was to conserve energy and utilize abundant food resources. Benson et al. (2007) found similar behavior on the Klamath and Trinity river systems with adult sturgeon acoustically tagged during their spawning migrations. Most fish held over the summer in discrete locations characterized by deep, low velocity pools until late fall or early winter when river flows increased with the first storms of the rainy season. Fish then moved rapidly downstream and out of the system. Recent data gathered from acoustically tagged adult green sturgeon revealed comparable behavior by adult fish on the Sacramento River based on the positioning of adult green sturgeon in holding pools on the Sacramento River above the Glenn Colusa Irrigation District (GCID) diversion (RM 205). Studies by Heublein (2006, 2009) and Vogel (2008) have documented the presence of adults in the Sacramento River during the spring and through the fall into the early winter months. These fish hold in upstream locations prior to their emigration from the system later in the year. Like the Rogue and Klamath river systems, downstream migration appears to be triggered by increased flows, decreasing water temperatures, and occurs rapidly once initiated. It should also be noted that some adults rapidly leave the system following their suspected spawning activity and enter the ocean only in early summer (Heublein 2006). This behavior has also been observed on the other spawning rivers (Benson et al. 2007) but may have been an artifact of the stress of the tagging procedure in that study.

Previously, spawning appeared to occur primarily above RBDD, based on the recovery of eggs and larvae at the dam in monitoring studies (Gaines and Martin 2002, Brown 2007) but more recent data indicates that several areas downstream of the site of the RBDD may be used as spawning areas for green sturgeon based on the recovery of eggs below deep holes in the Sacramento River (Poytress et al. 2011 – 2013). Green sturgeon larvae hatch from fertilized eggs after approximately

169 hours at a water temperature of 59°F (Van Eenennaam et al. 2001, Deng et al. 2002), which is similar to the sympatric white sturgeon development rate (176 hours). Studies conducted at the University of California, Davis by Van Eenennaam et al. (2005) indicated that an optimum range of water temperature for egg development ranged between 57.2°F and 62.6°F. Temperatures over 23°C (73.4°F) resulted in 100 percent mortality of fertilized eggs before hatching. Eggs incubated at water temperatures between 63.5°F and 71.6°F resulted in elevated mortalities and an increased occurrence of morphological abnormalities in those eggs that did hatch. At incubation temperatures below 57.2°F, hatching mortality also increased significantly, and morphological abnormalities increased slightly, but not statistically so.

Newly hatched green sturgeon are approximately 12.5 mm to 14.5 mm in length and have a large ovoid yolk sac that supplies nutritional energy until exogenous feeding occurs. These yolk sac larvae are less developed in their morphology than older juveniles and external morphology resembles a "tadpole" with a continuous fin fold on both the dorsal and ventral sides of the caudal trunk. The eyes are well developed with differentiated lenses and pigmentation.

Olfactory and auditory vesicles are present while the mouth and respiratory structures are only shallow clefts on the head. At 10 days of age, the yolk sac has become greatly reduced in size and the larvae initiates exogenous feeding through a functional mouth. The fin folds have become more developed and formation of fin rays begins to occur in all fin tissues. By 45 days of age, the green sturgeon larvae have completed their metamorphosis, which is characterized by the development of dorsal, lateral, and ventral scutes, elongation of the barbels, rostrum, and caudal peduncle, reabsorption of the caudal and ventral fin folds, and the development of fin rays. The juvenile fish resembles the adult form, including the dark olive coloring, with a dark mid-ventral stripe (Deng et al. 2002) and are approximately 75 mm TL. At this stage of development, the fish are considered juveniles and are no longer larvae.

Green sturgeon larvae do not exhibit the initial pelagic swim-up behavior characteristic of other Acipenseridae. They are strongly oriented to the bottom and exhibit nocturnal activity patterns. After 6 days, the larvae exhibit nocturnal swim-up activity (Deng et al. 2002) and nocturnal downstream migrational movements (Kynard et al. 2005). Juvenile fish continue to exhibit nocturnal behavior beyond the metamorphosis from larvae to juvenile stages. Kynard et al.'s (2005) laboratory studies indicated that juvenile fish continued to migrate downstream at night for the first 6 months of life. When ambient water temperatures reached 46.4°F, downstream migrational behavior diminished and holding behavior increased. These data suggest that 9 to 10 month old fish would hold over in their natal rivers during the ensuing winter following hatching, but at a location downstream of their spawning grounds.

Green sturgeon juveniles tested under laboratory conditions had optimal bioenergetics performance i.e. growth, food conversion, swimming ability) between 59°F and 66.2°F under either full or reduced rations (Mayfield and Cech 2004). This temperature range overlaps the egg incubation temperature range for peak hatching success previously discussed. Ambient water temperature conditions in the Rogue and Klamath river systems range from 39°F to approximately 75.2°F. The Sacramento River has similar temperature profiles, and, like the previous two rivers, is a regulated system with several dams controlling flows on its main stem (Shasta and Keswick dams), and its tributaries (Whiskeytown, Oroville, Folsom, and Nimbus dams).

Larval and juvenile green sturgeon are subject to predation by both native and introduced fish species. Prickly sculpin (*Cottus asper*) have been shown to be an effective predator on the larvae of sympatric white sturgeon (Gadomski and Parsley 2005). This study also indicated that the lowered turbidity found in tailwater streams and rivers due to dams increased the effectiveness of sculpin predation on sturgeon larvae under laboratory conditions.

Larval and juvenile sturgeons have been caught in traps at two sites in the upper Sacramento River: below the RBDD (RM 243) and from the GCID pumping plant (RM 205) (CDFG 2002). Larvae captured at the RBDD site are typically only a few days to a few weeks old, with lengths ranging from 24 mm to 31 mm. This body length is equivalent to 15 to 28 days post hatch as determined by Deng et al. (2002). Recoveries of larvae at the RBDD rotary screw traps (RSTs) occur between late April/early May and late August with the peak of recoveries occurring in June (1995-1999 and 2003-2008 data). The mean yearly total length of post-larval green sturgeon captured in the GCID RSTs, approximately 30 miles downstream of RBDD, ranged from 33 mm to 44 mm between 1997 and 2005 (CDFG 2002) indicating they are approximately 3 to 4 weeks old (Van Eenennaam et al. 2001, Deng et al. 2002). Taken together, the average length of larvae captured at the two monitoring sites indicate that fish were hatched upriver of the monitoring site and drifted downstream over the course of 2 to 4 weeks of growth. According to the CDFG document commenting on the NMFS proposal to list the Southern DPS (CDFG 2002), some green sturgeon rear to larger sizes above RBDD, or move back to this location after spending time downstream. Two sturgeon between 180 mm and 400 mm TL were captured in the RST during 1999 and green sturgeon within this size range have been impinged on diffuser screens associated with a fish ladder at RBDD (K. Brown, USFWS, pers. comm., as cited in CDFG 2002).

Juvenile green sturgeon have been salvaged at the Skinner Fish Facility (FCF) and Tracy FCF (together, the Fish Facilities) in the south Delta, and captured in trawling studies by CDFG during all months of the year (CDFG 2002). The majority of these fish were between 200 mm and 500 mm, indicating they were from 2 to 3 years of age based on Klamath River age distribution work by Nakamoto et al. (1995). The lack of a significant proportion of juveniles smaller than approximately 200 mm in Delta captures indicates that juveniles of the Southern DPS of North American green sturgeon likely hold in the main stem Sacramento River, as suggested by Kynard et al. (2005).

Population abundance information concerning the Southern DPS of North American green sturgeon is described in the NMFS status reviews (Adams et al. 2002, NMFS 2005). The California Department of Fish and Wildlife (CDFW) [formerly California Department of Fish and Game (CDFG)] conducts annual field sampling for sturgeon in San Pablo and Suisun bays in the months of August through September. Limited population abundance information comes from incidental captures of North American green sturgeon from the white sturgeon monitoring program by the CDFW sturgeon tagging program (CDFG 2002). By comparing ratios of white sturgeon to green sturgeon captures, CDFW provides estimates of adult and sub-adult North American green sturgeon abundance. Estimated abundance between 1954 and 2001 ranged from 175 fish to more than 8,000 per year and averaged 1,509 fish per year. Reports from 2005-2014 describe encounters with relatively small numbers of sub-adult and (to a lesser extent) adult fish (2005: 14; 2006: 28; 2007: 17; 2008: 14; 2009: 103; 2010: 37; 2011: 16; 2012: 17; 2013: 7; 2014: 30; annual reports are available at http://www.dfg.ca.gov/delta/data/sturgeon/bibliography.asp). The high capture rate in 2009 occurred because of an encounter with a large aggregation of green sturgeon, particularly in San Pablo Bay, during the CDFW white sturgeon surveys (pers. comm. with Marty Gingras [CDFW] and Phaedra Doukakis [NMFS], May 10, 2013). Since the study is primarily designed to study white sturgeon, the results cannot be interpreted for estimates of or trends in Southern DPS abundance.

The only existing information regarding long-term changes in the abundance of the Southern DPS of North American green sturgeon includes changes in abundance at the at the SWP and CVP fish collection facilities between 1968 and 2012. The average number of North American green sturgeon taken per year at the Skinner FCF prior to 1986 was 732; from 1986 on, the average per year was 47 (70 Federal Register [FR] 17386, April 6, 2005). For the Tracy FCF, the average number prior to 1986 was 889; from 1986 to 2001 the average was 32 (70 FR 17386, April 6, 2005). In light of the increased exports, particularly during the previous 10 years, it is clear that the abundance of the Southern DPS of North American green sturgeon is dropping. Additional analysis of North American green and white sturgeon taken at the Fish Facilities indicates that take of both North American green and white sturgeon per acre-foot of water exported has decreased substantially since the 1960s (70 FR 17386, April 6, 2005). No green sturgeon were recovered at either the CVP or SWP in 2010. In 2011, a total of 14 green sturgeon were salvaged, 12 at the CVP and 2 at the SWP facilities. In 2012 and 2013, no green sturgeon were salvaged at the Fish Facilities. Catches of sub-adult and adult North American green sturgeon by the IEP between 1996 and 2004 ranged from 1 to 212 green sturgeon per year (212 occurred in 2001), however, the percentage of the catch belonging to the Southern DPS of North American green sturgeon is unknown as these captures were primarily located in San Pablo Bay which is known to consist of a mixture of Northern and Southern DPS of North American green sturgeon.

Since 2006, modeling, genetic, and field-based studies have been conducted to describe the population characteristics of the Southern DPS of North American green sturgeon. Young-of-year abundance data have been collected incidentally during juvenile salmonid monitoring efforts at the RBDD and near the GCID pumping facility, both located on the upper Sacramento River. Using RSTs set downstream of RBDD, USFWS captured approximately 7,500 larval green sturgeon from 1994 to 2011. In 2011, a wet year, approximately 3,700 larvae were collected in in the monitoring efforts (Poytress et al. 2012). Over 2,000 larvae were also collected in fyke nets and RSTs at GCID between 1986 and 2003. No apparent trend in larval abundance at either site have emerged across years, though annual distributions have been found to peak during June at RBDD and July at GCID (Adams et al. 2002).

Recent spawning population estimates using sibling based genetics by Israel (2006) indicates spawning populations of 32 spawners in 2002, 64 in 2003, 44 in 2004, 92 in 2005, and 124 in 2006 above RBDD (with an average of 71). More recently, Israel and May (2010) used genetic analyses to estimate the number of spawning individuals in the upper Sacramento River (above RBDD). Their kinship analysis of larvae collected at RBDD suggests an estimated 10-28 individual Southern DPS of

North American green sturgeon effectively reproduce above RBDD in the upper Sacramento River annually (Israel and May 2010). This effective spawning population estimate was stable over the five year sampling period (2002-2006). It is important to note that this does not include animals spawning downstream of RBDD, and thus does not represent a complete estimate of the effective adult spawning population. The study was also conducted during the time when the gates at RBDD would be lowered for several months of the year from late spring through summer, thus prohibiting green sturgeon from ascending upstream to spawn above the location of the RBDD. Since 2012, the gates at RBDD have been in the up position year round.

DIDSON surveys of aggregating sites in the upper Sacramento River are providing the first data for abundance estimation of the adult portion of the Southern DPS population based on actual observations of fish in the river. Preliminary results from 2010 and 2011 surveys indicate abundance of (presumably) adult Southern DPS of North American green sturgeon in the Sacramento River as follows: 06/07/2010: 164 ± 47; 07/06/2010: 245 ± 64; 06/16/2011 220 ± 42 (Ethan Mora, University of California, Davis, unpublished data). These abundance estimates are smaller than observed numbers in rivers where Northern DPS green sturgeon occur (Klamath 2010: 349 ± 52; 2011: 471 ± 42; Rogue 2010: 327 ± 50; 2011: 454 ± 46 (Ethan Mora, University of California, Davis, unpublished data). Furthermore, estimates for the Klamath and Rogue rivers are about twice those in the Sacramento River.

The number of holes occupied in the Sacramento River for the two summer 2010 dates plus the one summer 2011 date was small (13) when compared to the number of total holes surveyed (125). Holes with sturgeon were, however, distributed across most of the study area, with green sturgeon found in holes spanning 75 miles of the river. There was also a difference in the holes occupied by sturgeon during any given sampling time: some holes were occupied on all three sampling dates, some on only two sampling dates, and some on just one date. Thus, there is temporal and spatial variation in the holes occupied by Southern DPS of North American green sturgeon within the Sacramento River.

Caution is needed in interpreting these survey data as representative of the total spawning population size of Southern DPS of North American green sturgeon. First, this estimate does not include green sturgeon spawning in the Feather River. Also, although most sturgeon encountered are likely green sturgeon, this must be verified by video surveys, which is in progress. Movement in and out of the study area could also confound the results. Still, the estimates provide a working number for modeling total population size as detailed below.

To generate a rough population estimate, the assumption can be made that the observations of 164 to 245 sturgeon in the main stem Sacramento River during the spawning seasons of 2010 and 2011 were observations of Southern DPS of North American green sturgeon adults and are representative of the total spawning run size for those survey years. The uncertainty associated with using these estimates, particularly given the caveats stated above, should be noted. Further assumptions include a spawning periodicity of 2 to 4 years and the age distribution expected at equilibrium generated by Beamesderfer et al. (2007) (25 percent juveniles, 63 percent sub-adults, 12 percent adults). This would amount to an estimate of a total of 328 to 980 adults and 1,722 to 5,145 sub-adults in the population. The estimated total population of juveniles, sub-adults, and adults combined ranges from 2,733 to 8,166 individuals.

In summary, recent information regarding the spawning population of adult green sturgeon in the Sacramento River suggests that they are spatially constrained during spawning and the post-spawning holding period in the summer months. This is concerning, given that a catastrophic event impacting just a few holes could affect a significant portion of the adult population. The information does not, however, indicate that the population status of Southern DPS of North American green sturgeon has changed since the last review, since no comparable data on spatial occupancy were available in 2006. Continued monitoring of the adult population in the Sacramento River will provide valuable trend data and information to enhance spatial protection. Of note is the fact that all of the holes where green sturgeon were found in the DIDSON survey area (Highway 32 overcrossing to the City of Redding) are currently included in the range where new CDFW restrictions prohibit fishing for sturgeon. Enforcement of these regulations is thus of great importance.

Available information on green sturgeon indicates that, as with winter-run Chinook salmon, the main stem Sacramento River may be the last viable spawning habitat (Good et al. 2005) for the Southern DPS of North American green sturgeon. The observation of fertilized green sturgeon eggs in the Feather River in 2011 is a significant event, as it indicates that at least in high flow years, the Feather River may support an additional spawning region for green sturgeon. Additional observations of spawning activity or evidence of fertilized eggs in the Feather River in subsequent years are needed to confirm this river as an additional spawning area for the Southern DPS of North American green sturgeon. Lindley et al. (2007) pointed out that an ESU represented by a single population at moderate risk is at a high risk of extinction over the long-term. Although the extinction risk of the Southern DPS of North American green sturgeon has not been assessed, NMFS believes that the extinction risk has increased because there is only one known population, and that population consistently spawns within the main stem Sacramento River.

Population Viability Summary for the Southern DPS of North American Green Sturgeon

The Southern DPS of North American green sturgeon has not been analyzed to characterize their status and viability as has been done in recent efforts for Central Valley salmonid populations (Good et al. 2005; Lindley et al. 2006; Lindley et al. 2007; NMFS 2011a, b, c) however, this review is in preparation. NMFS assumes that the general categories for assessing salmonid population viability will also be useful in assessing the viability of the Southern DPS of North American green sturgeon. The following summary has been compiled from the best available data and information on North American green sturgeon to provide a general synopsis of the viability parameters for this DPS.

Abundance: Currently, there are no reliable data on population sizes, and data on population trends are also lacking. Fishery data collected at the Skinner FCF and Tracy FCF in the south Delta indicate a decreasing trend in abundance between 1968 and 2006 (70 FR 17386). Captures of larval green sturgeon in the RBDD RSTs have shown variable trends in spawning success in the upper river over the past several years and have been complicated by the operations of the RBDD gates during the green sturgeon spawning season in previous years. In 2011, a wet year in the Sacramento River, captures in the RST have been substantially higher than in previous years (3,701 fish). The last strong year-class, based on captures of larval sturgeon was in 1995. This would suggest that the 2011 year-class for green sturgeon would be a strong year-class. However, only 14 green sturgeon juveniles were salvaged in 2011, and none in 2012 and 2013, which suggests that this large population may not have successfully emigrated downstream to the Delta to rear. Recent captures of juvenile green sturgeon in the RBDD RST were 289 fish in 2012 and 443 fish in 2013. Estimates of spawning adult population size range from 32 spawners in 2002, 64 in 2003, 44 in 2004, 92 in 2005, and 124 in 2006 above RBDD (with an average of 71) (Israel 2006). More recently, Israel and May, (2010) estimated that 10-28 individual Southern DPS of North American green sturgeon effectively reproduce above RBDD in the upper Sacramento River annually. DIDSON camera observations in 2010 and 2011 identified aggregations of (presumably) green sturgeon adults in the Sacramento River ranging between 164 and 245 individuals per observation cycle (Ethan Mora, University of California, Davis, unpublished data). Assuming that all of these observed sturgeons are truly green sturgeon adults, and adults spawn every 2 to 4 years, and using the population structure from Beamesderfer et al. (2007), the calculated estimate would be 328 to 980 adults and 1,722 to 5,145 sub-adults in the population. The estimated total population of juveniles, sub-adults, and adults combined ranges from 2,733 to 8,166 individuals.

Productivity: There is insufficient information to evaluate the productivity of green sturgeon. However, as indicated above, there appears to be a declining trend in abundance, which indicates low to negative productivity.

Spatial Structure: Current data indicate that the Southern DPS of North American green sturgeon is comprised of a single spawning population in the Sacramento River. Although some individuals have been observed in the Feather and Yuba rivers, it is not yet known if these fish represent separate spawning populations or are strays from the main stem Sacramento River. Therefore, the apparent presence of a single reproducing population puts the DPS at risk, due to the limited spatial structure. As mentioned previously, the confirmed presence of fertilized green sturgeon eggs in the Feather River suggests that spawning can occur in the river, at least during wet years with sustained high flows. Likewise, observations of several adult green sturgeon congregating below Daguerre Point Dam on the Yuba River suggest another potential spawning area. Consistent use of these two different river areas by green sturgeon exhibiting spawning behavior or by the collection of fertilized eggs and/or larval green sturgeon would indicate that a second spawning population of green sturgeon may exist in the Sacramento River basin besides that which has been identified in the upper reaches of the Sacramento River below Keswick Dam.

In general, sub-adult (from the age of ocean entry to age of first spawning) and adult North American green sturgeon spend most of their lives in oceanic environments where they occupy nearshore coastal waters from the Bering Sea, Alaska (Colway and Stevenson 2007) to Baja California, Mexico (Rosales-Casian and Almeda-Juaregui 2009). Telemetry data and genetic analyses suggests that Southern DPS of North American green sturgeon generally occur from Graves Harbor, Alaska to Monterey Bay, California (Moser and Lindley 2007; Lindley et al. 2008, 2011) and within this range, most frequently occur in coastal waters of Washington, Oregon, and Vancouver Island

and near San Francisco and Monterey bays (Huff et al. 2011). Within the nearshore marine environment, tagging data indicate that northern and southern DPSs of North American green sturgeon prefer marine waters of less than a depth of 110 m (Erickson and Hightower 2007). Modeling based on acoustic and satellite tag data indicate that Northern and Southern DPS of North American green sturgeon spend more time in areas with high seafloor complexity, including areas with boulders, and depths between 20 and 60 m and water temperatures from 9.5-16.0 °C (Huff et al. 2011). This habitat-use pattern may correspond with prey availability or refuge from predators.

Adult and sub-adult Southern DPS of North American green sturgeon are observed in large concentrations in the summer and autumn within coastal bays and estuaries along the west coast of the United States, including the Columbia River estuary, Willapa Bay, and Grays Harbor (Moser and Lindley 2007; Lindley et al. 2008, 2011). The Umpqua River estuary seems to be a preferred habitat for the Northern DPS (Lindley et al. 2011). These areas, particularly Willapa Bay, are likely used for foraging and possibly as thermal refugia (Moser and Lindley 2007). Both the northern and southern DPSs of North American green sturgeon co-occur on the continental shelf of western North America, and mixtures of these population also co-occur in the estuaries and bays along the West Coast of the United States. However, the two DPSs do not appear to comingle in their respective natal watersheds above tidal influence. Lindley et al. (2011) further confirms this green sturgeon DPS structure given that green sturgeon tagged in the Klamath or Rogue rivers were not detected at the Golden Gate Bridge area and green sturgeon tagged in San Pablo Bay/Sacramento River area were not detected in the Rogue or Klamath rivers. Green sturgeon tagged in the Klamath River were detected in the Rogue River, consistent with the idea that green sturgeon originating from these two rivers belong to one DPS (Northern). Movement between the two rivers was infrequent, however, suggesting that the Klamath and Rogue rivers should be managed separately. Northern DPS green sturgeon showed a high affinity for the Umpqua River estuary, which was used for summer and autumn holding. New acoustic tagging studies in the Umpqua River estuary found that only a small number of tagged fish (3 of 20) were subsequently detected in the Sacramento River. The patterns of detection in San Francisco Bay were consistent with this habitat being used by Southern DPS sub-adults and adults as a migration corridor. Other telemetry data suggests that sub-adults and non-spawning adults utilize the San Francisco Bay area in the summer for other reasons, possibly to feed, because residency periods are fairly long, averaging 49 days.

To date there have been no detections of acoustically-tagged Southern DPS of North American green sturgeon upstream of tidal influence in rivers north of, and including, the Eel River in northern California. All green sturgeon observed upstream of the head of the tide in freshwater rivers south of the Eel River are assumed to be Southern DPS fish. All green sturgeon observed upstream of the head of the tide in freshwater rivers north of and including the Eel River are assumed to be northern DPS fish, and those areas are not considered critical habitat for Southern DPS of North American green sturgeon. This is consistent with the original DPS structure for green sturgeon described in Adams et al. (2002).

In summary, the Southern DPS of North American green sturgeon is represented by one spawning population utilizing the Sacramento River main stem, and perhaps opportunistic use of some of the major tributaries to the Sacramento River (Feather River and Yuba River). The adults and sub-adults of the Southern DPS utilize the continental shelf along the Pacific Coast out to a depth of approximately 110 m from Alaska to northern Baja California, as well as numerous bays and estuaries along the coastline for migration, holding, and rearing. In these waters the Southern DPS co-occurs with the northern DPS of North American green sturgeon. There does not appear to be any straying between the two populations based on genetics and tagged fish movements.

Diversity: Green sturgeon genetic analyses shows strong differentiation between northern and southern populations, and therefore, the species was divided into northern and southern DPSs. However, the genetic diversity of the Southern DPS is not well understood.

Delta Smelt

A summary of the frequency of occurrence of delta smelt life stages from available survey data was provided by Merz et al. (2011; Table 10). The following account of the basic species life history is adapted from the USFWS (2014b) BO on the 2014 Georgiana Slough Floating Fish Guidance Structure Study.

Adult delta smelt spawn during the late winter and spring months, with most spawning occurring during April through mid-May (Moyle 2002). Spawning occurs primarily in sloughs and shallow edge areas in the Delta. Delta smelt spawning has also been recorded in Suisun Marsh and the Napa River (Moyle 2002). Most spawning occurs at temperatures between 12-18°C. Although spawning may occur at temperatures up to 22°C, hatching success of the larvae is very low (Bennett 2005).

Fecundity of females ranges from about 1,200 to 2,600 eggs, and is correlated with female size (Moyle 2002). Moyle et al. (1992) considered delta smelt fecundity to be "relatively low." However, based on Winemiller and Rose (1992), delta smelt fecundity is fairly high for a fish its size. In captivity, females survive after spawning and develop a second clutch of eggs (Mager et al. 2004); field collections of ovaries containing eggs of different size and stage indicate that this also occurs in the wild (Adib-Samii, pers comm. 2008). Captive delta smelt can spawn up to 4-5 times. While most adults do not survive to spawn a second season, a few (<5 percent) do (Moyle 2002; Bennett 2005). Those that do survive are typically larger (90-110 mm Standard Length [SL]) females that may contribute disproportionately to the population's egg supply (Moyle 2002 and references therein). Two-year-old females may have 3-6 times as many ova as first year spawners.

Most of what is known about delta smelt spawning habitat in the wild is inferred from the location of spent females and young larvae captured in the California Department of Fish and Wildlife Spring Kodiak Trawl (SKT) and 20-mm Survey, respectively. In the laboratory, delta smelt spawned at night (Baskerville-Bridges et al. 2000; Mager et al. 2004). Other smelts, including marine beach spawning species and estuarine populations and the landlocked Lake Washington longfin smelt, are secretive spawners, entering spawning areas during the night and leaving before dawn. If this behavior is exhibited by delta smelt, then delta smelt distribution based on the SKT, which is conducted during daylight hours in offshore habitats, may reflect general regions of spawning activity, but not actual spawning sites.

Table 10. Average Annual Frequency (Percent) of Delta Smelt Occurrence by Life Stage, Interagency Ecological Program Monitoring Program, and Region

Region	Average Annual Frequency (%)										
Life Stage:	**Larvae (<15 mm)**	**Sub-Juvenile (≥15, <30 mm)**		**Juvenile (30–55 mm)**			**Sub-Adult (>55 mm)**	**Mature Adults (>55 mm)**		**Pre-Spawning[a]**	**Spawning[a]**
Monitoring Program:	**20-mm**	**20-mm**	**STN**	**20-mm**	**STN**	**FMWT**	**FMWT**	**BS**	**BMWT**	**KT**	**KT**
Years of Data Used:	**1995–2009**	**1995–2009**	**1995–2009**	**1995–2009**	**1995–2009**	**1995–2009**	**1995–2009**	**1995–2009**	**1995–2006**	**2002–2009**	**2002–2009**
Time Period:	**Apr–Jun**	**Apr–Jul**	**Jun–Aug**	**May–Jul**	**Jun–Aug**	**Sep–Dec**	**Sep–Dec**	**Dec–May**	**Jan–May**	**Jan–Apr**	**Jan–May**
San Francisco Bay	NS	NS	NS	NS	NS	NS	NS	0.0	0.0	NS	NS
West San Pablo Bay	NS	NS	NS	NS	NS	0.2	0.0	0.0	1.2	NS	NS
East San Pablo Bay	0.0	1.0	0.0	2.8	3.6	0.7	0.6	NS	2.7	NS	NS
Lower Napa River	7.3	7.7	3.3	13.3	14.0	1.7	0.8	NS	NS	14.3	11.8
Upper Napa River	11.6	21.2	NS	12.0	NS	NS	NS	NS	NS	NS	NS
Carquinez Strait	5.7	9.3	1.1	24.4	33.7	1.9	3.3	NS	5.4	16.7	0.0
Suisun Bay (SW)	17.8	18.3	1.3	17.5	26.9	4.3	4.3	NS	4.3	23.3	5.6
Suisun Bay (NW)	2.2	8.9	1.1	21.7	34.8	7.3	10.0	NS	8.7	23.3	5.6
Suisun Bay (SE)	19.5	24.9	11.0	20.9	45.7	11.0	12.1	NS	6.5	28.3	6.9
Suisun Bay (NE)	17.8	19.2	33.6	29.7	66.7	20.3	29.3	NS	28.3	48.3	13.9
Grizzly Bay	16.3	27.6	17.9	42.9	72.8	15.0	19.6	NS	30.4	30.0	5.6
Suisun Marsh	21.4	33.6	14.2	18.5	19.2	22.8	27.2	NS	NS	62.0	23.1
Confluence	35.7	41.6	25.7	29.2	36.1	20.2	24.5	1.8	17.4	30.0	10.4
Lower Sacramento River	16.5	37.0	43.3	26.2	55.5	22.9	37.1	NS	18.8	54.4	17.8
Upper Sacramento River	10.8	8.2	1.3	0.0	0.0	2.7	8.0	5.8	16.7	21.7	15.3
Cache Slough and Ship Channel	17.2	47.3	NS	54.3	NS	9.8	26.7	NS	NS	33.9	21.1
Lower San Joaquin River	28.0	24.5	4.1	5.1	5.6	2.6	3.5	0.9	12.6	30.6	9.7
East Delta	14.6	8.8	0.0	1.2	0.0	0.0	0.0	1.6	NS	5.7	2.3
South Delta	18.4	10.8	0.0	1.4	0.3	0.0	0.0	0.3	NS	7.1	1.1
Upper San Joaquin River	NS	NS	NS	NS	NS	NS	NS	0.2	NS	NS	NS
Sacramento Valley	NS	NS	NS	NS	NS	NS	NS	0.2	NS	NS	NS

[a] Gonadal stages of male and female delta smelt found in Spring Kodiak Trawl database were classified by California Department of Fish and Wildlife following Mager (1996). Descriptions of these reproduction stages are available at: <http://www.dfg.ca.gov/delta/data/skt/eggstages.asp>.

Mature adults, pre-spawning: Reproductive stages[a]: females 1–3; males 1–4.

Mature adults: spawning: Reproductive stages[a]: females 4; males 5.

20-mm = 20-millimeter Townet

BMWT = Bay Midwater Trawl.

BS = Beach Seine.

FMWT = Fall Midwater Trawl.

KT = Kodiak Trawl.

NS = indicates no survey conducted in the given life stage and region.

SKT = Spring Kodiak Trawl.

STM = Summer Tow-Net.

Source: Merz et al. 2011

Delta smelt spawning has only been directly observed in the laboratory and eggs have not been found in the wild. Consequently, what is known about the mechanics of delta smelt spawning is derived from laboratory observations and observations of related smelt species. Delta smelt eggs are 1-mm diameter and are adhesive and negatively buoyant (Moyle 1976, 2002; Mager et al. 2004; Wang 1986, 2007). Laboratory observations indicate that delta smelt are broadcast spawners, discharging eggs and milt close to the bottom over substrates of sand and/or pebble in current (DWR and Reclamation 1994; Brown and Kimmerer 2002; Lindberg et al. 2003; Wang 2007). Spawning over gravel or sand can also aid in the oxygenation of delta smelt eggs. Eggs that may have been laid in silt or muddy substrates might get buried or smothered, preventing their oxygenation from water flow (Lindberg pers. comm. 2011). The eggs of surf smelts and other beach spawning smelts adhere to sand particles, which keeps them negatively buoyant but not immobile, as the sand may move ("tumble") with water currents and turbulence (Hay 2007). It is not known whether delta smelt eggs "tumble incubate" in the wild, but tumbling of eggs may moderately disperse them, which might reduce predation risk within a localized area.

The locations in the Delta where newly hatched larvae are present, most likely indicates spawning occurrence. The 20-mm trawl has captured small (5 mm SL) larvae in Cache Slough, the lower Sacramento River, San Joaquin River, and at the confluence of these two rivers (e.g., 20-mm trawl Survey 1 in 2005). Larger larvae and juveniles (size> 23 mm SL), which are more efficiently sampled by the 20-mm trawl gear, have been captured in Cache Slough and the Sacramento Deep Water Channel in July (e.g., 20-mm trawl Survey 9 in 2008). Because they are small fish inhabiting pelagic habitats with strong tidal and river currents, delta smelt larval distribution depends on both the spawning area from which they originate and the effect of transport processes caused by flows. Larval distribution is further affected by water salinity and temperature. Hydrodynamic simulations reveal that tidal action and other factors may cause substantial mixing of water with variable salinity and temperature among regions of the Delta (Monson et al. 2007). This could result in rapid dispersion of larvae away from spawning sites.

The timing of spawning may affect delta smelt population dynamics. Lindberg (2011) has suggested that smelt larvae that hatch early, around late February, have an advantage over larvae hatched during late spawning in May. Early season larvae have a longer growing season and may be able to grow larger faster during more favorable habitat conditions in the late winter and early spring. An early growing season may result in higher survivorship and a stronger spawning capability for that generation. Larvae hatched later in the season have a shorter growing season which effectively reduces survivorship and spawning success for the following spawning season.

Sampling of larval delta smelt in the Bay-Delta in 1989 and 1990 suggested that spawning occurred in the Sacramento River; in Georgiana, Prospect, Beaver, Hog, and Sycamore sloughs; in the San Joaquin River adjacent to Bradford Island and Fisherman's Cut; and possibly other areas (Wang 1991). However, in recent years, the densest concentrations of both spawners and larvae have been recorded in the Cache Slough/Sacramento Deepwater Ship Channel complex in the north Delta. Some delta smelt spawning occurs in Napa River, Suisun Bay and Suisun Marsh during wetter years (Sweetnam 1999; Wang 1991; Hobbs et al. 2007). Early stage larval delta smelt have also been recorded in Montezuma Slough near Suisun Bay (Wang 1986).

Mager et al. (2004) reported that embryonic development to hatching takes 11-13 days at 14-16°C for delta smelt, and Baskerville-Bridges et al. (2000) reported hatching of delta smelt eggs after 8-10 days at temperatures between 15-l7°C. Lindberg et al. (2003) reported high hatching rates of delta smelt eggs in the laboratory at 15°C, and Wang (2007) reported high hatching rates at temperatures between 14-17°C. Hatching success peaks near 15°C (Bennett 2005) and swim bladder inflation occurring at 60-70 days post-hatch at 16-17°C (Mager et al. 2004). At hatching and during the succeeding three days, larvae are buoyant, swim actively near the water surface, and do not react to bright direct light (Mager et al. 2004). As development continues, newly hatched delta smelt become semi-buoyant and sink in stagnant water. However, larvae are unlikely to encounter stagnant water in the wild.

Growth rates of wild-caught delta smelt larvae are faster than laboratory-cultured individuals. Mager et al. (2004) reported growth rates of captive-raised delta smelt reared at near-optimum temperatures (16°C-17°C). Their fish were about 12 mm long after 40 days and about 20 mm long after 70 days. In contrast, analyses of otoliths indicated that wild delta smelt larvae were 15-25 mm, or nearly twice as long at 40 days of age (Bennett 2005). By 70 days, most wild fish were 30-40 mm long and beyond the larval stage. This suggests there is strong selective pressure for rapid larval growth in nature, a situation that is typical for fish in general (Houde 1987). The food available to larval fishes is constrained by mouth gape and status of fin development. Larval delta smelt cannot capture as many kinds of prey as larger individuals, but all life stages have small gapes that limit their range of potential prey. Prey availability is also constrained by habitat use, which affects what types of prey are encountered. Larval delta smelt are visual feeders. They find and select individual prey organisms and their ability to see prey in the water is enhanced by turbidity (Baskerville-Bridges et al. 2004). Thus, delta smelt diets are largely comprised of small crustacean that inhabit the estuary's turbid, low-salinity, open-water habitats (i.e., zooplankton). Larval delta smelt have particularly restricted diets (Nobriga 2002). They do not feed on the full array of zooplankton with which they co-occur; they mainly consume three copepods: *Eurytemora affinis*, *Pseudodiaptomus forbesi*, and freshwater species of the family Cyclopidae. Further, the diets of first-feeding delta smelt larvae are largely restricted to the larval stages of these copepods; older, larger life stages of the copepods are increasingly targeted as the delta smelt larvae grow, their gape increases, and they become stronger swimmers.

In the laboratory, a turbid environment (>25 Nephelometric Turbidity Units [NTU]) was necessary to elicit a first feeding response (Baskerville-Bridges et al. 2000; Baskerville-Bridges 2004). Successful feeding seems to depend on a high density of food organisms and turbidity, and increases with stronger light conditions (Baskerville-Bridges et al. 2000; Mager et al. 2004; Baskerville-Bridges et al. 2004). Laboratory-cultured delta smelt larvae have generally been fed rotifers at first-feeding (Baskerville-Bridges et al. 2004; Mager et al. 2004). However, rotifers rarely occur in the guts of wild delta smelt larvae (Nobriga 2002). The most common first prey of wild delta smelt larvae is the larval stages of several copepod species. These copepod 'nauplii' are larger and have more calories than rotifers. This difference in diet may enable the faster growth rates observed in wild-caught larvae.

The triggers for and duration of delta smelt larval movement from spawning areas to rearing areas is not known. Hay (2007) noted that eulachon (*Thaleichthys pacificus*) larvae are probably flushed into estuaries from upstream spawning areas within the first day after hatching, but downstream movement of delta smelt larvae occurs much later. Most larvae gradually move downstream toward the two parts per thousand (ppt) isohaline (X2). X2 is scaled as the distance in kilometers from the Golden Gate Bridge (Jassby et al. 1995).

At all life stages, delta smelt are found in greatest abundance in the water column and usually not in close association with the shoreline. They inhabit open, surface waters of the Delta and Suisun Bay, where they presumably aggregate in loose schools where conditions are favorable (Moyle 2002). In years of moderate to high Delta outflow (above normal to wet water years), delta smelt larvae are abundant in the Napa River, Suisun Bay, and Montezuma Slough, but the degree to which these larvae are produced by locally spawning fish versus the degree to which they originate upstream and are transported by tidal currents to the bay and marsh is uncertain.

Most young-of-the-year delta smelt rear in the low salinity zone (LSZ) from late spring through fall and early winter. Once in the rearing area growth is rapid, and juvenile fish are 40-50-mm standard length by early August (Erkkila et al. 1950; Ganssle 1966; Radtke 1966). They reach adult size (55-70-mm standard length) by early fall (Moyle 2002). Delta smelt growth during the fall months slows considerably (only 3-9 mm total), presumably because most of the energy ingested is being directed towards gonadal development (Erkkila et al. 1950; Radtke 1966). Some delta smelt remain in areas upstream of the LSZ, in particular the Cache Slough complex including Liberty Island the Sacramento Deepwater Ship Channel (Sommer et al. 2011, Sommer and Mejia 2013).

Trends in Abundance and Population Viability

Delta smelt abundance, as indexed by relative abundance in fall midwater trawling conducted since 1967, underwent downward step changes in the early 1980s and again in the early 2000s (Thomson et al. 2010); the annual fall midwater trawl index generally has remained low and in 2013 was the third lowest of all time, with the lowest index of all time occurring in 2014 (see http://www.dfg.ca.gov/delta/data/fmwt/Indices/sld002.asp). See additional discussion in the Status of the Species in the Action Area portion of the Environmental Baseline section. Bennett (2005) conducted a population viability analysis as the probability of extinction based on fall midwater trawl data up to 2003. He specified three extinction levels of 800; 8,000; and 80,000 fish, with the value of 80,000 roughly corresponding to the then-lowest fall midwater trawl index of relative abundance from 1994. The fall midwater trawl index in 1994 was 102; the lowest subsequent value was 9 in 2014, which, if proportional to the estimated abundance calculated by Bennett, would be closer to the estimate of 800 fish used by Bennett (2005). The analysis by Bennett suggested that the median time to 50% of extinction probabilities would be 20 years for 8,000 fish and 42-55 years for 800 fish; there was an estimated 50-55% probability of abundance reaching 8,000 fish in 20 years, compared to an estimated 26-30% probability of reaching in 800 fish in 20 years.

Critical Habitat

Central Valley Spring-Run Chinook Salmon and Central Valley Steelhead

Critical habitat was designated for Central Valley spring-run Chinook salmon and California Central Valley steelhead on September 2, 2005, (70 FR 52488). Critical habitat for Central Valley spring-run Chinook salmon includes stream reaches such as those of the Feather and Yuba rivers, Big Chico, Butte, Deer, Mill, Battle, Antelope, and Clear creeks, the Sacramento River, as well as portions of the northern Delta. Critical habitat for California Central Valley steelhead includes stream reaches such as those of the Sacramento, Feather, and Yuba rivers, and Deer, Mill, Battle, and Antelope creeks in the Sacramento River basin; the San Joaquin River, including its tributaries, and the waterways of the Delta. Critical habitat includes the stream channels in the designated stream reaches and the lateral extent as defined by the ordinary high-water line. In areas where the ordinary high-water line has not been defined, the lateral extent will be defined by the bankfull elevation (defined as the level at which water begins to leave the channel and move into the floodplain; it is reached at a discharge that generally has a recurrence interval of 1 to 2 years on the annual flood series) (Bain and Stevenson 1999; 70 FR 52488). Critical habitat for Central Valley spring-run Chinook salmon and steelhead is defined as specific areas that contain the primary constituent elements (PCE) and physical habitat elements essential to the conservation of the species. Inland PCEs for Central Valley spring-run Chinook salmon and California Central Valley steelhead include spawning habitat, freshwater rearing habitat, freshwater migration corridors, and estuarine areas.

- Freshwater spawning habitat includes water quantity and quality conditions and substrate supporting spawning, incubation, and larval development. Most spawning habitat in the Central Valley for Chinook salmon and steelhead is located in areas directly downstream of dams containing suitable environmental conditions for spawning and incubation. Spawning habitat for Sacramento River winter-run Chinook salmon is restricted to the Sacramento River primarily between RBDD and Keswick Dam. Central Valley spring-run Chinook salmon also spawn on the main stem Sacramento River between RBDD and Keswick Dam and in tributaries such as Mill, Deer, and Butte creeks (however, little spawning activity has been recorded in recent years on the Sacramento River main stem for spring-run Chinook salmon). Spawning habitat for California Central Valley steelhead is similar in nature to the requirements of Chinook salmon, primarily occurring in reaches directly below dams (i.e., above RBDD on the Sacramento River) on perennial watersheds throughout the Central Valley. These reaches can be subjected to variations in flows and temperatures, particularly over the summer months, which can have adverse effects upon salmonids spawning below them. Even in degraded reaches, spawning habitat has a high conservation value as its function directly affects the spawning success and reproductive potential of listed salmonids.

- Freshwater rearing habitat includes water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large woody material, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Both spawning areas and migratory corridors comprise rearing habitat for juveniles, which feed and grow before and during their out-migration. Non-natal, intermittent tributaries also may be used for juvenile rearing. Rearing habitat condition is strongly affected by habitat complexity, food supply, and the presence of predators of juvenile salmonids. Some complex, productive habitats with floodplains remain in the system (e.g., the lower Cosumnes River, Sacramento River reaches with setback levees [i.e., primarily located upstream of the City of Colusa]) and flood bypasses (i.e., Yolo and Sutter bypasses). However, the channelized, leveed, and riprapped river reaches and sloughs that are common in the Sacramento-San Joaquin system typically have low habitat complexity, low abundance of food organisms, and offer little protection from either fish or avian predators. Freshwater rearing habitat also has a high conservation value even if the current conditions are significantly degraded from their natural state. Juvenile life stages of salmonids are dependent on the function of this habitat for successful survival and recruitment.

- Ideal freshwater migration corridors are free of migratory obstructions, with water quantity and quality conditions that enhance migratory movements. They contain natural cover such as riparian canopy structure, submerged and overhanging large woody objects, aquatic vegetation, large rocks, and boulders, side channels, and undercut banks which augment juvenile and adult mobility, survival, and food supply. Migratory corridors are downstream of the spawning areas and include the lower main stems of the Sacramento and San Joaquin rivers and the Delta. These corridors allow the upstream passage of adults, and the downstream emigration of out-migrant juveniles. Migratory habitat condition is strongly affected by the presence of barriers, which can include dams (i.e., hydropower, flood control, and irrigation flashboard dams), unscreened or poorly screened diversions, degraded water quality, or behavioral impediments to migration. For successful survival and recruitment of salmonids, freshwater migration corridors must function sufficiently to provide adequate passage. For this reason, freshwater migration corridors are considered to have a high conservation value even if the migration corridors are significantly degraded compared to their natural state.

- Estuarine areas free of migratory obstructions with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh and salt water are included as a PCE. Natural cover such as submerged and overhanging large woody material, aquatic vegetation, and side channels, are suitable for juvenile and adult foraging. Estuarine areas are considered to have a high conservation value as they provide factors which function to provide predator avoidance and as a transitional zone to the ocean environment.

Sacramento River Winter-Run Chinook Salmon

The designated critical habitat for Sacramento River winter-run Chinook salmon includes the Sacramento River from Keswick Dam (RM 302) to Chipps Island (RM 0) at the westward margin of the Delta; all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge; and all waters of San Francisco Estuary to the Golden Gate Bridge north of the San

Francisco/Oakland Bay Bridge. In the Sacramento River, critical habitat includes the river water column, river bottom, and adjacent riparian zone used by fry and juveniles for rearing. In the areas westward of Chipps Island, critical habitat includes the estuarine water column and essential foraging habitat and food resources used by Sacramento River winter-run Chinook salmon as part of their juvenile emigration or adult spawning migration.

Critical habitat for Sacramento River winter-run Chinook salmon in the Delta is limited to the Sacramento River and therefore does not include the proposed West False River salinity barrier site footprints; however, the proposed West False River salinity barrier does have the potential to affect the Sacramento River during its operation, through effects on water quality and hydrodynamics.

Southern DPS of North American Green Sturgeon

Critical habitat was designated for the Southern DPS of North American green sturgeon on October 9, 2009 (74 FR 52300). Critical habitat for Southern DPS green sturgeon includes the stream channels and waterways in the Delta to the ordinary high water line except for certain excluded areas. Critical habitat also includes the main stem Sacramento River upstream from the I Street Bridge to Keswick Dam, and the Feather River upstream to the fish barrier dam adjacent to the FRFH. Coastal marine areas include waters out to a depth of 60 m from Monterey Bay, California, to the Juan De Fuca Straits, Washington. Coastal estuaries designated as critical habitat include San Francisco Bay, Suisun Bay, San Pablo Bay, and the lower Columbia River estuary. Certain coastal bays and estuaries in California (Humboldt Bay), Oregon (Coos Bay, Winchester Bay, Yaquina Bay, and Nehalem Bay), and Washington (Willapa Bay and Grays Harbor) are also included as critical habitat for Southern DPS green sturgeon.

Critical habitat for the Southern DPS of North American green sturgeon includes the estuarine waters of the Delta, which contain the following PCEs: food resources, water flow, water quality, migratory corridors, water depth, and sediment quality.

- Abundant food resources within estuarine habitats and substrates for juvenile, sub-adult, and adult life stages are required for the proper functioning of this PCE for green sturgeon. Prey species for juvenile, sub-adult, and adult green sturgeon within bays and estuaries primarily consist of benthic invertebrates and fish, including crangonid shrimp, callianassid shrimp, burrowing thalassinidean shrimp, amphipods, isopods, clams, annelid worms, crabs, sand lances, and anchovies. These prey species are critical for the rearing, foraging, growth, and development of juvenile, sub-adult, and adult green sturgeon within the bays and estuaries.

- Within bays and estuaries adjacent to the Sacramento River (i.e., the Delta and the Suisun, San Pablo, and San Francisco bays), sufficient water flow into the bay and estuary to allow adults to successfully orient to the incoming flow and migrate upstream to spawning grounds is required. Sufficient flows are needed to attract adult green sturgeon to the Sacramento River from the bay and to initiate the upstream spawning migration into the upper river.

- Adequate water quality, including temperature, salinity, oxygen content, and other chemical characteristics, is necessary for normal behavior, growth, and viability of all life stages. Suitable water temperatures for juvenile green sturgeon should be below 24°C (75°F). At temperatures above 24°C, juvenile green sturgeon exhibit decreased swimming performance (Mayfield and Cech 2004) and increased cellular stress (Allen et al. 2006). Suitable salinities in the estuary range from brackish water (10 ppt) to salt water (33 ppt). Juveniles transitioning from brackish to salt water can tolerate prolonged exposure to salt water salinities, but may exhibit decreased growth and activity levels (Allen and Cech 2007), whereas sub-adults and adults tolerate a wide range of salinities (Kelly et al. 2007). Sub-adult and adult green sturgeon occupy a wide range of dissolved oxygen (DO) levels (Kelly et al. 2007, Moser and Lindley 2007). Adequate levels of DO are also required to support oxygen consumption by juveniles ranging from 61.78 to 76.06 milligrams (mg) oxygen (O_2) per hour per kilogram (kg) of weight (Allen and Cech 2007). Suitable water quality also includes water free of contaminants (e.g., organochlorine pesticides, poly aromatic hydrocarbons (PAHs), or elevated levels of heavy metals) that may disrupt the normal development of juvenile life stages, or the growth, survival, or reproduction of sub-adult or adult stages.

- Safe and unobstructed migratory corridors are necessary for the safe and timely passage of adult, sub-adult, and juvenile fish within the region's different estuarine habitats and between the upstream riverine habitat and the marine habitats. Within the waterways comprising the Delta, and bays downstream of the Sacramento River, safe and unobstructed passage is needed for juvenile green sturgeon during the rearing phase of their life cycle. Rearing fish need the ability to freely migrate from the river through the estuarine waterways of the delta and bays and eventually out into the ocean. Passage within the bays and the Delta is also critical for adults and sub-adults for feeding and summer holding, as well as to access the Sacramento River for their upstream spawning migrations and to make their outmigration back into the ocean. Within bays and estuaries outside of the Delta and the areas comprised by Suisun, San Pablo, and San Francisco bays, safe and unobstructed passage is necessary for adult and sub-adult green sturgeon to access feeding areas, holding areas, and thermal refugia, and to ensure passage to the ocean.

- A diversity of water depths is necessary for shelter, foraging, and migration of juvenile, sub-adult, and adult life stages. Tagged adults and sub-adults within the San Francisco Bay estuary primarily occupied waters over shallow depths of less than 10 m, either swimming near the surface or foraging along the bottom (Kelly et al. 2007). In a study of juvenile green sturgeon in the Delta, relatively large numbers of juveniles were captured primarily in shallow waters from 3–8 feet deep, indicating juveniles may require shallower depths for rearing and foraging (Radtke 1966). Thus, a diversity of depths is important to support different life stages and habitat uses for green sturgeon within estuarine areas.

- Sediment quality (i.e., chemical characteristics) is necessary for normal behavior, growth, and viability of all life stages. This includes sediments free of contaminants (e.g., elevated levels of selenium, PAHs, and organochlorine pesticides) that can cause negative effects on all life stages of green sturgeon.

Delta Smelt

USFWS designated critical habitat for the delta smelt on December 19, 1994 (59 FR 65256). The geographic area encompassed by the designation includes all water and all submerged lands below the ordinary high water line and the entire water column bounded by and contained in Suisun Bay (including the contiguous Grizzly and Honker bays); the length of Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma sloughs; and the existing contiguous waters contained within the legal Delta (as defined in section 12220 of the California Water Code) (USFWS 1994).

PCEs for delta smelt include physical habitat, water, river flow, and salinity.

- Physical habitat is defined as the structural components of habitat. Because delta smelt is a pelagic fish, spawning substrate is the only known important structural component of habitat. It is possible that depth variation is an important structural characteristic of pelagic habitat that helps fish maintain position within the estuary's LSZ (Bennett et al. 2002).

- Water is defined as water of suitable quality to support various delta smelt life stages with the abiotic elements that allow for survival and reproduction. Delta smelt inhabit open waters of the Delta and Suisun Bay. Certain conditions of water temperature, turbidity, and food availability characterize suitable pelagic habitat for delta smelt. Factors such as high entrainment risk and contaminant exposure can degrade this PCE even when the basic water quality is consistent with suitable habitat.

- River flow is defined as transport flow to facilitate spawning migrations and transport of offspring to LSZ rearing habitats. River flow includes both inflow to and outflow from the Delta, both of which influence the movement of migrating adult, larval, and juvenile delta smelt. Inflow, outflow, and Old and Middle River flows (OMR) influence the vulnerability of delta smelt larvae, juveniles, and adults to entrainment at the Banks and Jones pumping facilities. River flow interacts with the fourth primary constituent element, salinity, by influencing the extent and location of the highly productive LSZ where delta smelt rear.

- Salinity is defined as the LSZ nursery habitat. The LSZ is where freshwater transitions into brackish water; the LSZ is defined as 0.5-6.0 practical salinity units (psu) (Kimmerer 2004). The 2 psu isohaline is a specific point within the LSZ where the average daily salinity at the bottom of the water is 2 psu (Jassby et al. 1995). By local convention the location of the LSZ is described in terms of the distance from the 2 psu isohaline to the Golden Gate Bridge (X2); X2 is an indicator of habitat suitability for many San Francisco Estuary organisms and is associated with variance in abundance of diverse components of the ecosystem (Jassby et al. 1995; Kimmerer 2002a). The LSZ expands and moves downstream when river flows into the estuary are high. Similarly, it contracts and moves upstream when river flows are low. During the past 40 years, monthly average X2 has varied from as far downstream as San Pablo Bay (45 km) to as far upstream as Rio Vista on the Sacramento River (95 km). At all times of year, the location of X2 influences both the area and quality of habitat available for delta smelt to successfully complete their life cycle. In general, delta smelt habitat quality and surface area are greater when X2 is located in Suisun Bay. Both habitat quality and quantity diminish the more frequently and further the LSZ moves upstream, toward the confluence of the Sacramento and San Joaquin rivers.

Environmental Baseline

The environmental baseline "includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process" (50 CFR §402.02). The discussion below presents general temporal patterns of occurrence of the species in the Action Area based on historic data; additional information specific to 2015 is provided in the Effects Assessment section.

Status of the Species and Critical Habitat in the Action Area

Status of the Species Within the Action Area

NMFS-Managed Species

The description of environmental baseline conditions in the Action Area for NMFS-managed species is largely derived from the NMFS (2014) BO on the Georgiana Slough Floating Fish Guidance Structure Study. The Action Area for the construction, operation, and removal of the proposed West False River salinity barrier functions primarily as a migratory corridor for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, California Central Valley steelhead, and the Southern DPS of North American green sturgeon, but it also provides some use as holding and rearing habitat for each of these species as well.

Central Valley Spring-Run Chinook Salmon

CVP and SWP salvage records and northern and central Delta fish monitoring data indicate that juvenile spring-run Chinook salmon, based on the Delta length–at-date criteria, first begin to appear in the Delta in December and January, but that a significant presence does not occur until March and peaks in April (17.2 and 65.9 percent of average annual salvage, respectively; see Table 10 of NMFS 2014). By May, the salvage of juvenile Central Valley spring-run Chinook salmon declines sharply and essentially ends by the end of June (15.5 and 1.2 percent of average annual salvage, respectively). The data from the northern and central Delta fish monitoring programs indicate that a small proportion of the annual juvenile spring-run emigration occurs in January (3 percent) and is considered to be mainly composed of older yearling spring-run juveniles based on their size at date (Table 11). Based on the Delta size criteria by date, the majority of spring-run Chinook salmon juveniles (young-of-the- year size) emigrate in March (53 percent) and April (43 percent), and the proportion emigrating tails off sharply by May (1 percent); the main juvenile migration through the Delta is thus from March to May. This pattern is further supported and consistent with salmonid passage estimates derived from RST data collected by USFWS dating back to 2003, which indicate two significant peaks in the annual passage of juvenile spring-run Chinook salmon at RBDD occurring in the months of December and April. During the proposed WFRSB construction period (commencing in April), historical monitoring data suggest that over 40 percent of the annual spring-run juvenile population would move into the waterways within the Delta (Table 11). Therefore the proposed WFRSB operational period (late April to September/October) has the potential to temporally overlap an appreciable proportion of juvenile spring-run Chinook salmon moving into and through the Delta. As an example of the pattern of temporal occurrence in a drought year, more detailed information regarding occurrence in the Action Area during 2015 is provided in the Effects Assessment section below.

Table 11. Percentage of Juvenile Sacramento River-watershed Salmonids Entering the Delta by Month

Month	Fall-Run	Spring-Run	Winter-Run	Sacramento Steelhead
January	14	3	17	5
February	13	0	19	32
March	23	53	37	60
April	6	43	1	0
May	26	1	0	0
June	0	0	0	0
July	0	0	0	0
August	1	0	0	0
September	0	0	0	1
October	9	0	0	0
November	8	0	3	1
December	0	0	24	1

Source: National Marine Fisheries Service 2009: 633.

Adult spring-run Chinook salmon would be expected to start entering the Delta in approximately January. Low levels of adult migration would be expected through early March. The peak of adult spring-run Chinook salmon movement through the Delta would be expected to occur between April and June with adults continuing to enter the system through the summer (see Table 12), during the proposed WFRSB operational period.

During the proposed WFRSBconstruction (April/May) and operational period (late April to September/October), it is estimated that much of the adult spring-run Chinook salmon escapement would move upriver through the Delta. The removal period of the proposed WFRSB (commencing in fall, with full removal by November 30) would be expected to occur outside of the adult spring-run Chinook salmon upstream migration period. Currently, all known populations of Central Valley spring-run Chinook salmon inhabit the Sacramento River watershed.

Table 12. Percentage of Adult Chinook Salmon Passing Above Red Bluff Diversion Dam By Month

Month	Fall-Run	Late Fall–Run	Spring-Run	Winter-Run
January	0	17.5	0	3.75
February	0	17.5	0	13.75
March	0	6.25	1.25	37.5
April	0	1.25	1.25	25
May	0	0	4.5	10
June	0	0	10.5	7
July	2.5	0	15	1.5
August	10	0	25	1.5
September	32.5	0	27.5	0
October	40	20	15	0
November	12.5	17.5	0	0
December	2.5	20	0	0

Source: Adapted from Vogel and Marine (1991), averaging wet and dry years and assuming midpoints for values denoted as 'greater than' or 'less than' by Vogel and Marine (1991).

Sacramento River Winter-Run Chinook Salmon

The temporal occurrence of Sacramento River winter-run Chinook salmon smolts and juveniles within the northern Delta and central Delta are best described by a combination of the salvage records of the CVP and SWP fish collection facilities (see Table 10 of NMFS 2014) and the fish monitoring programs conducted in the northern and central Delta (Table 11). Based on salvage records covering the period between 1999 and 2009 at the south Delta fish salvage facilities, juvenile Sacramento River winter-run Chinook salmon, based on the Delta length-at-date criteria, typically are present in the south Delta starting in December. Their presence peaks in March and then rapidly declines from April through June. Nearly 50 percent of the average annual salvage of Sacramento River winter-run Chinook salmon juveniles occurs in March. Salvage in April accounts for only 2.8 percent of the average annual salvage and falls to less than 1 percent for May and June combined. Using the fish monitoring data from the northern and central Delta, on average 3 percent of the annual winter run juvenile population emigrates into the Delta in November, 24 percent in December, 17 percent in January, 19 percent in February, 37 percent in March, 1 percent in April, and very low numbers from May onwards. Therefore it would be expected that only a small percentage of winter-run juveniles would potentially be in the south Delta during the proposed WFRSBconstruction window (April/May). The proposed WFRSBoperational period (late April to September/October) would be almost entirely outside the juvenile winter-run population migration period, as would the barrier removal period (October/November). As an example of the pattern of temporal occurrence in a drought year, more detailed information regarding occurrence in the Action Area during 2015 is provided in the Effects Assessment section below.

Presence of adult winter-run Chinook salmon in the Delta is inferred from historical data derived from the passage of adults fish past RBDD (Table 12). It is assumed that based on a migratory movement rate of 25 km per day, fish would be in the Delta approximately 2 weeks earlier than the dates at RBDD. Adult winter-run Chinook salmon are expected to enter the Delta starting in January (approximately 3 percent), with the majority of adults passing through the Delta between February 1 and the end of April (approximately 66 percent). Most of the remaining adults would be expected to have reached RBDD by the end of June (Table 12). During the proposed WFRSB construction period (April/May), over 30 percent of the adult winter-run spawning population may have passed through the Delta (based on half of the total percentage historically reaching Red Bluff Diversion Dam in March and all of the total percentage in April; Table 12). During the barrier operation period (late April to September/October), a similar proportion of the adult spawning population (over 30%, based on RBDD data for half of April and May-November) would be anticipated to move through the Delta. The removal phase of the project (September/October/November) would be outside the migration period of winter-run Chinook salmon adults (Table 12).

Central Valley Steelhead

California Central Valley steelhead occur in both the Sacramento River and the San Joaquin River watersheds. However the spawning population of fish is much greater in the Sacramento River watershed and accounts for nearly all of the DPS' population. Small, remnant populations of California Central Valley steelhead are known to occur on the Stanislaus River and the Tuolumne River and their presence is assumed on the Merced River due to regional proximity, similar aquatic habitats, otolith microchemistry indicating maternal anadromy in some specimens collected within the tributary (Zimmerman 2008, 2009), and historical presence prior to dam construction.

California Central Valley steelhead smolts first start to appear in the Delta in November based on the records from the CVP and SWP fish salvage facilities (Table 10 of NMFS 2014), as well as the fish monitoring program in the northern and central Delta (Table 11). This coincides with the latter portion of the removal period of the proposed WFRSB (full removal of WFRSBby November 30). Steelhead presence increases through December and January (21.6 percent of average annual salvage) and peaks in February (37.0 percent) and March (31.1 percent) before rapidly declining in April (7.7 percent). By June, the emigration has essentially ended, with only a small number of fish being salvaged through the summer at the CVP and SWP. Kodiak trawls conducted by the USFWS and CDFW on the mainstem of the San Joaquin River upstream from the City of Stockton routinely catch low numbers of out-migrating steelhead smolts from the San Joaquin River Basin during the months of April and May. Data from the northern and central Delta fish monitoring programs indicate that steelhead smolts begin to enter the northern Delta as early as November and December, but do not substantially increase in number until February and March. Based on these data, relatively few juvenile steelhead emigrants would be expected to move into and through the Delta during the earliest proposed barrier installation (i.e., beginning on April 1). The barrier operation period would extend from late April to September/October, during which time only a very low proportion of the juvenile steelhead population would be expected to enter the Delta (Table 11). As an example of the pattern of temporal occurrence in a drought year, more detailed information regarding occurrence in the Action Area during 2015 is provided in the Effects Assessment section below.

The peak of adult steelhead upstream migration occurs from August through November on the Sacramento River, with relatively low abundance from December/January to July (Hallock et al. 1957). Therefore, it is anticipated that there would be little overlap with construction of the proposed WFRSBfor adult steelhead moving upstream to spawn several months later given that construction would occur in April/May. There is potential for exposure of adult steelhead moving back downstream through the Action Area in a post-spawn condition (i.e., kelts) during the barrier construction period. It is expected that more kelts would be likely to occur earlier in the construction period because the timing of spawning in the Sacramento River basin generally would precede construction which would begin in April (Figure 28 in NMFS 2014). A significant proportion of adult steelhead upstream migrants could encounter the barrier during the operational period (late April to September/October). Adult steelhead also are likely to be present in appreciable numbers in the Delta during barrier removal in September/October/November.

Southern DPS of North American Green Sturgeon

Juvenile green sturgeon from the Southern DPS are routinely collected at the Fish Facilities throughout the year. However, numbers are considerably lower than for other species of fish monitored at the Fish Facilities. Based on the salvage records from 1981 through 2013, green sturgeon may be present during any month of the year, and have been particularly prevalent during July and August. The sizes of these fish are less than 1 m and average 330 mm with a range of 136 mm to 774 mm. The size range indicates that these are sub-adult fish rather than adult or larval/juvenile fish. It is believed that these sub-adult fish utilize the Delta for rearing for up to a period of approximately 3 years. The Action Area is located on the main migratory route that juvenile green sturgeon would utilize to enter the Delta from their natal areas upstream on the upper Sacramento River. The fact that juvenile green sturgeon are captured at the Fish Facilities, which are in the southwest portion of the Delta, suggests that green sturgeon are more likely to be present in the Action Area during the project, and in higher densities, than are observed at the Fish Facilities. Juvenile green sturgeon therefore would be present in the Action Area during all phases of the project (construction, operation, and removal).

Because the Action Area is on the main adult green sturgeon migratory route for access to the spawning grounds in the upper Sacramento River, it is likely that adult green sturgeon would be present in the Action Area during proposed WFRSB implementation. Adult green sturgeon begin to enter the Delta in late February and early March during the initiation of their upstream spawning run. The peak of adult entrance into the Delta appears to occur in late February through early April with fish arriving upstream in April and May. Adults continue to enter the Delta until early summer (June-July) as they move upriver to spawn. Data for arrival of 30 acoustically tagged green sturgeon to spawning grounds in the upper Sacramento River in 2007-2013 gave the following cumulative arrival percentages (Woodbury pers. comm.): 6.7% by end of February, 40% by end of March, 77% by end of April, 97% by end of May, and 100% by end of June. These data suggest that an appreciable portion of upstream migrants could encounter barrier operations (late April to September/October) and, allowing for travel time from the Delta to spawning grounds, a sizeable portion of the population would pass through the Delta during construction in April/May. The acoustic data suggest perhaps 40% of spawners may move through the Delta in April, some of which may experience effects of construction during this month. Adult green sturgeon may move back downstream through the Action Area, either as post spawners or as unsuccessful spawners, during spring, summer, or fall (with fall the most common period; see Life History section above and Heublein et al. 2009). Therefore these downstream migrants could encounter the barrier during construction, operation, or removal.

Delta Smelt

The Action Area functions as a migratory corridor, as rearing habitat, and as spawning habitat for delta smelt. Given the long list of stressors discussed in the USFWS (2008) OCAP BO, the range-wide status of the delta smelt is currently declining and abundance levels were the lowest ever recorded in 2014/2015. Although there was a spike in the population in 2011, the declining abundance of delta smelt is clear. The 2013 fall midwater trawl index was the second lowest ever; the 2014 index was the lowest ever. The 2015 Spring Kodiak Trawl index is the lowest since the survey began in 2002, and the 2015 Summer Townet Survey age-0 delta smelt abundance index is 0.0, which is the lowest index reported in the history of this survey (implemented in 1959) and is consistent with the downward trend observed in recent years. This abundance trend has been influenced by multiple factors, some of which are affected or controlled by CVP and SWP operations and others that are not. Although it is becoming increasingly clear that the long-term decline of the delta smelt was very strongly affected by ecosystem changes caused by non-indigenous species invasions and other factors influenced but not controlled by CVP and SWP operations, the CVP and SWP have played an important direct role in that decline, especially in terms of entrainment and habitat-related impacts that add increments of additional mortality to the stressed delta smelt population. Further, past CVP and SWP operations have played an indirect role in the decline of the delta smelt by creating an altered environment in the Delta that has fostered both the establishment of non-indigenous species and habitat conditions that exacerbate their adverse influence on delta smelt population dynamics. Past CVP and SWP operations have been a primary factor influencing delta smelt abiotic and biotic habitat suitability, health, and mortality.

Within the Action Area, based on historical distribution surveys, delta smelt probably are likely to occur near the WFRSB. Merz et al. (2011) examined survey data for occurrence of different delta smelt life stages in a number of regions within the Delta (Table 10). They found that the Lower San Joaquin River region (including the WFRSB area) had the second highest occurrence of delta smelt larvae of all sampled regions (found in 28% of 20-mm survey samples from April to June of 1995 to 2009); only the confluence of the Sacramento and San Joaquin rivers had a higher frequency of occurrence of delta smelt larvae (36%). The frequency of occurrence of sub-juveniles (15-30 mm) from the same survey was slightly greater than the all-zone average. The frequency of occurrence of juvenile and sub-adult delta smelt during summer and fall in the Lower San Joaquin River zone was well below the all-zone average, which is in keeping with the generally poorer rearing habitat in relation to other zones such as the confluence and Suisun Bay. Mature, pre-spawning, and spawning adult delta smelt frequency of occurrence from various surveys in the Lower San Joaquin River zone was similar to the all-zone average frequency of occurrence (Merz et al. 2011; Table 10). More detailed information regarding occurrence in the Action Area during 2015 is provided in the Effects Assessment section below.

As described in the March 2015 Biological Review for Endangered Species Act Compliance with the WY 2015 Drought Contingency Plan April through September Project Description, written as part of the March 24 TUCP, research presented at the Interagency Ecological Program (IEP) workshop (March 18-20, 2015) showed that the current drought impacts delta smelt in a number of ways. It can reduce the area of low salinity habitat to which delta smelt migrate for spawning and thereby reduce food availability for adults and for juveniles moving there to rear. Drought can indirectly impact reproductive potential by lowering the number of oocytes females produce. This is brought about by a link between low outflow and elevated water temperature. Warming temperature shortens the spawning window, which causes fewer clutches to be produced per female. Both of these mechanisms combine with low adult abundance to impair population fecundity. Lower outflow also tends to reduce turbidity. Delta smelt use turbid water to avoid predators and they also use it as foraging habitat. Otolith analysis has revealed that since 1999, delta smelt experienced an 8% decline in growth between dry and wet years and spawning is more successful in the north Delta during drought. The quality of delta smelt habitat is further compromised by concentrations of herbicides such as diuron and hexazinone, which increase with reduced outflow and have synergistic effects that reduce food availability for juveniles. Furthermore, warm, slow moving water characterized by drought promotes conditions in which parasites like Ich (*Ichthyophthirius multifiliis*) and cyanobacteria like *Microcystis* thrive. Ich causes skin lesions to form on a variety of fish and has an increased prevalence among captive delta smelt above 17°C. *Microcystis* is a cyanobacterium that can produce toxic hepatotoxins that became established throughout the Delta in 2000; it thrives in water above 17°C with low turbulence. Because of the extended high water temperatures associated with drought, *Microcystis* blooms extended into December of 2014. This highly toxic cyanobacterium is known to kill phytoplankton, zooplankton and compromise fish health. Finally, the abundance of non-native Delta Smelt predators, such as black bass, increased in the Delta in response to the drought in 2014, mainly because it expanded their preferred habitat. The same pattern was found for non-native competitors, such as clams like *Corbicula*, which seem to be expanding throughout the Delta despite the drought.

Status of Critical Habitat Within the Action Area

NMFS-Managed Species

The Action Area occurs within the CALWATER Hydrologic Unit (HU) for the Sacramento Delta (HU 5510) and San Joaquin Delta Subbasin (HU 5544). Designated critical habitat for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, California Central Valley steelhead, and the Southern DPS of North American green sturgeon occur in these HUs. The PCEs for steelhead and spring-run Chinook salmon habitat within the action area include freshwater rearing habitat, freshwater migration corridors, and estuarine areas. The features of the PCEs included in these different sites essential to the conservation of California Central Valley steelhead and Central Valley spring-run Chinook salmon include the following: sufficient water quantity and floodplain connectivity to form and maintain physical habitat conditions necessary for salmonid development and mobility, sufficient water quality, food and nutrient sources, natural cover and shelter, migration routes free from obstructions, no excessive predation, holding areas for juveniles and adults, and shallow water areas and wetlands. Habitat within the action area is primarily utilized for freshwater rearing and migration by California Central Valley steelhead and Central Valley spring-run Chinook salmon juveniles and smolts and for adult freshwater migration. No spawning of California Central Valley steelhead or Central Valley spring-run Chinook salmon occurs within the Action Area.

Critical habitat for winter-run Chinook salmon includes the Sacramento River reach within the Action Area. Critical habitat elements include the river water, river bottom, and adjacent riparian zone used by fry and juveniles for rearing. Downstream migration of juveniles and upstream migration of adults should not be impeded or blocked. Adequate forage base is required to provide food for emigrating juvenile winter-run.

With respect to the designated critical habitat for the Southern DPS of North American green sturgeon, the Action Area includes PCEs concerned with adequate food resources for all life stages utilizing the Delta; water flows sufficient to allow adults, sub-adults, and juveniles to orient to flows for migration and normal behavioral responses; water quality sufficient to allow normal physiological and behavioral responses; unobstructed migratory corridors for all life stages utilizing the Delta; a broad spectrum of water depths to satisfy the needs of the different life stages present in the estuary; and sediment with sufficiently low contaminant burdens to allow for normal physiological and behavioral responses to the environment.

The general condition and function of the aquatic habitat in the Delta was described by NMFS in recent biological opinions such as that for the 2014 Georgiana Slough Floating Fish Guidance Structure (NMFS 2014). In brief, the substantial degradation over time of several of the essential critical elements has diminished the function and condition of freshwater rearing and migration habitat in the Action Area; the habitat has only rudimentary function compared to its historical status. The channels of the Delta have been heavily riprapped with coarse stone slope protection on artificial levee banks and these channels have been straightened to enhance water conveyance through the system. The extensive riprapping and levee construction has precluded natural river channel migrations and the formation of riffle pool configurations in the Delta's channels. The natural floodplains have essentially been eliminated, and the once extensive wetlands and riparian zones have been drained and cleared for farming. Little natural old growth riparian vegetation remains in the Delta, having been substantially replaced by non-native species. Remaining native vegetation is primarily limited to tules or cattails growing along the foot of artificial levee banks. Shallow water habitat along the toe of the levees is limited to a narrow bench that extends out towards mid-channel from the levee, and is frequently infested with non-native plant species such as the Brazilian waterweed (*Egeria densa*).

Although the habitat within the Delta, and in particular along the main stem Sacramento and San Joaquin Rivers, has been substantially altered and its quality diminished through years of human actions, its conservation value remains high for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, California Central Valley steelhead, and Southern DPS of North American green sturgeon. All juvenile winter-run and spring-run Chinook salmon, Southern DPS of North American green sturgeon, as well as those California Central Valley steelhead smolts originating in the Sacramento River basin must pass into and through the Sacramento Delta

Subbasin HU to reach the lower Delta and the ocean. A portion of these Sacramento-origin fish, together with all of the Central Valley steelhead originating in the San Joaquin River basin, also pass through the San Joaquin Delta Subbasin HU. Likewise, adults originally born in the Sacramento basin that are migrating upstream to spawn must pass through Sacramento Delta HU to reach their upstream spawning areas on the tributary watersheds or main stem Sacramento River, and may pass through the San Joaquin Delta HU. Central Valley steelhead from the San Joaquin Basin will pass back through the San Joaquin Delta HU on their way to upstream spawning habitat. Therefore, it is of critical importance to the long-term viability of Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon, the Southern DPS of North American green sturgeon, and California Central Valley steelhead to maintain a functional migratory corridor and freshwater rearing habitat through the Action Area and the Sacramento and San Joaquin Delta Subbasin HUs.

Delta Smelt

The existing physical appearance and hydrodynamics of the Action Area have changed substantially from the environment in which native fish species like delta smelt evolved. The Action Area once consisted of tidal marshes with networks of diffuse dendritic channels connected to floodplains of wetlands and upland areas (Moyle 2002). The in-Delta channels were further connected to drainages of larger and smaller rivers and creeks entering the Action Area from the upland areas. In the absence of upstream reservoirs, freshwater inflow from smaller rivers and creeks and the Sacramento and San Joaquin Rivers were highly seasonal and more strongly and reliably affected by precipitation patterns than they are today. Consequently, variation in hydrology, salinity, turbidity, and other characteristics of the Delta aquatic ecosystem was greater in the past than it is today (Kimmerer 2002b). For instance, in the early 1900s, the location of maximum salinity intrusion into the Delta during dry periods varied from Chipps Island in the lower Delta to Stockton along the San Joaquin River and Merritt Island in the Sacramento River (DWR Delta Overview[1]). Operations of upstream reservoirs have reduced spring flows while releases of water for Delta water export and increased flood control storage have increased late summer and fall inflows (Knowles 2002), though Delta outflows have been tightly constrained during late summer-fall for several decades.

Channelization, conversion of Delta islands to agriculture, and water operations have substantially changed the physical appearance, water salinity, water clarity, and hydrology of the Action Area. As a consequence of these changes, most life stages of the delta smelt are now distributed across a smaller area than historically (Arthur et al. 1996, Feyrer et al. 2007). Wang (1991) noted in a 1989 and 1990 study of delta smelt larval distribution that, in general, the San Joaquin River was used more intensively for spawning than the Sacramento River. Though not restricting spawning per se, based on particle tracking modeling, export of water by the CVP and SWP would usually restrict reproductive success of spawners in the San Joaquin River by entraining most larvae during downstream movement from spawning sites to rearing areas (Kimmerer and Nobriga 2008). There is one, non-wet year exception to this generalization: in 2008, delta smelt entrainment was managed under a unique system of restrictions imposed by the Court in NRDC v Kempthorne. The USFWS

[1] http://baydeltaoffice.water.ca.gov/sdb/tbp/deltaoverview/delta_overview.pdf

(2008) OCAP BO subsequently limited CVP/SWP operations to reduce entrainment of adult, larval, and early juvenile delta smelt.

As described in recent BOs such as the USFWS (2014b) BO on the Georgiana Slough Floating Fish Guidance Structure, a number of factors in addition to SWP/CVP have affected delta smelt critical habitat in the Action Area, e.g., contaminants and *Microcystis*, both of which may affect delta smelt prey. Introduced species have also impacted the Action Area in several ways including added predation to adult and juvenile delta smelt from introduced piscivorous fishes, changes in prey composition due to the introduction of several copepod species, added competition for food resources from introduced filter feeders, and submerged aquatic vegetation (particularly *Egeria densa*) that traps sediment and provides habitat for introduced piscivorous fishes.

In addition to the general status of critical habitat in the action area described above, further information on drought-related impacts was provided in the section discussing the Status of the Species in the Action Area.

Factors Affecting the Species and Habitat in the Action Area

NMFS-Managed Species

The Action Area encompasses a small portion of the area utilized by Sacramento River winter-run and Central Valley spring-run Chinook salmon, California Central Valley steelhead, and the Southern DPS of North American green sturgeon. Many of the factors affecting these species throughout their range are discussed in recent BOs such as that for the 2014 Georgiana Slough Floating Fish Guidance Structure (NMFS 2014), and are considered the same in the Action Area.

The magnitude and duration of peak flows during the winter and spring are reduced by water impoundment in upstream reservoirs affecting listed salmonids in the Action Area. Instream flows during the summer and early fall months have increased over historic levels for deliveries of municipal and agricultural water supplies. Overall, water management now reduces natural variability by creating more uniform flows year-round. Current flood control practices require peak flood discharges to be held back and released over a period of weeks to avoid overwhelming the flood control structures downstream of the reservoirs (i.e., levees and bypasses). Consequently, managed flows in the main stem of the river often truncate the peak of the flood hydrograph and extend reservoir releases over a protracted period. These actions reduce necessary cues for upstream spawning migrations and downstream emigration to the ocean created by variability in the hydrograph.

Levee construction and bank protection have affected salmonid habitat availability and the processes that develop and maintain preferred habitat by reducing floodplain connectivity, changing riverbank substrate size, and decreasing riparian habitat and shaded riverine aquatic (SRA) cover. Individual bank protection sites typically range from a few hundred to a few thousand linear feet in length. Such bank protection generally results in two levels of impacts to the environment: (1) site-level impacts which affect the basic physical habitat structure at individual bank protection sites; and (2) reach-level impacts which are the accumulative impacts to ecosystem functions and processes that accrue from multiple bank protection sites within a given river reach (USFWS 2000). Revetted embankments result in loss of sinuosity and braiding and reduce the amount of aquatic habitat. Impacts at the reach level result primarily from halting erosion and controlling riparian vegetation. Reach-level impacts which cause significant impacts to fish are reductions in new habitats of various kinds, changes to sediment and organic material storage and transport, reductions of lower food-chain production, and reduction in large woody debris (LWD). Levee construction substantially reduces and typically eliminates any overbank flooding typical of natural river courses. Any overbank flows typically occur on small terraces adjacent to the riverside of the levee crown, providing minimal floodplain habitat for salmonids.

The use of rock armoring limits recruitment of LWD (i.e., from non-riprapped areas), and greatly reduces, if not eliminates, the retention of LWD once it enters the river channel. Riprapping creates a relatively clean, smooth surface which diminishes the ability of LWD to become securely snagged and anchored by sediment. LWD tends to become only temporarily snagged along riprap, and generally moves downstream with subsequent high flows. Habitat value and ecological functioning aspects are thus greatly reduced, because wood needs to remain in place to generate maximum values to fish and wildlife (USFWS 2000). Recruitment of LWD is limited to any eventual, long-term tree mortality and whatever abrasion and breakage may occur during high flows (USFWS 2000). Juvenile salmonids are likely being impacted by reductions, fragmentation, and general lack of connectedness of remaining nearshore refuge areas.

Point and non-point sources of pollution resulting from agricultural discharge and urban and industrial development occur upstream of, and within the Action Area. Environmental stressors as a result of low water quality can lower reproductive success and may account for low productivity rates in fish (e.g. green sturgeon; Klimley 2002). Organic contaminants from agricultural drain water, urban and agricultural runoff from storm events, and high trace element (i.e. heavy metals) concentrations may deleteriously affect early life-stage survival of fish in the Sacramento River (USFWS 1995b). The high numbers of diversions in the Action Area on the Sacramento River and in the north Delta are also potential threats to listed fish within the Action Area. Other impacts to adult migration present in the Action Area include migration barriers, water conveyance factors, water quality, and are discussed further by NMFS (2014).

Delta Smelt

Factors affecting delta smelt and its critical habitat were previously discussed in the sections discussing Status of the Species Within the Action Area and Status of Critical Habitat Within the Action Area.

Environmental Baseline Conditions Specific to Drought Years

The environmental baseline in the Action Area was described previously in general terms. Drought conditions in 2014 and 2015 necessitated management actions that require special consideration in the environmental baseline. These factors, which are specific to 2014/2015 are summarized below, as they are likely to be representative of conditions that could occur in 2016 in which the proposed WFRSB would be implemented.

Drought Contingency Plan

On January 29, 2014, drought-related conditions prompted DWR and Reclamation to jointly file a TUCP that requested the SWRCB to temporarily modify water right permit and license terms for the CVP and SWP. Specifically, the TUCP requested temporary modification of Delta outflow and DCC gate requirements imposed pursuant to State Water Board Decision 1641 (D-1641). On January 31, 2014, the SWRCB Executive Director, acting under delegated authority, issued an Order approving the temporary change, including allowing a reduced level of Delta outflow for upstream reservoir water conservation, providing flexibility in DCC gate operation to conserve water and limit salinity intrusion, and allowing limited water exports from the Delta for public health and safety needs. The Order was amended several times during the following months, culminating in a September 24 order and October 7 modification that addressed planning for water year 2015.

The SWRCB's September 24 order and October 7 modification of the January 31 order required DWR and Reclamation to develop, in consultation with the fisheries agencies, a water year 2015 drought contingency plan for operations in the Delta and the associated Project reservoirs in the event that water supplies remain inadequate to satisfy the Projects' water right permit and license requirements and other uses. The drought contingency plan was required to identify the biological and other justifications for the plan. In addition, the drought contingency plan was required to identify planned minimum monthly flow and storage conditions that consider Delta salinity control, fishery protection, and supplies for municipal water users related to projected flow and storage conditions using 50, 90, and 99 percent exceedance probabilities for assumed hydrology, and any other information that may be requested by the SWRCB Executive Director or his designee. The plan for the beginning of the water year through January 15, 2015, was submitted to SWRCB on October 15, 2014. The plan for the remainder of the water year after January 15, 2015, was submitted to SWRCB by January 15, 2015, and was to be updated as necessary based on changed circumstances. The Plan for the remainder of the water year specifies the following with respect to EDB:

> In addition to any TUCP provisions requested in the 99% scenario, at any time when the installation of Emergency Drought Barriers (EDB) is deemed to be necessary for water quality and human health and safety water supply needs, the following modification provisions would likely be requested:
>
> EDB (1): Table 2 Western Delta Sacramento River requirement at Emmaton would be requested to be suspended.
>
> EDB (2): The minimum Net Delta Outflow Index (NDOI) described in Figure 3 of D-1641 during the months of June, July, August, and September would be requested to be suspended.
>
> EDB (3): The Table 3 Sacramento River at Rio Vista flow requirements for September would be requested to be suspended.

However, the TUCP request for the period during which the EDB was installed differs from the above (see discussion below).

Interagency 2015 Drought Strategy for the Central Valley Project and State Water Project

The 2015 Drought Strategy was developed by Reclamation, DWR, USFWS, NMFS, and CDFW and was released as a working draft on December 12, 2014. The 2015 Drought Strategy informs stakeholders about the agencies' anticipated drought response efforts. The goals outlined in the 2015 Drought Strategy are to operate the CVP and SWP and take other related actions consistent with the following core principles:

1. Operate the CVP and SWP during the continuing drought to meet essential human health and safety needs and lessen critical economic losses throughout the CVP and SWP service areas from January 15 through November 15, 2015.

2. Control of salt water intrusion in the Delta.

3. Preserve cold water pools in upstream reservoirs for temperature management to maintain cool water temperatures for salmon and steelhead.

4. Maintain adequate protections for state and federally endangered and threatened species and other fish and wildlife resources.

5. Provide an overview of biological monitoring that may be implemented to assist in development of forecasted operations as well as guide daily operations to increase the agencies' ability to support and improve water deliveries while also meeting water quality and species requirements.

6. Highlight other drought-related measures that the federal and state agencies will pursue in 2015.

As noted in the 2015 Drought Strategy, with respect to control of salt water intrusion in the Delta, installation of barriers would be considered. Specifically, the document states:

> Maintaining Salinity Control through Possible Emergency Drought Barriers: Reclamation and DWR's planning assumptions for 2015 include the possibility of installing temporary rock barriers across three Delta waterways to mitigate water quality impacts when there is not enough water in upstream reservoirs to meet other beneficial uses and repel the saltwater. The three barriers would be constructed at Sutter Slough[2], Steamboat Slough and West False River. Releases from Shasta, Folsom, Oroville and other reservoirs to provide sufficient Delta outflow to repel saltwater and protect Delta water quality could be reduced with the temporary barriers

[2] The Interagency 2015 Drought Strategy was written when barriers in Sutter and Steamboat sloughs also were considered in addition to the EDB.

in place. If the barriers are determined to be necessary, DWR would complete installation within 30-60 days, delaying construction as long as possible to minimize effects on fish. In the event barriers are installed, barrier-associated biological and physical monitoring will be initiated in a timely fashion, in some cases in advance of barrier installation. Additionally, adjustments to D-1641 will need to occur.

TUCP Modifications

On January 23, 2015, DWR and Reclamation jointly filed a new TUCP to temporarily modify requirements in their water right permits and license for the SWP and CVP for the next 180 days, with specific requests for February and March of 2015. In response, on February 3, 2015, the SWRCB issued an order for February and March modifying minimum monthly Delta outflows to 4,000 cfs; modifying minimum monthly San Joaquin River flows at Vernalis to 500 cfs; allowing the DCC gates to be opened consistent with triggers to protect fish species; adding export constraints to allow exports of 1,500 cfs when Delta outflows are below 7,100 cfs regardless of DCC gate status; and allowing exports up to D-1641 limits when Delta outflows are above 7,100 cfs and the DCC gates are closed. The order was modified on March 5, 2015, to address several concerns, namely to specify that the conserved water from the modifications approved in the February 3 order should be used in accordance with DWR and Reclamation's 2015 Drought Contingency Plan and Temperature Management Plan for the Sacramento River; to clarify that water transfers are not constrained by the export limits in the Order; and to modify the maximum export limits established in the February 3 order. The modification of export limits were specified for limited circumstances: when Delta outflow is between 5,500 cfs and 7,100 cfs, the DCC gates are closed, and DWR or Reclamation determines that additional water is necessary to meet minimum public health and safety needs, exports can be increased from 1,500 cfs up to 3,500 cfs, after notifying the SWRCB Executive Director and describing the timing and amount of the increase, the beneficiaries of the increase and the purpose of use of the water.

DWR and Reclamation submitted a TUCP on March 24, 2015 to request modifications to D-1641 through the end of September. On April 6, 2015, the SWRCB Executive Director approved an Order that modified various conditions of D-1641 through the end of June; among the conditions in that order was the need to have a Net Delta Outflow Index of 4,000 cfs. DWR and Reclamation had requested additional modifications beyond June (e.g., a Net Delta Outflow Index of 3,000 cfs in July, August, and September).

On May 21, 2015, DWR and Reclamation submitted a TUCP that sought to modify D-1641 requirements for July through November to allow management of reservoir releases on a pattern that conserves upstream storage for fish and wildlife protection and Delta salinity control while providing critical water needs. In response to the TUCP, a modified and renewed Order was issued on July 3, 2015, by the SWRCB Executive Director. The USFWS, NMFS, and CDFW provided consultation on the TUCP and current water operations are consistent with their findings.

The July 3, 2015 Order approved the following changes to D-1641 requirements, subject to conditions: 1) For July, to reduce the minimum Delta outflow from a monthly average of 4,000 cubic feet per second (cfs), with a seven-day running average of no less than 3,000 cfs, to a monthly average of 3,000 cfs, with a seven-day running average of no less than 2,000 cfs; 2) To reduce the minimum Sacramento River flow requirements at Rio Vista from a monthly average of 3,000 cfs in September and October, and 3,500 cfs in November, to a monthly average of 2,500 cfs for all three months, with a seven-day running average of no less than 2,000 cfs; and 3) To extend through August 15 the change of the compliance point for the Western Delta agricultural salinity requirement from Emmaton on the Sacramento River to Threemile Slough on the Sacramento River.

The July 3, 2015 Order continued export constraints when the above requirements were not being met. In addition, the Order continued and modified consultation, monitoring, modeling, reporting, and planning requirements included in the April 6 Order. Specifically, this Order imposed additional consultation, monitoring, modeling, reporting and planning requirements, among which was to better understand the effects of reduced Delta outflows with the 2015 EDB in place.

Effects Assessment

This section describes the potential effects of implementing the proposed WFRSB on the species and habitats listed in Table 1. The assessment is divided into Construction and Removal Effects on Fish and Operations Effects on Fish. 'Operations' are understood to mean the effects of the barrier following closure. The assessment includes observed data from 2015's EDB installation. As noted in the Introduction to this BA, it is considered that the 2015 implementation of the EDB is suitably similar to the future implementation of the proposed WFRSB so that the data collected in 2015 are representative of the conditions that could occur with the proposed WFRSB implementation, which is the subject of this BA. This assessment does not include consideration of broad-scale, Delta-wide effects during summer/fall (e.g., on salinity and the distribution of the low-salinity zone) that are contingent on system-wide SWP/CVP operations because such an assessment can be reasonably anticipated to occur as part of TUCP modification petitions for Bay-Delta standards contained in D-1641 (see Murillo and Cowin 2015 for an example from 2015).

Construction and Removal Effects on Fish

In-Water Construction Activity Timeline

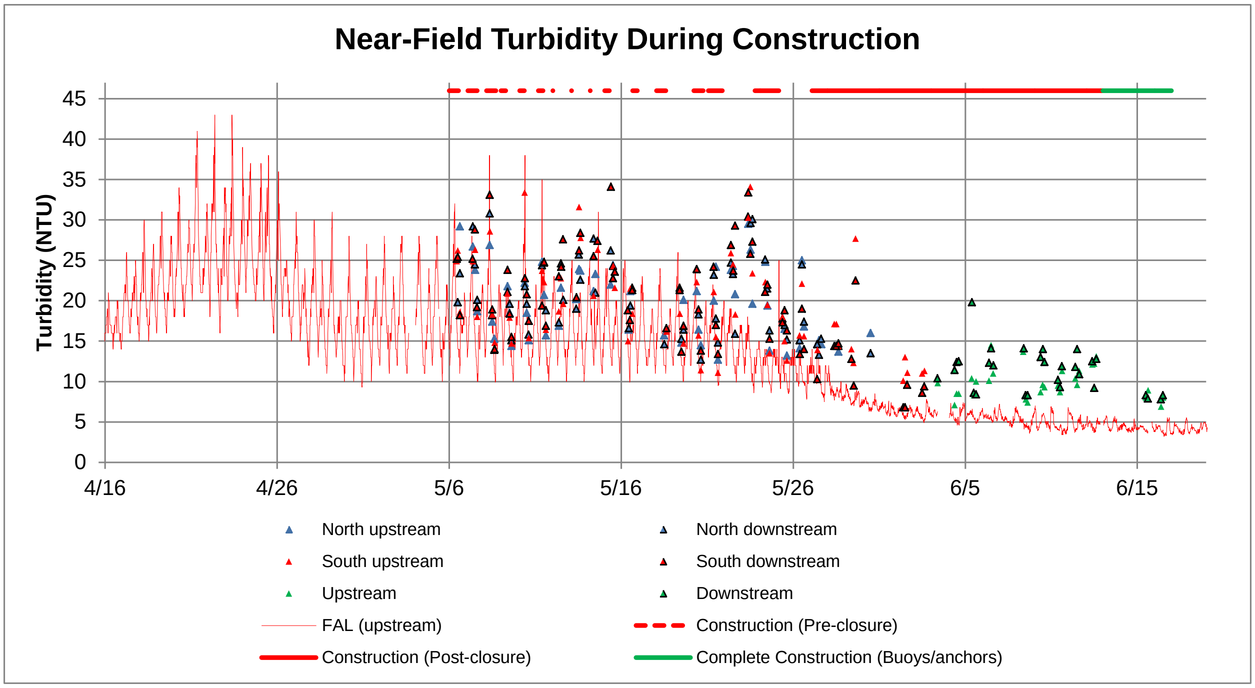
In 2015, in-water construction work (principally rock placement) at the EDB commenced on May 6, 2015, with barrier closure on May 28 and completion of rock placement on June 12. In-water construction was completed on June 16 following installation of float lines and warning signs near the barrier. This duration of in-water work (41 days) is representative of the in-water construction activity that would occur during the 2016 implementation of the proposed WFRSB.

Sediment Disturbance and Turbidity

Rock placement in the river channel has the potential to increase turbulence and turbidity in the water column. In turn, increased turbidity associated with construction has the potential to negatively impact juvenile fishes temporarily through reduced availability of food, reduced feeding efficiency, and exposure to toxic sediment released into the water column. However, for juvenile delta smelt in particluar, is it postulated that increased turbidty provides greater forage and capture rates and also increased protection from predators. In 2015, discrete turbidity data were collected in the vicinity of the construction while in-water work was occurring, generally three times per day (morning [around 09:00]; mid-day [around 12:00]; and afternoon [around 15:00]) on the upstream and downstream sides of the barrier footprint. From May 6 to June 2 the data were collected on the north and south sides of the channel, depending on the work that was being undertaken; from June 3 until in-water work ceased on June 16, the data were collected in various locations near the barrier.

The monitoring data from 2015 suggested that there were relatively minor increases in turbidity during construction and that the increases were limited to near the barrier. All measurements were well below the 150 NTU specified in the Conservation Measures based on the Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins (Central Valley Regional Water Quality Control Board 2011). Prior to barrier closure, mean turbidity from the discrete measurements was 20.6 NTU (range (10.3 to 34.3 NTU), which compared to 15.4 NTU (range 7.5 to 38 NTU) at the nearby FAL continuous turbidity monitor (Figure 5). Following barrier closure and during continued rock placement until June 12, mean turbidity from the discrete measurements was 11.8 NTU (range 6.8 to 27.7 NTU), which compared to 6.0 NTU (range 3.4 to 12 NTU) at the FAL continuous monitor. This illustrates the appreciable reduction in turbidity at FAL because of the barrier reducing tidal flow and velocity in the False River channel, although the turbidity at the Jersey Point station was also decreasing in the month of May (see below). During the last phase of in-water work following rock placement (i.e., placement of buoys and anchors), mean turbidity from discrete measurements was 8.0 NTU (range 6.9 to 8.9 NTU), which compared to 4.3 NTU (range 3.2 to 5.8 NTU) at FAL (Figure 5).

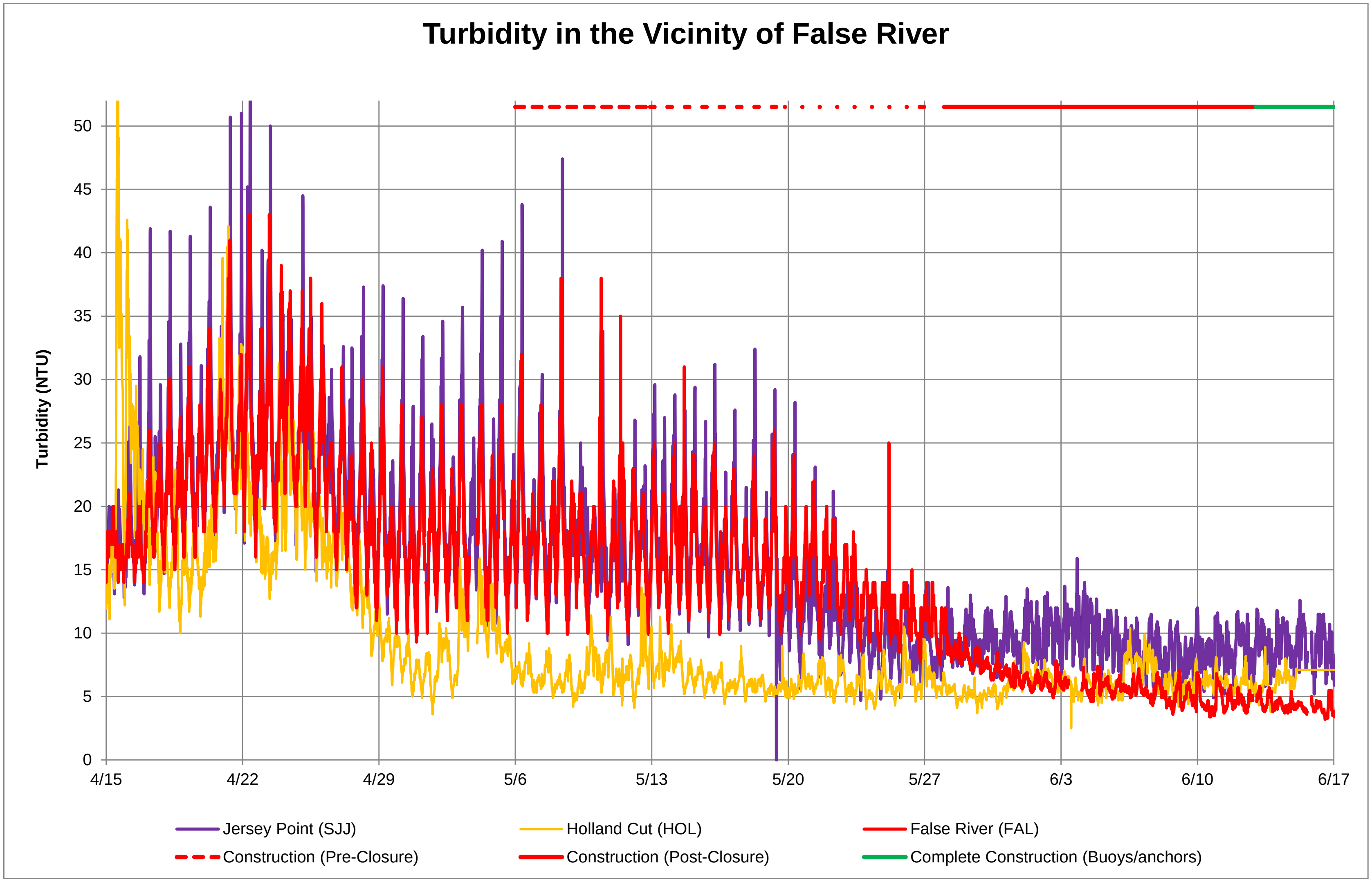
Turbidity data from channels in the vicinity of False River and Franks Tract confirm that EDB construction activities (e.g., rock placement) in 2015 likely had negligible effects beyond the immediate vicinity of the construction site; however, the turbidity data also indicate that the hydrodynamic changes caused by barrier closure had appreciable effects on turbidity in some adjacent channels. False River (FAL) turbidity was very similar to Jersey Point (SJJ) turbidity prior to barrier closure (May 28); the turbidity fluctuated tidally with highest turbidity at the end of flood-tide, because the turbidity was generally highest downstream of Jersey Point (Figure 6). The turbidity at Jersey Point and False River was 15-20 NTU on April 15, and both stations increased to 20-40 NTU from April 18 to April 24 (prior to construction). Turbidity stabilized at about 10-20 NTU from April 28-May 20, including the period after rock placement began. Turbidity at Jersey Point and False River decreased to about 10 NTU during the week prior to closure (May 28), and False River turbidity decreased to about 5 NTU while the Jersey Point turbidity remained about 10 NTU after barrier closure. The turbidity in Holland Cut (a dredged channel parallel to Old River, on the southeast side of Franks Tract) was similar to the Jersey Point and False River turbidity in April, decreased to 5-10 NTU at the end of April (prior to construction) and remained at about 5 NTU throughout construction. Although there were changes in turbidity prior to construction of the EDB, these is no indication that turbidity was substantially increased by the construction activities.



Source: Karcher, pers. comm; California Data Exchange Center, cdec.water.ca.gov. Notes: Discrete turbidity measurements were collected upstream and downstream of the barrier during construction. The horizontal lines above the graph indicate the construction period, and are split into pre-closure (including rock placement and other in-water activities such as pile-driving), post-closure (with continued rock placement), and completion of construction (no rock placement, only placement of buoys and anchors for boater warning signs).

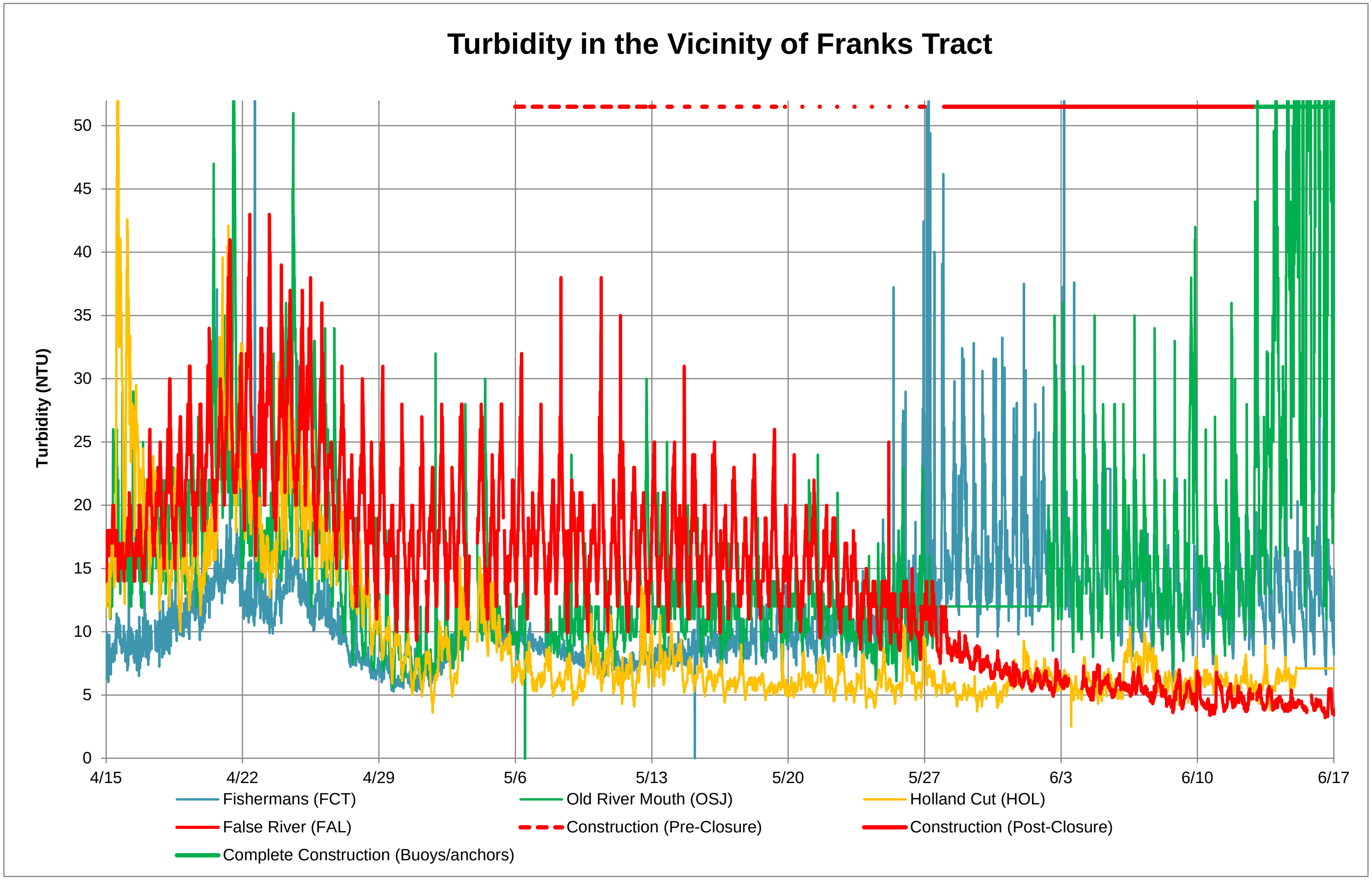
Figure 5. Turbidity at the EDB Construction Site and the Nearby False River (FAL) Continuous Monitoring Site, April 16 to June 16, 2015.

Prior to barrier construction in 2015, turbidity in Fishermans Cut (FCT) and at the mouth of Old River (OSJ) generally was similar to or lower than turbidity in False River (FAL) and Holland Cut (HOL), and was quite variable during April at all of these sites (Figure 7). Turbidity during construction prior to barrier closure (May 6 to May 27) was tidally variable but generally less variable at Fishermans Cut, Old River mouth, and Holland Cut than at False River. As previously noted, following barrier closure turbidity fell considerably to around 5 NTU in False River, whereas there was little difference in turbidity at Holland Cut (Figure 6). In contrast, turbidity increased substantially in Fishermans Cut and Old River mouth as the barrier was closed, in response to much greater tidal flow that otherwise would have entered False River. The turbidity fluctuated tidally with highest turbidity at the end of flood and ebb tides (from sustained higher velocities). The turbidity in Fishermans Cut and Old River mouth after barrier closure was 10-30 NTU, similar or slightly greater than the Jersey Point and False River turbidities in late April and May, prior to barrier closure. However, the turbidity in Fishermans Cut and Old River mouth was higher than the Jersey Point turbidity after closure, suggesting that the high turbidity was from local scour/ resuspension rather than tidal transport upstream in the San Joaquin River.



Source: California Data Exchange Center, cdec.water.ca.gov. Notes: The horizontal lines above the graph indicate the construction period, and are split into pre-closure (including rock placement and other in-water activities such as pile-driving), post-closure (with continued rock placement), and completion of construction (no rock placement, only placement of buoys and anchors for boater warning signs).

Figure 6. Turbidity in the Vicinity of False River, April 16 to June 16, 2015.



Source: California Data Exchange Center, cdec.water.ca.gov. Notes: The horizontal lines above the graph indicate the construction period, and are split into pre-closure (including rock placement and other in-water activities such as pile-driving), post-closure (with continued rock placement), and completion of construction (no rock placement, only placement of buoys and anchors for boater warning signs).

Figure 7. Turbidity in the Vicinity of Franks Tract, April 16 to June 16, 2015.

Overall, the potential effects of increased turbidity and suspended sediment from construction (rock placement and other in-water work) in 2015 were concluded to have been limited because they were temporary and did not appear to extend far beyond the construction area (ICF International 2015). It is anticipated that similar effects would occur during the proposed WFRSB. In 2015, closure of the EDB caused turbidity in Fisherman's Cut and in Old River at the mouth to increase substantially because of increased tidal flows (velocity) in these channels; this is discussed further in the analysis of Operations Effects on Fish (Water Quality Effects on delta smelt).

Underwater Noise and Disturbance

General Noise and Disturbance

As occurred in 2015, most materials needed for the construction of the WFRSB would be brought to the site by barge; land-based activities such as bringing materials to the site by truck would be less likely to generate noise that could potentially disturb fish in the immediate area than in-channel activities. The placement of rock below the waterline also would generate noise and create a physical disturbance that may harass, injur, kill or displace listed fishes.

Disturbance of the False River channel habitat could startle fish and make them attempt to leave the area, possibly making them more susceptible to predation. In 2015, California sea lions were observed many times during construction, sometimes close to working equipment (e.g., clam-shell dredges placing rocks) without apparently being deterred (Table 13). The sea lions may have been taking advantage of startled fish that were avoiding construction activities, and were observed to have caught fish prey on three occasions, two of which were unidentified bass species.

Displaced fish may be slightly more prone to predation in areas away from the zone of disturbance because of water levels being lower because of drought (low outflow) conditions. However, this is likely to be a very small effect because of the tidal environment near the construction area. Data for 2015 from the False River (FAL) CDEC station indicate that the median stage during the main in-water construction period (May 6 to June 12, when rock placement ceased) was 17.0 ft (range 15.0 to 19.0 ft); in comparison, the median stage during a recent high-flow year (2011) during the May 6 to June 12 period was 17.3 ft (range 15.1 to 20.0 ft). The difference in stage over the 90th percentile of observations was around 0.3 ft or less (Table 14). The much higher Delta inflow in 2011 raised the average water elevation by about 0.3 feet, while the tidal variation in elevation remained about 4-5 feet.

Table 13. Observations of Potential Predators of Listed Fishes During Construction Monitoring at the Emergency Drough Barrier Site, May 5 to June 16, 2015.

Date	Time	Location	Species	Number	Observations
5/5/2015[§]	13:10*	NA	California sea lion	1	Observed twice in the channel
5/7/2015	10:45	North	California sea lion	3	Seen near barge; not seen again for 40 minutes (unknown where they went); apparently undeterred by or afraid of equipment
5/7/2015	13:00*	NA	California sea lion	NA	NA
5/8/2015	8:30	NA	California sea lion	NA	NA
5/10/2015	6:45	North	California sea lion	1	Seen within 50m of barge, swimming west out of project site, prior to start of day's work
5/10/2015	11:05	Mid-channel	California sea lion	1	Young male; playing with bass above barrier footprint, between two active cranes placing rock; behavior unaffected during sheet pile driving on south side
5/12/2015	8:00	Mid-channel	California sea lion	1	Breached at least 5 times on west side of barrier
5/12/2015	10:45	Mid-channel	California sea lion	1	Bull with bass
5/14/2015	5:15*	NA	California sea lion	NA	
5/16/2015	5:15*	NA	California sea lion	NA	
5/17/2015	11:20	South	California sea lion	1	Approached floating wooden dock at king piles, then moved away
5/18/2015	12:40*	NA	California sea lion	NA	
5/19/2015	9:00	North	seal	1	Adult
5/19/2015	11:00	NA	seal	2	Adults; downstream of project area near rock storage barges
5/21/2015	15:00	North	California sea lion	1	Large fish in mouth
5/23/2015	17:40	NA	California sea lion	1	
5/25/2015	13:00*	NA	California sea lion	NA	
5/26/2015	11:00	NA	California sea lion	1	Small female; swimming downstream, visibly fighting stronger current caused by barrier, was pushed back several times before no longer being seen after several minutes
5/26/2015	13:30	NA	California sea lion	1	Swimming upstream of barrier
5/27/2015	5:35*	NA	California sea lion	1	
5/27/2015	19:45	NA	California sea lion	1	Upstream of barrier
5/28/2015	14:00	NA	California sea lion	1	Upstream of barrier
5/28/2015	19:00		California sea lion	1	Upstream of barrier

Date	Time	Location	Species	Number	Observations
6/1/2015	11:29	NA	California sea lion	1	Young individual approached barrier on upstream side (seen multiple times throughout day)
6/1/2015	14:32	NA	California sea lion	NA	Multiple approaches of sea lions throughout the day; most appeared small/female
6/1/2015	15:41	NA	Caspian tern	1	Fishing along barrier on downstream side; diving several feet down; prey fully inside beak, not visible; continued foraging until end of work day
6/3/2015	15:00	NA	California sea lion	1	
6/3/2015	15:30	NA	California sea lion	1	
6/4/2015	11:00	NA	striped bass	1	Dead; observed floating ~1/4 mile upstream of barrier
6/5/2015	5:15*	NA	river otter	NA	Signs of presence; not directly observed
6/6/2015	8:38	NA	California sea lion	1	Small male; performed full back flip near buoy line

Notes: §Work on May 5 was preparation for the start of in-water work on May 6.*Time at start of monitoring session. NA = Data not recorded.
Source: Marquez, pers. comm.

Table 14. False River (FAL) Stage Percentiles (Elevation, feet) During May 6 to June 12 in 2011 and 2015.

Percentile	2011	2015	Difference (2015 minus 2011)
0	15.1	15.0	-0.1
10	15.9	15.9	0.0
20	16.4	16.3	-0.1
30	16.8	16.6	-0.2
40	17.1	16.9	-0.2
50	17.3	17.1	-0.2
60	17.6	17.3	-0.2
70	17.8	17.6	-0.2
80	18.1	17.8	-0.3
90	18.5	18.2	-0.3
100	20.0	19.0	-1.0

Note: Reported stage data are 10 feet above the NAVD elevation
Source: http://cdec.water.ca.gov/cgi-progs/queryF?FAL. Accessed: May 12, 2015.

Pile Driving

Pile driving would be used in the construction of the WFRSB abutments. High levels of underwater noise from pile driving can adversely affect some fish species,[3] as discussed by NMFS and others (Hastings and Popper 2005; Popper et al. 2006; Carlson et al. 2007; NMFS 2008a). Based on the EDB installation in 2015, the sheet pile walls and king piles forming the abutments at the WFRSB would be installed solely with vibratory hammers; impact driving is likely to be unnecessary. Vibratory hammers are generally much quieter than impact hammers and are routinely used on smaller piles (ICF Jones & Stokes and Illingworth & Rodkin 2009). In comparison to impact pile driving, vibratory pile driving is acknowledged to minimize the amount of noise and turbidity and to substantially reduce or avoid the potential to cause take of listed species (USFWS 2015). Fish impacts from exposure to pile driving activities were reviewed by Hastings and Popper (2005), and they provided recommendations to protect fish from physical injury (see also Popper et al. 2006; Carlson et al. 2007). In 2008 NMFS, USFWS and DFG adopted interim criteria of a peak sound pressure level of 206 decibels (dB) referenced to 1 µPascal per second and a cumulative sound exposure level (SEL) of 187 dB referenced to 1µPascal per second for fish greater than or equal to 2 grams in weight and 183 dB referenced to 1µPascal per second for fish less than 2 grams in weight (Fisheries Hydroacoustic Working Group 2008, ICF Jones & Stokes and Illingworth & Rodkin 2009).

[3] Three metrics are commonly used in evaluating hydroacoustic impacts on fish: peak sound pressure level, root mean square (RMS) sound pressure, and sound exposure level (SEL) (ICF Jones & Stokes and Illingworth & Rodkin 2009). SEL is defined as the constant sound level acting for one second, which has the same amount of acoustic energy as the original sound (Hastings and Popper 2005). Reference sound levels from pile driving normally are reported at a fixed distance of 10 meters. Underwater peak and RMS decibel levels are usually referenced to 1 micropascal (µPa), and the SEL is referenced to 1 micropascal squared per second (dB re: 1μPa^2-s) (Hastings and Popper 2005).

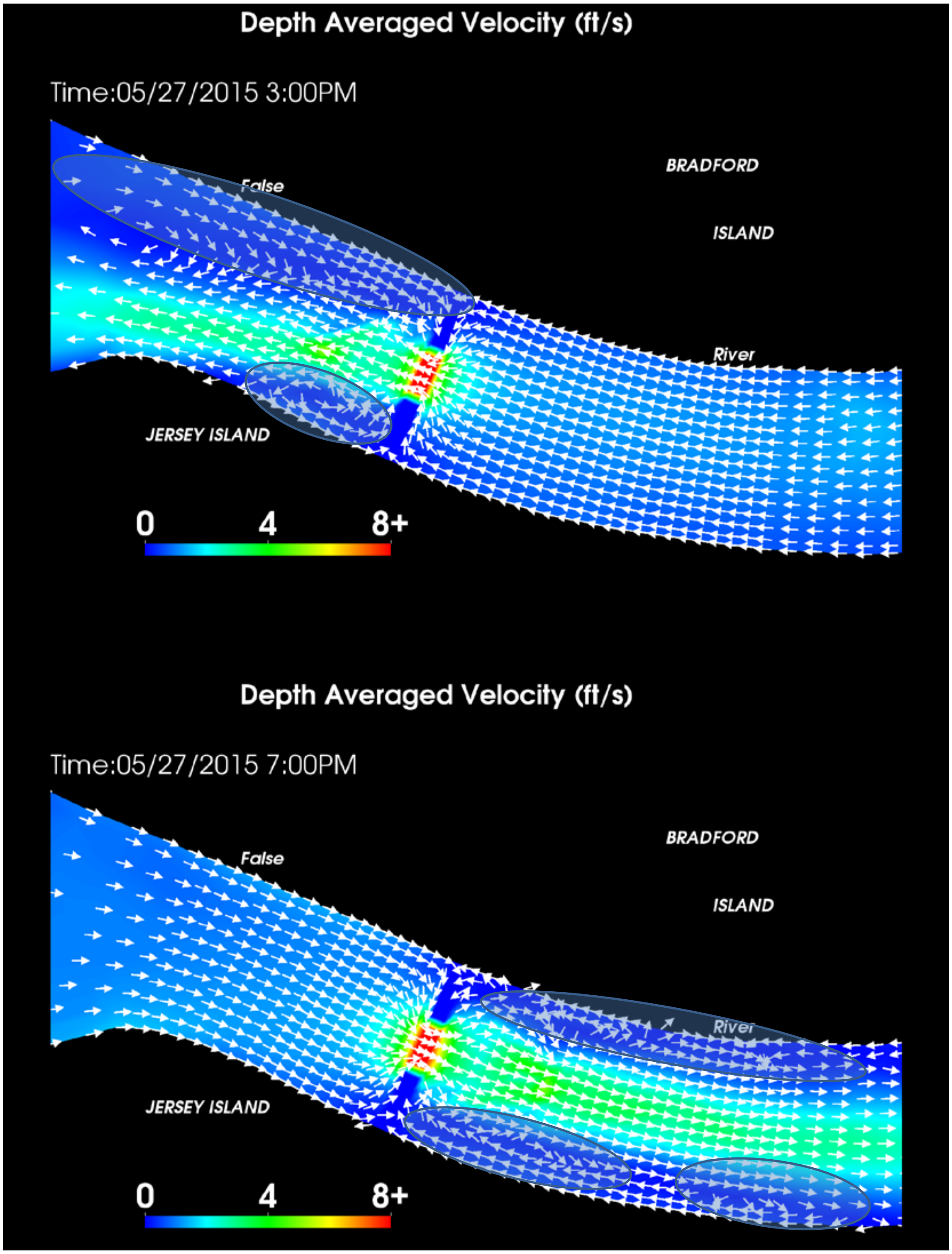
In 2015, in-water pile driving with a vibratory hammer at the EDB site occurred over May 14 to May 22 to install the two sheet pile walls and associated eight king piles forming the barrier abutments. Sound monitoring was conducted on all days that in-water pile driving was scheduled, although on some days pile driving was occurring at both abutments simultaneously and so it was not possible to monitor both locations at once. The total driving time for each pile driving session that was monitored for sound is shown in Table A1 in Appendix A. Exceedance of the 187-dB cumulative SEL threshold for impact driving on May 15 led to a several-hour delay in pile driving before clarification from the NOAA Fisheries California Fish Hydroacoustics Coordinator that the various sound threshold criteria are specific only to impulsive sound sources (i.e., impact hammers) and are not for application to vibratory hammers (Pearson-Meyer, pers. comm.). There are no criteria accepted by the fishery agencies to assess the area affected by vibratory driving; however, Hastings' (2010) proposed thresholds were used in the present Effects Assessment to inform a quantitative analysis (see Appendix A).

A detailed analysis of the potential pile driving effects during construction is presented in Appendix A, based on data from 2015. The data gathered in 2015 are considered representative of the potential effects that could occur during the installation of the WFRSB that is the subject of this BA. Pile driving at the barrier abutments (king piles and sheet piles) in 2015 was undertaken on 8 days from May 14 to May 22 (Table A1 in Appendix A). Noise monitoring data indicate that the total duration spent pile driving on each day ranged from just under an hour on May 14 (king piles, south side) to around 4.5 hours on May 20 (sheet piles, north side); as noted previously, on some days the duration of time spent pile driving was greater than could be monitored because of simultaneous driving at both abutments. The analysis presented in Appendix A calculated distances away from the pile driving to which the proposed non-auditory tissue injury thresholds of Hastings (2010) would have extended, based on daily cumulative SEL, for several species/sizes of listed fish included in this BA. For larval delta smelt, the mean distance affected was 79.9 m (range 4.2 to 171.0 m), or approximately262 feet (range 14 to 560 feet) (see Table A1 in Appendix A). For adult delta smelt, the mean distance affected was 7.0 m (range 0.4 to 14.9 m), or approximately23 feet (range 1 to 49 feet). For juvenile Chinook salmon, the mean distance affected was 2.3 m (range 0.1 to 2.3 m), or approximately 8 feet (range 0 to 16 feet). For juvenile/adult steelhead and adult Chinook salmon, the mean distance affected was 0.11 m (range 0.0 to 0.2 m), or well below one foot (see Table A1 in Appendix A). On the days when pile driving was occurring simultaneously at both abutments, a greater area would have been affected than estimated from the monitoring data that were limited to one abutment.

Anticipated responses of any fish within the work area affected by the noise of pile driving (and other in-water work, such as rock placement) were more likely to be have been behavioral in nature (e.g., startle response and avoidance) as opposed to direct injury, with these effects diminishing with distance from the construction site. Hastings and Popper (2005) concluded that data are lacking on behavioral responses to pile driving, such as a startle response to noise or movement away from highly utilized habitats impacted by sound. Carlson et al. (2001) reported migrating juvenile salmon reacting with startle behavior in response to routine channel maintenance activities in the Columbia River. Some of the fish that did not immediately recover from the disorientation of turbidity and noise from channel dredges and pile driving swam directly into the point of contact with predators.

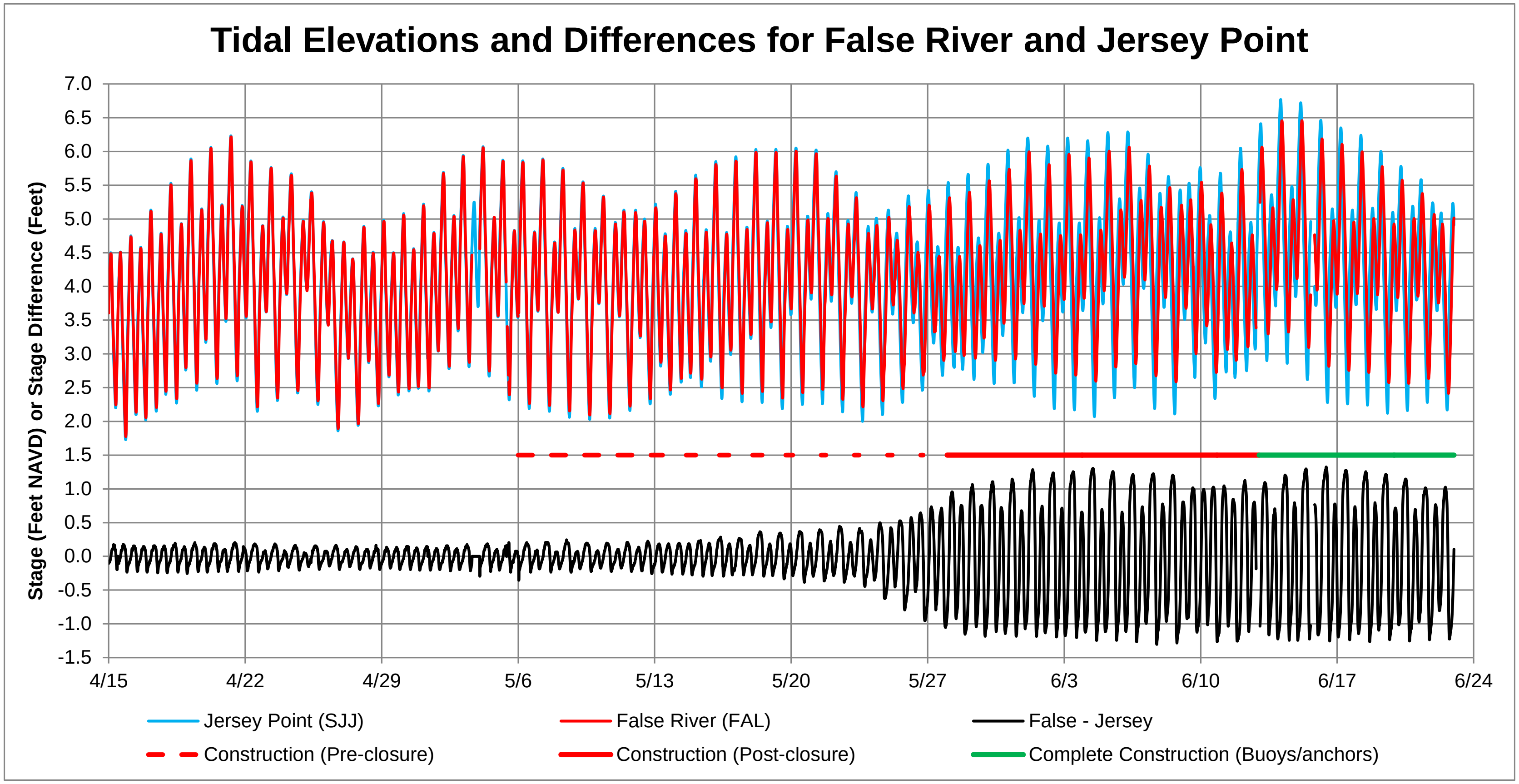
Hydrodynamic Effects

As WFRSB construction proceeds and the amount of rock placed in the False River channel increases, the barrier's in-water structure would have increasing effects on hydrodynamics in False River, as observed in 2015. Hydrodynamic modeling of the barrier illustrates that after partial placement of rocks, but prior to barrier closure, the velocity through the unclosed portion of the barrier on flood and ebb tides would be very high (Figure 8). With the progession of barrier construction, the tidal flows in False River would be gradually reduced, but the water surface elevation differences (i.e., water head) across the barrier would increase, because flood-tide flows moving upstream in the SJR to the mouth of Old River and into Franks Tract would be delayed by 1-2 hours. A similar delay in the ebb-tide flows would create a larger water head across the barrier opening. The larger heads would create much faster velocities through the remaining barrier opening, up to ~15 ft/sec in the hydrodynamic modeling simulation (Figure 8). Note, however, that such high velocity would affect the ability to effectively place the sizes of rock used for construction, but no such difficulties were actually experienced during construction in 2015; this suggests that the simulation may have overestimated the velocity through the barrier, and the resulting hydrodynamic effects. Regardless, small fish that are entrained through this portion of the barrier could become disoriented and susceptible to predation when transitioning to slower waters beyond the barrier, analogous to other locations in the Delta with fish passing in-water structures involving turbulent flow, such as Clifton Court Forebay radial gates (Vogel 2011) and Woodbridge Irrigation District Diversion Dam (Sabal 2014). The hydrodynamic modeling also suggests that flow through the barrier before closure would create several hydrodynamic eddies in the False River channel (see transparent polygons in Figure 8). Small fish being entrained into these eddies may be more susceptible to predation because of the potential for increased duration of exposure to predators in the channel. Without the barrier, flow streaklines in this area would be straighter and more uniform (Ateljevich pers. comm.). Hydrodynamic effects such as those illustrated in Figure 8 would occur as barrier closure nears; the tidal data from 2015 indicate a head across the barrier developed in the last week of construction before closure (May 21 to May 28). Figure 9 shows the comparison of the SJR at Jersey Point (SJJ) stage and the False River (FAL) stage for the April 15-June 23 period in 2015. The tidal elevations were nearly identical until the week prior to barrier closure on May 28.



Source: Ateljevich, pers. comm. Notes: Upper panel: ebb tide of 17,000 cfs at FAL gauge, May 27, 3:00 PM. Lower panel: flood tide of 19,000 cfs at FAL gauge, May 27, 7:00 PM. The middle (open) section of the barrier was assumed to be -8 ft NAVD, whereas the remaining (closed) section of the barrier was assumed to be 9.8 ft NAVD; the riverbed in the vicinity of the barrier is -22 ft NAVD. The assumed width of the notch was ~160 feet, and the water elevation was about 3 ft NAVD, so the water depth through the notch was about 12 feet. Hydrodynamic eddies developed on both sides of the channel, upstream and downstream of the barrier (highlighted with transparent polygons).

Figure 8. Depth-Averaged Velocity and Flowlines in False River Prior to Full Barrier Closure, as Simulated with the SCHISM 3-Dimensional Model.



Source: California Data Exchange Center (cdec.water.ca.gov). Notes: The stage data for FAL had 10 feet subtracted to account for the datum elevation and 2.375 feet subtracted to adjust for the vertical datum corresponding to National Geodetic Vertical Datum of 1929 (http://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl) and 0.54 feet subtracted for the datum offset from NAVD (estimated from mean elevations at False River compared to Jersey Point) . The horizontal lines at 1.5 feet indicate the construction period, and are split into pre-closure (including rock placement and other in-water activities such as pile-driving), post-closure (with continued rock placement), and completion of construction (no rock placement, only placement of buoys and anchors for boater warning signs).

Figure 9. Tidal Elevation (Stage) and Differences at False River (CDEC Station FAL) and San Joaquin River at Jersey Point (CDEC Station, SJJ), April 15 to June 23, 2015.

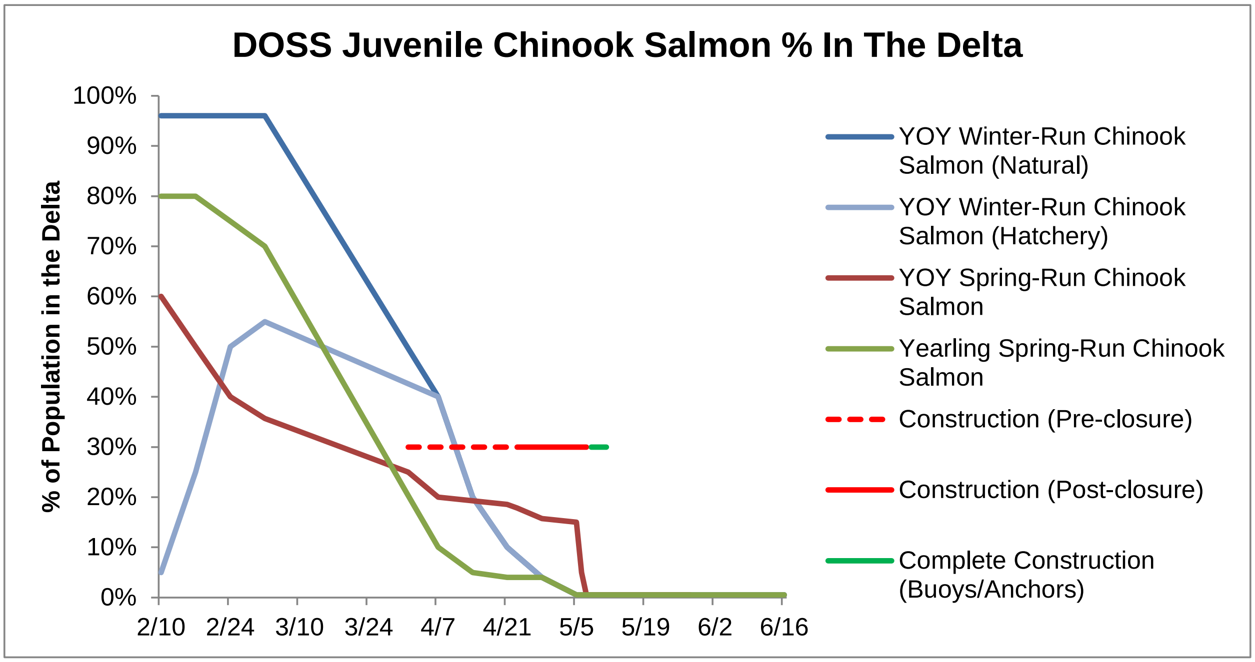
Barrier Removal Effects

Removal of the WFRSB could result in some of the same effects evident during construction. Rock excavation has the potential to result in sediment disturbance and turbidity in the channel, although based on the observations during construction, the effects may be localized to relatively near the barrier. Underwater noise is likely to be less during removal than during construction because rock would be removed with clamshell buckets (resulting in some impact and scraping noises) as opposed to being dropped into the channel. It is anticipated that cutting of the sheet pile/king pile abutments by divers would result in minimal disturbance. Because the barrier rocks would be removed starting from the center of the channel and working outward, with rocks removed from the top of the barrier to the streambed at each portion of the barrier, similar hydrodynamic effects resulting in greater predation on small fish could occur as were possible during barrier construction (Figure 8).

Effects on Chinook Salmon and Central Valley Steelhead

As noted in the Environmental Baseline description, historic data suggest that varying proportions of the juvenile populations of Central Valley spring-run and Sacramento River winter-run Chinook salmon and Central Valley steelhead would overlap with the proposed WFRSB construction (starting in early April), operation (April/May-October) and removal (September/October/November) periods (Table 11). The 2015 implementation of the EDB provides a useful assessment of the extent of overlap that could occur during implementation of the WFRSB. Monitoring data for 2015 that were collated by the Delta Operations for Salmonids and Sturgeon (DOSS) Group suggested that there would have been a greater degree of temporal overlap of listed salmonids with barrier construction in 2015, had construction begun on April 1 (as may occur under the implementation of the WFRSB that is the subject of this BA). For juvenile winter-run Chinook salmon, over 50% of young-of-the-year natural-origin fish and over 40% of hatchery-origin fish were, based on DOSS's estimation, present in the Delta around April 1 (Figure 10). By the time of barrier closure, around 3 weeks later, less than 10% of both natural-origin and hatchery-origin juvenile winter-run Chinook salmon would have left the Delta, with the percentage having decreased to essentially zero by the end of in-water work, again, assuming a similar duration of work as occurred in 2015 (Figure 10). For juvenile spring-run Chinook salmon, the start of construction on April 1 would have temporally overlapped the Delta occurrence of around 25% of young-of-the-year fish and 20% of yearling fish, based on DOSS's estimation, which would have decreased to less than 20% (young-of-the-year) and less than 5% (yearling) by the time of barrier closure, before diminishing to essentially zero by the end of in-water work. These patterns are considered to be representative of the potential extent of overlap for the proposed WFRSB implementation that is the subject of this BA.

DOSS has limited data with which to estimate the percentage of natural-origin steelhead from the Sacramento River watershed in the Delta. Historic data for Sacramento River watershed juvenile steelhead suggest that most individuals would be expected to leave the Delta well before the earliest date (April 1) that construction could commence (Table 11); however, this may reflect the earlier timing of hatchery-origin steelhead because Nobriga and Cadrett (2001) showed occurrence of natural-origin individuals into May and June (see Table 8). South Delta export facility salvage data for unclipped (natural-origin) juvenile steelhead in 2015 showed that most individuals were salvaged in February and April, although to some extent this reflected higher levels of Delta exports (Table 15).



Source: http://www.westcoast.fisheries.noaa.gov/central_valley/water_operations/ocapwy2015.html, accessed May 29, June 3, June 9, and September 9. 2015. Note: Values from DOSS were interpreted as follows: >99% out of Delta = 0.5% in Delta; <5% in Delta = 4% in Delta. Where DOSS gave ranges, the midpoint of the range was used. Values for dates when DOSS did not meet were interpolated from preceding and succeeding data.

Figure 10. Percentage of Juvenile Winter-Run and Spring-Run Chinook Salmon in the Delta during EDB Construction, February-June 2015, as Estimated by the Delta Operations for Salmonids and Sturgeon (DOSS) Group, with Horizontal Lines Indicating a Potential Construction Timeline Beginning April 1 that is Based on the 2015 Construction Timeline.

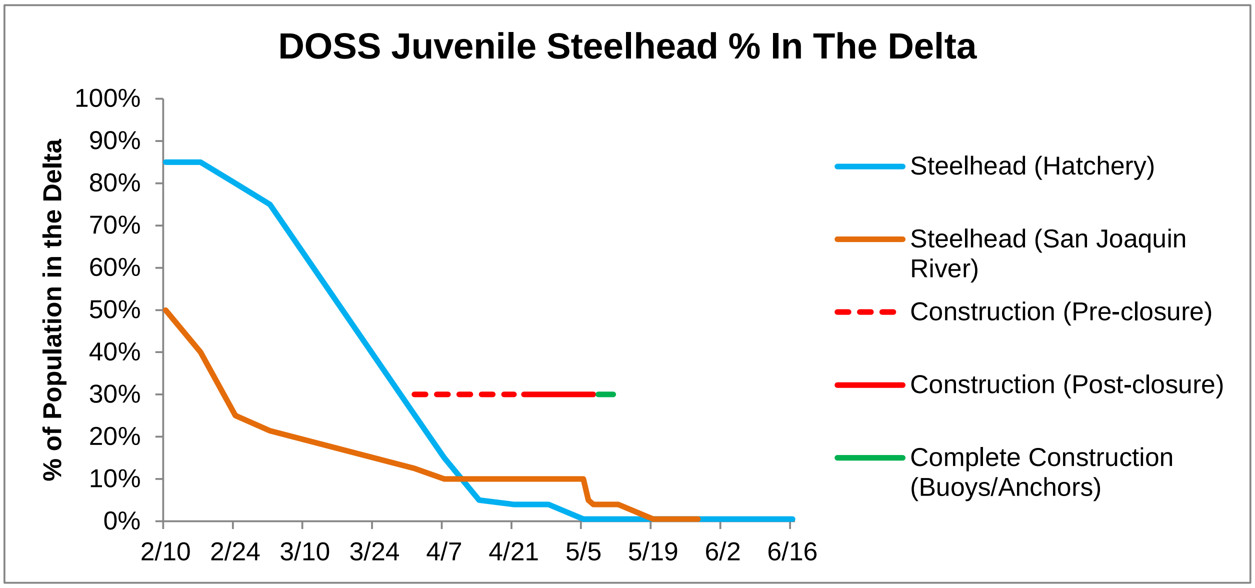
Table 15. Salvage of Unclipped (Natural-Origin) Juvenile Steelhead at the South Delta Export Facilities, January to June 2015.

Month	State Water Project		Central Valley Project	
	Number Salvaged	Exports (Acre Feet)	Number Salvaged	Exports (Acre Feet)
January	0	238,160	0	76,956
February	18	220,853	0	55,580
March	0	72,424	0	104,410
April	13	30,273	4	56,115
May	0	16,057	4	62,399
June*	0	13,938	0	17,554

Note: *Includes data up to 23 June.

Source: http://www.usbr.gov/mp/cvo/fishrpt.html and http://www.usbr.gov/mp/cvo/vungvari/steelheaddly.pdf. Accessed: June 24, 2015.

In 2015, over 20% of hatchery-origin juvenile steelhead were estimated by DOSS to have been in the Delta around April 1, which is the earliest proposed starting date for the WFRSB; based on historic patterns, DOSS estimated that just over 10% of juvenile steelhead from the San Joaquin River watershed would have occurred in the Delta at the commencement of construction, with around 10% occurring at the time of barrier closure, based on a similar construction timeline to that which occurred in 2015 (Figure 11). This is considered to be representative of the extent of temporal overlap for the proposed WFRSB implementation that is the subject of this BA.



Source: http://www.westcoast.fisheries.noaa.gov/central_valley/water_operations/ocapwy2015.html, accessed May 29, June 3, June 9, and September 9, 2015. Note: Values from DOSS were interpreted as follows: >99% out of Delta = 0.5% in Delta; <5% in Delta = 4% in Delta. Where DOSS gave ranges, the midpoint of the range was used. Values for dates when DOSS did not meet were interpolated from preceding and succeeding data.

Figure 11. Percentage of Juvenile Steelhead in the Delta during EDB Construction, February-June 2015, as Estimated by the Delta Operations for Salmonids and Sturgeon (DOSS) Group, with Horizontal Lines Indicating a Potential Construction Timeline Beginning April 1 that is Based on the 2015 Construction Timeline.

Also as described in the Environmental Baseline section, an appreciable portion of the adult spring-run Chinook salmon population would be expected to migrate upstream through the Delta towards spawning areas during the construction and operation of the proposed WFRSB, and a portion of the adult winter-run Chinook salmon also would be expected to do so (Table 12). The data in Table 12 refer to passage above RBDD because detailed data do not exist for passage through the Delta; assuming an upstream migration rate of 25 km per day (see Williams [2006] for a range of migration rates), the adult salmonids would have passed through the Delta approximately two weeks before reaching Red Bluff. McEwan (2001) describes peak steelhead migration as occurring from September to March, although the species has a protracted migration and holding period that encompasses much of the year (NMFS 2009: Table 4-6 of OCAP BO). Adult steelhead captures from Knights Landing fyke-net trapping in the early 1950s suggest the main period of upstream migration to be August to November (Hallock et al. 1957). As noted in the Environmental Baseline section, upstream steelhead adult migration has relatively low potential to coincide with barrier construction in April/May, whereas the upstream migration would be likely to coincide with barrier operations (April/May-October) and removal (September/October/November).

As discussed above, proposed WFRSB construction and removal have the potential to affect some listed salmonids because of sediment disturbance and turbidity, underwater noise, and hydrodynamic effects leading to predation. Overall, however, it is concluded that the potential adverse effects of barrier construction and removal on Central Valley spring-run Chinook salmon, Sacramento River winter-run Chinook salmon, and Central Valley steelhead would be limited for the following reasons:

- construction and removal would avoid the peak occurrence periods of listed juvenile salmonids in the Action Area;
- the effects would be temporary (e.g., in 2015 the total in-water construction period was around 38 days, and the total removal period would be up to 90 days);
- sound data taken during the 2012 installation of rock barriers as part of the TBP showed that noise levels at 100 m from construction were below the NMFS criteria for adverse behavioral effects (Shields 2012),[4] suggesting that the area of construction effects from rock placement would be smaller than 100 m (recognizing that there remains the potential for much of the channel width to be affected by intense transient noises during construction);
- the effect of noise on fish is likely to be limited to avoidance behavior in response to movements, noises, and shadows caused by construction personnel and equipment operation in or adjacent to the river (recognizing that avoidance of the disturbed areas could make fish more susceptible to predation);
- most fish would be expected to move away from the area of disturbance, and the tidal nature of the action area would facilitate fish movement away from the area because of tidal flows (although tidal flows would be diminished after barrier closure; however, by the time of barrier closure it is expected that there would be a considerably lower proportion of most juvenile salmonid populations in the Delta than when construction started, except juvenile steelhead from the San Joaquin River, based on DOSS estimates of fish occurrence for 2015);
- DWR will employ a number of conservation measures to limit the potential for take during construction and removal (see Conservation Measures section).

[4] The greatest measured peak sound pressure at 100 m was 149 dB for a single bucket drop of rock at the Old River near Tracy barrier. No measurements exceeded the NMFS 2012 South Delta Temporary Barriers Project BO ecological surrogate threshold of 150 dB at 100 m (Shields 2012). Applying the 149-dB peak value to equation 4-2 of ICF Jones and Stokes and Illingworth and Rodkin (2009; i.e., distance to threshold = distance to 149-dB measurement/($10^{[149\text{dB} - \text{pressure threshold in dB}]/15 \text{ (i.e., the assumed attenuation coefficient)}}$)) gives distances to peak thresholds of 86 m for a 150-dB threshold and less than a meter for a 206-dB threshold.

Effects on Southern DPS of North American Green Sturgeon

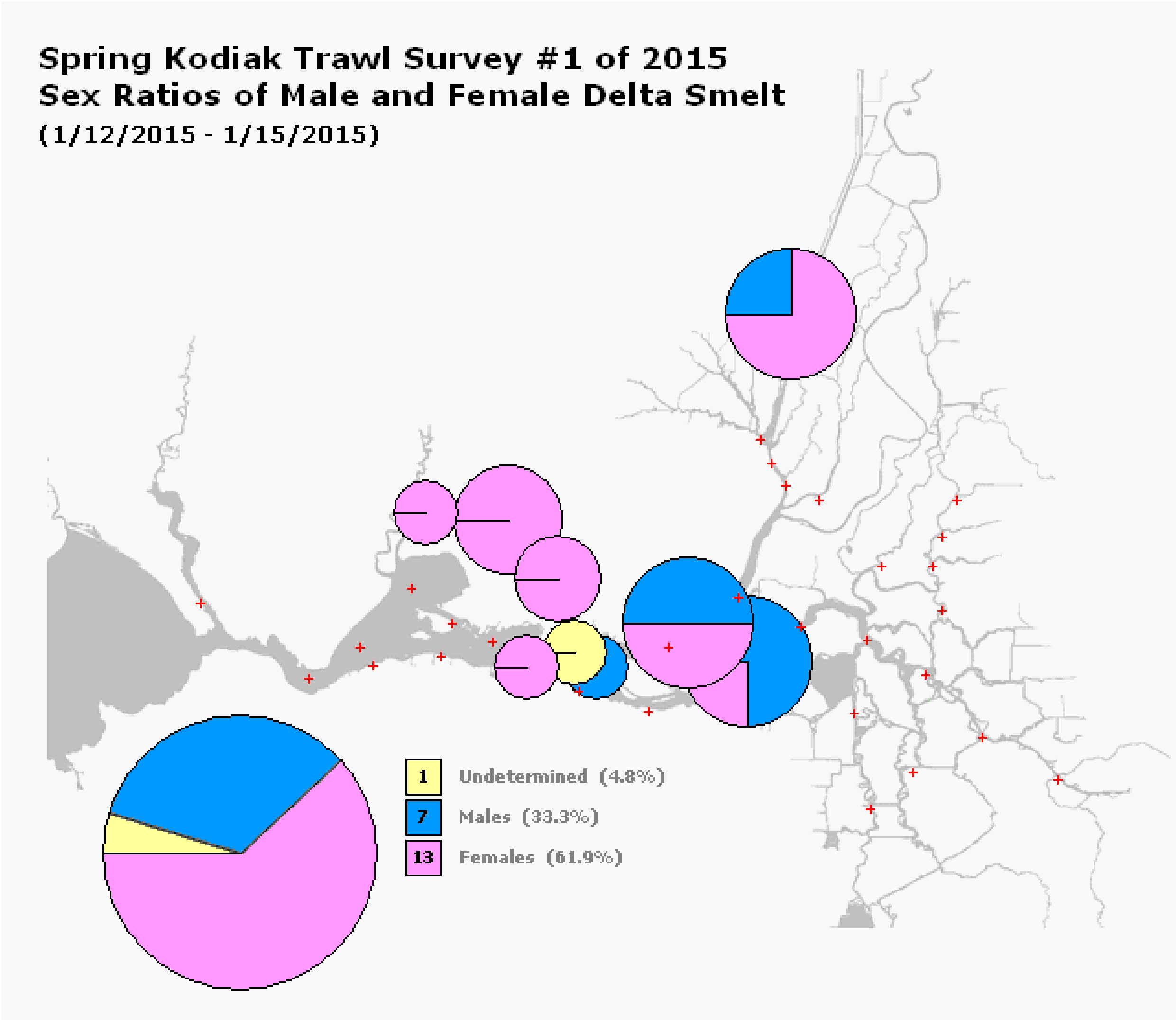
There are insufficient quantitative data from which to assess the percentage of green sturgeon within the Action Area during construction, operation, and removal of the proposed WFRSB. Occurrence in the Action Area was discussed in the Environmental Baseline section. Adult green sturgeon may be present in the San Francisco Bay-Delta from March to September, with the principal occurrence in upstream spawning areas in the Sacramento River occurring from mid-April to mid-June (NMFS 2009: Table 4-7 of OCAP BO). As described in the Environmental Baseline section, tagged adult green sturgeon data suggest that 40% of green sturgeon reach their spawning grounds in the upper Sacramento River by the end of March, nearly 80% by the end of April, and nearly 100% by the end of May (Woodbury pers. comm.). Therefore, construction could have appreciable temporal overlap with adult upstream migration. Juvenile green sturgeon are routinely collected at the SWP and CVP salvage facilities throughout the year (NMFS 2009).

As noted in the Environmental Baseline, older juvenile green sturgeon (between 10 months and 3 years old) may be present in the Delta year-round (NMFS 2009: Table 4-7 of OCAP BO). Salvage records indicate that sub-adult green sturgeon may be present in the Delta during any month of the year in low numbers, but are most commonly salvaged in July and August; these fish range in size from 136 to 744 mm (NMFS 2009). Therefore juvenile green sturgeon could experience the effects of proposed WFRSB construction, operation, and removal.

Green sturgeon entering the project area during construction and removal periods are likely to experience increased turbidity and sediment-associated toxicant levels, noise, and potential harassment by construction and removal activities. However, any adverse effects are expected to have a limited negative impact on green sturgeon because the effects would be localized to the False River channel in the vicinity of the construction site, would be quite short-term in nature, and because in comparison to other species (e.g., juvenile salmonids), green sturgeon would be less susceptible to enhanced predation (e.g., from hydrodynamic effects caused by the barrier's in-water structure prior to closure) because of their relatively large size.

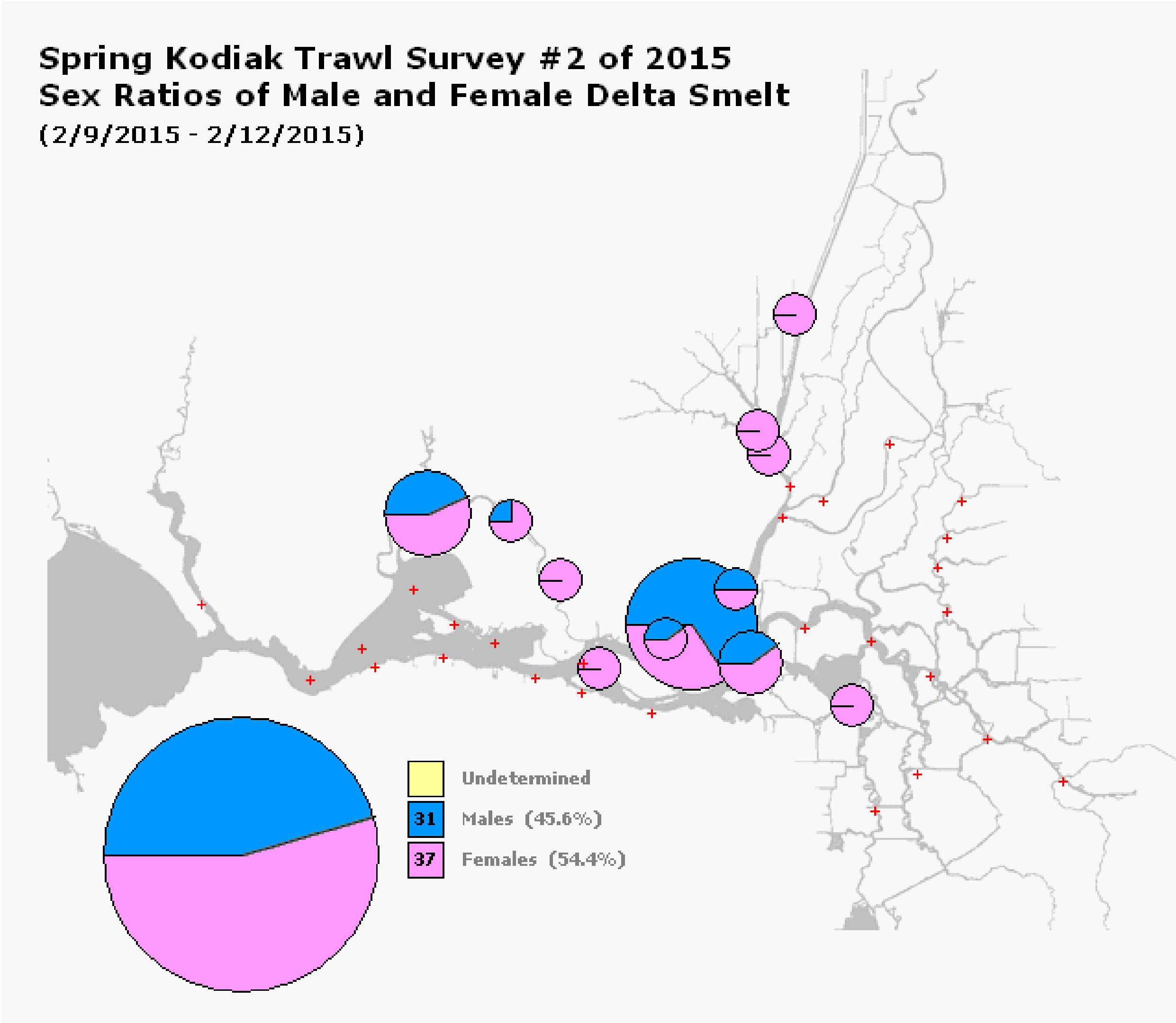
Effects on Delta Smelt

Based on historic patterns, migrating and spawning adult delta smelt may be present in the Action Area during the construction of the WFRSB because construction activities beginning in early April could coincide with the delta smelt spawning period (as noted in the Life Histories section of this BA, historically most spawning has occurred during April through mid-May). In 2015, mature or maturing male and female delta smelt were collected in the vicinity of the WFRSB (e.g., in the lower San Joaquin River and lower Old River near Franks Tract) during Spring Kodiak Trawl surveys in January and February (Figures 12 and 13), but all subsequent collections were on the northern side of the Delta and Suisun Marsh, including the lower Sacramento River and the Sacramento Deep Water Ship Channel/Cache Slough area (Figures 14-16). Most members of the Smelt Working Group agreed during their meeting on March 16, 2015, that the most likely reason for a decrease in the number of delta smelt between surveys 2 and 3 was that the fish did not survive after their first spawn, which occurred relatively early in 2015 (Smelt Working Group 2015a). Following surveys



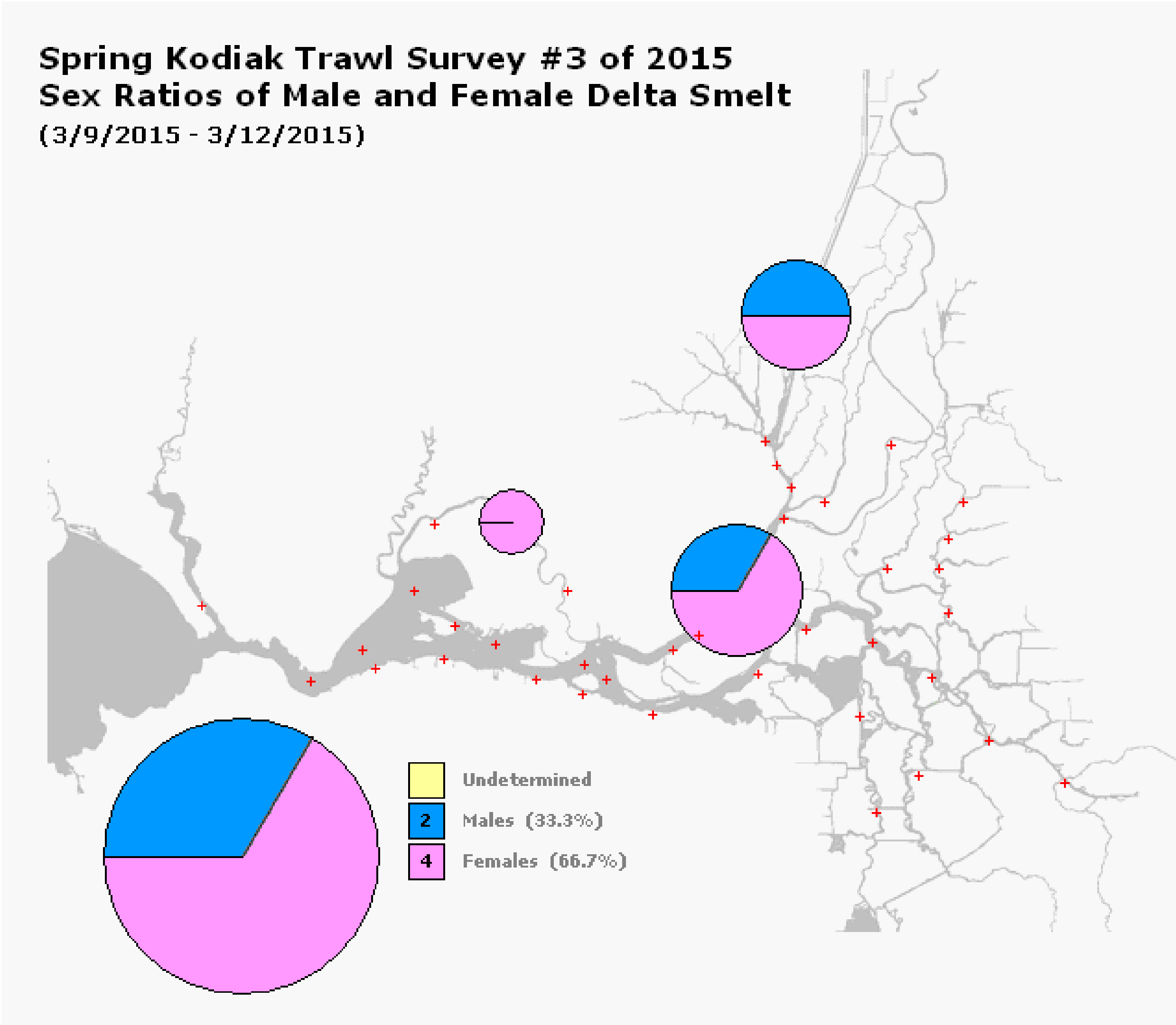
Source: http:// www.dfg.ca.gov/delta/data/skt/DisplayMaps.asp. Accessed: June 12, 2015. Note: Circle width is proportional to number of fish collected. '+' indicates fish were not collected at that station.

Figure 12. Sex Ratios of Delta Smelt from Spring Kodiak Trawl Survey 1, 2015.



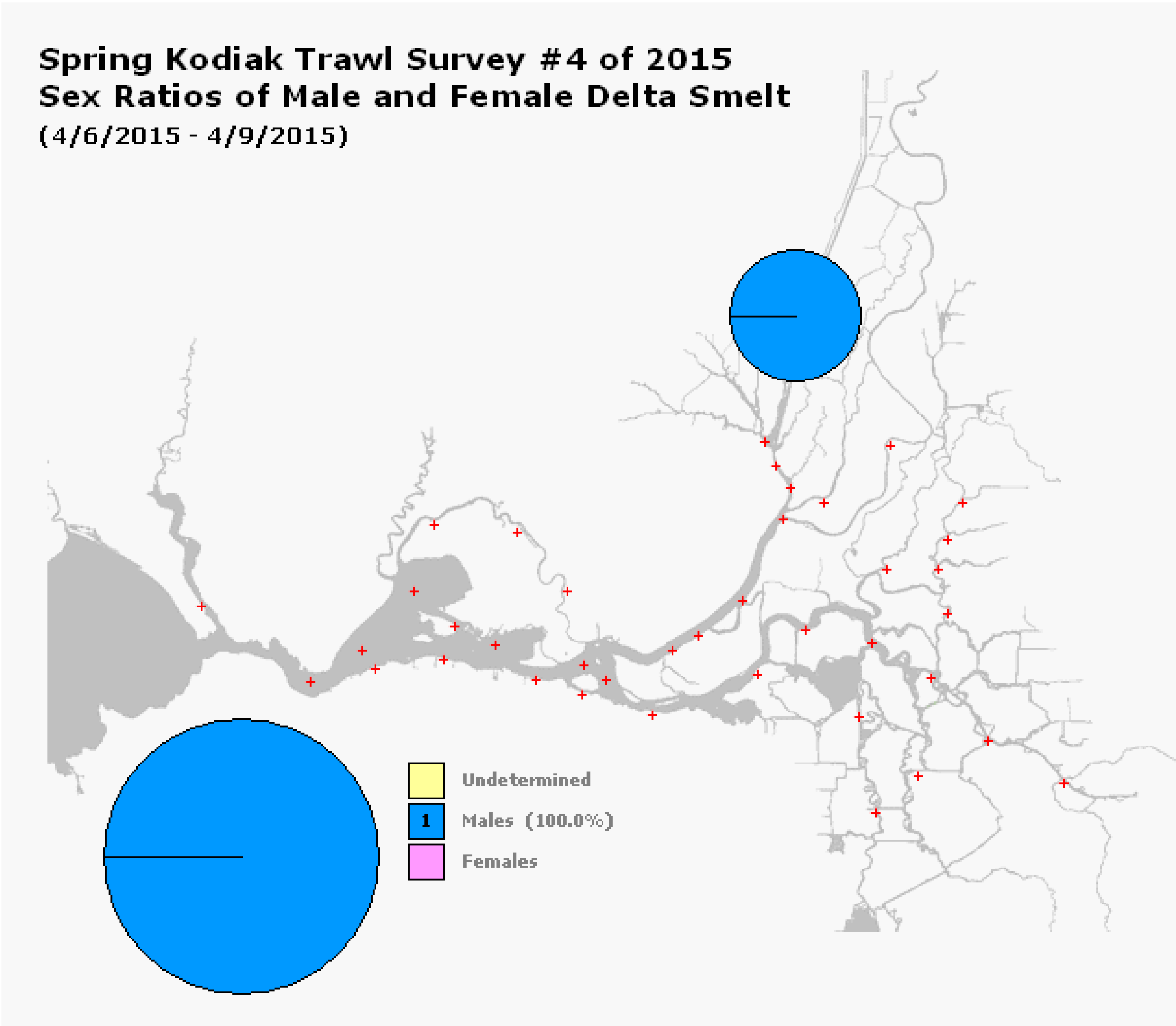
Source: http:// www.dfg.ca.gov/delta/data/skt/DisplayMaps.asp. Accessed: June 12, 2015. Note: Circle width is proportional to number of fish collected. '+' indicates fish were not collected at that station.

Figure 13. Sex Ratios of Delta Smelt from Spring Kodiak Trawl Survey 2, 2015.



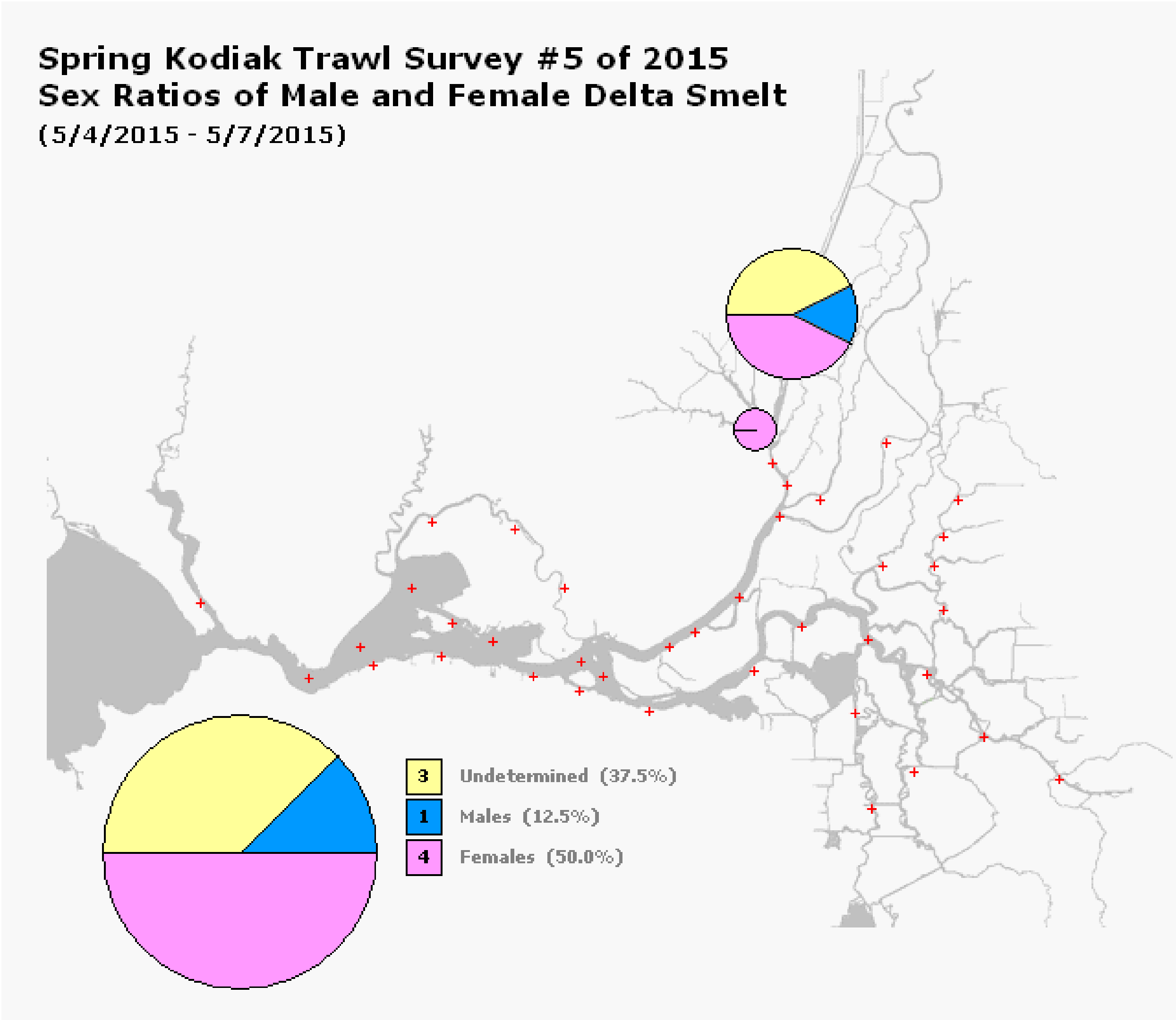
Source: http:// www.dfg.ca.gov/delta/data/skt/DisplayMaps.asp. Accessed: June 12, 2015. Note: Circle width is proportional to number of fish collected. '+' indicates fish were not collected at that station.

Figure 14. Sex Ratios of Delta Smelt from Spring Kodiak Trawl Survey 3, 2015.



Source: http:// www.dfg.ca.gov/delta/data/skt/DisplayMaps.asp. Accessed: June 12, 2015. Note: Circle width is proportional to number of fish collected. '+' indicates fish were not collected at that station.

Figure 15. Sex Ratios of Delta Smelt from Spring Kodiak Trawl Survey 4, 2015.



Source: http:// www.dfg.ca.gov/delta/data/skt/DisplayMaps.asp. Accessed: June 12, 2015. Note: Circle width is proportional to number of fish collected. '+' indicates fish were not collected at that station.

Figure 16. Sex Ratios of Delta Smelt from Spring Kodiak Trawl Survey 5, 2015.

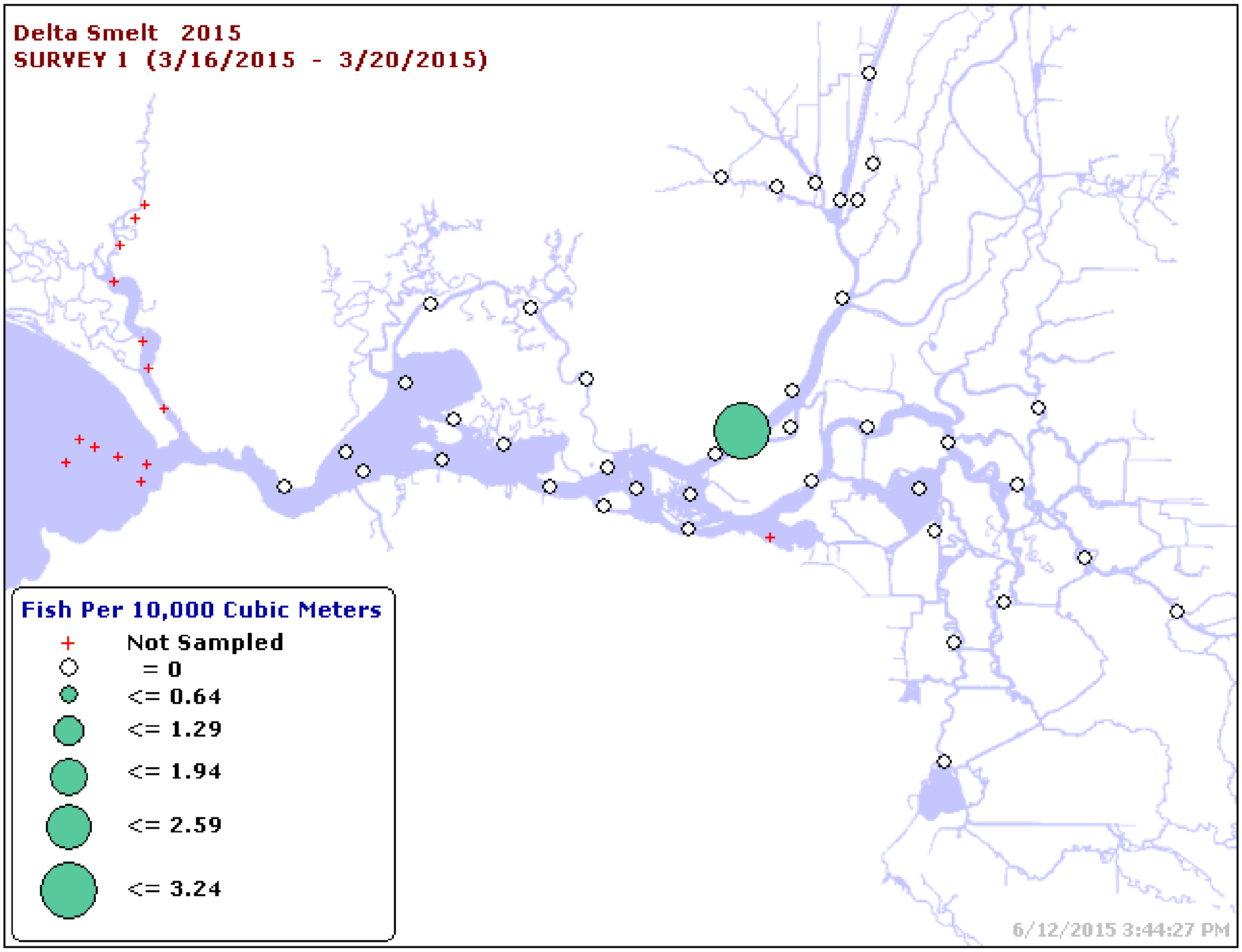
4 and 5, the Smelt Working Group noted that it was difficult to reliably detect delta smelt, likely because of very low abundance, so there was some uncertainty in the distribution (Smelt Working Group 2015b, c). Overall, it is likely that in 2015 relatively few adult delta smelt were present in the vicinity of the WFRSB during construction because none were detected by nearby surveys, but this also reflects the low overall abundance of the population. This situation may be representative of future implementation of the proposed WFRSB (the subject of this BA) if the delta smelt spawning period and location is similar to that of 2015, which might be the case because of drought conditions. However, it is possible that a greater proportion of the adult delta smelt population could be exposed to construction effects, depending on antecedent environmental conditions. During 2014, another drought year in which installation of a barrier in West False River was contemplated, near-daily trawling at Jersey Point collected adult delta smelt on almost every day during the February 6 to April 10 sampling period (Polansky et al. 2014) , indicating presence in the general area of the proposed WFRSB and potential spatial and temporal overlap with construction beginning as early as April 1. With respect to barrier removal effects, the fact that maturing delta smelt migrate upstream in response to early winter storms with increases in precipitation (Grimaldo et al. 2009; Sommer et al. 2011) means that it is not anticipated that barrier removal in September/October/November would affect adult delta smelt, as the barrier would be intended to be removed before such increases in river flow in order to limit flooding risk.

As described in the Life Histories section of this BA, laboratory studies found delta smelt to spawn at night, whereas eggs have not been found in the wild. As also noted in the Life Histories section of this BA, laboratory observations indicate that delta smelt are broadcast spawners, discharging eggs and milt close to the bottom over substrates of sand and/or pebble in current. The most recent synthesis of delta smelt biology by the Interagency Ecological Program, Management, Analysis, and Synthesis Team (2015: 100) stated:

> It is believed that Delta Smelt spawn over sandy substrates in shallow areas based on the observation that first hatch larvae are collected in high concentrations in areas near expansive sandy shoals...; confirmation of this hypothesis has not been verified through egg collections or observations of spawning adults, except in mesocosm studies.

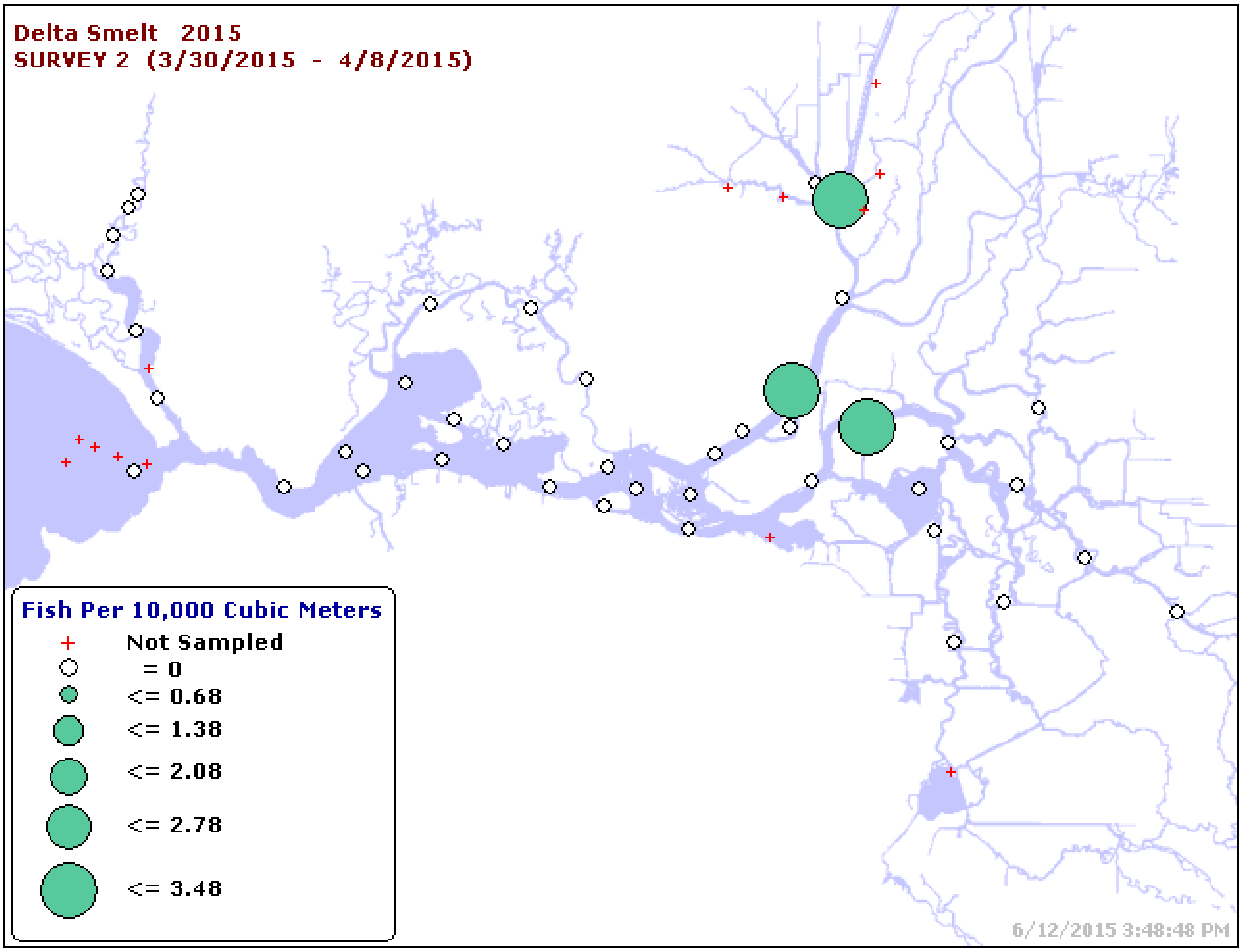
Spawning habitat exhibiting these hypothesized characteristics (i.e., sandy shoals) appears to be limited or absent near the WFRSB site, where the habitat consists of primarily steep-sloped, riprapped banks. Therefore, although in-water nighttime construction activities at the WFRSB site have the potential to take adult delta smelt moving inshore to spawn, it is concluded that such take would be limited in extent because the hypothesized preferred spawning habitat is limited or absent in the area, and, if 2015 conditions are representative of spawning seasonality during drought conditions, the peak of the spawning season may occur earlier in the year than barrier construction.

The early life stages of the subsequent generation of delta smelt (larvae and early juveniles) could occur near the WFRSB during construction, based on the observed historic frequency of occurrence from sampling in the lower San Joaquin River during spring (Merz et al. 2011; Table 10; see also 20-mm Survey summaries in Appendix D). As with adult delta smelt, the abundance of early juvenile delta smelt in the 2015 20-mm Survey was very low (Figures 17-23). The density of early juvenile



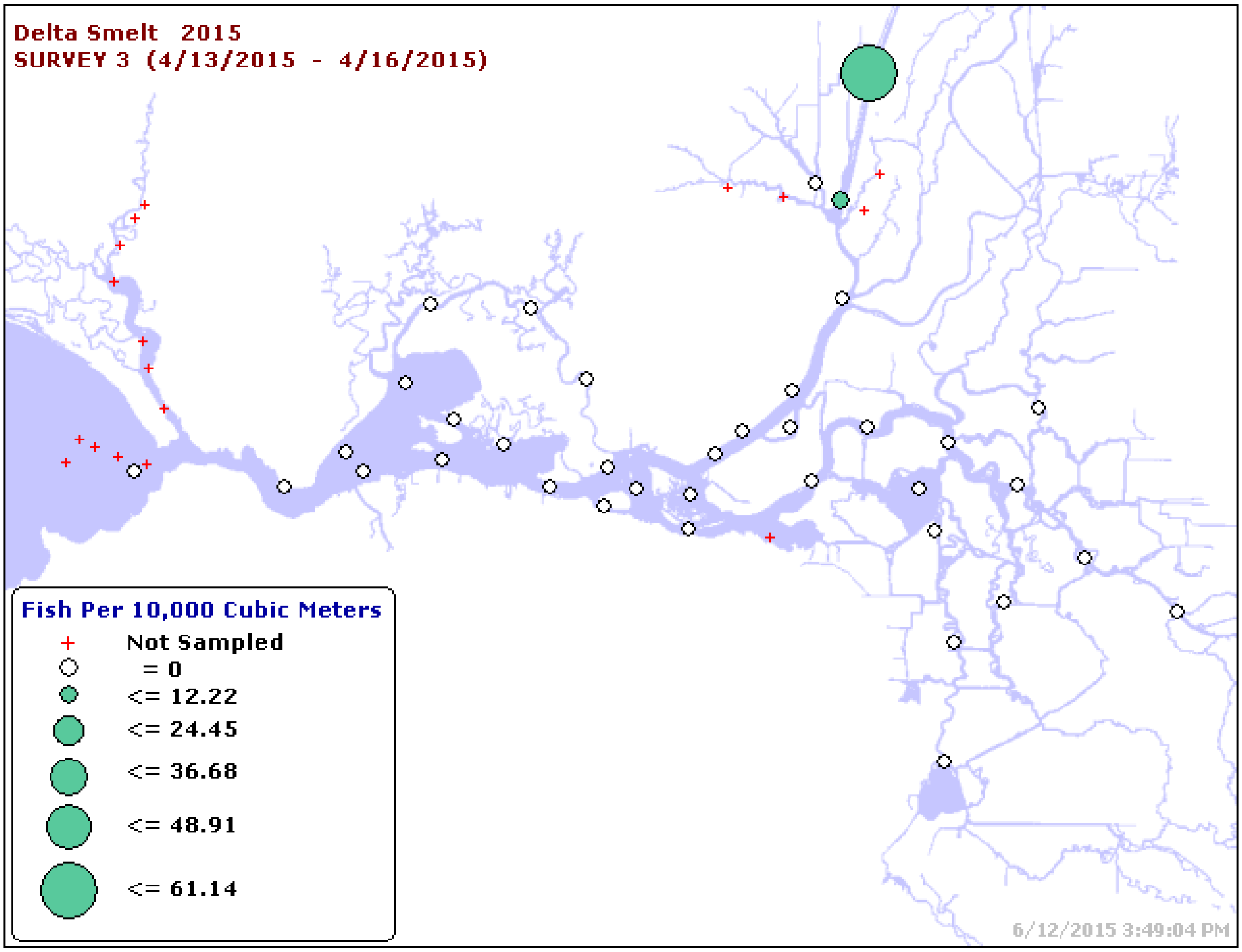
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: June 12, 2015. '+' indicates stations that were not sampled.

Figure 17. Density of Delta Smelt from 20-mm Survey 1, 2015.



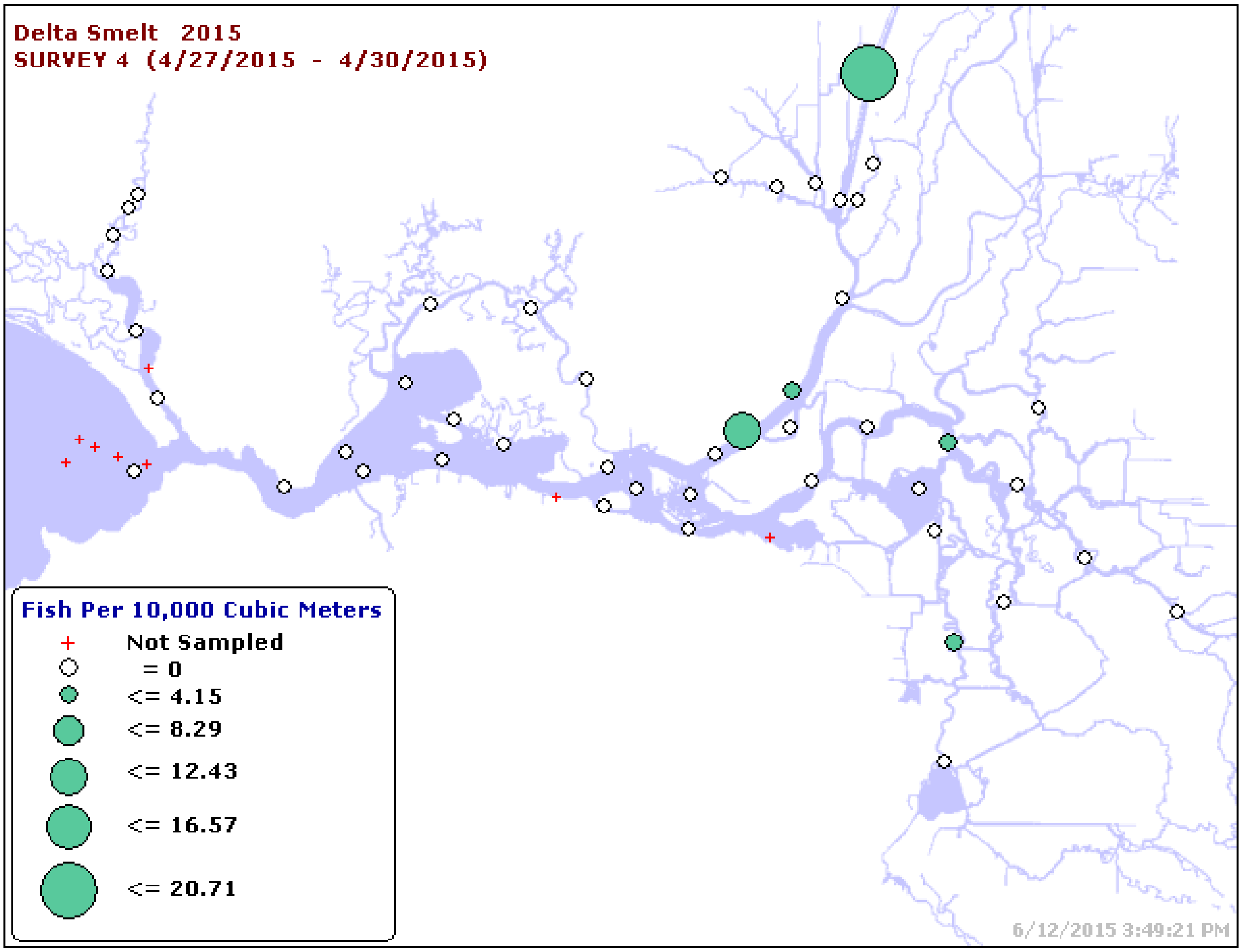
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: June 12, 2015. '+' indicates stations that were not sampled.

Figure 18. Density of Delta Smelt from 20-mm Survey 2, 2015.



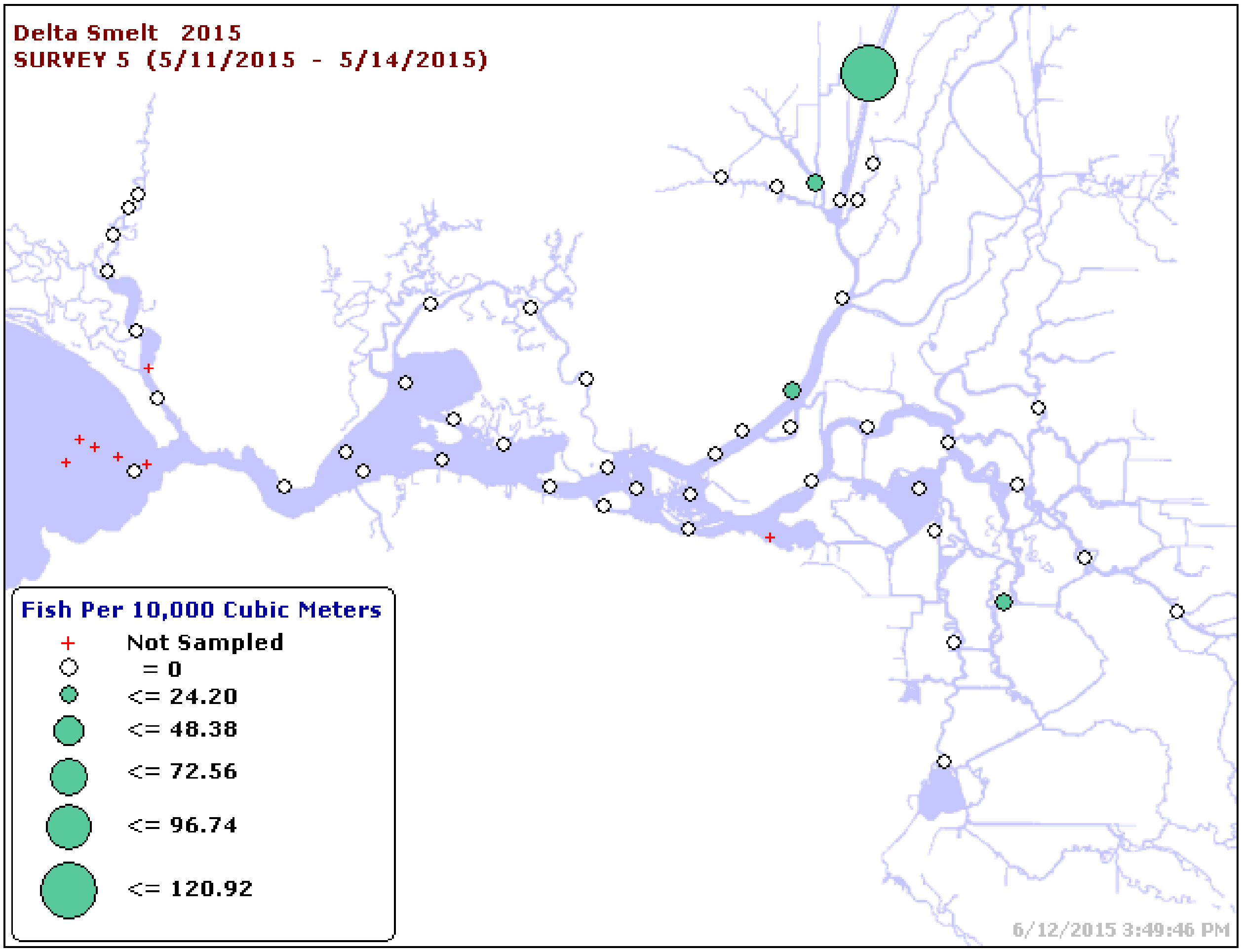
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: June 12, 2015. '+' indicates stations that were not sampled.

Figure 19. Density of Delta Smelt from 20-mm Survey 3, 2015.



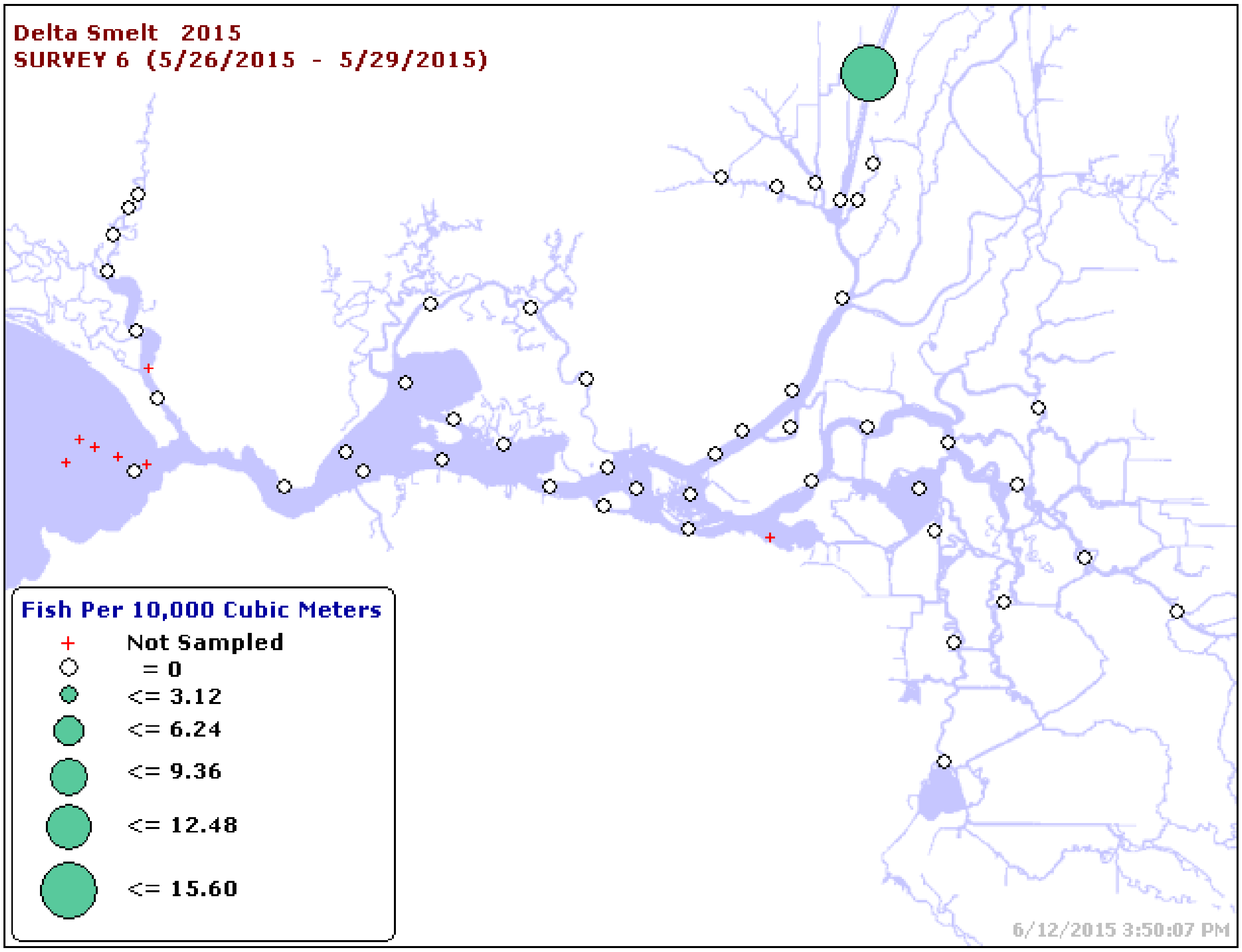
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: June 12, 2015. '+' indicates stations that were not sampled.

Figure 20. Density of Delta Smelt from 20-mm Survey 4, 2015.



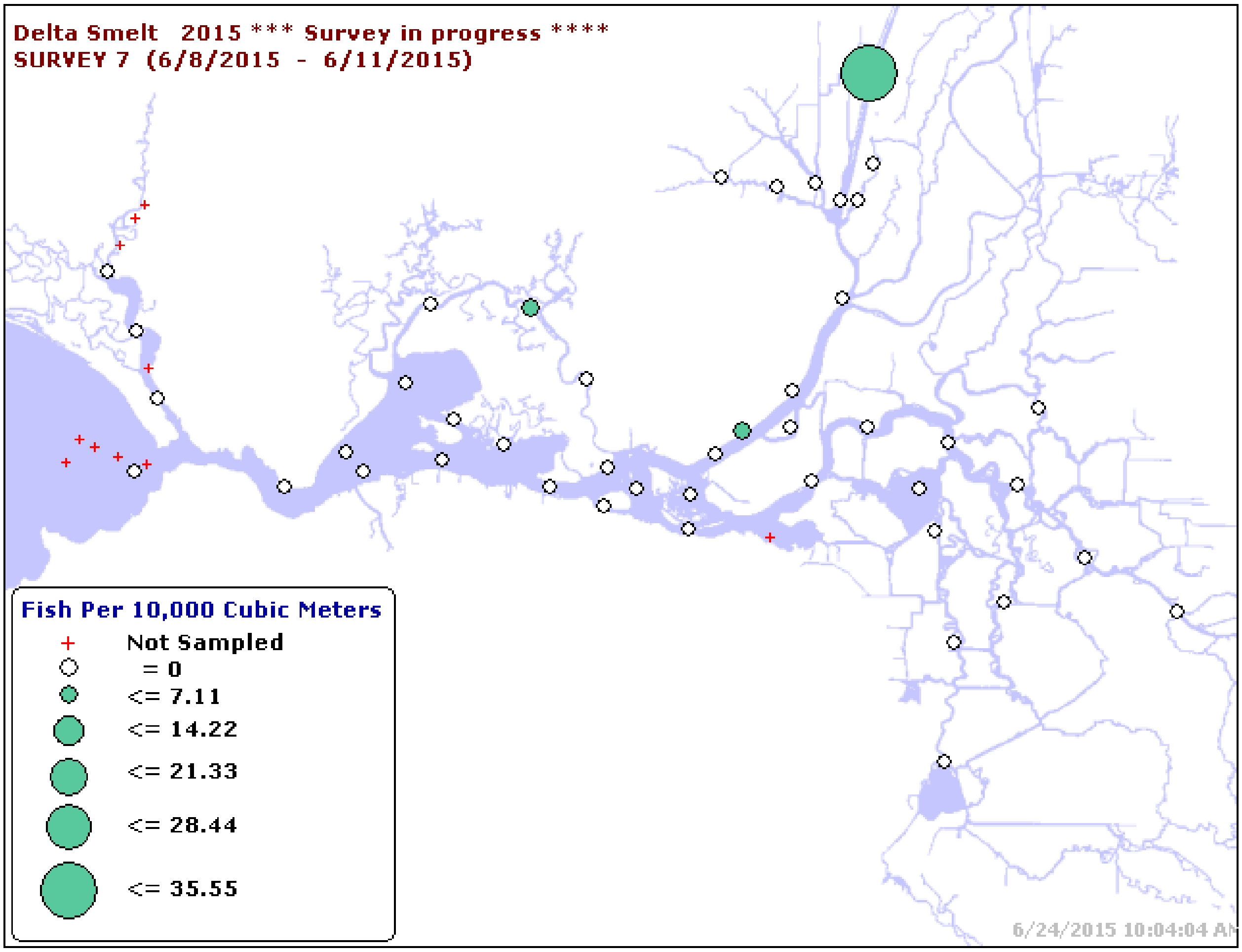
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: June 12, 2015. '+' indicates stations that were not sampled.

Figure 21. Density of Delta Smelt from 20-mm Survey 5, 2015.



Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: June 12, 2015. '+' indicates stations that were not sampled.

Figure 22. Density of Delta Smelt from 20-mm Survey 6, 2015.



Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: June 24, 2015. '+' indicates stations that were not sampled.

Figure 23. Density of Delta Smelt from 20-mm Survey 7, 2015.

delta smelt near the WFRSB construction area during survey 2 (late March/early April) in 2015 was as high as in the lower Sacramento River and lower Sacramento Deep Water Ship Channel (Figure 18), which indicates the potential for appreciable presence of the species in the area at the earliest potential construction date (April 1). From survey 3 onwards, the density in the Sacramento Deep Water Ship Channel was higher than in other areas. Small numbers of early juvenile delta smelt were collected at survey stations in the central/south Delta upstream or downstream of the WFRSB just after the date when the barrier could be closed (survey 4: April 27-30; Figure 20), which could be approximately 3 weeks after construction began from the 2015 EDB installation. Small numbers of these early juvenile delta smelt were also collected in early/mid-May (survey 5: May 11-14; Figure 21), which, based on the observed construction timeline in 2015, would coincide with the latter stages of construction following barrier closure. This, combined with observed salvage of four juvenile delta smelt at the CVP on May 4 (which, as noted previously, would coincide with the latter stages of construction, based on the 2015 timeline for construction), suggests that some proportion of larval and early juvenile delta smelt would have been likely to be in the False River channel vicinity at around the time of a hypothetical construction timeline starting April 1, with potential for effects from barrier construction. This extent of spatial and temporal overlap of delta smelt based on the 2015 observed fish occurrence data and backdating of the 2015 construction timeline to reflect an April 1 start date is considered representative of the potential overlap that could occur with the proposed WFRSB implementation. Removal of the WFRSB (September/October/November) would be expected to have the potential to affect only a very limited portion of delta smelt juveniles, based on historic frequency of occurrence from fall midwater trawling in the lower San Joaquin River (Merz et al. 2011; Table 10).

The construction of the WFRSB has the potential to harass and displace delta smelt present in the general area of the construction activity, primarily because of in-water rock placement. Delta smelt moving away from the zone of effect could be more prone to predation in areas away from the zone of disturbance. Additionally, the increased turbidity levels associated with construction could negatively affect delta smelt temporarily through reduced availability of food and exposure to toxic sediments released into the water column; however, as described above in Sediment Disturbance and Turbidity, the 2015 monitoring data suggest that these effects would have been very localized near the barrier construction site. As discussed in Hydrodynamic Effects above, the 2015 EDB affected flow patterns as the barrier neared full closure, leading to conditions such as hydrodynamic eddies that could have resulted in increased predation on delta smelt occurring in the False River channel. Such effects could occur with future implementation of the proposed WFRSB. Removal of the barrier in September/October/November could also affect delta smelt occurring near the barrier through disturbance, sediment/turbidity, and hydrodynamic (predation) mechanisms. The likelihood of presence near the barrier would depend on the environmental conditions (principally water temperature, salinity, and turbidity) and as noted above, Merz et al. (2011) found that the percentage of the population occurring in the general area in the fall typically would be very low.

The construction and removal of the proposed WFRSB may take delta smelt, however, take is anticipated to be limited because:

- construction and removal is spatially limited relative to the potential areas in which the species occurs;
- the effects would be temporary (e.g., in 2015 the total in-water construction period was around 38 days, and the total removal period would be up to 90 days);
- sound data taken during the 2012 installation of rock barriers as part of the TBP showed that noise levels at 100 m from construction were below the NMFS criteria for adverse behavioral effects (Shields 2012),[5] suggesting that the area of construction effects from rock placement

[5] As described for the analysis of juvenile salmonids, the greatest measured peak sound pressure at 100 m was 149 dB for a single bucket drop of rock at the Old River near Tracy barrier. No measurements exceeded the NMFS 2012 South Delta Temporary Barriers Project BO ecological surrogate threshold of 150 dB at 100 m (Shields 2012). Applying the 149-dB peak value to equation 4-2 of ICF Jones and Stokes and Illingworth and Rodkin (2009; i.e., distance to threshold = distance to 149-dB measurement/($10^{[149\text{dB} - \text{pressure threshold in dB}]/15 \text{ (i.e., the assumed attenuation coefficient)}}$)) gives distances to peak thresholds of 86 m for a 150-dB threshold and less than a meter for a 206-dB threshold.

would be smaller than 100 m (recognizing that there remains the potential for much of the channel width to be affected by intense transient noises during construction);

- the effect of noise on fish is likely to be limited to avoidance behavior in response to movements, noises, and shadows caused by construction personnel and equipment operation in or adjacent to the river (recognizing that avoidance of the disturbed areas could make fish more susceptible to predation);
- there is little to no hypothesized preferred spawning habitat for adult delta smelt in the construction area, and in 2015 the spawning period was largely completed when construction began (which may be representative of spawning timing in drought years);
- juvenile and adult delta smelt would be expected to move away from the area of disturbance (although any larval delta smelt present may move away more slowly because of their smaller size and weaker swimming ability, therefore resulting in more exposure to potential adverse effects than juvenile and adult delta smelt);
- DWR will employ a number of conservation measures to limit the potential for take during construction and removal (see Conservation Measures section).

Operations Effects on Fish

As described earlier in this BA, the assessment of proposed WFRSB operations in this BA does not include consideration of broad-scale, Delta-wide effects (e.g., on salinity and the distribution of the low-salinity zone) that are contingent on system-wide SWP/CVP operations. It is reasonable to anticipate that such an assessment would be provided in TUCP modification petitions for Bay-Delta standards contained in D-1641, as occurred in 2015 (Murillo and Cowin 2015). As such, the analysis of operations presented herein focuses on the near-field effects of barrier presence (e.g., predation and potential for impingement on barrier rocks), as well as the potential for the barrier to block movements of listed fishes.

Chinook Salmon and Central Valley Steelhead

The 2015 operations timeline provides a reasonable representation of the potential timeline of operation effects for the proposed WFRSB implementation that is the subject of this BA. In 2015, operation of the EDB began following closure of the barrier, which occurred around 3 weeks after construction began, although in-water construction continued for around 20 days after barrier closure. As described in the Construction and Removal Effects section, based on the 2015 species occurrence information from DOSS, varying proportions of listed juvenile salmonid populations would have been in the Delta at the time of barrier closure, assuming barrier closure 3 weeks after construction began: less than 5% for winter-run Chinook salmon and yearling spring-run Chinook salmon, less than 20% for young-of-the-year spring-run Chinook salmon, and just under 10% for San Joaquin River steelhead (Figures 10 and 11).

Hydrodynamic Effects

Operations of the proposed WFRSB (i.e., the presence of the barrier) have the potential to change the likelihood of entrainment toward the south Delta export facilities of juvenile salmonids occurring in the lower San Joaquin River compared to the situation without the barrier. The WFRSB eliminates the potential for juvenile salmonids to move from the lower San Joaquin River through False River and Franks Tract into Old River and upstream towards the export pumps (where the risk of entrainment-related mortality is high). However, because water exports from the south Delta are likely to be low in response to drought conditions (e.g., SWP/CVP average of 818 cfs during 1-24 June, 2015), the risk of entrainment for juvenile salmonids in the lower San Joaquin River would likely be relatively low, so blockage of passage from the San Joaquin River through False River may have relatively little effect.

Operation of the WFRSB has the potential to trap juvenile salmonids upstream of the barrier (e.g., in the Franks Tract area) that otherwise might have moved (emigrated) through False River into the lower San Joaquin River; this may be most likely to occur for juvenile steelhead emigrating from the San Joaquin River watershed. However, even with low south Delta exports, juvenile salmonids occurring closer to the south Delta export pumps (e.g., in Old River from Bacon Island and south) would have a relatively high probability of entrainment, regardless of the presence of the barrier (Kimmerer and Nobriga 2008).

In general, it can be anticipated that a portion of the listed adult Chinook salmon populations may occur in the Action Area during the earlier part of the operations period and adult steelhead may occur in greatest numbers during the latter part of the operational period (see Environmental Baseline section). Adult salmonids returning to upstream natal tributaries—or, in the case steelhead kelts, migrating downstream after spawning—could encounter the WFRSB and therefore have passage blocked, but this would represent only a minor delay and in some cases may reduce migration time through the Delta (e.g., for fish returning to the Sacramento River that had entered the lower San Joaquin River, and otherwise would have penetrated farther into the interior Delta through False River).

Near-field Predation Effects

Enhanced predation of juvenile salmonids in relation to artificial structures has been observed in the Delta (e.g., juvenile salmonids downstream of the Woodbridge Irrigation District Dam; Sabal 2014). Small fish, including juvenile salmonids, could be entrained toward the barrier by seepage flows and then hold station in front of it to avoid being impinged on the rocks, resulting in concentrations of small fish near the barrier. Such concentrations of fish could attract piscivorous fishes and other predators. Evidence for this mechanism comes from biological monitors having observed a Caspian tern fishing along the downstream side of the 2015 barrier for several hours commencing in mid-afternoon on 1 June (Table 13); at this time, the tide was incoming with an approximate head (stage) difference of about -1 foot between downstream and upstream, which would have resulted in around -1,500 cfs of seepage flow and velocity of about 0.08 ft/s toward the barrier (see estimates of seepage flows in Appendix C). There were no other such observations of predatory birds during biological monitoring, and it was not possible to establish whether predatory fishes also were exploiting concentrated small fishes in this manner. As described in Appendix C, the

2015 barrier was estimated to have blocked over 95% of flow into and out of False River, which would greatly limit the potential for fish to be entrained into the False River channel from the San Joaquin River or Franks Tract area. This would therefore limit the number of fish being concentrated at the barrier if the fish were moving primarily with tidal flows, although fish swimming without reliance on tidal flows could still enter the channel and be susceptible to near-field predation at the barrier. As described in the project description, spike strips and metal baffles were installed on the Jersey Island whaler system for rodent migration prevention; these strips also would reduce perching habitat for predatory birds.

The abutments of the WFRSB would be removed in the same year that the remainder of the barrier would be removed and therefore would not provide an additional predation risk to juvenile salmonids.

As described in the Conservation Measures section, DWR would coordinate with the California Department of Parks and Recreation Division of Boating and Waterways Aquatic Weed Control Program for the control of invasive water hyacinth, Brazilian elodea (*Egeria densa*) or other invasive water weeds covered by the control program in the vicinity of the WFRSB while the barrier is in place. This would prevent an increase in the risk of predation of juvenile salmonids occurring near the barrier by vegetation-associated predatory fishes such as largemouth bass.

Southern DPS of North American Green Sturgeon

The Southern DPS of North American green sturgeon could be affected by operational effects of the proposed WFRSB, particularly with respect to blockage of migratory pathways. The timing of barrier closure—based on the approximate 3-week period between construction starting and barrier closure that occurred in 2015, this would be around April 22 with an April 1 construction start date—could overlap a considerable portion of the spring upstream migration period of adult green sturgeon (see sections discussing Environmental Baseline and Construction and Removal Effects on Fish). However, for adult green sturgeon migrating to the Sacramento River, the barrier may prevent the fish from following what otherwise may be a more circuitous pathway through the central/south Delta, and could reduce the overall migration time. Juvenile green sturgeon occur year-round in the Delta and therefore could encounter the barrier during operations. Blockage of passage would represent a delay in migration, although this would be of minor importance to juvenile green sturgeon generally moving around the Delta and seeking foraging areas without specific destinations; green sturgeon actively migrating toward the ocean from the south Delta would be affected more by the presence of the barrier, but would be able to seek alternative pathways.

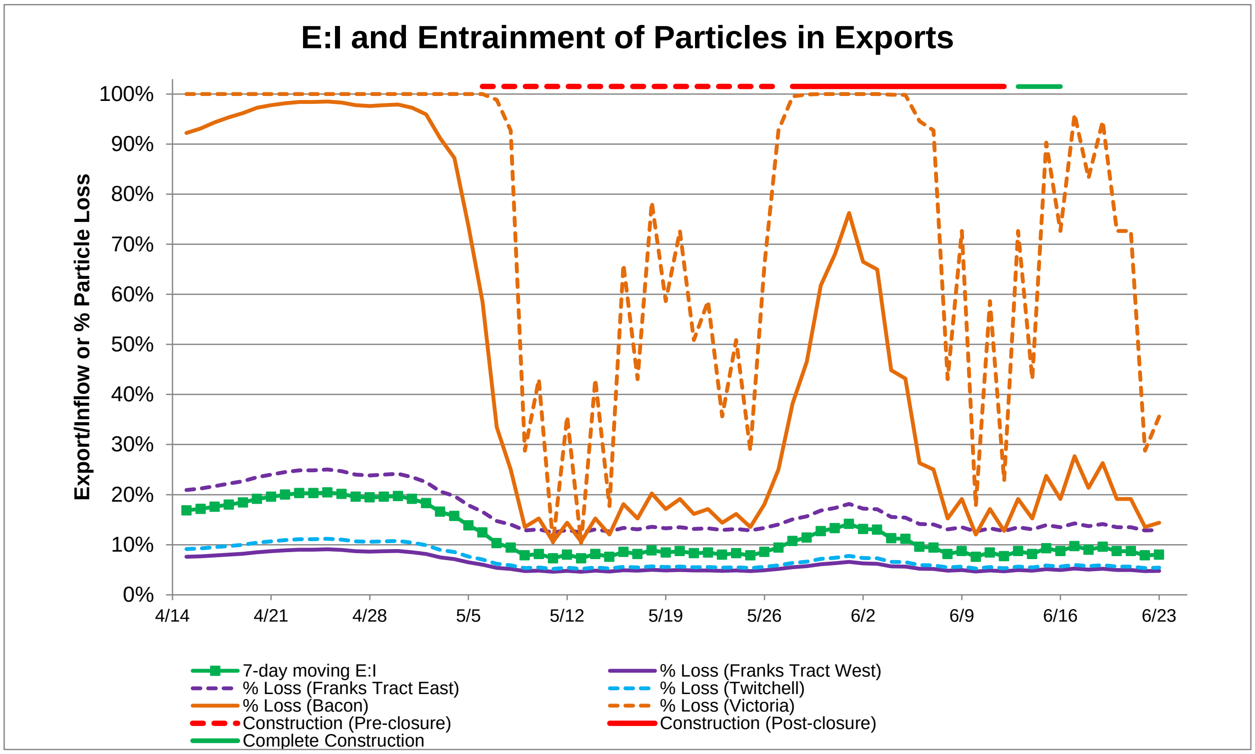
Delta Smelt

The Environmental Baseline section described that occurrence of delta smelt in the lower San Joaquin River was more frequent during the mature adult and earliest life stages, with relatively low occurrence during the juvenile and sub-adult life stages in summer/fall (Table 10; Merz et al. 2011); this suggests that juvenile delta smelt would have less potential to occur near the WFRSB during much of barrier operations (which may cover the late April-October period based on the construction timeline). In general, some delta smelt would be expected to occur near the WFRSB in spring and would be expected to gradually move further downstream as they grow older (e.g., Dege and Brown 2004); however, the species is distributed according to habitat features such as salinity, water temperature, and water clarity (e.g., Nobriga et al. 2008; Sommer and Mejia 2013) and so occurrence near the barrier during the operational period would be dependent on habitat conditions. In 2015, data from the 20-mm Survey suggest that delta smelt juveniles were present near the WFRSB at around the time that the barrier would have been closed if construction had started on April 1 and barrier closure occurred three weeks later. Because of low inflow conditions, the low-salinity zone that is occupied by delta smelt would be further upstream in summer/fall of a severe drought year when the proposed WFRSB may be implemented than in non-drought years, so the distribution of delta smelt occurring in the West Delta/Suisun Bay would be expected to be further upstream than in higher flow years. It is reasonable to assume that the broad-scale effects of the proposed WFRSB in the context of Delta operations would be analyzed as part of TUCP requests, as occurred in 2015 (Murillo and Cowin 2015). The analysis below focuses only on specific near-field or hydrodynamic effects of proposed WFRSB operations that are unlikely to be analyzed as part of TUCP requests, based on the contents of the analyses in the 2015 requests (Murillo and Cowin 2015).

Hydrodynamic Effects

South Delta Entrainment

As discussed for juvenile salmonids, operations of the proposed WFRSB (i.e., the presence of the barrier) have the potential to change the likelihood of entrainment toward the south Delta export facilities of delta smelt larvae/juveniles occurring in the lower San Joaquin River compared to the situation without the barrier. The WFRSB eliminates the potential for delta smelt to move from the lower San Joaquin River through False River and Franks Tract into Old River and upstream towards the export pumps (where the risk of entrainment-related mortality is high). However, because water exports from the south Delta are likely to be low in response to drought conditions (e.g., SWP/CVP average of 818 cfs during 1-24 June, 2015), the risk of entrainment for juvenile delta smelt in the lower San Joaquin River would likely be relatively low, so blockage of passage from the San Joaquin River through False River may have relatively little effect. This is illustrated using relationships between loss of neutrally buoyant particles and export to inflow (E:I) ratio developed by Kimmerer and Nobriga (2008), using data from 2015 as an example. The E:I prior to barrier construction beginning May 6, 2015, averaged just under 20%, but E:I during construction and following barrier closure on May 28 averaged just under 10%, because exports were limited to the San Joaquin River inflow. The predicted entrainment for an E:I of 10% would be about 6% of particles released in the San Joaquin River near Twitchell Island (location TWI; see Kimmerer and Nobriga 2008: their Figure 1), as illustrated in Figure 24.



Sources: E:I data from http://www.usbr.gov/mp/cvo/vungvari/dout0415.pdf, http://www.usbr.gov/mp/cvo/vungvari/dout0515.pdf, and http://www.usbr.gov/mp/cvo/vungvari/doutdly.pdf; accessed June 15 and 24, 2015. % Loss based on regression coefficients provided by Nobriga (pers. comm.).

Figure 24. Estimated Particle Loss at Locations upstream of the West False River Salinity Barrier for 7-Day-Moving-Average Export/Inflow Ratios Prior to and During EDB Construction and Operations up to June 24, 2015.

Operation of the WFRSB has the potential to trap larval/juvenile delta smelt upstream of the barrier (e.g., in the Franks Tract area) that otherwise might have moved (emigrated) through False River into the lower San Joaquin River. Application of the relationships between loss of neutrally buoyant particles and E:I developed by Kimmerer and Nobriga (2008) suggests that in 2015 an appreciable portion of delta smelt occurring closer to the south Delta export facilities would have been entrained (Figure 24). With a 7-day moving average mean E:I of 9% during 28 May to 24 June, a mean of 32% of particles from Bacon (location BAC) and 76% of particles from Victoria (location VIC) would have been entrained.[6] Delta smelt occurring nearer the WFRSB, on the west and east sides of Franks Tract, would have been less likely to be entrained: based on the E:I of 9% during the May 28 to 14 June period, an average of 14% of particles from Franks Tract East (location FTE) and an average of 5% of particles from Franks Tract West (location FTW) would be estimated to be entrained based on the relationships from Kimmerer and Nobriga (2008). Taken together and assuming that delta smelt would have used the False River channel as opposed to other channels, these estimates of particle

[6] No delta smelt were salvaged during the period of barrier construction and early operations; the last salvage was on 4 May. Lack of salvage does not indicate entrainment was not occurring, as entrained fish have a high probability of being preyed upon prior to salvage, particularly with warm temperatures and low pumping rates (Castillo et al. 2012).

loss suggest that blockage of the False River channel could have increased the loss of delta smelt, at least until habitat in the south Delta warmed and became less hospitable to delta smelt.[7] These observations from 2015 are representative of the potential situation that could occur during the implementation of the proposed WFRSB that is the subject of this BA. As previously noted, delta smelt abundance in 2015 is low and so it is challenging to determine the proportion of the population that would have been affected by being blocked upstream of WFRSB, although the available survey data suggest that the greatest density of delta smelt was in the Sacramento Deep Water Ship Channel, lower Sacramento River, and Suisun Marsh area (Figures 22 and 23).

Seepage Flow and Impingement

Seepage flow between the rocks of the WFRSB may result in impingement of small delta smelt (e.g., larvae and early juveniles) occurring upstream and downstream of the WFRSB. As described in Appendix C, seepage flow through the barrier in 2015 was estimated from a field survey of flow and velocity just upstream of the barrier, in combination with 15-minute tidal elevation (stage) data upstream and downstream of the barrier. Because tidal flow dominates the hydrodynamics of False River, the 2015 data are representative of futureimplementation of the proposed WFRSB. It is estimated that absolute seepage flow after barrier closure ranges from around -2,000 cfs to 2,000 cfs, based on data from May 29 to June 22, 2015 (see Table C2 in Appendix C). Measured water velocities just upstream of the barrier were around 0.1 ft/s, which would translate into velocity of around 1 ft/s with rock porosity of 10% and 0.5 ft/s with porosity of 20% (rock porosity values for the barrier are unknown). Such velocity could impinge larval and early juvenile delta smelt occurring near the barrier on the rock matrix of the barrier: the critical swimming speed for larger delta smelt (~3-7 cm long) is about 30 cm/s (1 ft/s) (Swanson et al. 1998), and the swimming ability of larval and smaller juveniles would be less than for these larger fish. The estimates of seepage flow in 2015 suggest that rock barriers of this type block over 95% of the tidal flow into and out of False River; this means that the exchange of water between False River and adjacent water bodies such as the San Joaquin River and Franks Tract also is greatly reduced, which limits the potential for additional delta smelt (beyond those already occurring in False River) to be entrained into the False River channel (assuming that most delta smelt use tidal flows as the primary means of transport over longer distances).

Water Quality Effects

As noted previously, it is reasonable to assume that broad-scale water quality effects of the proposed WFRSB on delta smelt in the context of proposed Delta operations would be undertaken by DWR and Reclamation in the context of a TUCP request, as occurred in 2015 (Murillo and Cowin 2015). Based on the 2015 TUCP requests, such analyses can be anticipated to focus on changes in habitat related to conductivity and the distribution of the low salinity zone in summer/early fall, when

[7] Note that in 2015 Clifton Court Forebay water temperature reached 25°C for three days on June 10. This is the offramp criterion for juvenile delta smelt entrainment protection from Action 3 of the USFWS (2008) BiOp, i.e., the Smelt Working Group no longer would provide recommendations in water year 2015 for south Delta export restrictions because the likelihood of occurrence or survival of delta smelt above this water temperature becomes very low.

delta smelt would not be expected to be in the vicinity of the WFRSB or adjacent channels. As described in the Sediment Disturbance and Turbidity section of the Construction and Removal Effects analysis of this BA, hydrodynamic effects of the 2015 implementation of the EDB following closure led to greatly increased turbidity in Fishermans Cut and the mouth of Old River because of higher water velocity, and decreased turbidity in False River because of lower velocity. Based on the positive correlation between delta smelt and turbidity (Sommer and Mejia 2013), these changes may have increased habitat value in Fishermans Cut and the mouth of Old River from the perspective of turbidity; however, the greatly increased water velocity may have diminished habitat value: for example, mean channel velocity at the mouth of Old River (CDEC station OSJ) went from around ±0.75 ft/s prior to barrier closure to ±2ft/s after closure. Such velocity is considerably greater than the sustained or critical swimming ability of delta smelt (Swanson et al. 1998). Such effects are a reasonable representation of the types of effects that could be anticipated to occur with a future implementation of the WFRSB.

Near-Field Predation Effects

Whereas enhanced predation of juvenile salmonids in relation to artificial structures has been observed in the Delta (e.g., juvenile salmonids downstream of the Woodbridge Irrigation District Dam; Sabal 2014), there have not been observations of such predation on delta smelt. Nevertheless, predation at greater rates than normal may result should delta smelt occur in close proximity to the WFRSB.

As discussed for juvenile salmonids, small fish, including delta smelt, may be entrained toward the barrier by seepage flows and then hold station in front of it to avoid being impinged on the rocks, resulting in concentrations of fish near the barrier. Such concentrations of fish could attract piscivorous fishes and other predators. Evidence for this mechanism comes from biological monitors having observed a Caspian tern fishing along the downstream side of the 2015 EDB for several hours commencing in mid-afternoon on 1 June (Table 13); at this time, the tide was incoming with an approximate head (stage) difference of about -1 foot between downstream and upstream, which would have resulted in around -1,500 cfs of seepage flow and velocity of about 0.08 ft/s toward the barrier. There were no other such observations of predatory birds during biological monitoring, and it was not possible to establish whether predatory fishes also were exploiting concentrated small fishes in this manner. As noted in the discussion of seepage flows, the 2015 EDB was estimated to have blocked over 95% of flow into and out of False River, which would greatly limit the potential for fish to be entrained into the False River channel from the San Joaquin River or Franks Tract area. This would therefore limit the number of fish being concentrated at the barrier if the fish were moving primarily with tidal flows, although fish swimming without reliance on tidal flows could still have entered the channel and been susceptible to near-field predation at the barrier. As described in the project description, spike strips and metal baffles were installed on the Jersey Island whaler system for rodent migration prevention; these strips also would reduce perching habitat for predatory birds.

As described in the Conservation Measures section and previously for juvenile salmonids, DWR would coordinate with the California Department of Parks and Recreation Division of Boating and

Waterways Aquatic Weed Control Program for the control of invasive water hyacinth, Brazilian elodea (*Egeria densa*) or other invasive water weeds covered by the control program in the vicinity of the WFRSB while the barrier is in place. This would prevent an increase in the risk of predation of delta smelt occurring near the barrier by vegetation-associated predatory fishes such as largemouth bass.

The abutments of the WFRSB would be removed in the same year that the remainder of the barrier would be removed and therefore would not provide an additional predation risk to delta smelt.

Effects on Critical Habitat

Central Valley Spring-Run Chinook Salmon, Sacramento River Winter-Run Chinook Salmon, and Central Valley Steelhead

The WFRSB would have an aquatic footprint of 2.49 acres. The duration of the physical coverage of the channel bottom by the rocks of the barrier would be approximately four to five months or less, depending on removal dates. Disturbance of the channel substrate due to the installation and removal of the proposed WFRSB, and, to a lesser extent, due to any incidental sediment removal activities, would affect the benthic community within the barrier's footprint, and non-native species, capable of rapidly colonizing the disturbed substrate, may be favored following removal of the barrier.

The installation of the proposed WFRSB likely would affect some salmonids migrating through the Action Area. The hydrodynamic effects of the WFRSB on outmigrating juvenile salmonids would be very limited because essentially all juveniles would be expected to have left the Delta prior to barrier closure, based on the data from 2015 (Figures 10 and 11). As described previously, the barrier would create an impediment to free movement of fish within False River (e.g., for adult salmonids), as well as potentially attracting predators such as sea lions. These effects would marginally reduce the functionality of the PCEs of Central Valley spring-run Chinook salmon and Central Valley steelhead critical habitat in the Delta.

The use of construction equipment near the river has the potential to impair water quality if hazardous chemicals (e.g., fuels and petroleum-based lubricants) are spilled or enter the river; however, this did not occur during construction in 2015 because of the implementation of a number of Conservation Measures, and it is reasonable to anticipate that these measures would be effective for a future implementation of the barrier. Should such events occur during barrier removal, the potential effects would be minimal because they would be temporary. DWR would implement a spill prevention and control plan to ensure avoidance of any accidental spills or releases (see Conservation Measures below). The spill prevention and control plan would describe procedures for minimization of effects from vessel traffic collision with the WFRSB once installed. Additionally, DWR would adhere to the standard construction best management practices (BMPs) described in the current California Department of Transportation Construction Site Best Management Practices Manual (California Department of Transportation 2003).

Southern DPS of North American Green Sturgeon

As previously described in the Effects Assessment section of this BA, water quality, hydrodynamics, and passage could potentially be affected by proposed WFRSB implementation; these each contribute important aspects of critical habitat for green sturgeon. Additionally, green sturgeon food resources have the potential to be affected in the project area as a result of sediment disturbance and sediment removal. Adult green sturgeon are believed to feed primarily upon benthic invertebrates such as clams, mysid and grass shrimp, and amphipods (NMFS 2008b) and the construction and removal of the WFRSB would disturb and reduce benthic habitat in the area occupied by the barrier. However, because this area is only a very small portion of the total critical habitat for green sturgeon, the overall impact to critical habitat would be very low.

Delta Smelt

Physical habitat would be affected by construction and removal of the proposed WFRSB. River flow and salinity generally would not be affected during construction of the barrier, however these PCEs would be affected to some degree by the hydrodynamic changes caused by the operation of the barrier. The effect of construction activities on physical habitat in areas where the rock barrier is proposed to be installed would be limited to the footprint area of the WFRSB. Approximately 2.49acres of delta smelt critical habitat, in the form of physical habitat, would be directly adversely affected by the barrier. In 2015, construction activities did not impair water quality because hazardous chemicals (e.g., fuels and petroleum-based lubricants) were not spilled and did not enter the waterways near the EDB, as a result of the implemented conservation measures, including the spill prevention and control plan. As noted in the Construction and Removal Effects section of the Effects Assessment, increases in turbidity during construction in 2015 were relatively small and localized to near the construction site (Figure 5). As such, and because it is reasonable to assume that the 2015 observations are a reasonable representation of potential future conditions, it is concluded that there would be minimal effects on the water PCE from construction, and it is anticipated that continued implementation of the conservation measures would minimize effects during barrier removal activities. As noted above for salmonids, the spill prevention plan would include procedures for minimizing the effects of any vessel collisions with the WFRSB during the operational period.

As described in the Operations Effects on Fish section, it is reasonable to assume that TUCP requests would analyze the water quality effects (e.g., on salinity and the distribution of the low salinity zone) of the proposed WFRSB on delta smelt in the context of proposed Delta operations during summer/fall of future drought years, as occurred in 2015 (Murillo and Cowin 2015).

Effects on Essential Fish Habitat

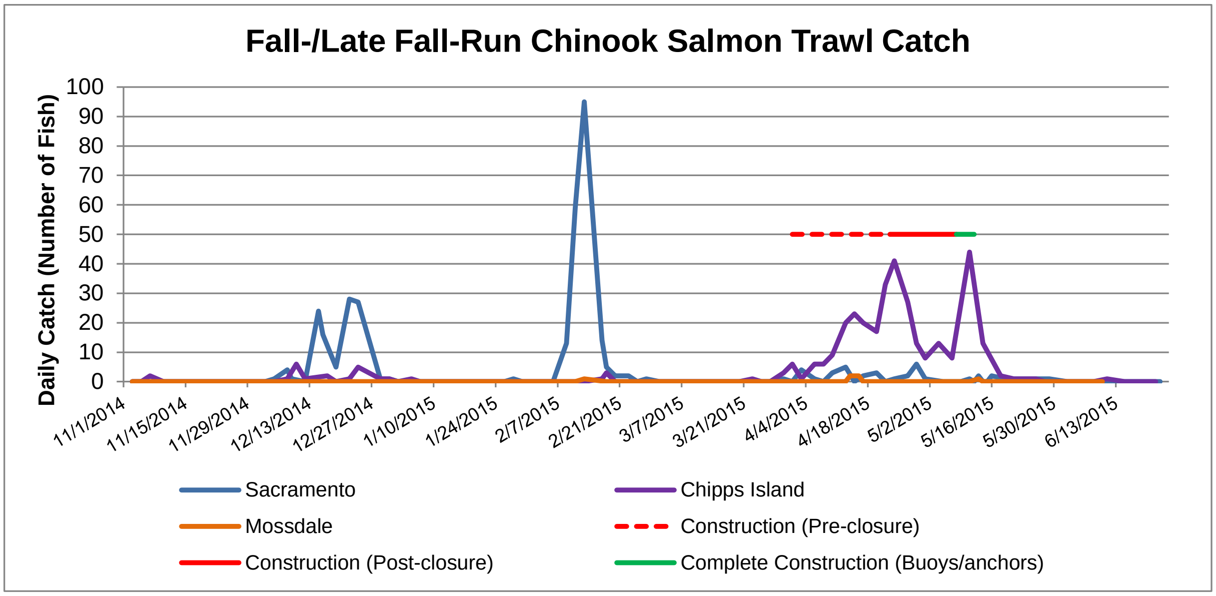
The Magnuson-Stevens Act defines EFH as “those waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity.” The 1996 amendments to the Magnuson-Stevens Act require federal agencies to consult with NMFS regarding effects on EFH for those species managed under federal Fishery Management Plans (FMP). The northern anchovy and starry flounder are managed by the Coastal Pelagic Species FMP and the Pacific Coast Groundfish FMP of the Pacific Fishery Management Council (PFMC), respectively. The PFMC manages Chinook salmon under the Pacific Coast Salmon FMP.

EFH is defined as those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. The following EFH components must be adequate for spawning, rearing, and migration: substrate composition; water quality; water quantity, depth, and velocity; channel gradient and stability; food; cover and habitat complexity; space; access and passage; and habitat connectivity. EFH is designated for starry flounder, northern anchovy, and Chinook salmon in the Bay-Delta and includes areas where the proposed WFRSB would be implemented.

Chinook Salmon EFH

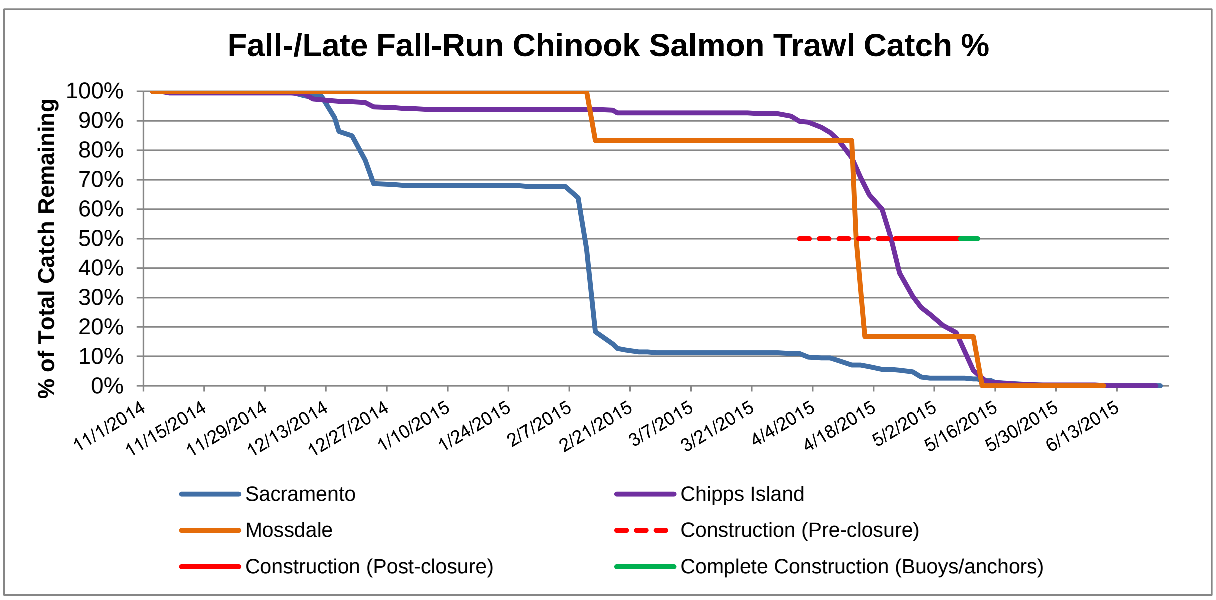
The effects of the proposed WFRSB on salmonid habitat were described above for winter-run and spring-run Chinook salmon, and generally are expected to apply to Chinook salmon EFH. However, it is also important to consider the specific timing of the fall-run/late fall-run ESU, which because of numerical dominance contributes the greatest proportion of Central Valley Chinook salmon to fisheries. As shown in the Environmental Baseline section, historic north Delta monitoring data suggest that a portion of downstream-migrating fall-run juveniles would be expected to be exposed to construction beginning in April (Table 11), whereas juvenile late fall-run Chinook salmon tend to migrate later in the year (e.g., October; Moyle et al. 2008) and compose a much smaller proportion of the two runs making up the ESU. Trawl monitoring data for November 2014 to June 2015 suggest that the start of construction beginning April 1 would have occurred later than the main migration of unmarked fall-/late fall-run Chinook salmon from the Sacramento River watershed into the Delta, but would have coincided with entry of San Joaquin River fall-run (Figure 25).[8] The main periods of juvenile entry into the Delta from the Sacramento River watershed (as indexed by Sacramento trawls) were in December (108 fish caught, of which all but 5 were fall-run) and February (191 fish, all fall-run). Late fall-run Chinook salmon entering the Delta were larger migrating juveniles and left the Delta rapidly: all but one of 18 fall-/late fall-run fish caught at Chipps Island in December were late fall-run, and only three more individuals were caught at Chipps Island in January/February. Consistent with historic observations (Kjelson et al. 1982), fall-run Chinook juveniles arriving in February appeared to rear for about two months before leaving the Delta beginning in April. Assuming that the cumulative percentage of total November-June Chipps Island catch remaining indexes the percentage of the population still to leave the Delta, construction beginning on April 1 would have coincided with about 90% of the population remaining in the Delta (Figure 26). By the time of barrier closure—assuming around 3 weeks to barrier closure, per the 2015 timeline—there would have been over 60% of the population remaining in the Delta, and completion of in-water construction would have occurred at the very end of the outmigration as indicated by capture of fish at Chipps Island. The pattern for fall-run Chinook salmon entry from the San Joaquin River watershed (as indexed by Mossdale trawling) was similar to the pattern for Chipps Island trawling, although only six fall-run-sized fish were caught. Overall, the trawl monitoring data from 2015

[8] Race of fish was assigned by length at data criteria. Unmarked fish consist of a mixture of natural-origin and hatchery fish, because most hatchery-origin fish are unmarked.



Source: Speegle, pers. comm. Notes: Effort within each survey was approximately equal on each day, so catch is summed across all trawls at each location on each day. Fish were assigned to race by length at date, and only unmarked fish are included. Data end on June 23 (Sacramento), June 22 (Chipps), and June 10 (Mossdale).

Figure 25. Daily Catch of Fall- and Late Fall-Run-sized Chinook Salmon from Delta Juvenile Fish Monitoring Program Trawling, November 1, 2014, to June 23, 2015, with Horizontal Lines Indicating a Potential Construction Timeline Beginning April 1 that is Based on the 2015 Construction Timeline.



Source: Speegle, pers. comm. Notes: Effort within each survey was approximately equal on each day, so catch is summed across all trawls at each location on each day, with the cumulative percentage remaining of total November-June catch remaining. Fish were assigned to race by length at date, and only unmarked fish are included. Data end on June 23 (Sacramento), June 22 (Chipps), and June 10 (Mossdale).

Figure 26. Daily Percentage Remaining of Total November-June Catch of Fall- and Late Fall-Run-sized Chinook Salmon from Delta Juvenile Fish Monitoring Program Trawling, with Horizontal Lines Indicating a Potential Construction Timeline Beginning April 1 that is Based on the 2015 Construction Timeline.

suggest that EFH for Chinook salmon juvenile migration had the potential for appreciable temporal overlap with WFRSB construction. The operations effects described in the Effects Assessment for winter-run and spring-run Chinook salmon (i.e., hydrodynamic effects, including barriers to passage, and near-field predation effects) would have temporally overlapped an appreciable portion of juvenile fall-/late fall-run Chinook salmon in the Delta, and based on spatial overlap, might have greater potential to affect fall-run Chinook salmon from the San Joaquin River watershed. It is reasonable to assume that the patterns of juvenile Chinook salmon occurrence observed in 2015 are representative of the timing that would occur during implementation of the WFRSB in 2016, which is the subject of this BA.

A minor proportion of downstream-migrating fall-run Chinook juveniles could be exposed to the tail end of the proposed WFRSB operational period in October, and could also be exposed to barrier removal in September/October/November (Table 11). As noted above, late fall-run Chinook salmon downstream migration can occur in October (Moyle et al. 2008), coinciding with the period of barrier removal.

Upstream movement of adult fall-run Chinook salmon at RBDD peaks in October (approximately 40%) and is substantial in August (10%), September (>30%), and November (12.5%); only minor proportions (2.5%) of the upstream migrants pass RBDD in July and December (Table 12; Vogel and Marine 1991). The proposed WFRSB construction therefore would not be expected to overlap adult fall-run Chinook salmon upstream migration. Barrier operations (April/May to October) would be expected to appreciably overlap fall-run Chinook salmon upstream migration and would have the potential for effects to EFH by blocking or delaying upstream migration, possibly mostly for fish returning to the San Joaquin River watershed. However, as previously noted in the Operations Effects on Fish section, this would represent only a minor delay and in some cases may reduce migration time through the Delta (e.g., for fish returning to the Sacramento River that had entered the lower San Joaquin River, and otherwise would have penetrated farther into the interior Delta through False River). As judged from migration timing at RBDD (Table 12), it would be expected that effects on late fall-run Chinook salmon adults migrating upstream would be limited to operations effects near the end of the barrier operational period in October and during removal effects in September/October/November; nearly 40% of the population passes above RBDD in October and November. Based on seasonality of migration, it is unlikely that there were any effects to late fall-run Chinook salmon adults from barrier construction activities.

Starry Flounder and Northern Anchovy EFH

Installation and operation of the proposed WFRSB could degrade certain functional habitat characteristics of northern anchovy and starry flounder EFH (i.e., free movement of fish, passage obstructions, alterations of water quality parameters, and creation of lentic conditions) during the period of operation.

Starry flounder would be most likely to occur in the vicinity of the barrier during low outflows as young-of-the-year fish, with abundance tending to be very low prior to June, when recruitment begins in earnest (Baxter et al. 1999). Although found in the west Delta from July to December, the relative abundance of young-of-the-year starry flounder is very low compared to other areas such as Suisun Bay and San Pablo Bay (Baxter et al. 1999). As the species grows, it tends to move into higher salinity waters and so would be unlikely to be present in the Action Area as yearling or older fish.

A total of nearly 2,800 northern anchovy were collected from 2002 to 2014 during the annual Spring Kodiak Trawl sampling program that is undertaken at 40 stations in the Bay-Delta from January to May (California Department of Fish and Wildlife 2015); the majority (nearly 2,200, or nearly 80%) were collected in 2014. The species was collected in January-May. The furthest upstream that the species was collected from this sampling program during 2002-2014 is from station 801 at the confluence of the Sacramento and San Joaquin rivers. Northern anchovy abundance is generally low in winter, increasing in spring, and high in summer, before declining again in the fall (Baxter et al. 1999). It is likely that northern anchovy abundance would be low in the vicinity of the WFRSB.

Northern anchovy and starry flounder are primarily marine and estuarine species that are more abundant seaward of the proposed WFRSB. EFH for these species is expected to be only minimally affected by the alteration of habitat from the implementation of the proposed barrier.

Cumulative Effects

Under the ESA, cumulative effects are "those effects of future state, tribal, local, or private actions that are reasonably certain to occur within the action area of the federal action subject to consultation" (50 Code of Federal Regulations [CFR] 402.2). Future federal actions that are unrelated to the proposed action are not considered in this assessment because they require separate consultation pursuant to Section 7 of the ESA.

The following discussion is adapted from the NMFS (2014) and USFWS (2014b) BOs on the Georgiana Slough Floating Fish Guidance Structure Study. Of the factors discussed, several (urbanization, bank protection, and climate change) may be more applicable to longer term effects on the species than the relatively limited duration of the proposed WFRSB.

Entrainment

Within the Action Area, non-federal diversions of water (e.g., municipal and industrial uses, as well as diversions through intakes serving numerous small, private agricultural lands) are on-going and likely to continue into the foreseeable future. These non-federal diversions are not likely to entrain many delta smelt based on the results of a study by Nobriga et al. (2004). Nobriga et al. (2004) reasoned that the littoral location and low-flow operational characteristics of these diversions reduced their risk of entraining delta smelt. Although these non-federal diversions do not appear to entrain large numbers of delta smelt, they are a source of entrainment for delta smelt. These diversions also entrain juvenile salmonids and, based on laboratory studies, may pose a risk to juvenile green sturgeon approaching close to them during operating periods (Mussen et al. 2014).

Contaminants

Adverse effects to ESA-listed fishes and their critical habitat may result from point and non-point source chemical contaminant discharges within the Action Area. These contaminants include, but are not limited to ammonia/ammonium, numerous pesticides and herbicides, and oil and gasoline product discharges. Oil and gasoline product discharges may be introduced into Delta waterways from shipping and boating activities and from urban activities and runoff. Implicated as potential stressors of delta smelt, these contaminants may adversely affect fish reproductive success and survival rates.

Ammonia loading in the Bay-Delta has increased significantly in the last 25 years (Jassby 2008). Effects of elevated ammonia levels on fish range from irritation of skin, gills, and eyes to reduced swimming ability, and mortality (Wicks et al. 2002). Delta smelt have shown direct sensitivity to ammonia at the larval and juvenile stages (Werner et al. 2008). Connon et al. (2011) investigated the sublethal effects of ammonia exposure on the genes of juvenile delta smelt and found that ammonia altered gene transcription including specific genes related to cell membrane integrity, energy metabolism, and cellular responses to environmental stimuli. The study supports the possibility of ammonia exposure-induced cell membrane destabilization that would affect membrane permeability and thus enhance the uptake of other contaminants. Ammonia also can be toxic to several species of copepods important to larval and juvenile fishes (Werner et al. 2010; Teh et al. 2011). There is increasing evidence that ammonium loading has affected the lower food web by changing nutrient balance (e.g., Parker et al. 2012).

Implementation of the proposed WFRSB is unlikely to measurably change the dilution of any contaminants that are discharged into Delta waterways because changes in diluting flows would be very small, and limited to the False River channel where tidal flows have been greatly reduced.

Urbanization

Increases in urbanization and housing developments can impact habitat by altering watershed characteristics, and changing both water use and stormwater runoff patterns. A number of cities in the Delta watershed anticipate in their respective general plans rapid growth in the future. The anticipated growth will occur along both the I-5 and US-99 transit corridors in the east and Highway 205/120 in the south and west. Increased growth will place additional burdens on resource allocations, including natural gas, electricity, and water, as well as on infrastructure such as wastewater sanitation plants, roads and highways, and public utilities. Some of these actions, particularly those that are situated away from waterbodies, will not require federal permits, and thus will not undergo review through the ESA Section 7 consultation processes with the USFWS or NMFS; they therefore may contribute to cumulative effects.

Increased urbanization also is expected to result in increased recreational activities in the region. Among the activities expected to increase in volume and frequency is recreational boating. Boating activities typically result in increased wave action and propeller wash in waterways. This potentially will degrade riparian and wetland habitat by eroding channel banks and mid-channel islands, thereby causing an increase in siltation and turbidity. Wakes and propeller wash also churn up benthic sediments thereby potentially resuspending contaminated sediments and degrading areas of submerged vegetation and other littoral habitats. This in turn would reduce habitat quality for the invertebrate forage base that is consumed by juvenile salmonids and green sturgeon moving through the system, and may affect delta smelt occurring in littoral areas (e.g., during spawning). Increased recreational boat operation in the Delta is anticipated to result in more contamination from the operation of gasoline and diesel powered engines on watercraft entering the water bodies of the Delta. Furthermore, increased recreational boating greatly increases the risk of spreading non-native invasive species into the Delta, particularly if boats are trailered between different water bodies.

Bank Protection

Bank protection actions may cumulatively affect listed fishes by altering riparian and littoral habitat through installation of large rock. Such actions may be undertaken by state and local agencies, but are likely to require USFWS and NMFS consultations because of the need to acquire USACE permits for in-water work.

Climate Change

Effects of climate change could be particularly profound for aquatic ecosystems and include increased water temperatures and altered hydrology, along with changes in the extent, frequency, and magnitude of extreme events such as droughts, floods, and wildfires (Reiman and Isaak 2010). Numerous climate models predict changes in precipitation frequency and pattern in the western United States (Intergovernmental Panel on Climate Change [IPCC] 2007). Projections indicate that temperature and precipitation changes will diminish snowpack, changing the availability of natural water supplies (U.S. Bureau of Reclamation 2011). Warming may result in more precipitation falling as rain and less storage as snow. This would result in increased rain on snow events and increase winter runoff as spring runoff decreases (U.S. Bureau of Reclamation 2011). Earlier seasonal warming increases the likelihood of rain-on-snow events, which are associated with mid-winter floods. Smaller snowpacks that melt earlier in the year result in increased drought frequency and severity (Rieman and Isaak 2010). These changes may lead to increased flood and drought risk during the 21st century (U.S. Bureau of Reclamation 2011). The National Academy of Sciences (NAS) projected that sea levels along the California coast south of Cape Mendocino will rise 4-30 cm (2-12 inches) by 2030, 12-61 cm (5-24 inches) by 2050, and 42-167 cm (16-66 inches) by 2100 (NAS 2012) compared to 2000 sea levels.

Increased summer temperatures and less flow in upstream tributaries would make habitat less suitable for listed salmonid survival. The cold snowmelt that furnishes the late spring and early summer runoff is expected to be replaced by warmer precipitation runoff. This should shorten the duration of suitable cold-water conditions below existing reservoirs and dams due to the warmer inflow temperatures to the reservoir from rain runoff. Without the necessary cold water pool developed from melting snowpack filling reservoirs in the spring and early summer, late summer and fall temperatures below reservoirs, such as Lake Shasta, could potentially rise above thermal tolerances for juvenile and adult salmonids (i.e., Sacramento River winter-run Chinook salmon and California Central Valley steelhead) that must hold below dams over the summer and fall periods. Climate change effects also are predicted to be adverse to spring-run Chinook salmon that inhabit tributaries throughout the summer, e.g., in Butte Creek (Thompson et al. 2012).

It is uncertain how a change in the timing and duration of freshwater flows will affect delta smelt. The melting of the snowpack earlier in the year could result in higher flows in January and February, ahead of peak spawning and hatching months for delta smelt. This could alter the timing or magnitude of migration and spawning cues, and potentially result in decreased spawning success. Sea level rise is likely to increase the frequency and range of saltwater intrusion. Salinity within the northern San Francisco Bay is projected to rise by 4.5 psu by the end of the century (Cloern et al. 2011). Elevated salinity levels could push the LSZ farther up the estuary and could result in increased distances that delta smelt must migrate to reach spawning habitats. The upstream movement of the LSZ would result in a decrease in suitable abiotic habitat (Brown et al. 2013). As the freshwater boundary moves farther inland into the Delta with increasing sea level and reduced flows, adult delta smelt would need to migrate farther into the Delta to spawn, increasing the risk of predation and the potential for entrainment into water export facilities and diversions for both themselves and their progeny. Warmer water temperatures could increase delta smelt mortality and constrict suitable habitat throughout the Delta during the summer months. Due to warming temperatures, delta smelt are projected to spawn between 10-25 days earlier in the season depending on the location (Brown et al. 2013). Also due to expected temperature increases, total number of high mortality days is expected to increase for all IPCC climate change scenarios (Brown et al. 2013). The number of stress days is expected to be stable or decrease partly because many stress days will become high mortality days. This could lead to delta smelt being forced to grow under highly stressful conditions during summer and fall with less time to mature because of advanced spawning (Brown et al. 2013).

Conservation Measures

DWR would implement a number of conservation measures as part of the project to assist with avoiding and minimizing potential environmental impacts from the proposed WFRSB, including those to the listed fishes included in this BA. This section summarizes these measures.

Prepare and Implement an Erosion Control Plan

An Erosion Control Plan will be prepared before beginning construction activities that will cause ground disturbance. Site-specific erosion-control, spill-prevention, sedimentation control, and runoff measures will be developed and implemented during construction activities as part of the plan to minimize the potential for erosion and sedimentation during barrier construction and removal.

If applicable, tightly woven fiber netting (mesh size less than 0.25 inch) or similar material will be used for erosion control and other purposes at the project site to ensure wildlife does not become trapped or entangled in the erosion control material. Coconut coir matting is an acceptable erosion control material, but no plastic mono-filament matting will be used for erosion control. Where feasible, the edge of the material will be buried in the ground to prevent wildlife from crawling underneath the material.

Prepare and Implement a Spill Prevention and Control Program

A Spill Prevention and Control Program will be prepared before the start of construction to minimize the potential for hazardous, toxic, or petroleum substances to be released into the project area during construction and operation. The program will be implemented during construction. In addition, DWR will place sand bags, biologs, or other containment features around the areas used for fueling or other uses of hazardous materials to ensure that these materials do not accidentally leak into the river. DWR will adhere to the standard construction best management practices described in the current California Department of Transportation Construction Site Best Management Practices Manual (California Department of Transportation 2003).

The Spill Prevention and Control Program will include procedures for mitigating potential spills caused by collision/stranding of vessel traffic with the barrier during its operation. Spill control materials will be kept at the barrier site and at additional DWR-owned locations in the Delta. The barrier will have clear signage with telephone contact details for DWR personnel as well as the Governor's Office of Emergency Services (CalOES) hazardous materials (HAZMAT) spill notifications contact number (1-800-852-7550).

Prepare and Implement a Hazardous Materials Management Program

A Hazardous Materials Management Program (HMMP) will be prepared and implemented to identify the hazardous materials to be used during construction; describe measures to prevent, control, and minimize the spillage of hazardous substances; describe transport, storage, and disposal procedures for these substances; and outline procedures to be followed in case of a spill of a hazardous material. The HMMP will require that hazardous and potentially hazardous substances stored onsite be kept in securely closed containers located away from drainage courses, storm drains, and areas where stormwater is allowed to infiltrate. It will also stipulate procedures to minimize hazard during onsite fueling and servicing of construction equipment. Finally, the HMMP will require that adjacent land users be notified immediately of any substantial spill or release.

Conduct a Worker Environmental Awareness Program

Construction workers will participate in a Worker Environmental Awareness Program that addresses species under jurisdiction of the permitting agencies (CDFW, USFWS, and NMFS). Workers will be informed about the potential presence of listed and other protected species, and habitats associated with such species, and that unlawful take of the species or destruction of their habitat is a violation of the federal ESA, California Endangered Species Act (CESA), and/or Migratory Bird Treaty Act. Before the start of construction activities, a qualified biologist approved by the permitting agencies will instruct all construction workers about the life histories of the protected species and the terms and conditions of the applicable Biological Opinions (BOs), CESA Incidental Take Permit (ITP), and other regulatory permits that include biological resource protection measures. Proof of this instruction will be submitted to the permitting agencies.

Conduct Biological Monitoring

A qualified biologist approved by the permitting agencies will be onsite when daytime construction occurs to conduct compliance inspections and monitoring during barrier installation and removal. The qualifications of the biologist(s) will be presented to the permitting agencies for review and approval before beginning project activities at the project site. The complete set of permitting documents will be onsite during construction. The biologist(s) will be given the authority to stop work that may result in, or in the event that there is, take of listed species in excess of limits provided by the permitting agencies in any permitting document (BOs, CESA ITP). Should the biologist(s) exercise this authority, the permitting agencies will be notified by telephone and electronic mail within 1 working day.

A report of daily records from monitoring activities and observations will be prepared and provided to the permitting agencies upon completion of project activities.

Conduct Real-Time Monitoring and Adjust Construction Activities Accordingly

DWR will monitor weather patterns and river forecasts for the period preceding the start of construction. If precipitation events or increases in river levels and flows are predicted to occur immediately before the start of construction, DWR will notify NMFS, USFWS, and CDFW before the start of construction and informally will confer with them to determine whether construction actions are still feasible as previously considered. Sudden increases in river flows, imminent precipitation events that create changes in river stage in the Sacramento and San Joaquin valleys, or observed sudden increases in turbidity in the Sacramento or San Joaquin rivers upstream of the Delta may initiate pulses of fish migration into the project channels (e.g., juvenile salmonids moving downstream, pre-spawning delta smelt moving upstream).

DWR also will monitor the capture of listed fishes in the fish monitoring programs currently being employed in and close to the barrier site, (i.e., at the nearest Interagency Ecological Program monitoring stations). If increasing presence of listed fishes (principally juvenile salmonids and smelts) is detected in these monitoring efforts during project implementation, DWR will immediately contact NMFS, USFWS, and CDFW to allow informal consultation to determine whether construction actions will place fish at substantial additional risk near the barrier site.

Conduct Pile Driving With a Vibratory Driver To The Extent Possible; Minimize Effects of Impact Driving

DWR will conduct pile driving using a vibratory hammer to minimize to the extent possible the noise generated from pile-driving activities. NMFS (2015:50) noted in the Biological Opinion for the

Woodward Island Bridge Project over Middle River that only the driving of piles with an impact hammer is expected to produce sound levels that could result in injury to fish, so the use of a vibratory hammer for the West False River salinity barrier abutments substantially reduces or avoids the potential to cause take of listed species. However, in certain circumstances (e.g., vibratory driving is not capable of reaching required embedment), impact pile driving may be necessary. If impact pile driving is necessary, bubble curtains will be employed to attenuate noise. Monitoring of underwater sound generated by the impact hammer during pile driving in the vicinity of the West False River barrier will be conducted to verify that sound level criteria are not being exceeded, i.e., 183-decibel sound exposure level (SEL) at 10 meters from pile driving. If levels are exceeded, the permitting fish agencies will be notified and work halted until corrective actions are instituted to achieve sound level criteria. Sound monitoring is not proposed for vibratory pile driving because there are no accepted threshold criteria for vibratory pile driving (Pearson-Meyer, pers. comm.).

Install In-Water Navigational Buoys, Lights, and Signage

Navigational buoys, lights, and signage will be installed in West False River upstream and downstream from the West False River salinity barrier, and proximate to Fisherman's Cut, to advise boaters about the presence of the emergency salinity barrier and maintain navigation along both waterways. Temporary floating signs and buoys will be anchored to the bottom with cables and concrete anchor blocks. DWR will coordinate with the U.S. Coast Guard on signage and buoys.

Implement Turbidity Monitoring during Construction

DWR will monitor turbidity levels in West False River during ground-disturbing activities, including placement of rock fill material and any major maintenance. Monitoring will be conducted by measuring upstream and downstream of the disturbance area to ensure compliance with the Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins (Central Valley Regional Water Quality Control Board 2011). For Delta waters, the general objectives for turbidity apply, except during periods of stormwater runoff; the turbidity of Delta waters shall not exceed 150 Nephelometric Turbidity Units (NTU). Exceptions to the Delta specific objectives are considered when a dredging operation can cause an increase in turbidity. In this case, an allowable zone of dilution within which turbidity in excess of limits can be tolerated will be defined for the operation and prescribed in a discharge permit.

DWR contractors will slow or adjust work to ensure that turbidity levels do not exceed those conditions described in the 401 certification issued by the SWRCB. If slowing or adjusting work to lower turbidity levels is not practical or if thresholds cannot be met, DWR will consult with the SWRCB and permitting agencies to determine the most appropriate measures to minimize turbidity impacts to the maximum extent feasible.

Develop and Implement a Water Quality Monitoring Plan

DWR will develop and implement a Water Quality Monitoring Plan to assess the effects of the proposed project on flow and water quality throughout the Delta. Monitoring data will be provided by strategically-placed stations installed as part of the EDB project. DWR also may use data from other existing and recently upgraded stations throughout the Delta.

DWR will monitor flow, stage, water velocity, water temperature, specific conductance, turbidity, chlorophyll, nutrients, bromide, and organic carbon, pH, and dissolved oxygen. DWR staff will post weekly water quality data summaries of the continuous data. Chlorophyll and nutrient data will be posted online as soon as the results are available.

The water quality monitoring plan will document the procedures for producing the following elements:

- Water quality data from monitoring sites;
- Weekly water quality summaries;
- Chlorophyll and nutrient data (discrete data) summaries as soon as the results are available;
- Final report on project effects on water quality.

Limit Habitat Disturbance, Return Disturbed Areas to Pre-Project Conditions, And Provide Mitigation Habitat

DWR and its construction contractors will strive to limit habitat disturbance during project-related construction activities. Immediately following barrier removal, DWR will restore habitat to approximate pre-project conditions.

DWR will provide mitigation through a mitigation bank approved by USFWS and CDFW at a 1:1 ratio for temporary (less than 1 year) impacts on shallow water habitat associated with the barrier rock.

DWR will provide mitigation, as determined by USFWS and CDFW, for temporary impacts on giant garter snake habitat through purchase of credits at a USFWS- and CDFW-approved mitigation bank.

Limit Land-Based Access Routes and Construction Area

The number of land-based access routes and size of the construction area will be limited to the minimum area necessary. Access routes will be restricted to established roadways. Construction area boundaries will be clearly demarcated.

Minimize Wildlife Attraction

To eliminate attraction of wildlife to the project site, all food-related trash items, such as wrappers, cans, bottles, and food scraps, will be disposed of in closed containers and removed from the site on a daily basis.

Remove Invasive Species

DWR will coordinate with the California Department of Parks and Recreation Division of Boating and Waterways Aquatic Weed Control Program for the control of invasive aquatic weeds in the vicinity of the barrier that are covered by the control program while the barrier is in place. As needed, the Division of Boating and Waterways will conduct herbicide treatments to control infestations of covered aquatic weeds that may result from changes in flow due to installation of the barrier. DWR will coordinate with the Division of Boating and Waterways on removal strategies for covered invasive aquatic weeds as necessary to ensure that the barrier does not exacerbate current aquatic invasive weed problems.

Conclusions

ESA-Listed Fish and Critical Habitat

It is concluded that the WFRSB would adversely affect all of the ESA-listed fish species occurring in the Action Area, and adversely modified the critical habitat for the species with designated critical habitat in False River (Table 16).

Implementation of the conservation measures would avoid or minimize adverse effects to the maximum extent practicable.

Table 16. Effects Determinations on ESA-Listed Fishes and Critical Habitat From the West False River Salinity Barrier Project

Species	Status*	Effect Determination
Central Valley spring-run Chinook salmon (*Oncorhynchus tshawytscha*)	FT, ST	May Affect, Likely to Adversely Affect
Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*)	FE, SE	May Affect, Likely to Adversely Affect
Central Valley steelhead (*Oncorhynchus mykiss*)	FT	May Affect, Likely to Adversely Affect
North American green sturgeon (*Acipenser medirostris*), southern distinct population segment (DPS)	FT	May Affect, Likely to Adversely Affect
Delta smelt (*Hypomesus transpacificus*)	FT, SE	May Affect, Likely to Adversely Affect
Central Valley steelhead designated critical habitat	X	May Affect, Likely to Adversely Affect
North American green sturgeon designated critical habitat	X	May Affect, Likely to Adversely Affect
Delta smelt designated critical habitat	X	May Affect, Likely to Adversely Affect

DPS = distinct population segment.
* Status definitions:
FE = listed as Endangered under the federal Endangered Species Act.
FT = listed as Threatened under the federal Endangered Species Act.
X = designated Critical Habitat under the Federal Endangered Species Act.
SE = listed as Endangered under the California Endangered Species Act.
ST = listed as Threatened under the California Endangered Species Act.

Essential Fish Habitat

It is concluded that the West False River Salinity Barrier Project would have an adverse effect on EFH for Chinook salmon, starry flounder, and northern anchovy. Implementation of the above conservation measures would avoid or minimize adverse effects to the maximum extent practicable.

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Appendix A
Potential Pile Driving Effects

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Methods

The West False River Emergency Drought Barrier Project of 2015 involved in-water pile driving at the West False River barrier site in order to install two king pile-supported sheet pile walls forming the barrier abutments, which extended out from each levee into the channel for a distance of 75 feet. The analysis presented below refers to the king and sheet piles as 'barrier piles'. The data gathered in 2015 are considered representative of the potential effects that could occur during the future installation of the WFRSBthat is the subject of this BA.

All pile driving in 2015 was conducted with a vibratory driver. Bubble curtain attenuation was provided, although the integrity of the bubble curtain was often compromised by the swift tidal currents in False River. Sound was monitored at 10 m during driving of the barrier piles. It was not possible to monitor all pile driving noise because pile driving occurred simultaneously at both sides of the False River channel on some days; when this occurred, monitoring was undertaken for the piles likely to generate greater noise effects.

An interagency working group including NMFS has established interim criteria for evaluating underwater noise impacts from pile driving on fish. These criteria are defined in the document entitled "Agreement in Principal for Interim Criteria for Injury to Fish from Pile Driving Activities" dated June 12, 2008 (Fisheries Hydroacoustic Working Group 2008). This agreement identifies a peak sound pressure level of 206 decibels (dB) and an accumulated sound exposure level (SEL)[9] of 187 dB as thresholds for injury to fish. For fish less than 2 g, the accumulated SEL threshold is reduced to 183 dB. Although there has been no formal agreement on a "behavioral" threshold, NMFS uses 150 dB-RMS as the threshold for adverse behavioral effects.

However, the interim criteria adopted by the Fisheries Hydroacoustic Working Group (2008) apply only to impact pile driving. There are no accepted sound criteria for vibratory driving (see, for example, the recent NMFS [2015] biological opinion on the Woodward Island Bridge Project over Middle River). In comparison to impact pile driving, vibratory pile driving is acknowledged to minimize the amount of noise and turbidity and to substantially reduce or avoid the potential to cause take of the listed species (USFWS 2015). Proposed criteria for vibratory driving suggest considerably higher threshold levels than for impact pile driving (Hastings 2010):

- Non-auditory tissue damage
  - Mass ≤ 0.6 g = 191 dB cumulative SEL
  - For fish between 0.6 and 102 g mass, cumulative SEL = 195.28 + 19.28*log10(mass)
  - Mass ≥ 102 g = 234 db cumulative SEL

[9] Sound exposure level (SEL) is defined as the constant sound level acting for one second, which has the same amount of acoustic energy as the original sound. Expressed another way, the sound exposure level is a measure of the sound energy in a single pile driver strike. Cumulative SEL results from successive pile strikes. Cumulative SEL is based on the number of pile strikes and the SEL per strike; the assumption is made that all pile strikes are of the same SEL.

- Auditory tissue damage
    - Hearing generalists (e.g., salmonids): > 234 dB cumulative SEL
    - Hearing specialists (e.g., carp): 222 dB cumulative SEL
- Temporary threshold shift (hearing loss)
    - Hearing generalists: 234 dB cumulative SEL
    - Hearing specialists: 185 dB cumulative SEL

Note, however, that vibratory pile driving is considered to be very protective of listed fishes. For example, in the BO for the Woodward Island Bridge Project over Middle River, NMFS (2015: 50) noted: "Only the driving of piles with an impact hammer is expected to produce sound levels that could result in injury to fish." The analysis below estimated the distance from the pile driving to where non-auditory tissue damage would no longer occur, based on the proposed thresholds of Hastings (2010). This can be considered a conservative analysis. The calculations were made for four representative species/sizes of listed fish:

- Larval delta smelt (≤ 0.6 g): 191 dB SEL
- Adult delta smelt (4.0 g for 70-mm standard length [Kimmerer et al. 2005]): 206.9 dB SEL
- Juvenile Chinook salmon (9.5 g for 90-mm standard length juvenile Chinook salmon [Kimmerer et al. 2005]): 214.1 dB SEL
- Juvenile and adult steelhead, adult Chinook salmon (≥ 102 g): 234 db cumulative SEL

The cumulative SEL was provided for each pile driving session (Mahmodi, pers. comm.), with a session consisting of a continuous period of driving of the same pile. For the barrier piles, driving on any given day was only undertaken on one type of pile (king or sheet) and on one side of the channel (north or south). To simplify the calculations, it was assumed that all pile driving sessions on a given day occurred at the same location. The cumulative sound energy for all sessions in a given day was calculated by summing the cumulative sound energy from each individual session:

$$\text{Cumulative sound energy per session} = 10^{(\text{Cumulative SEL/Distance to pile driving})}$$

The distance to pile driving from the acoustic monitoring equipment was always 10 m.

The summed cumulative sound energy was then converted to the daily cumulative SEL:

$$\text{Daily cumulative SEL: } 10*\log(\text{summed cumulative sound energy across sessions})$$

The daily cumulative SEL was then used to estimate the distance up to which the proposed thresholds of Hastings (2010) would have extended, based on the formula from the NMFS calculator spreadsheet[10]:

$$\text{Distance to threshold} = \text{Distance to pile driving}*10^{((\text{Cumulative SEL} - \text{threshold})/\text{transmission loss constant}))}$$

As stated above, the distance to pile driving was always 10 m; per the NMFS calculator spreadsheet, the transmission loss constant was assumed to be 15.

Results

In 2015, in-water pile driving was undertaken on 8 days from May 14 to May 22 (Table A1). The number of pile driving sessions per day that was monitored ranged from 3 to 8, with the total duration spent pile driving ranging from just under an hour on May 14 (king piles, south side) to around 4.5 hours on May 20 (sheet piles, north side). The mean cumulative SEL per session that was monitored for sound was 193.8 dB (range 178.7 to 205.1 dB). As previously noted, pile driving on some days occurred simulataneously at both abutments and it was not possible to monitor both locations.

The calculated distance up to which the proposed non-auditory tissue injury thresholds of Hastings (2010) would have extended, based on daily cumulative SEL, varied by species/size. For larval delta smelt, the mean distance affected was 79.9 m (range 4.2 to 171.0 m), or approximately262 feet (range 14 to 560 feet) (Table A1). For adult delta smelt, the mean distance affected was 7.0 m (range 0.4 to 14.9 m), or approximately23 feet (range 1 to 49 feet). For juvenile Chinook salmon, the mean distance affected was 2.3 m (range 0.1 to 2.3 m), or approximately 8 feet (range 0 to 16 feet). For juvenile/adult steelhead and adult Chinook salmon, the mean distance affected was 0.11 m (range 0.0 to 0.2 m), or well below one foot (Table A1). These distances represent the distance from the locations that were monitored; as noted previously, pile driving occurred at both abutments simultaneously on some days, so the area of potential effect would have been greater than suggested by monitoring on those days.

[10] Downloaded from http://www.dot.ca.gov/hq/env/bio/files/NMFS%20Pile%20Driving%20Calculations.xls on 3/20/2014.

Table A1. Summary of In-Water Pile Driving at Emergency Drought Barrier with Sound Monitoring Data, May 2015, Including Cumulative Sound Exposure Level (SEL).

Date	Start	Stop	Pile Type (Location[1])	Duration Driven (Hr: Min:Sec)	Cum. SEL (dB)	Daily Distance Exceeding Proposed Non-Auditory Tissue Damage Threshold (Hastings 2010), Meters[2]			
						191 dB (larval delta smelt)	206.9 dB (adult delta smelt)	215.6 dB (juvenile Chinook salmon)	234 dB (juvenile/adult steelhead; adult Chinook salmon)
14-May-15	7:06	7:18	King (South)	0:12:19	180.9	4.17	0.36	0.12	0.01
	16:20	16:45	King (South)	0:24:46	181.5				
	16:57	17:16	King (South)	0:19:02	178.7				
15-May-15	7:29	8:01	King (South)	0:31:59	202.1	85.44	7.45	2.45	0.12
	8:35	8:40	King (South)	0:05:06	190.2				
	9:28	9:42	King (South)	0:14:06	189.8				
	9:49	10:07	King (South)	0:18:04	179.4				
	12:34	12:37	King (South)	0:02:48	181				
	12:49	13:32	King (South)	0:43:01	200.9				
	14:36	15:19	King (South)	0:42:51	185.2				
	15:51	16:18	King (South)	0:26:59	185.7				
16-May-15	9:17	11:03	Sheet (North)	1:46:04	192.8	48.35	4.21	1.39	0.07
	12:42	13:18	Sheet (North)	0:36:17	195.6				
	14:04	14:35	Sheet (North)	0:31:09	187.8				
	15:17	15:51	Sheet (South)	0:33:53	198.6				
18-May-15	10:58	11:22	Sheet (South)	0:24:05	198.9	136.87	11.93	3.93	0.19
	11:50	12:17	Sheet (South)	0:26:27	202.3				
	13:34	14:02	Sheet (South)	0:27:55	201.1				
	15:19	16:07	Sheet (South)	0:48:17	203				
	17:03	17:20	Sheet (South)	0:16:51	197.9				
19-May-15	7:58	8:17	Sheet (North)	0:19:00	189.8	39.46	3.44	1.13	0.05
	8:18	9:25	Sheet (North)	1:07:33	196.5				
	11:40	11:50	Sheet (North)	0:09:21	186.3				
	12:50	12:58	Sheet (North)	0:08:23	188.1				
	13:37	14:10	Sheet (North)	0:32:30	193				
	14:36	15:45	Sheet (North)	1:09:03	191.4				

Date	Start	Stop	Pile Type (Location[1])	Duration Driven (Hr: Min:Sec)	Cum. SEL (dB)	Daily Distance Exceeding Proposed Non-Auditory Tissue Damage Threshold (Hastings 2010), Meters[2]			
						191 dB (larval delta smelt)	206.9 dB (adult delta smelt)	215.6 dB (juvenile Chinook salmon)	234 dB (juvenile/adult steelhead; adult Chinook salmon)
20-May-15	7:28	8:12	Sheet (North)	0:44:44	203.3	171.04	14.91	4.91	0.23
	10:12	10:38	Sheet (North)	0:26:15	202.4				
	12:04	12:41	Sheet (North)	0:36:59	200.6				
	13:22	13:27	Sheet (North)	0:05:21	192.5				
	15:54	17:46	Sheet (North)	1:52:20	205.1				
	19:01	19:50	Sheet (North)	0:49:20	196.7				
21-May-15	9:20	9:40	Sheet (South)	0:19:57	197.8	90.67	7.90	2.60	0.12
	12:52	14:27	Sheet (South)	1:34:49	204.2				
	15:21	16:16	Sheet (South)	0:54:37	193.1				
22-May-15	7:25	7:50	Sheet (North)	0:25:29	196.3	63.13	5.50	1.81	0.09
22-May-15	8:33	8:56	Sheet (North)	0:22:40	198.6				
	10:19	10:25	Sheet (North)	0:06:10	193.5				
	13:11	13:24	Sheet (North)	0:13:13	194.4				
	15:16	15:35	Sheet (North)	0:19:23	195.4				

Notes:

1 South = Jersey Island side; north = Bradford Island side.

2 Based on proposed thresholds of Hastings (2010) for a) mass ≤ 0.6 g (191 dB, e.g., larval delta smelt); b) for fish between 0.6 and 102 g mass: cumulative SEL = 195.28 + 19.28*log10(mass), where mass is 4.0 g for a 70-mm delta smelt and 11.4 g for a 90-mm juvenile spring-run Chinook salmon; and c) mass ≥ 102 g (234 dB, e.g., for juvenile and adult steelhead, and for adult Chinook salmon).

Source: Mahmodi, pers. comm. (pile driving data); daily distances exceeding thresholds developed by ICF.

Table A2. Summary of Pile Driving at Water Quality Monitoring Piles, June 2015, Including Cumulative Sound Exposure Level (SEL).

Date	Start	Stop	Location	Duration Driven (Minutes: seconds)	Cum. SEL (dB)	Distance Exceeding Proposed Non-Auditory Tissue Damage Threshold (Hastings 2010), Meters[1]			
						191 dB (larval delta smelt)	206.9 dB (adult delta smelt)	215.6 dB (juvenile Chinook salmon)	234 dB (juvenile/adult steelhead; adult Chinook salmon)
4-Jun-15	8:52	9:00	Fisherman's Cut	0:08:00	150.4	0.02	0.00	0.00	0.00
	12:30	12:36	Franks Tract	0:06:00	149	0.02	0.00	0.00	0.00
5-Jun-15	7:12	7:20	Twitchell Island	0:08:00	171.7	0.52	0.05	0.01	0.00
	11:30	11:42	Sacramento River No. 1	0:12:00	178.2	1.40	0.12	0.04	0.00
6-Jun-15	8:00	8:11	Liberty Island No. 1 (Left)[2]	0:11:00	180.2	2.36	0.21	0.07	0.00
	8:30	8:43	Liberty Island No. 2 (Right)[2]	0:13:00	176				
	12:03	12:10	Miner Slough	0:07:00	202.5	58.43	5.09	1.68	0.08
8-Jun-15	7:11	7:14	Steamboat Slough	0:02:09	172.9	0.62	0.05	0.02	0.00
	8:54	8:59	Sacramento River No. 2	0:05:08	184.3	3.58	0.31	0.10	0.00
9-Jun-15	7:25	7:31	Honker Bay	0:05:42	167.4	0.27	0.02	0.01	0.00
	9:52	9:59	Ryer Island	0:06:18	157	0.05	0.00	0.00	0.00
10-Jun-15[3]	7:56	8:01	Grizzly Bay	0:04:48	147.4	Pile was pushed into muddy bottom rather than driven			

Notes:

1 Based on proposed thresholds of Hastings (2010) for a) mass ≤ 0.6 g (191 dB, e.g., larval delta smelt); b) for fish between 0.6 and 102 g mass: cumulative SEL = 195.28 + 19.28*log10(mass), where mass is 4.0 g for a 70-mm delta smelt and 11.4 g for a 90-mm juvenile spring-run Chinook salmon; and c) mass ≥ 102 g (234 dB, e.g., for juvenile and adult steelhead, and for adult Chinook salmon).

2 The pile was a double pile , with the individual piles approximately 5 ft apart (treated as the same location for the pile-driving analysis)

3 Pile did not require driving and was simply pushed into the muddy bottom.

Source: Mahmodi, pers. comm. (pile driving data); distances exceeding thresholds developed by ICF.

Appendix B
Seepage Flow Between Barrier Rocks

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The 2015 EDB was constructed of rocks of mixed sizes and therefore was somewhat permeable to flow. The future implementation of the WFRSB that is the subject of this BA would be of the same design and therefore also would be somewhat permeable, resulting in seepage flow. This seepage flow could result in impingement of small fishes (such as delta smelt larvae/early juveniles) on the rocks of the barrier as the water flows through the small pores between the rocks. This appendix provides estimates of flow seepage between barrier rocks to inform the effects analysis on listed fishes.

The analysis of flow seeping between barrier rocks relies on observed stage data from 2015, following barrier closure on May 28, and covers the period from May 29 to June 22, 2015. The highly tidal nature of the system means that this assessment can be considered representative of conditions that would occur in a future barrier implementation. Prior to the 2015 assessment, there was no previous field study of the amount of seepage flow that occurs through temporary rock barriers of the type being implemented for the 2015 EDB, e.g., the South Delta Temporary Barriers Project.

The 2015 EDB was constructed with a gradation of rocks according to the specifications provided in Table B1.

Table B1. Rock Specifications for Proposed Emergency Drought Barrier

Rock Diameter (Inches)	Percent Passing
22	100
18	70-100
12	50-80
8	32-58
5	20-40
2	12-30
0.5	3-15

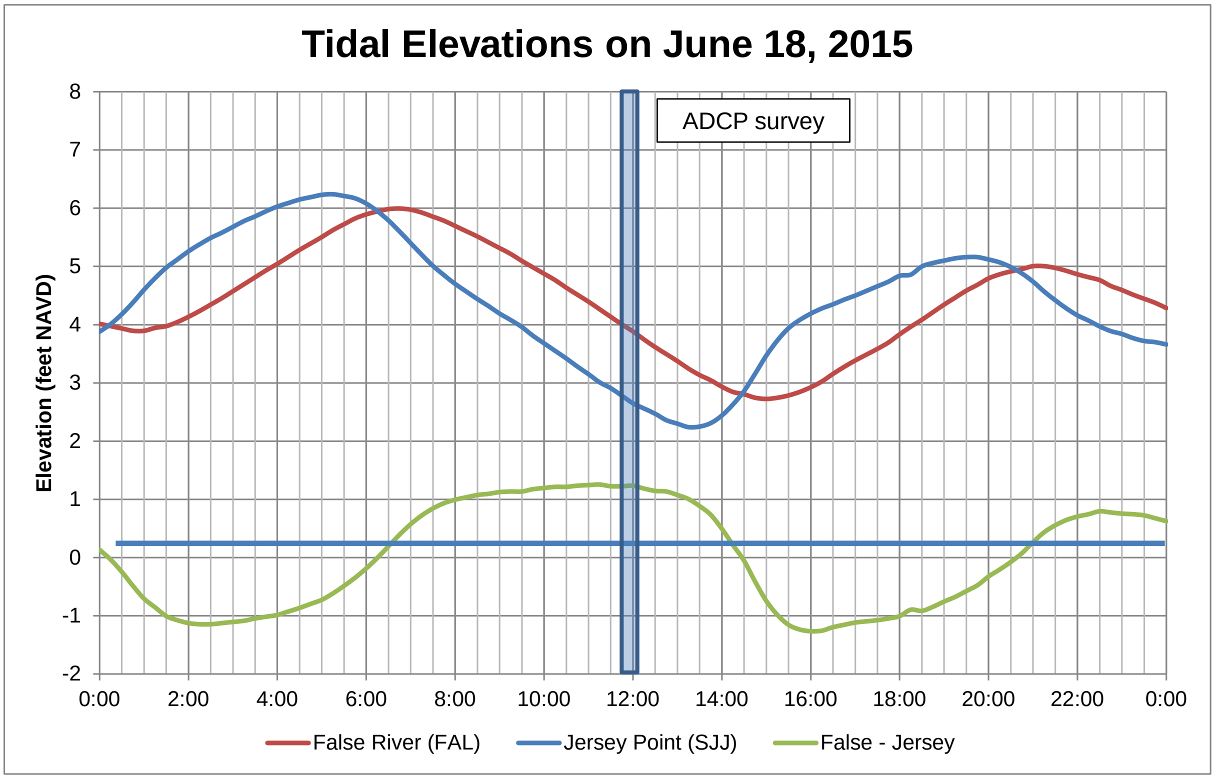
Source: McQuirk pers. comm., April 7 2014

Head (stage) differences upstream and downstream of the barrier were developed from the San Joaquin River at Jersey Point (CDEC station SJJ) representing the downstream stage and False River (CDEC station FAL) representing the upstream stage. For each 15-minute observation, the difference (FAL – SJJ) in stage was calculated after correcting for datum differences[11]. The average tide at these two nearby locations was assumed to be identical.

A DWR field crew measured channel velocities just upstream from the barrier during ebb tide on 18 June, using boat-mounted acoustic Doppler current profiler (ADCP) equipment during two cross-channel transects. The measurements were of ebb tide seepage flow between 11:49 and 12:05 PDT:

[11] The stage data for FAL had 10 feet subtracted to account for the datum elevation and 2.375 feet subtracted to adjust for the vertical datum corresponding to National Geodetic Vertical Datum of 1929 (http://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl) and 0.54 feet subtracted for the datum offset from NAVD (estimated from mean elevations at False River compared to Jersey Point).

the two transects had measured velocity of 0.089 ft/s and 0.125 ft/s (mean = 0.107 ft/s), and estimated flow of 1,912.7 cfs and 1,873.0 cfs (mean = 1892.9 cfs) (Baldwin, pers. comm.). The approximate head difference during the surveys was 1.23 feet, which was close to the maximum ebb tide (Figure B1).



Source: California Data Exchange Center (cdec.water.ca.gov). Note: The transparent blue rectangle indicates the approximate period of the ADCP Survey.

Figure B1. Tidal Elevation at the FAL and SJJ Gauges During the June 18 DWR Acoustic Doppler Current Profiler Survey Just Upstream of the Emergency Drought Barrier.

Assuming a linear relationship between head difference and seepage flow through the barrier, seepage flow during May 29 to June 22 ranged from a flood tide maximum of around -2,000 cfs to a maximum ebb tide of around 2,000 cfs (Table B2). Absolute seepage flows through the barrier at the approximate mid-points of the flood and ebb tides (i.e., the 25th and 75th percentiles) were about 1,200-1,300 cfs.

Table B2. Estimated Seepage Flow Through the Emergency Drought Barrier (May 29 to June 22, 2015), From False River (FAL) Minus Jersey Point (SJJ) Head Differences.

Percentile	Head Difference (ft)	Seepage Flow (cfs)
0	-1.31	-2,008
10	-1.10	-1,685
20	-0.95	-1,470
30	-0.87	-1,331
25	-0.75	-1,162
40	-0.41	-639
50	0.06	85
60	0.51	777
70	0.71	1,100
75	0.80	1,223
80	0.94	1,448
90	1.11	1,700
100	1.33	2,039

Source: California Data Exchange Center, cdec.water.ca.gov. Accessed: June 24, 2015.

As noted above, the mean channel velocity was around 0.1 ft/s; with 10% porosity of the rocks making up the EDB, the velocity through the barrier would be 1 ft/s; with 20% porosity, the velocity would be 0.5 ft/s. During the period prior to barrier closure (April 15 to May 26, after which the gauge was taken offline as the readings became less reliable), the mean flows through False River (CDEC station FAL) were around 33,000 cfs on the ebb tide and -37,000 cfs on the flood tide, which compares to just under ±100,000 cfs for the ebb and flood tides at Jersey Point (CDEC station SJJ). This suggests that typically around 35% of the San Joaquin River flow at Jersey Point leaves or enters False River on flood and ebb tides. Therefore the seepage flow estimates above suggest that the EDB blocked over 95% of the tidal flow into and out of False River in 2015. These conditions are representative of the situation that would occur with implementation of the WFRSB.

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Appendix C
20-mm Survey Data of Delta Smelt Distribution

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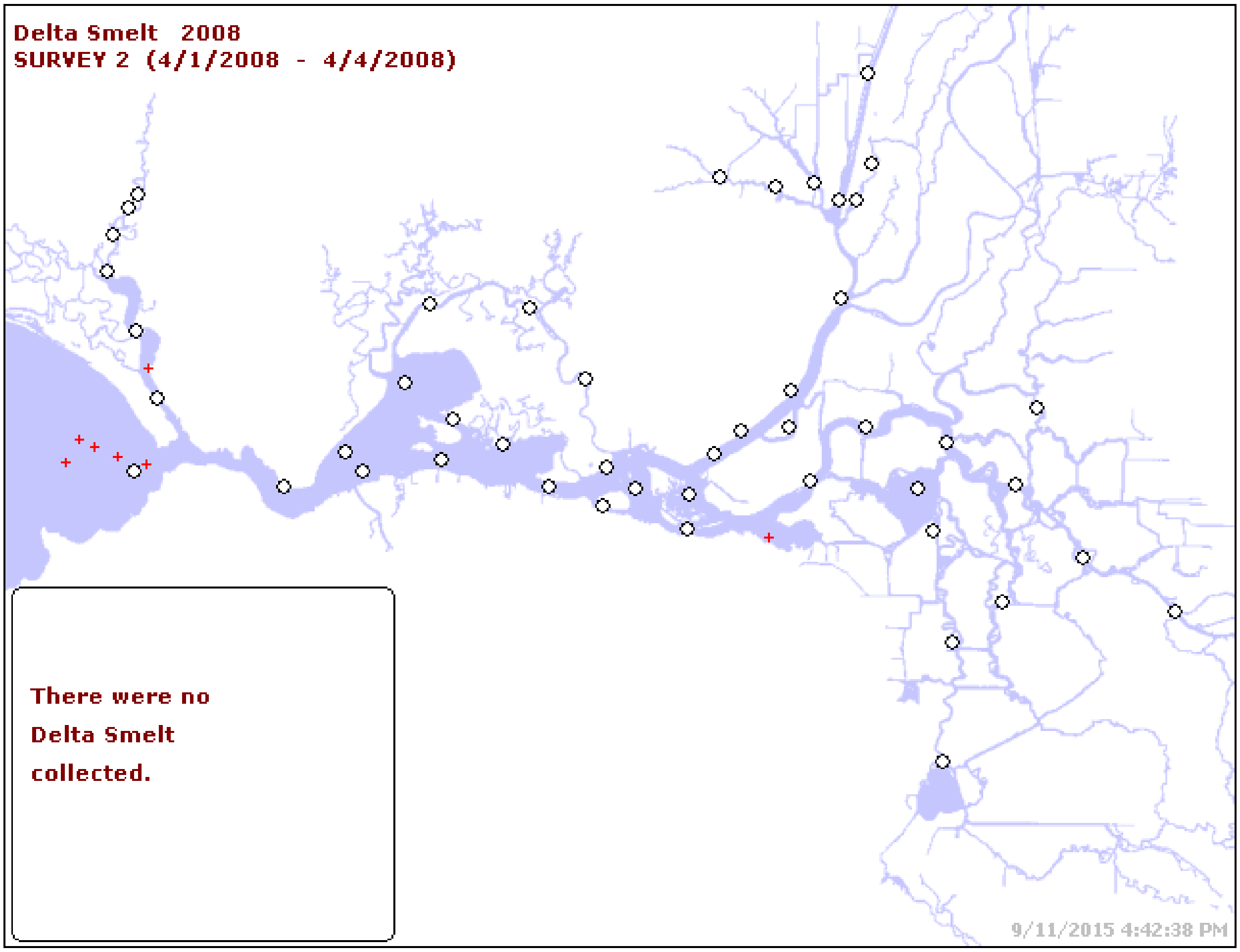
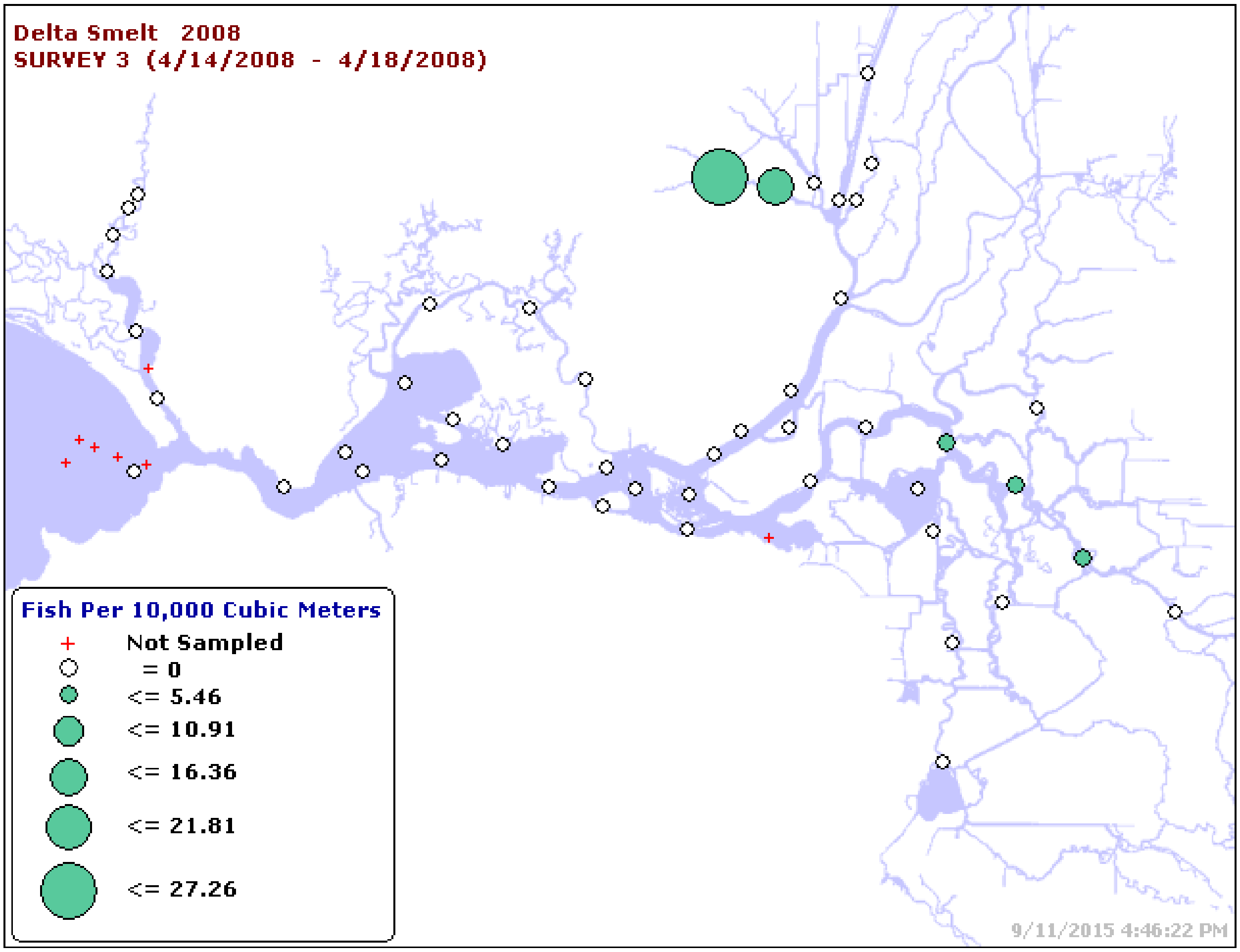
This appendix provides distribution data for larval and early juvenile delta smelt from the ongoing 20-mm Survey. Since 2008, the 20-mm Survey sampled a broader range within the Delta, including the Cache Slough and Sacramento Deep Water Ship Channel area. Delta smelt occurred at the stations near the proposed WFRSB in more than 50% of the April-June 20-mm surveys from 2008 to 2015 (Figures C1-C51).



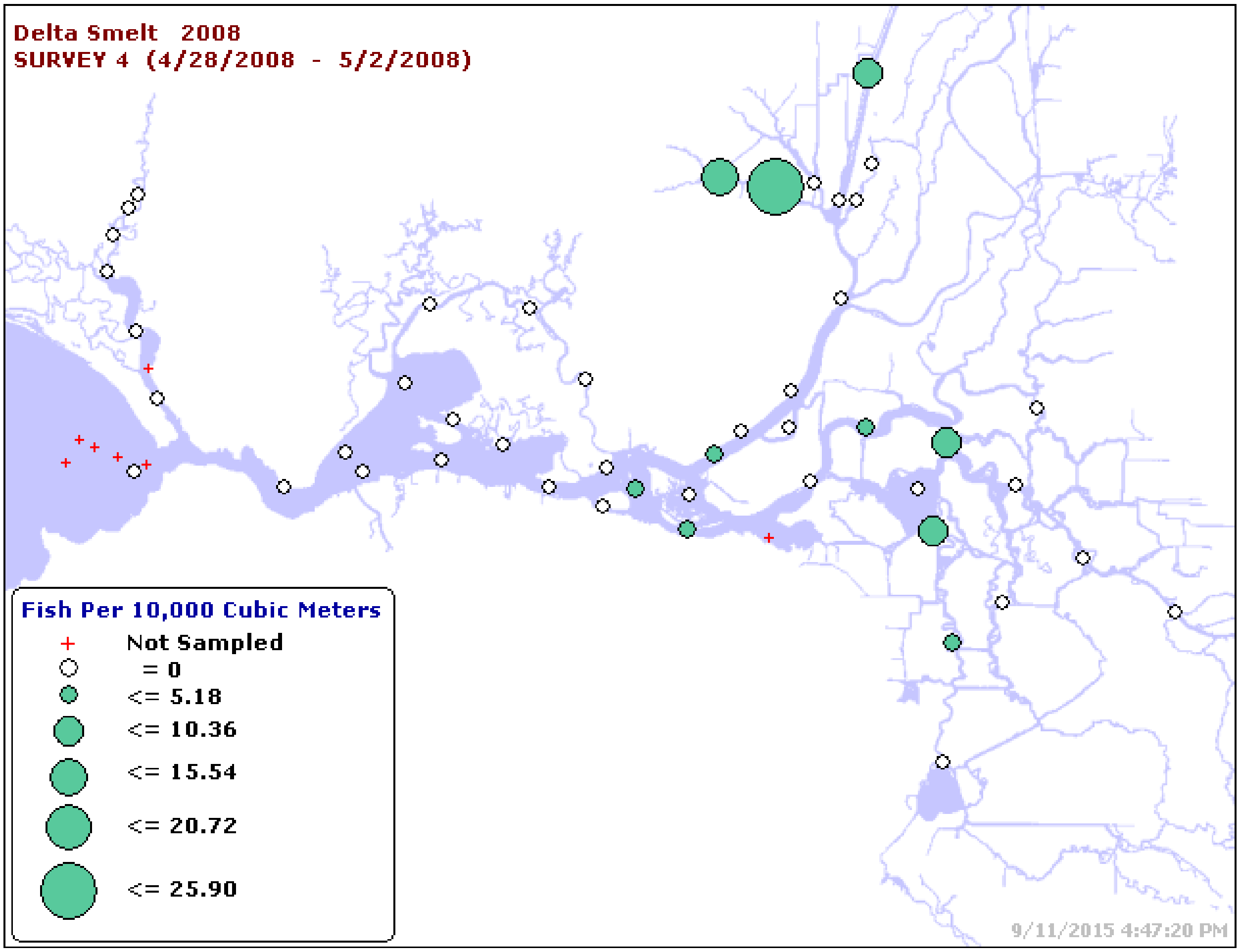
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 11, 2015.

Figure C1. Density of Delta Smelt from 20-mm Survey 2, 2008.



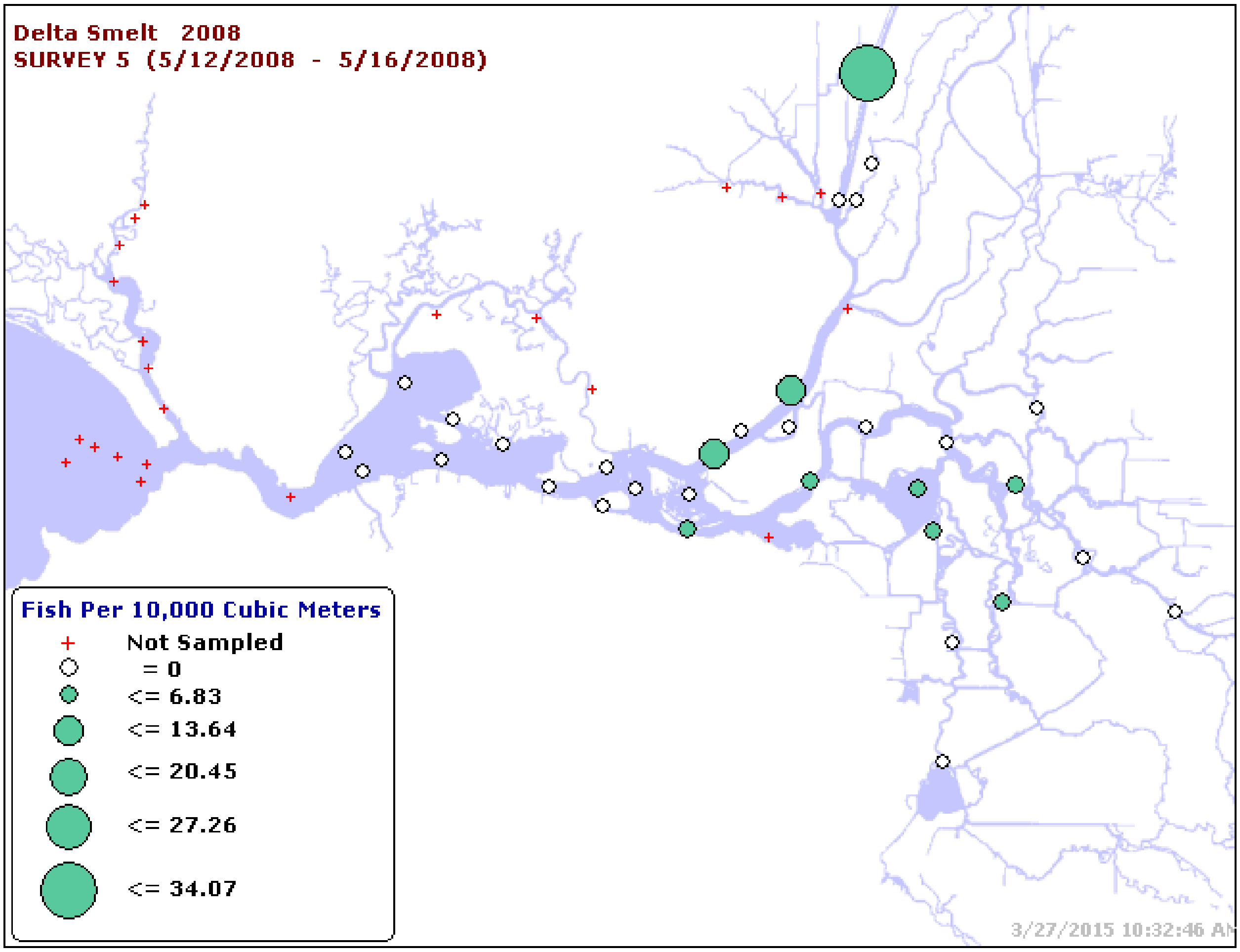
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 11, 2015.

Figure C2. Density of Delta Smelt from 20-mm Survey 3, 2008.



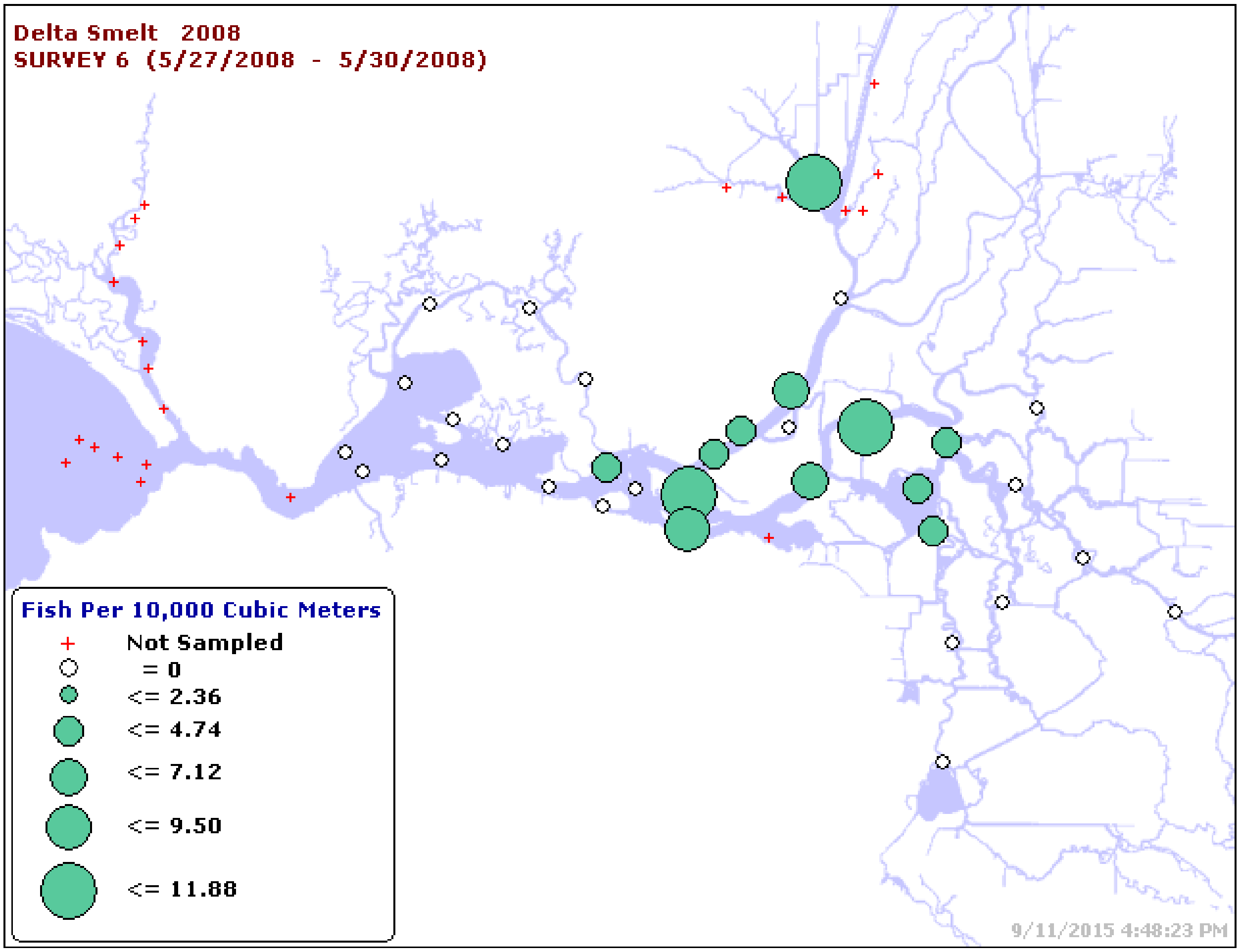
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 11, 2015.

Figure C3. Density of Delta Smelt from 20-mm Survey 4, 2008.



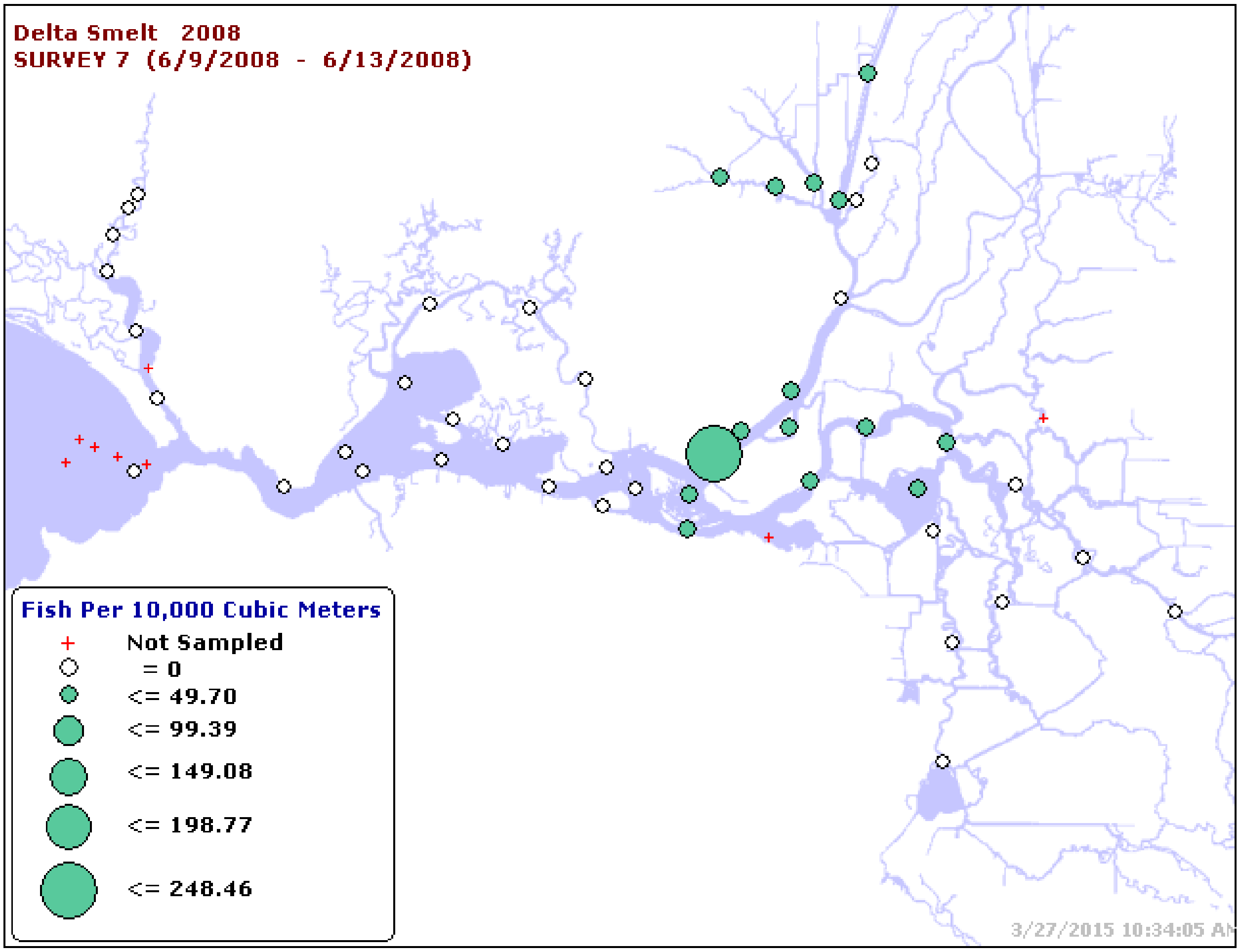
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C4. Density of Delta Smelt from 20-mm Survey 5, 2008.



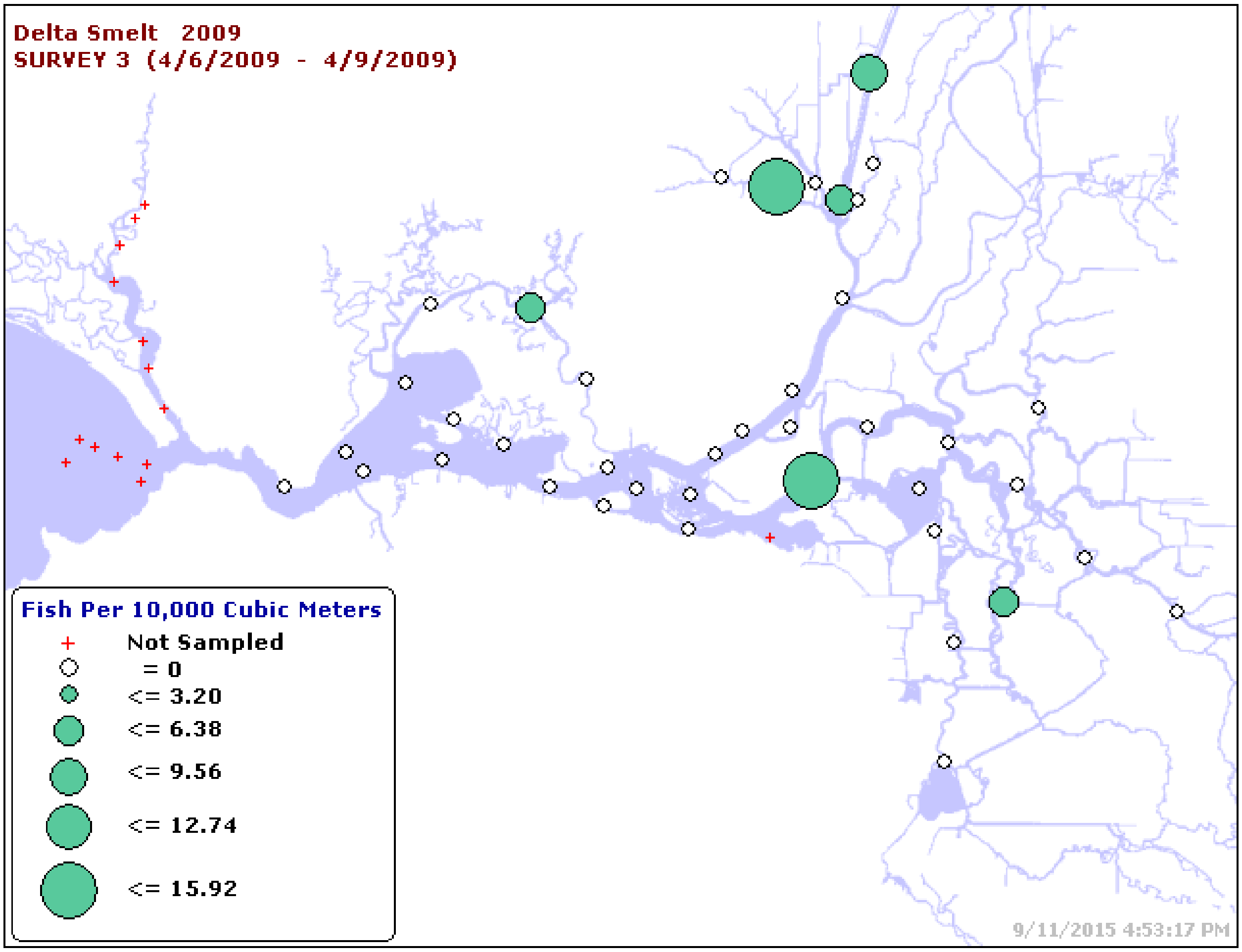
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 11, 2015.

Figure C5. Density of Delta Smelt from 20-mm Survey 6, 2008.



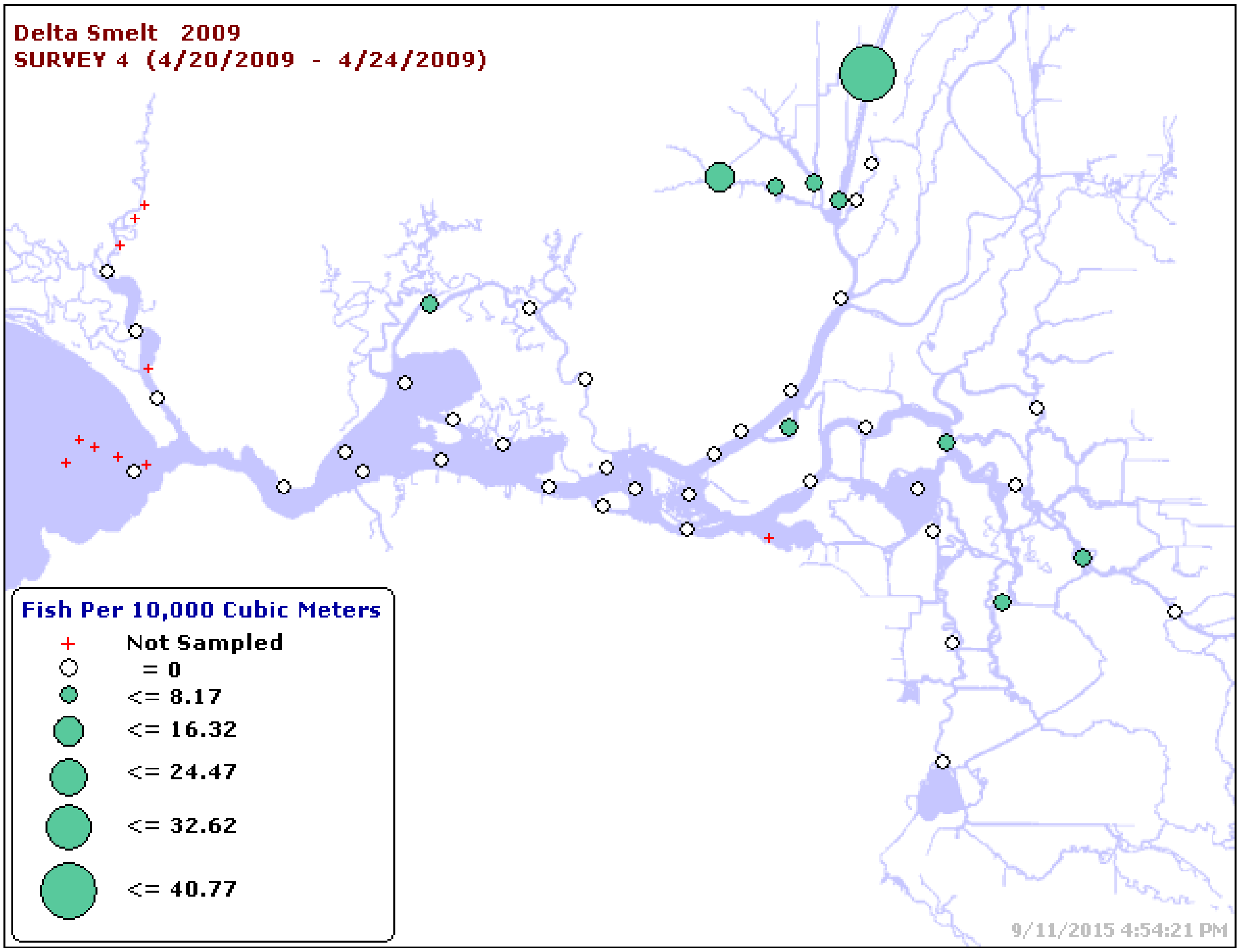
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C6. Density of Delta Smelt from 20-mm Survey 7, 2008.



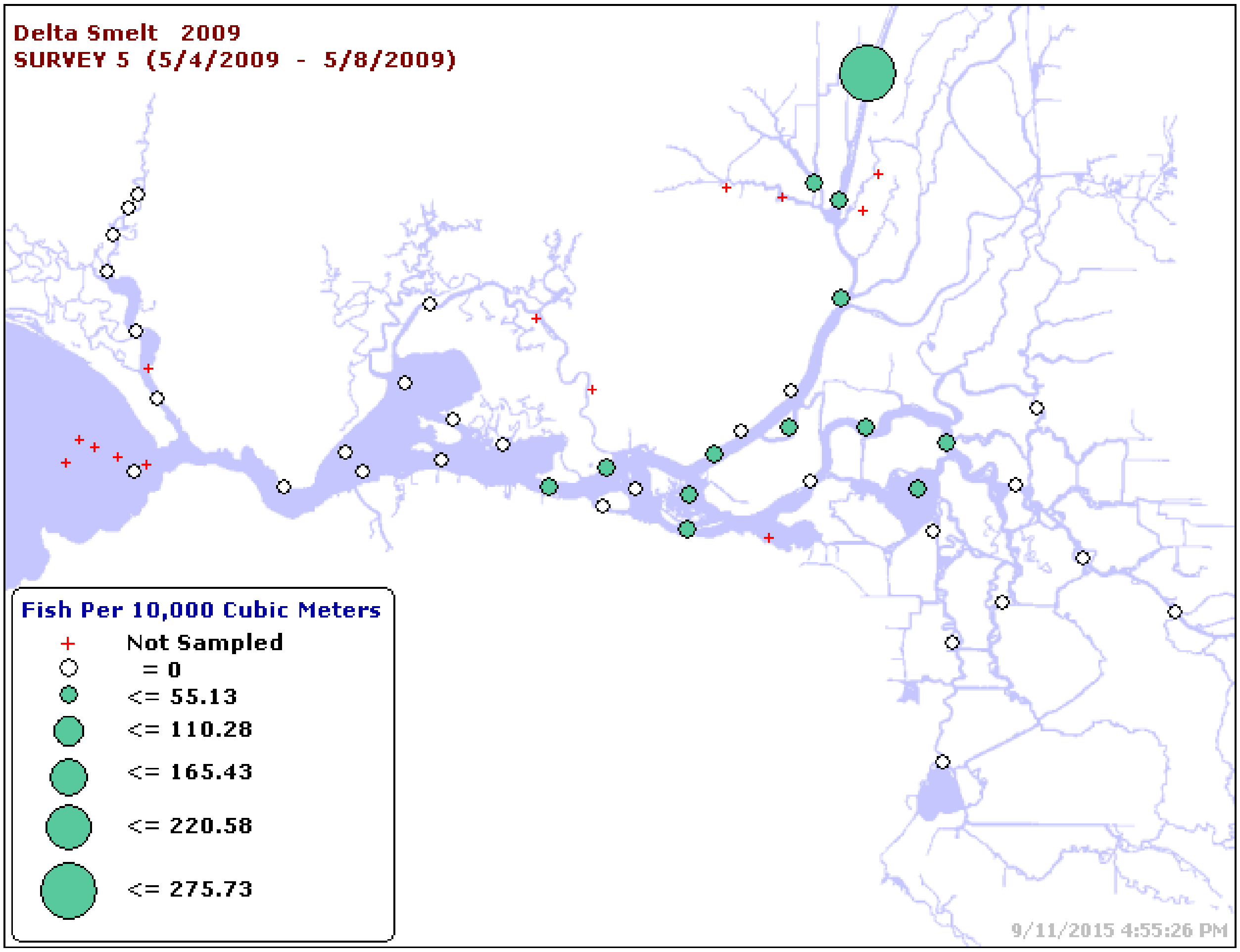
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 11, 2015.

Figure C7. Density of Delta Smelt from 20-mm Survey 3, 2009.



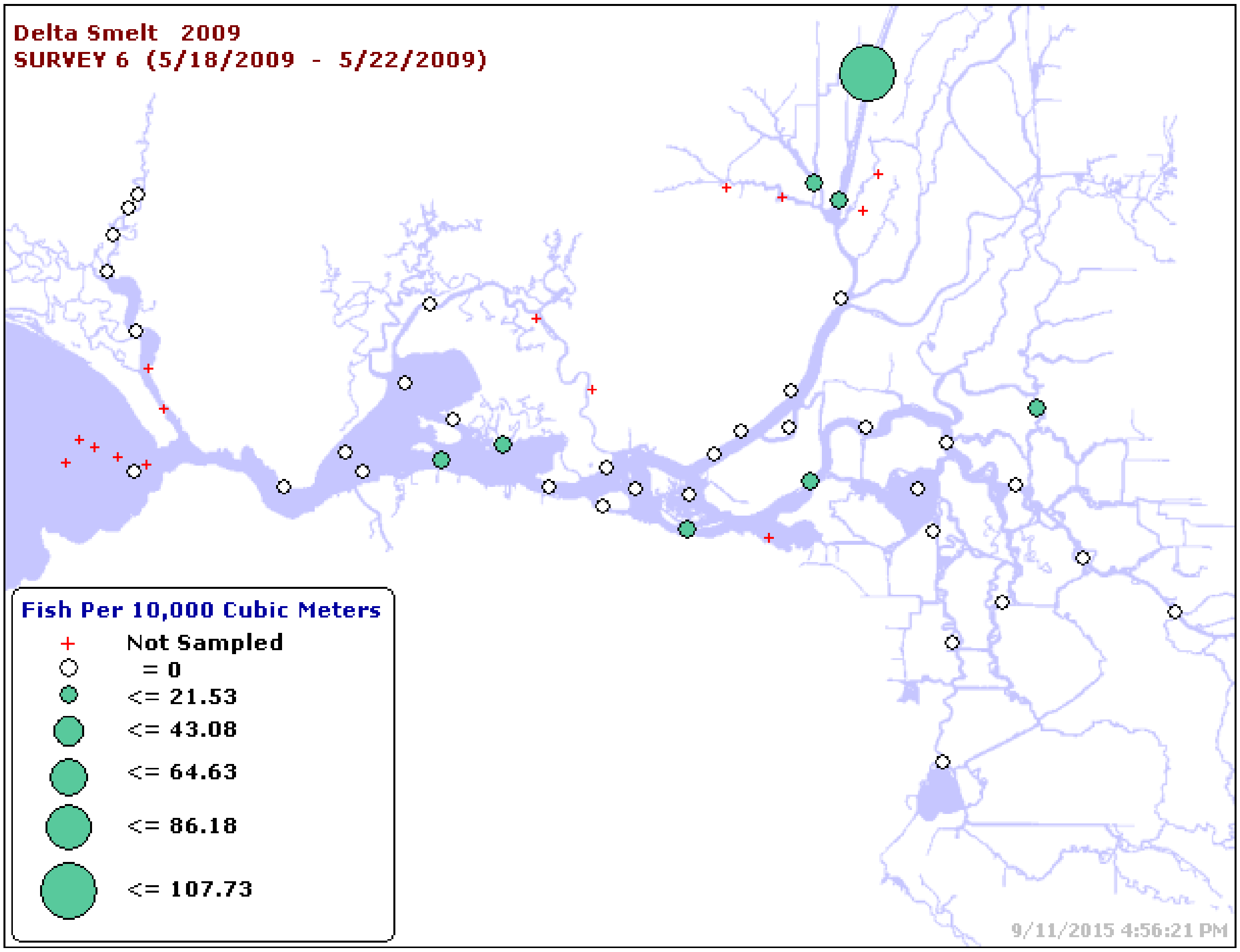
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 11, 2015.

Figure C8. Density of Delta Smelt from 20-mm Survey 4, 2009.



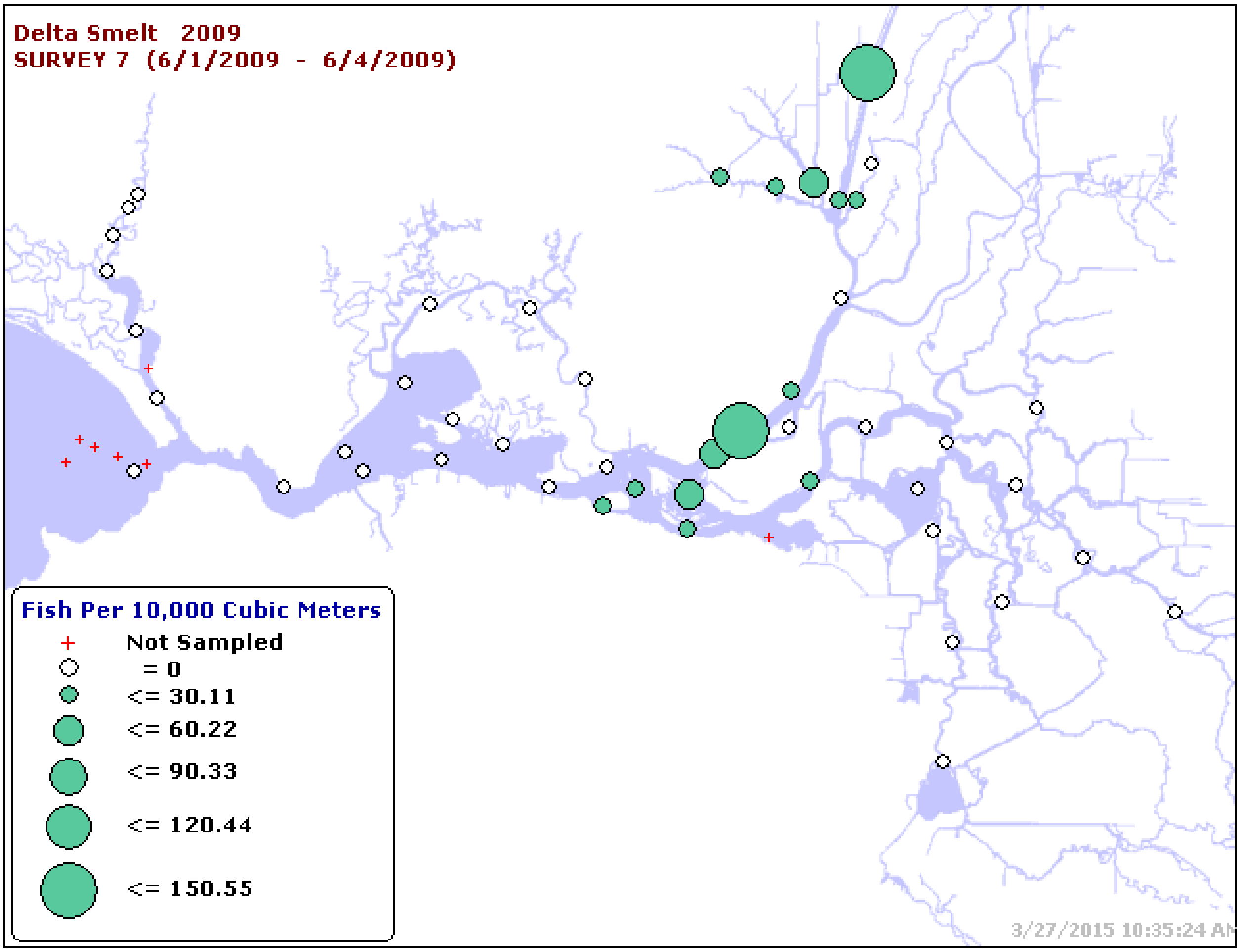
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 11, 2015.

Figure C9. Density of Delta Smelt from 20-mm Survey 5, 2009.



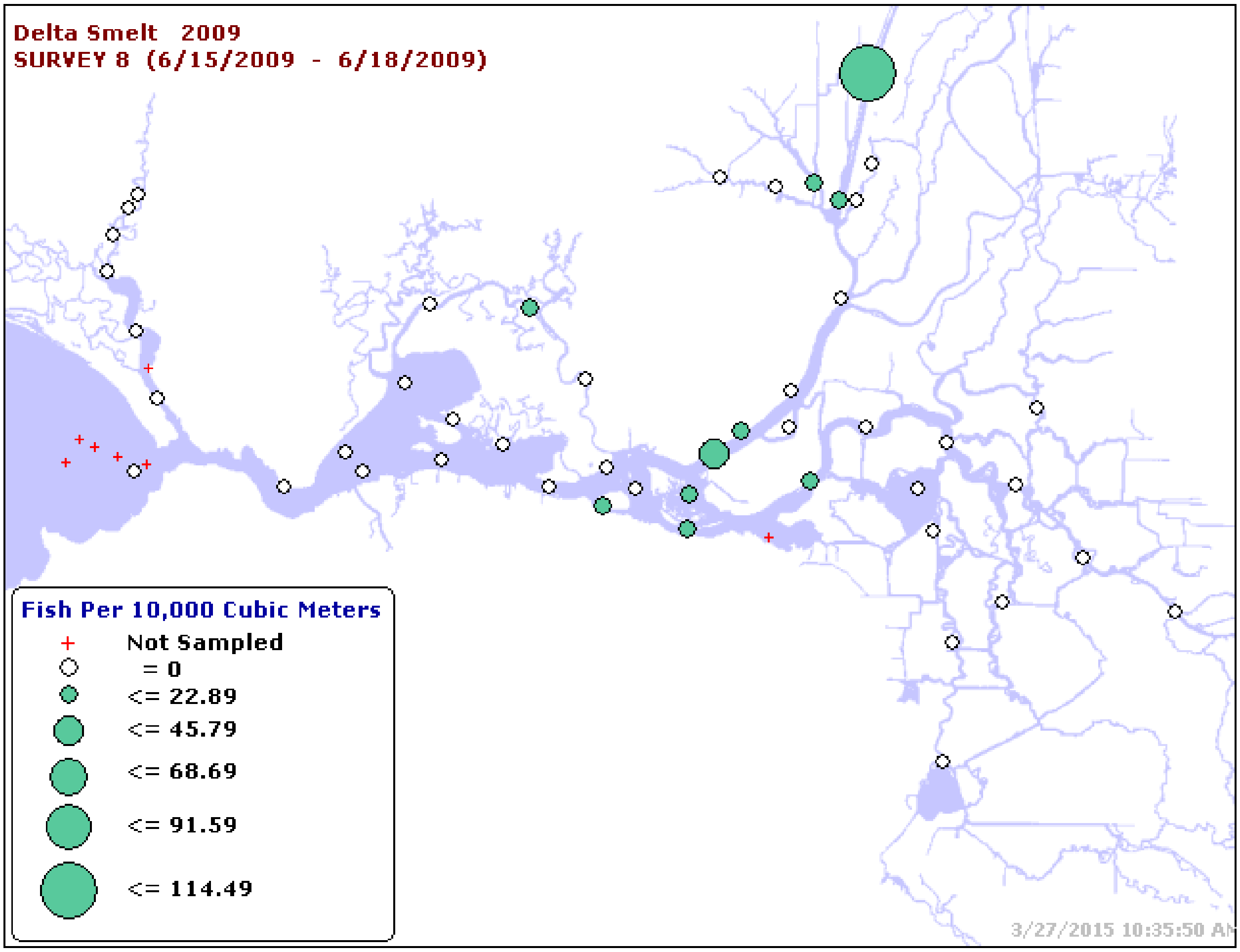
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 11, 2015.

Figure C10. Density of Delta Smelt from 20-mm Survey 6, 2009.



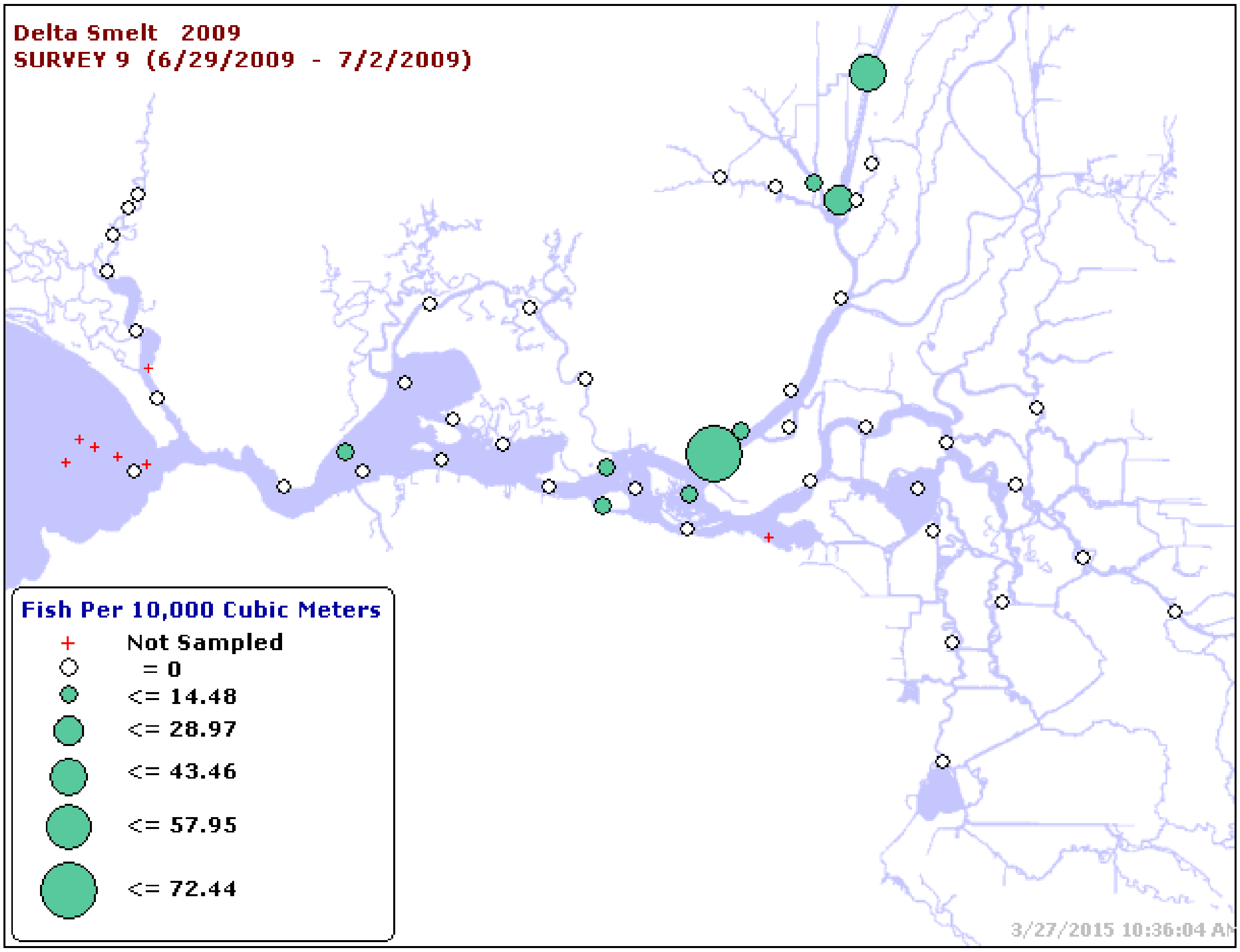
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C11. Density of Delta Smelt from 20-mm Survey 7, 2009.



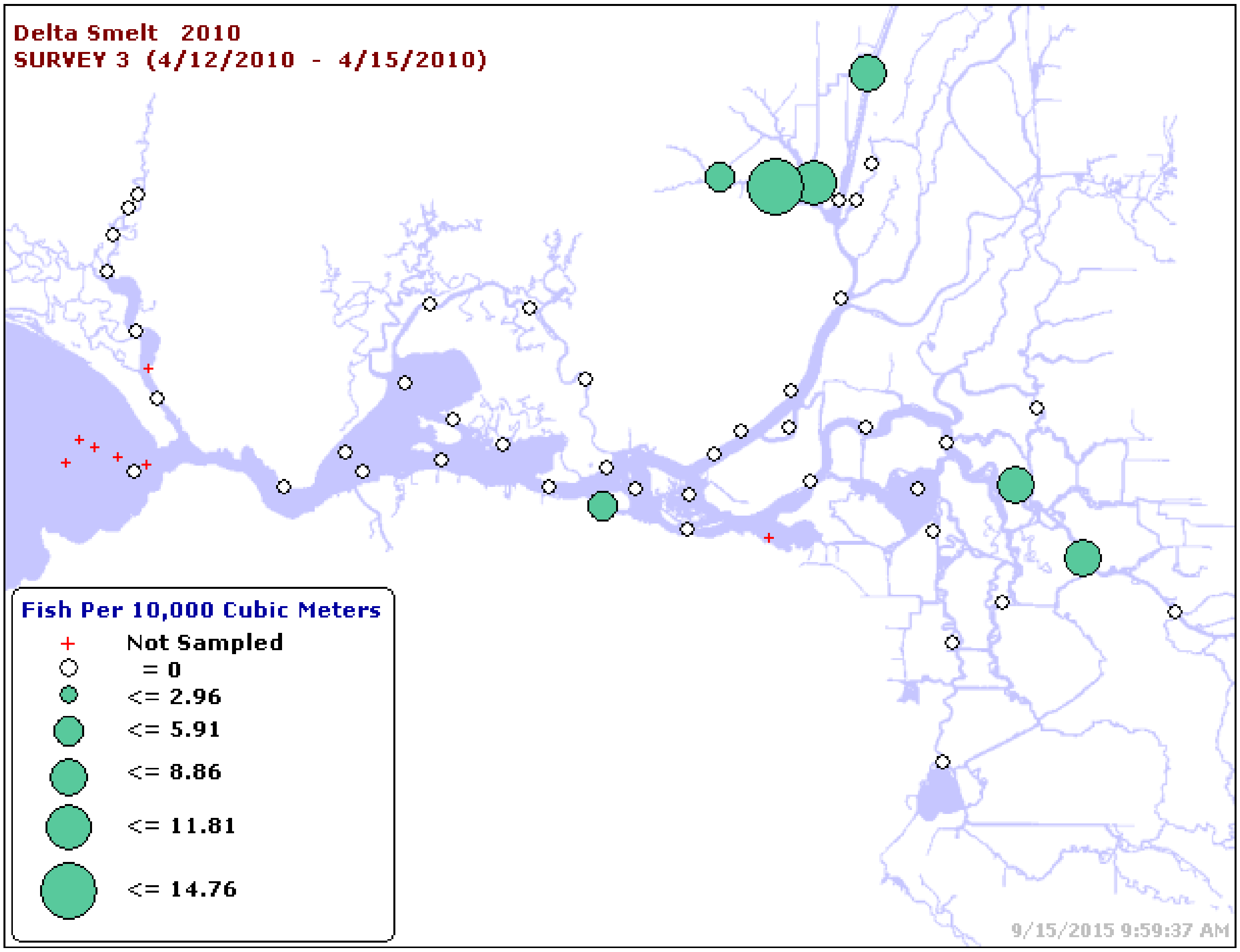
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C12. Density of Delta Smelt from 20-mm Survey 8, 2009.



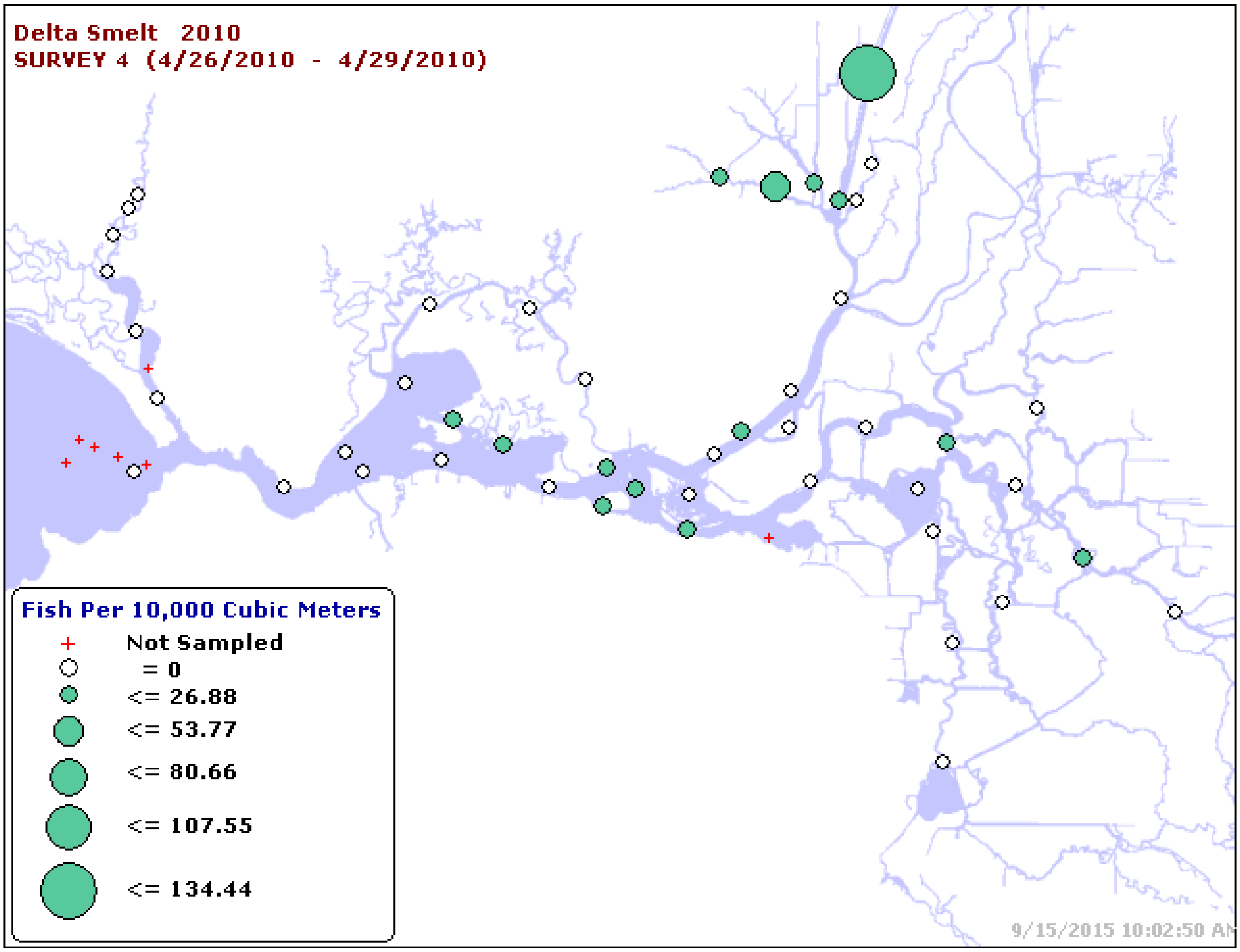
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C13. Density of Delta Smelt from 20-mm Survey 9, 2009.



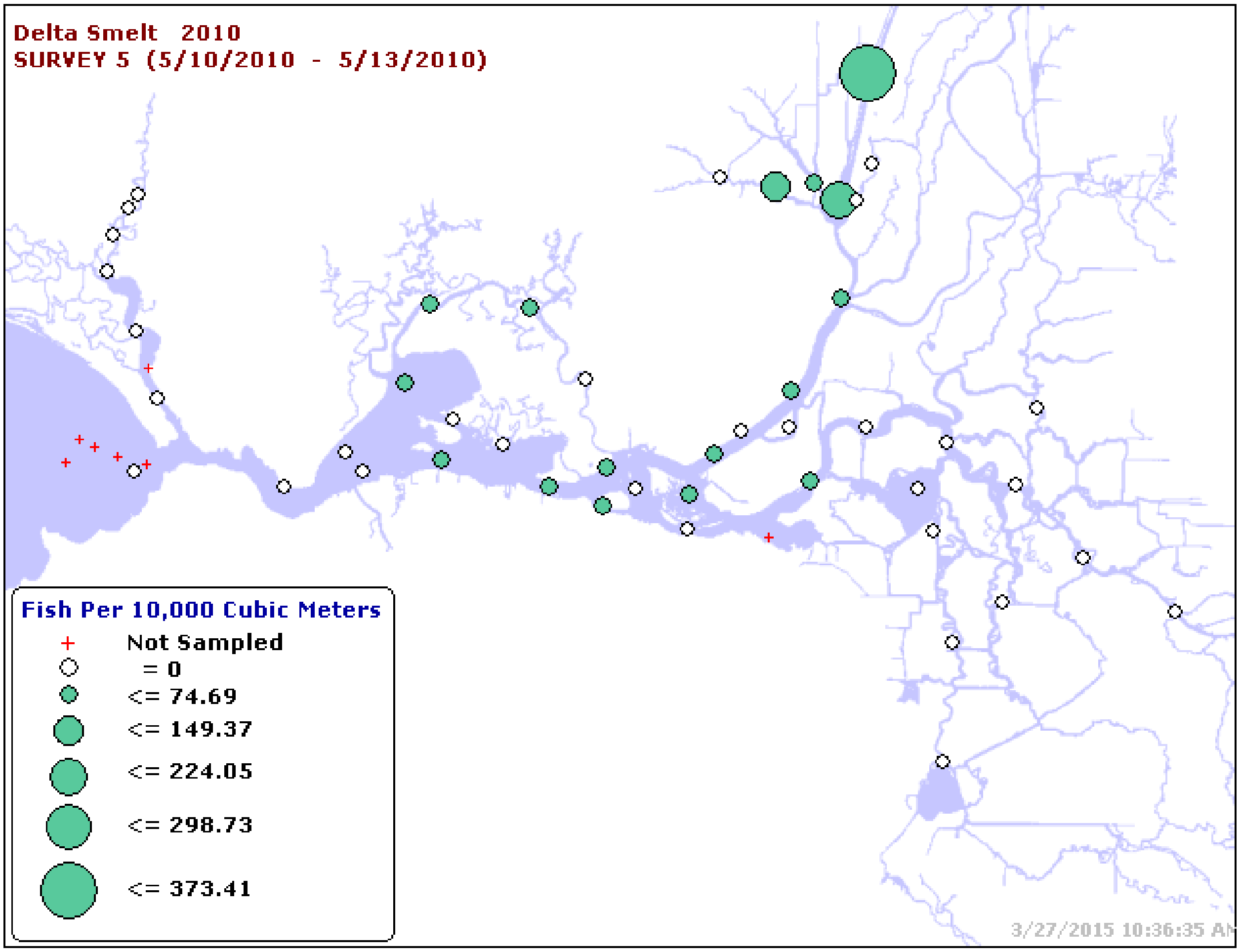
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C14. Density of Delta Smelt from 20-mm Survey 3, 2010.



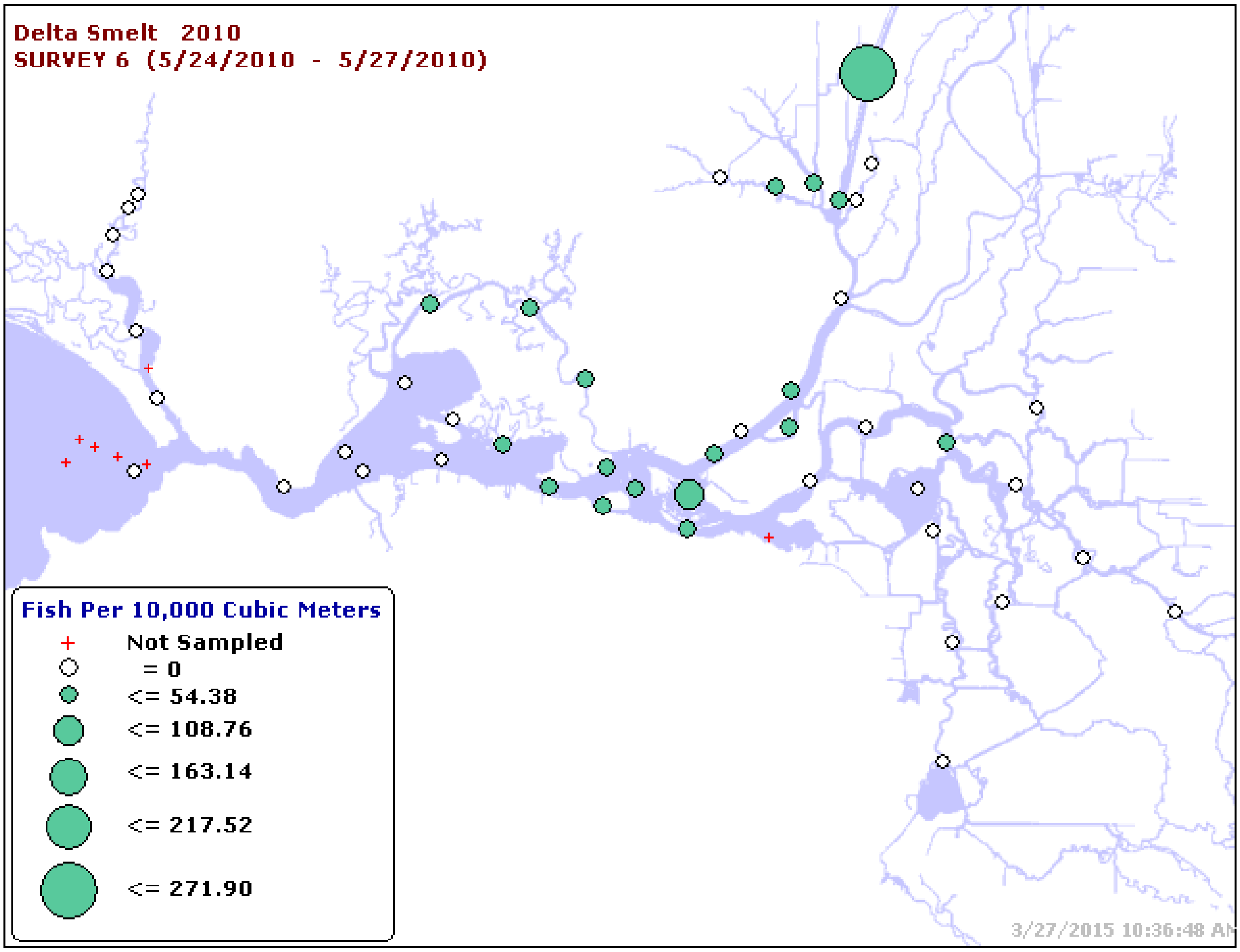
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C15. Density of Delta Smelt from 20-mm Survey 4, 2010.



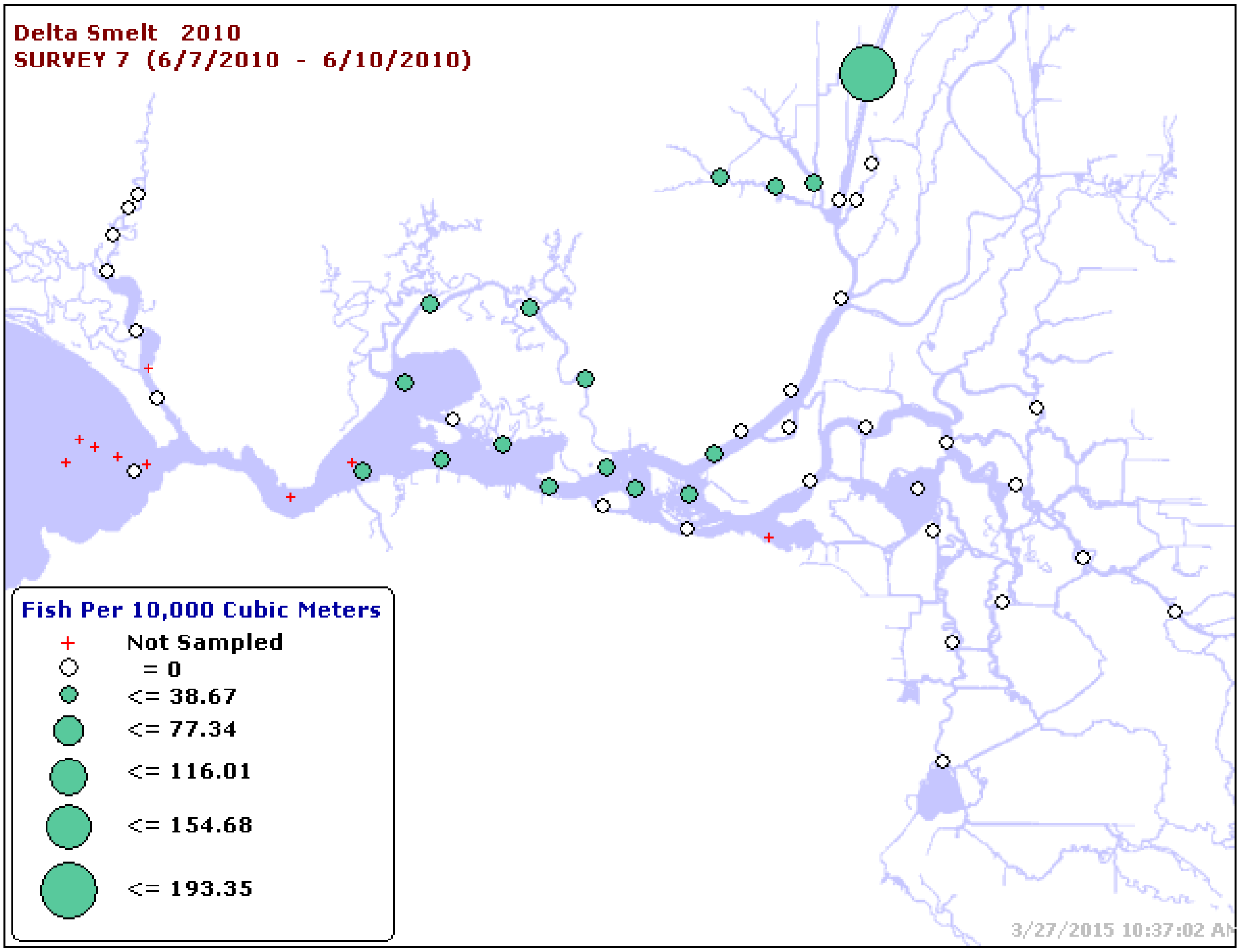
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C16. Density of Delta Smelt from 20-mm Survey 5, 2010.



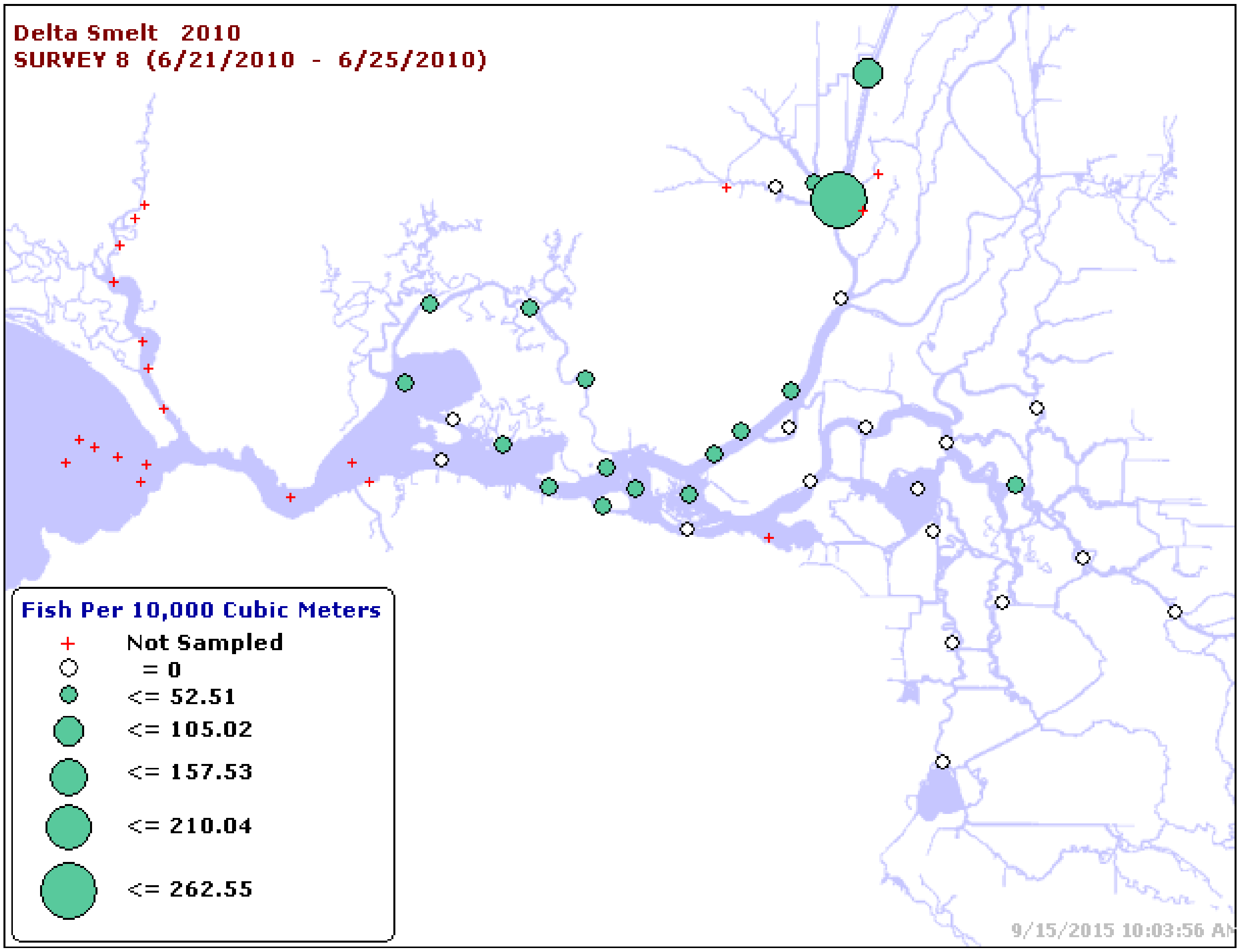
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C17. Density of Delta Smelt from 20-mm Survey 6, 2010.



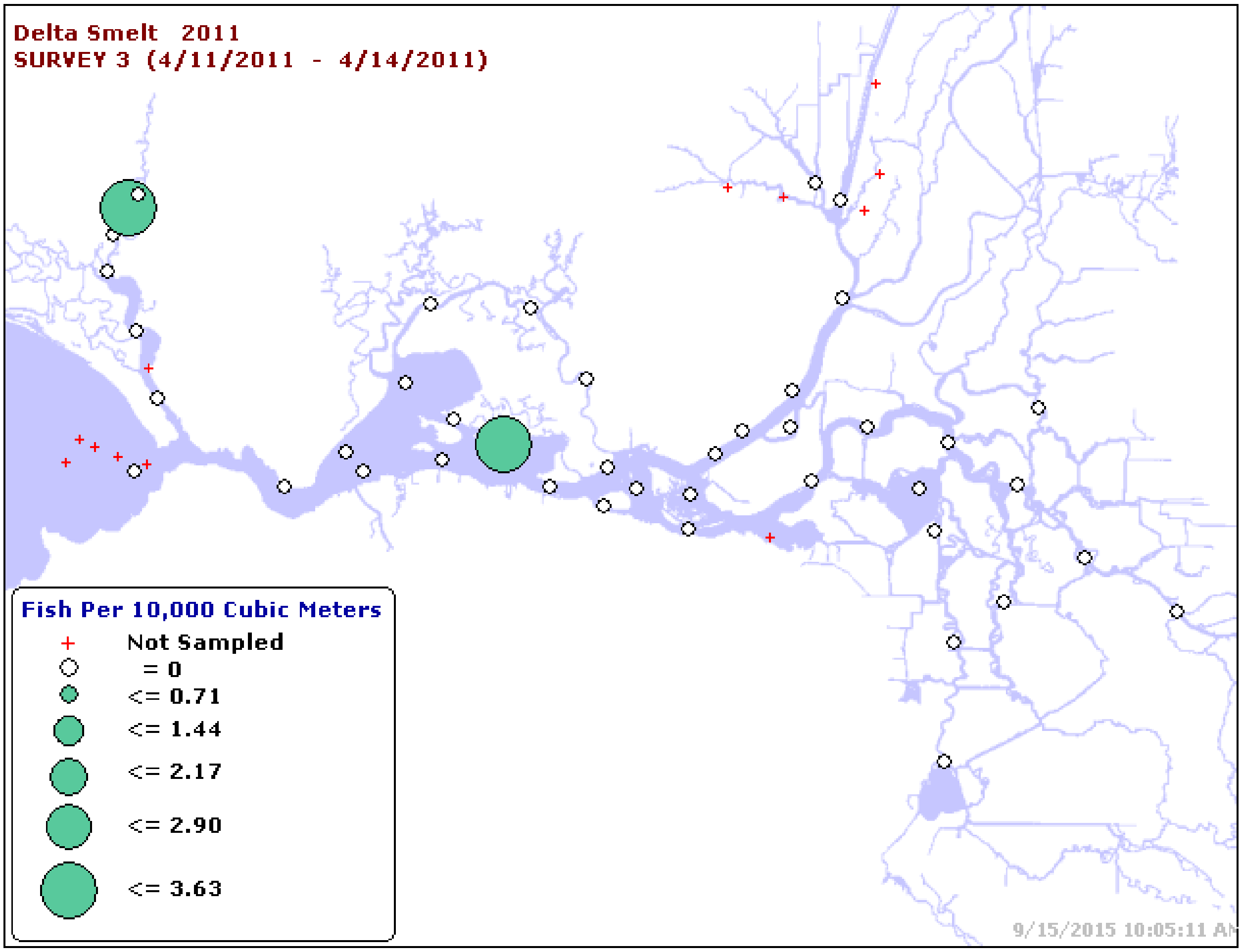
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C18. Density of Delta Smelt from 20-mm Survey 7, 2010.



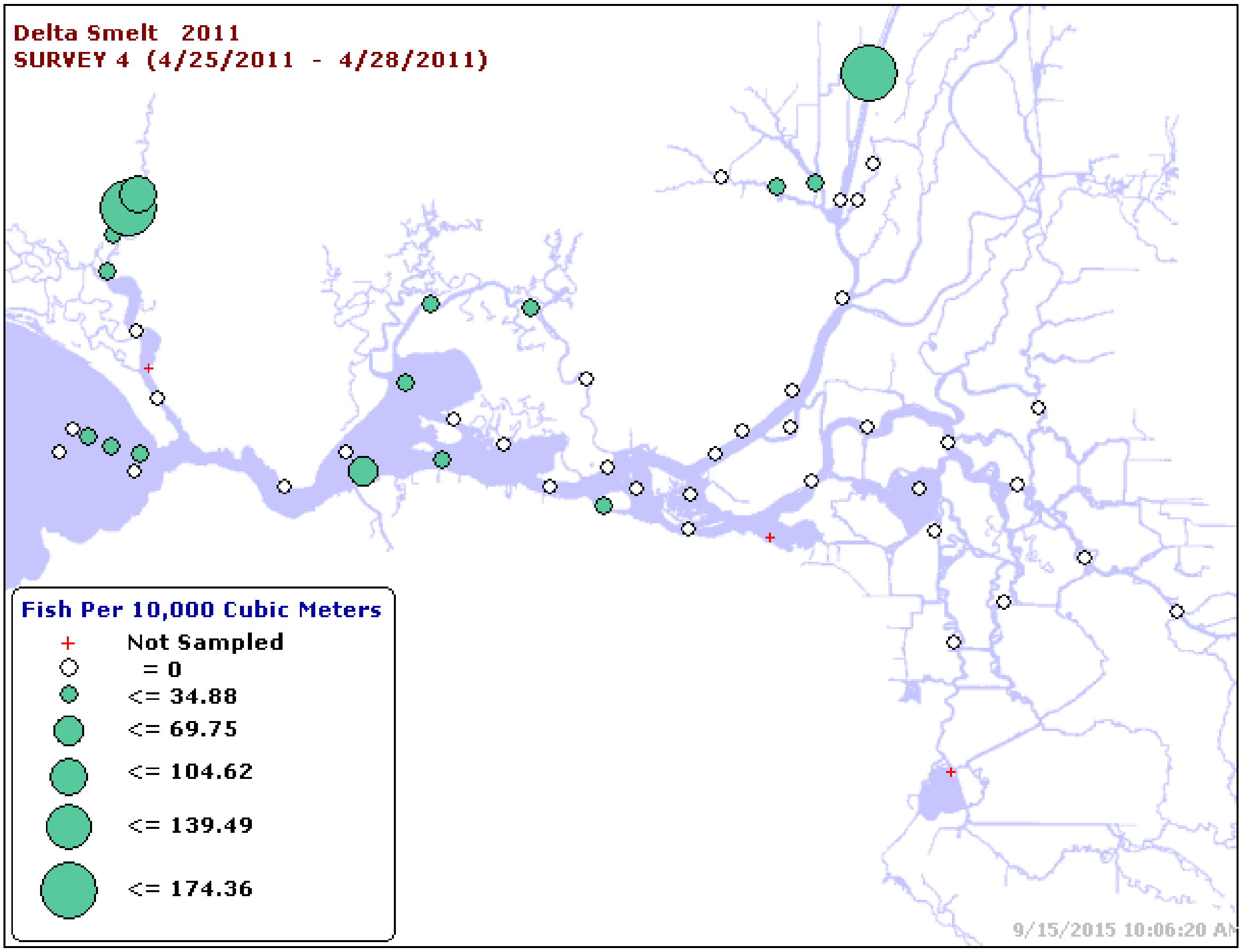
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C19. Density of Delta Smelt from 20-mm Survey 8, 2010.



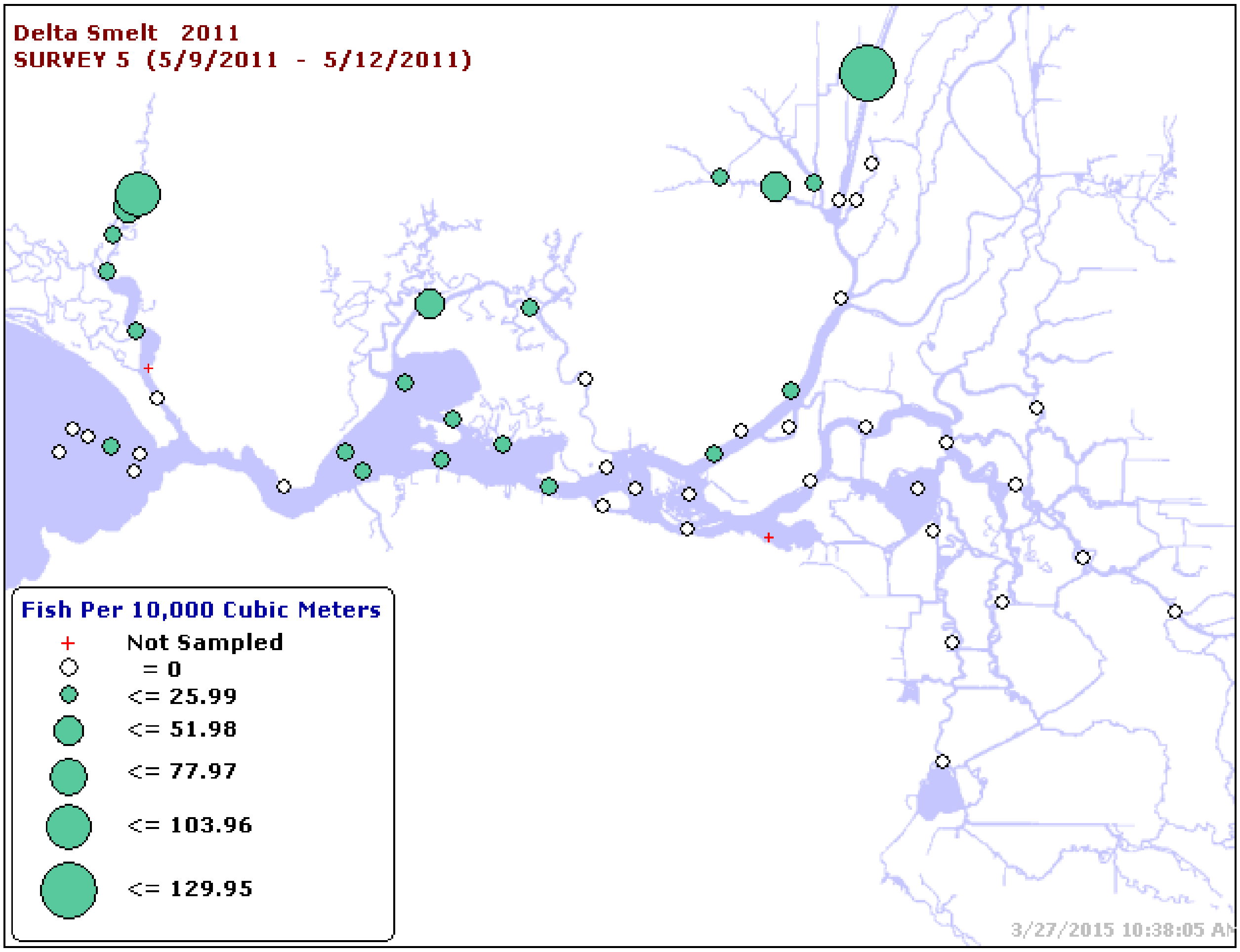
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C20. Density of Delta Smelt from 20-mm Survey 3, 2011.



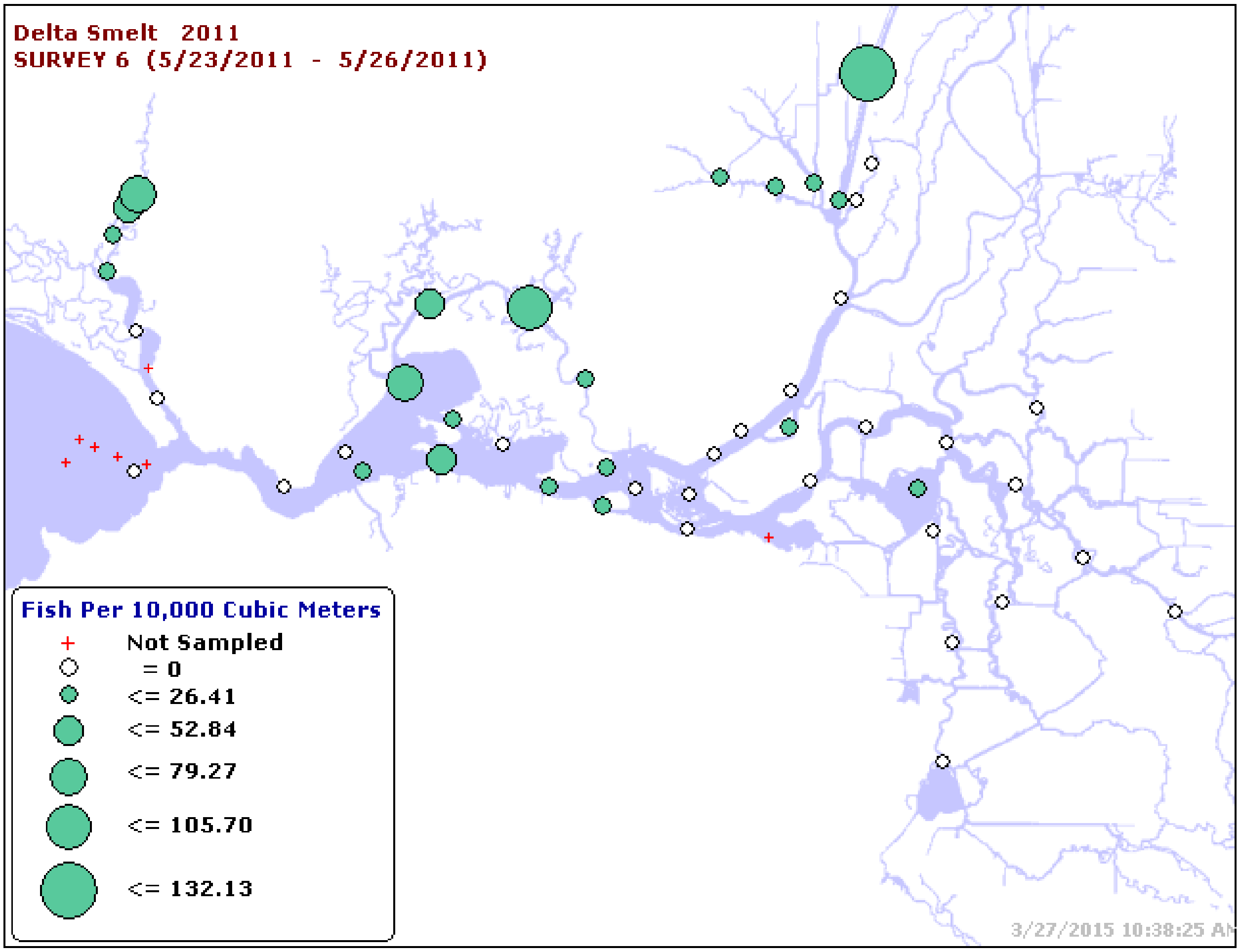
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C21. Density of Delta Smelt from 20-mm Survey 4, 2011.



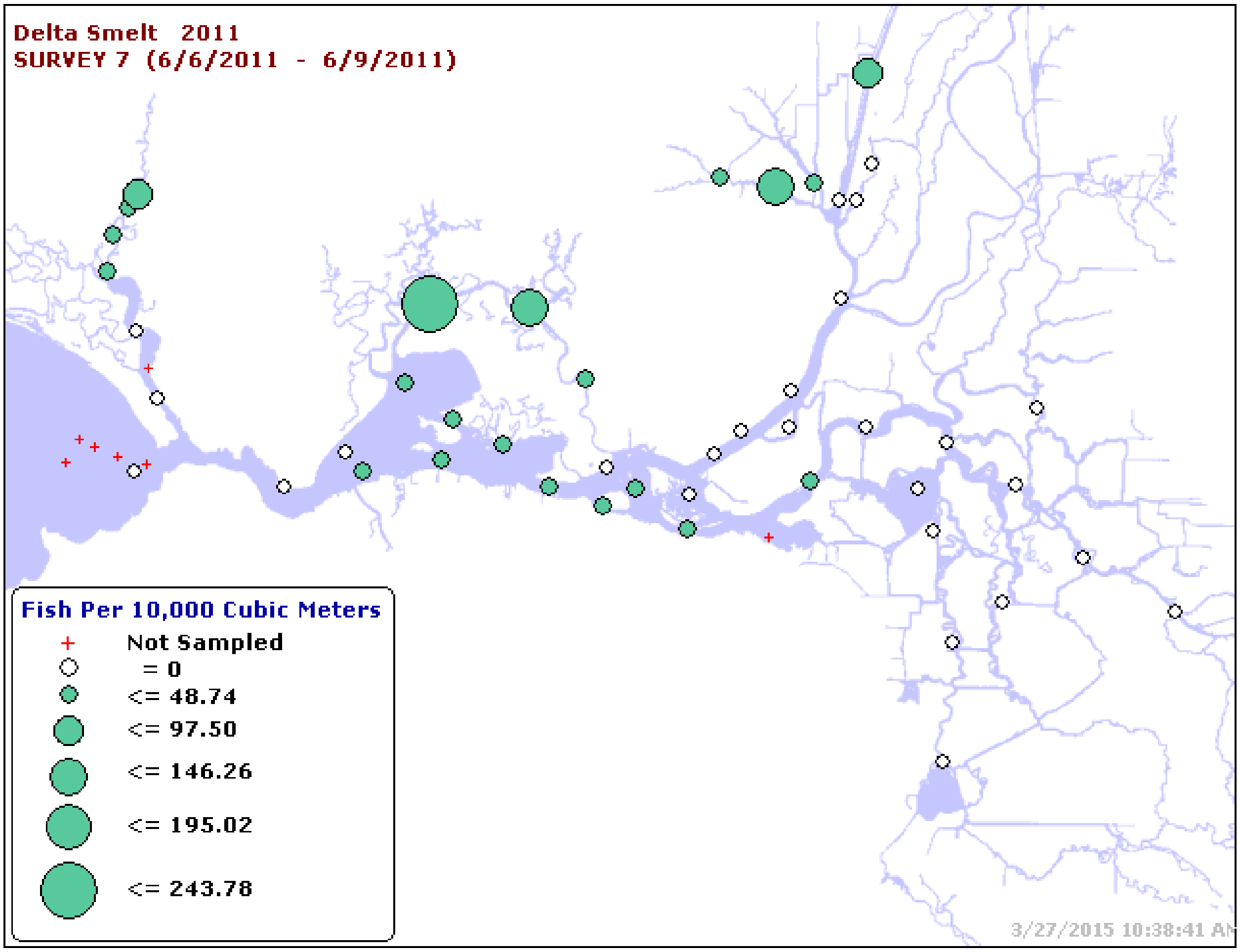
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C22. Density of Delta Smelt from 20-mm Survey 5, 2011.



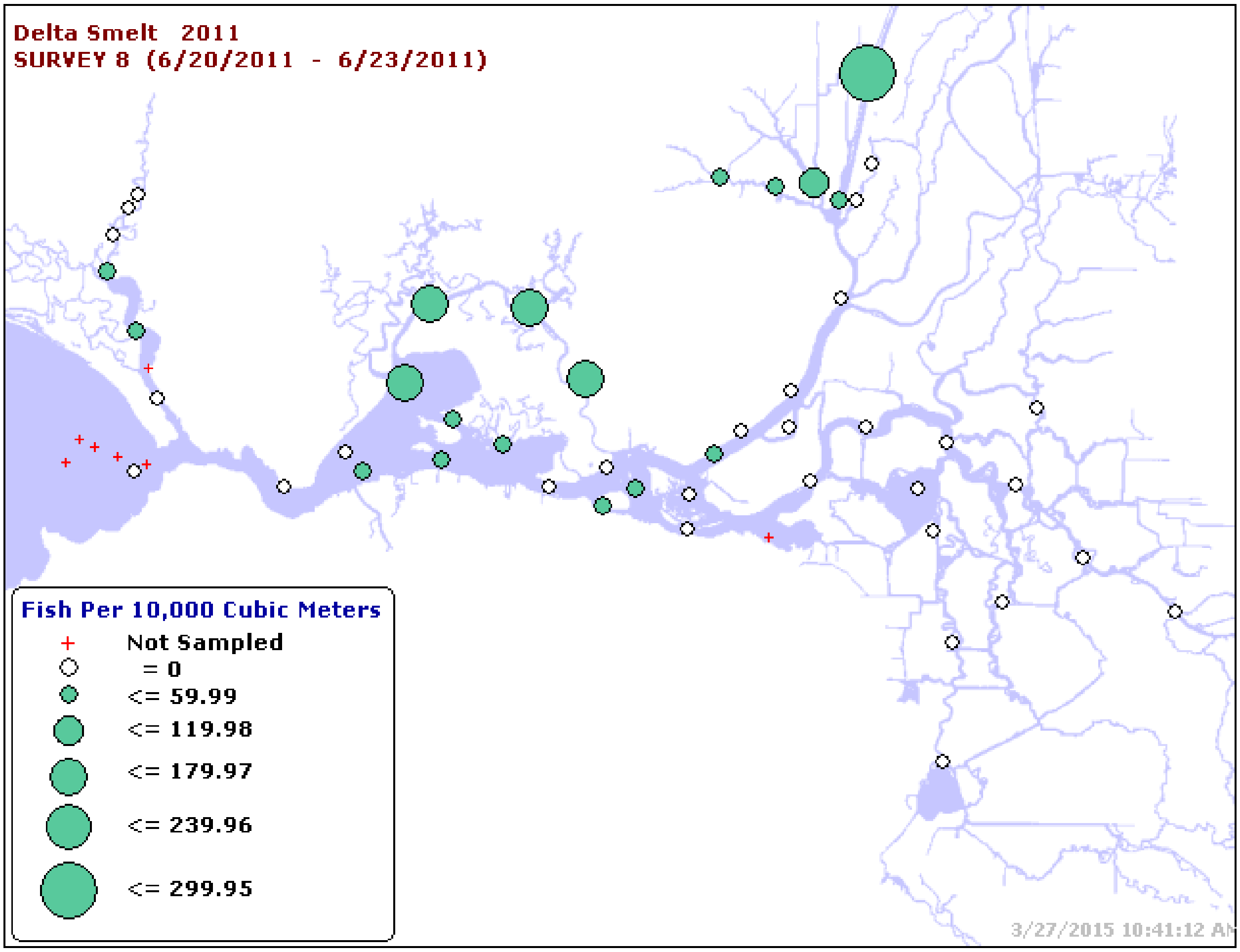
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C23. Density of Delta Smelt from 20-mm Survey 6, 2011.



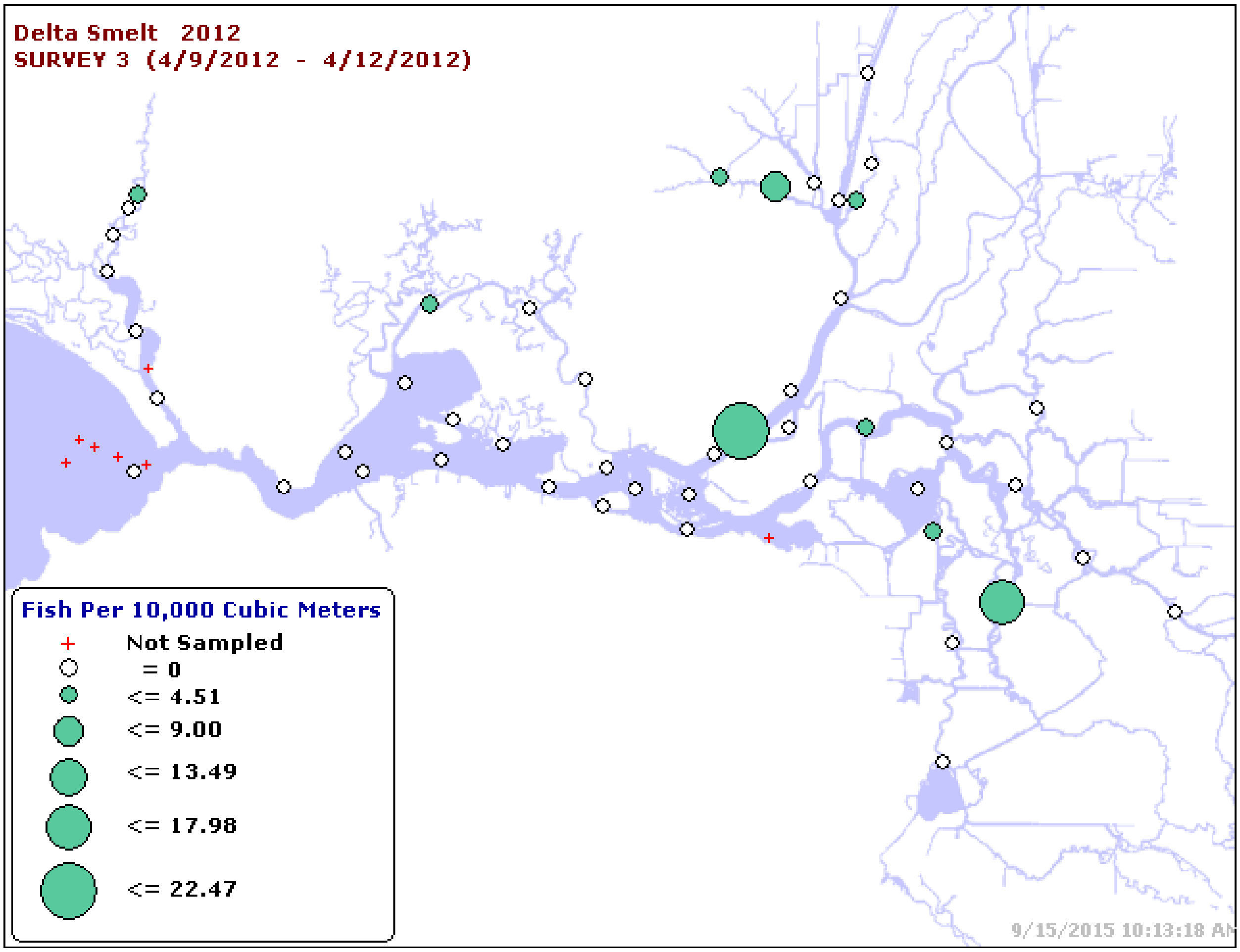
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C24. Density of Delta Smelt from 20-mm Survey 7, 2011.



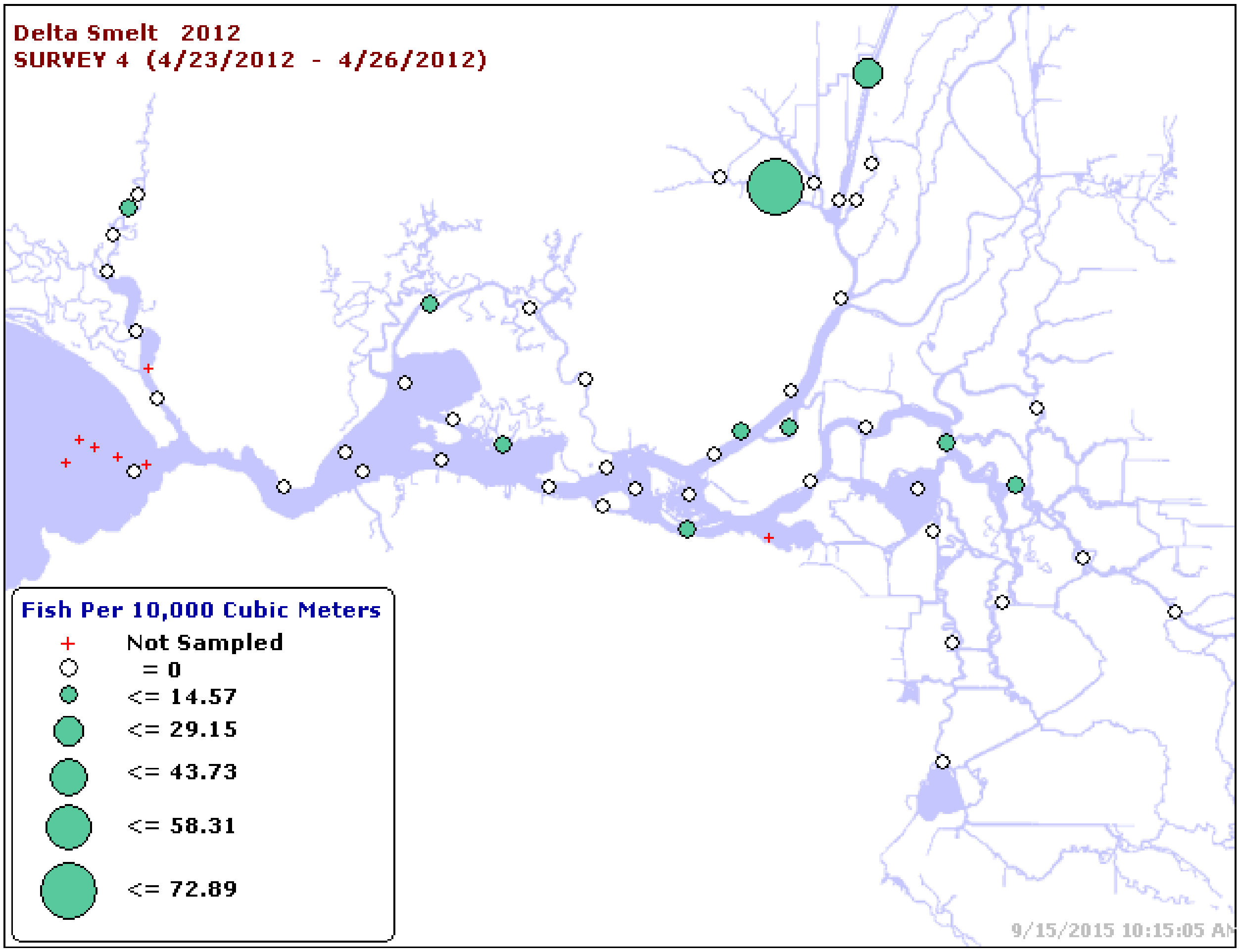
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C25. Density of Delta Smelt from 20-mm Survey 8, 2011.



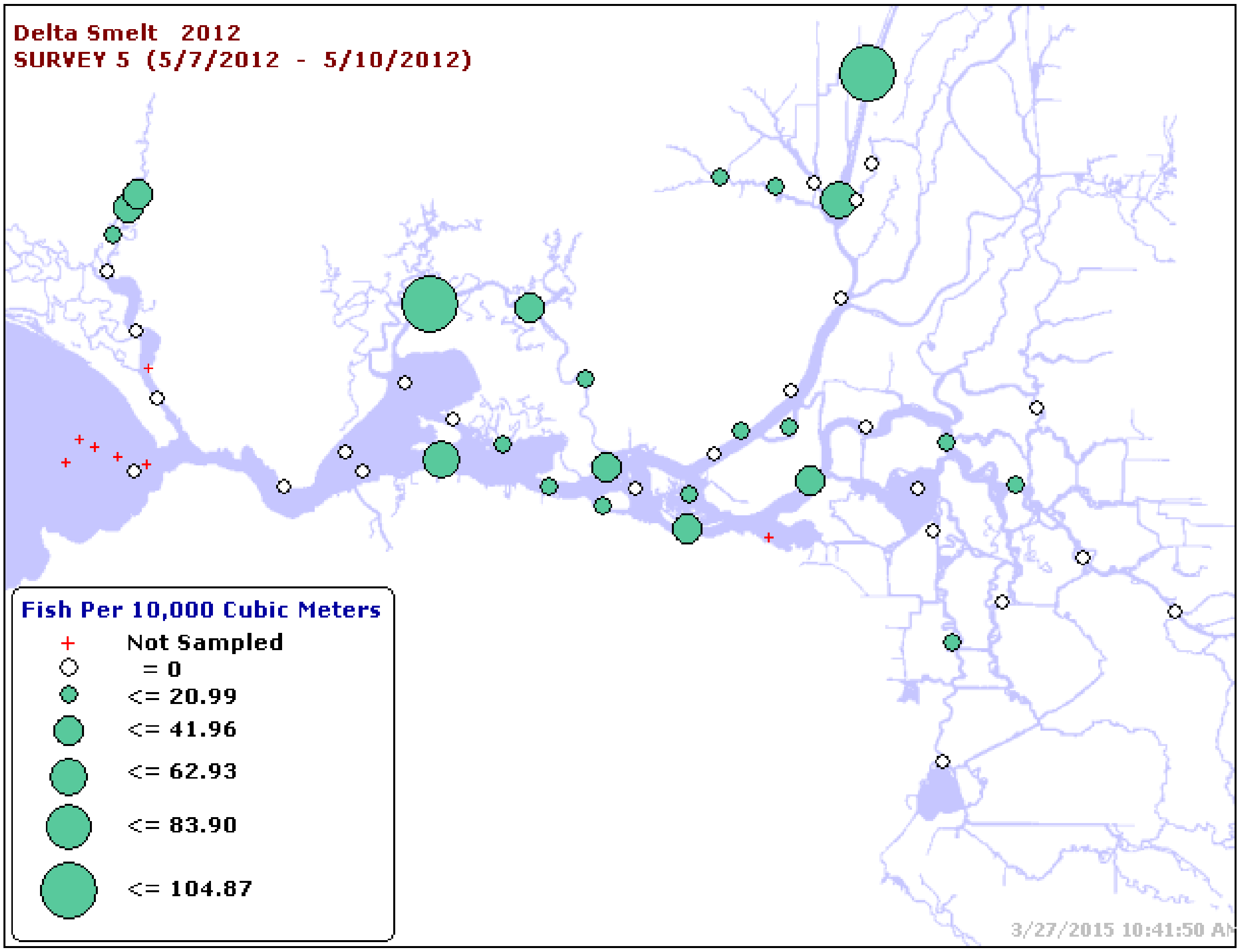
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C26. Density of Delta Smelt from 20-mm Survey 3, 2012.



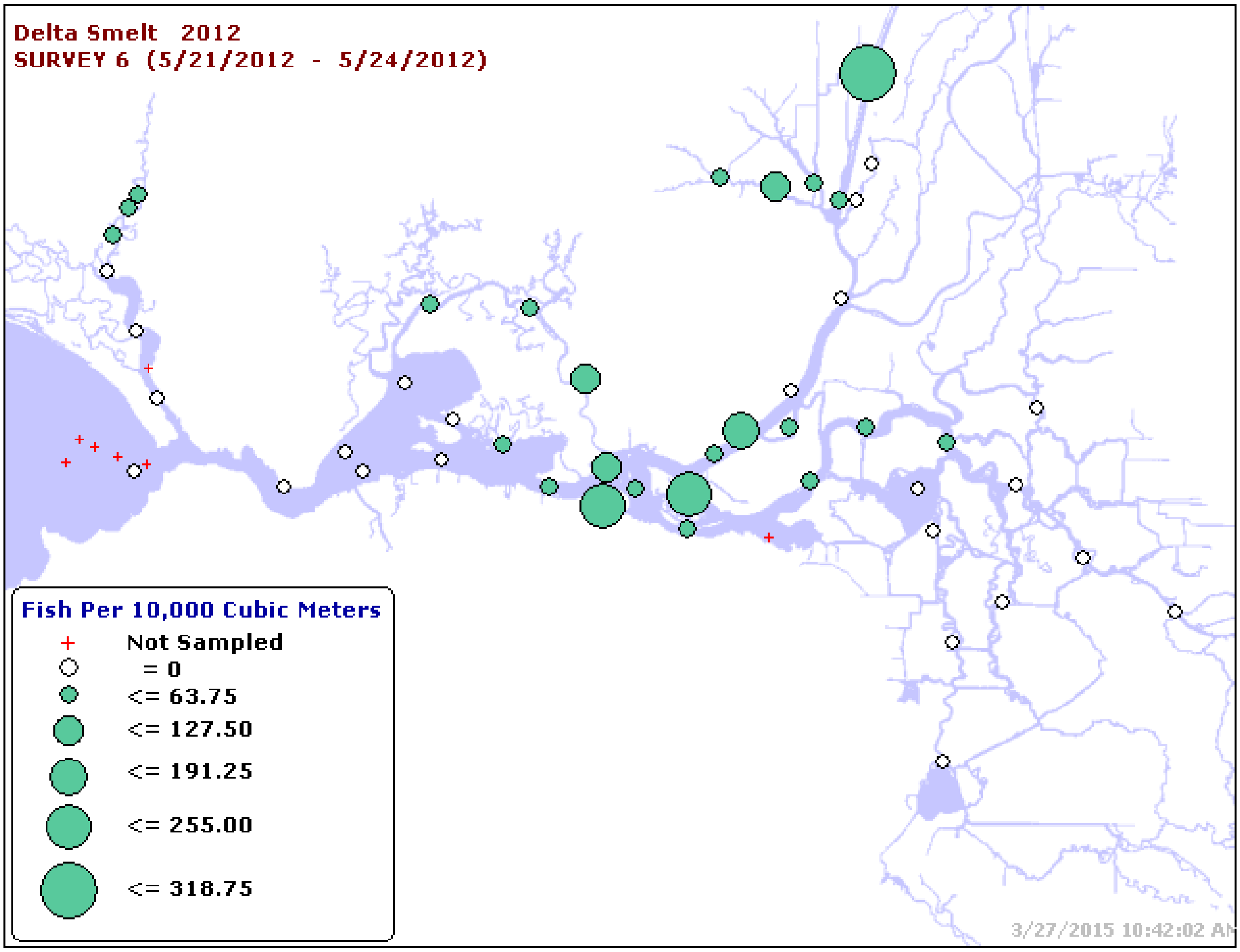
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C27. Density of Delta Smelt from 20-mm Survey 4, 2012.



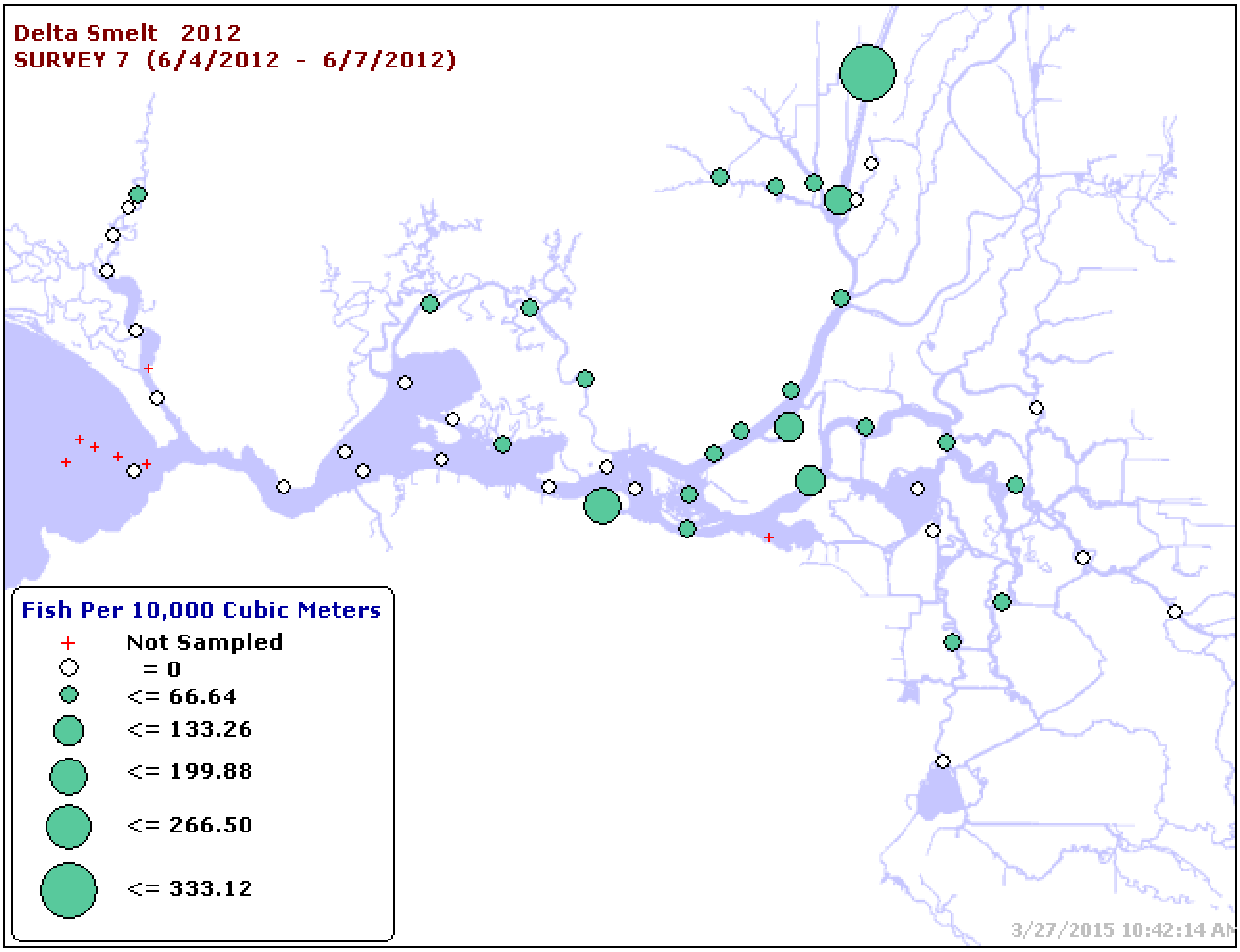
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C28. Density of Delta Smelt from 20-mm Survey 5, 2012.



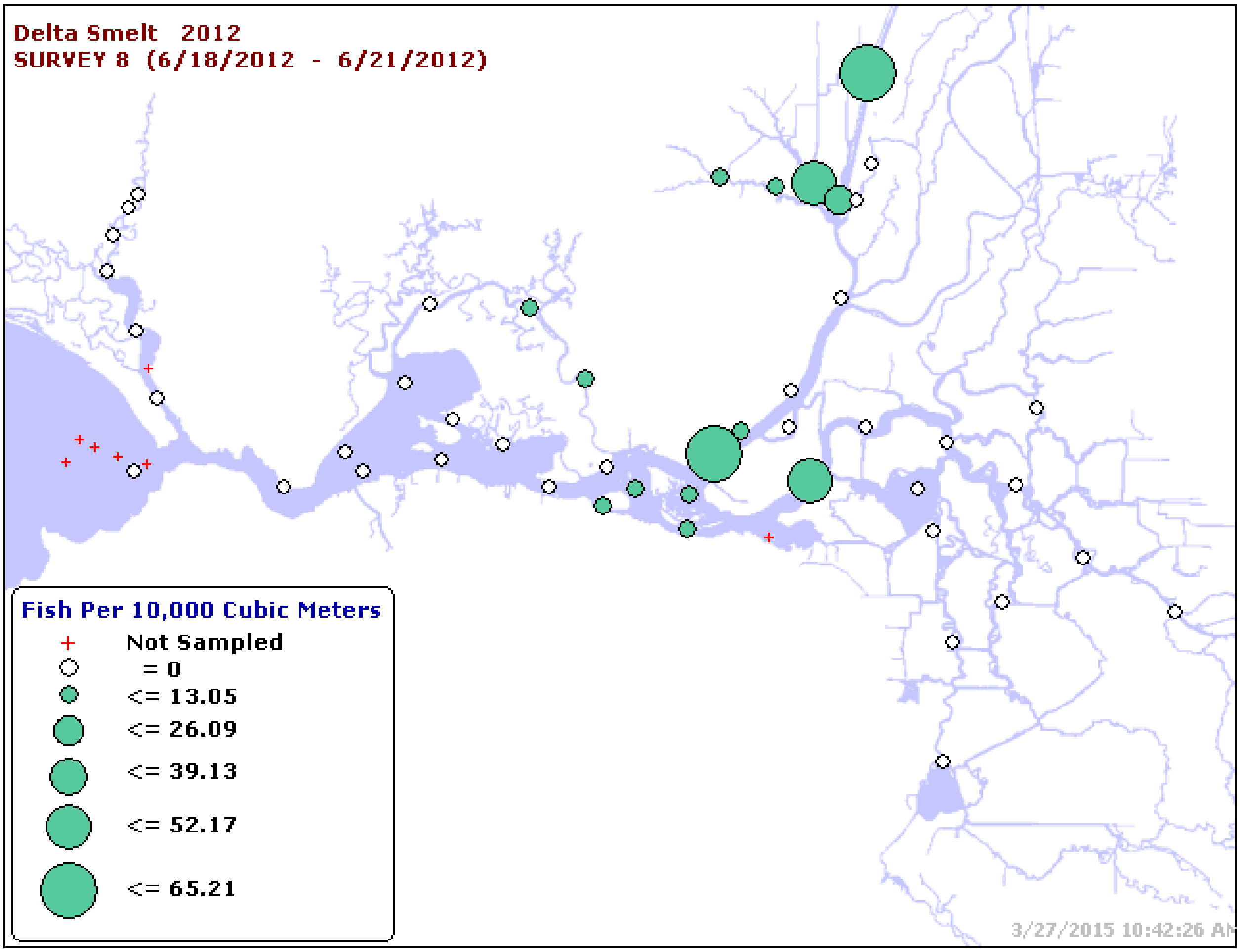
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C29. Density of Delta Smelt from 20-mm Survey 6, 2012.



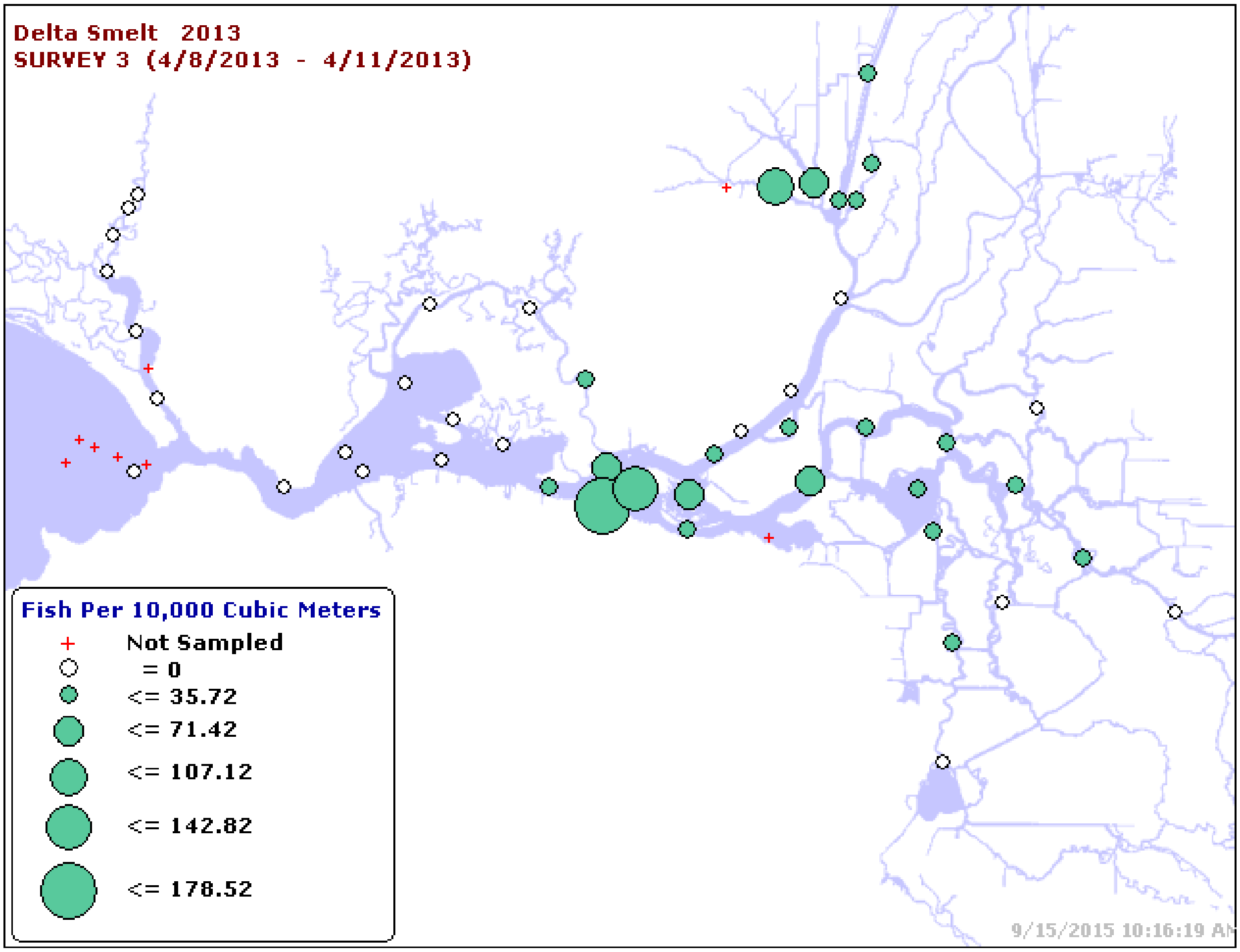
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C30. Density of Delta Smelt from 20-mm Survey 7, 2012.



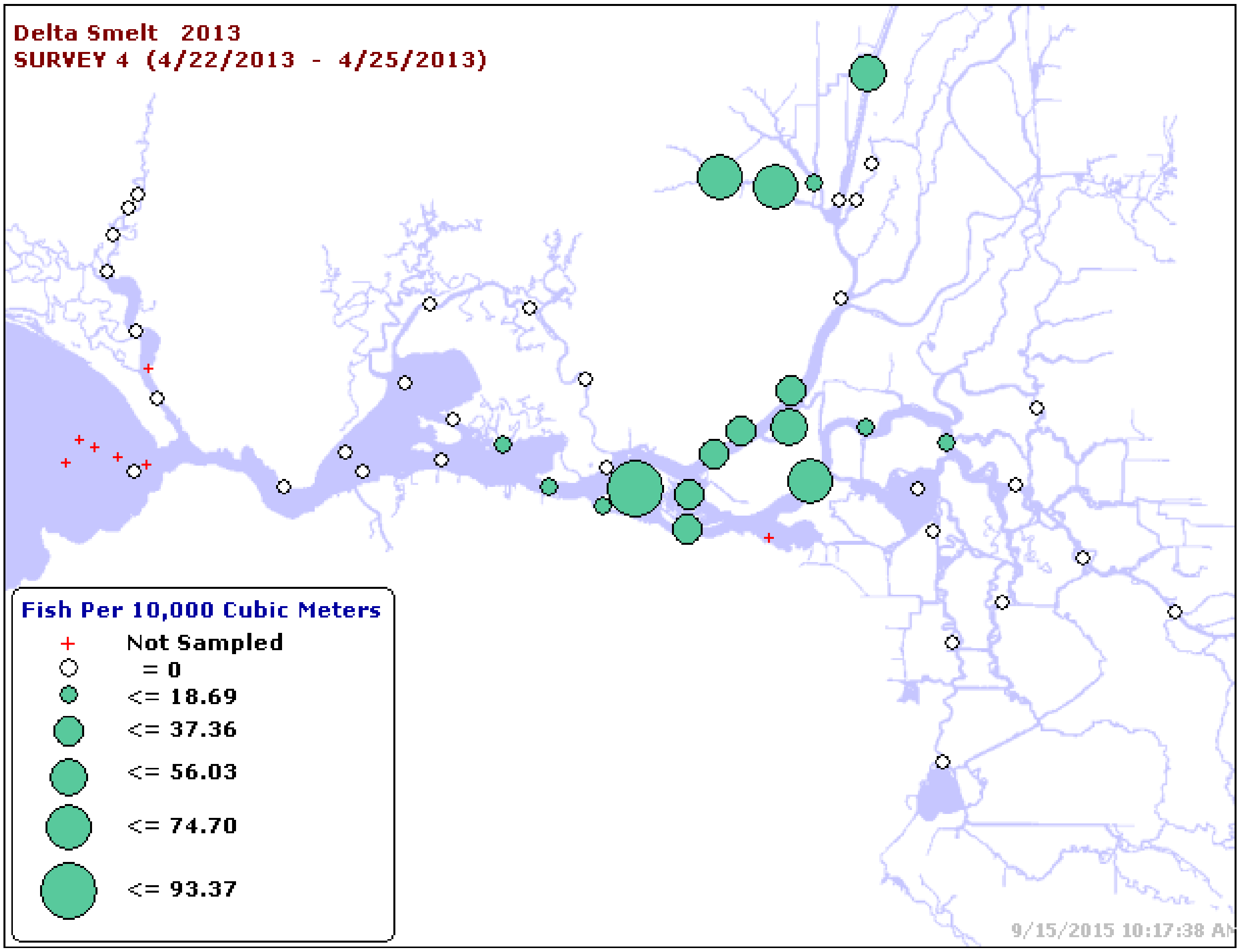
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C31. Density of Delta Smelt from 20-mm Survey 8, 2012.



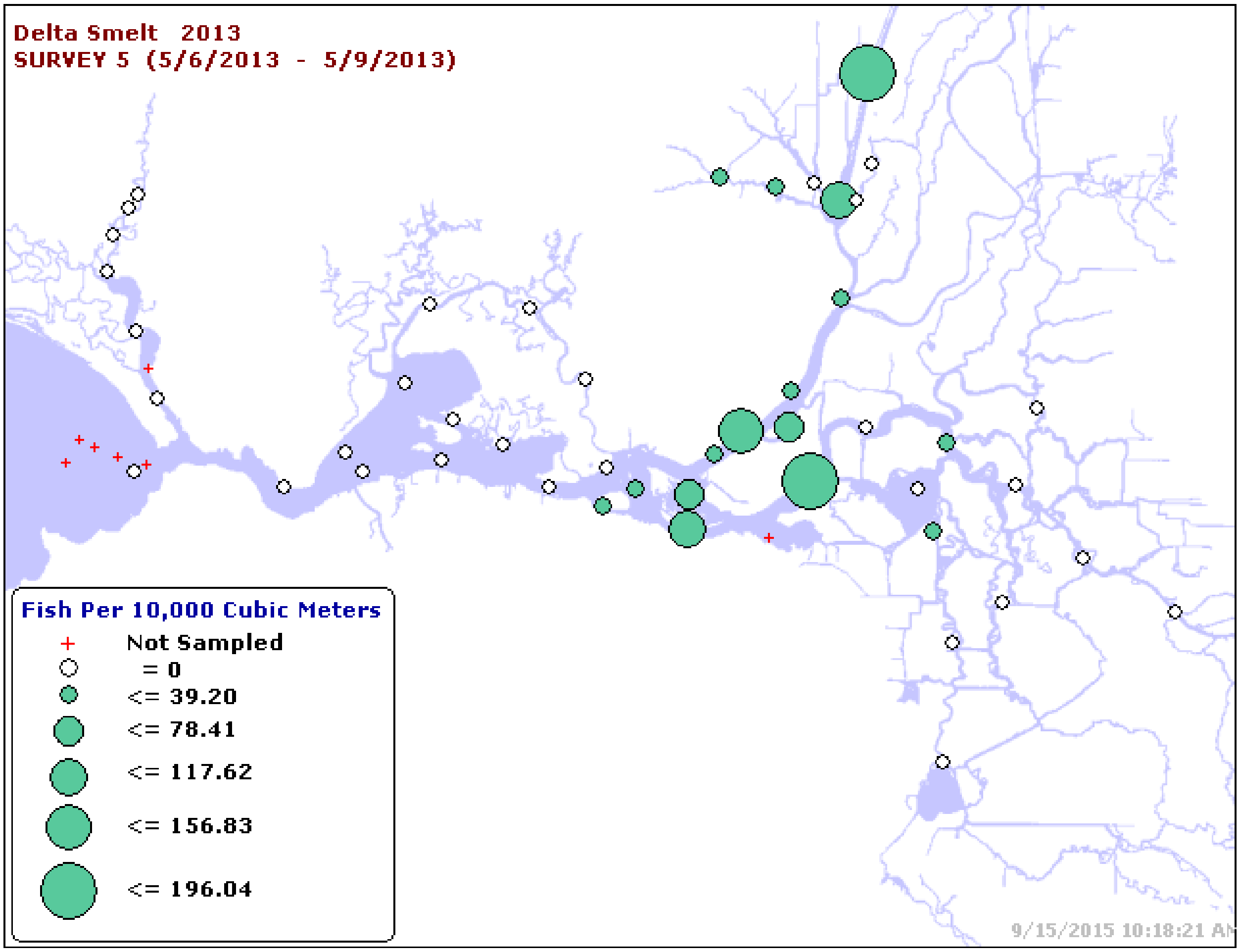
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C32. Density of Delta Smelt from 20-mm Survey 3, 2013.



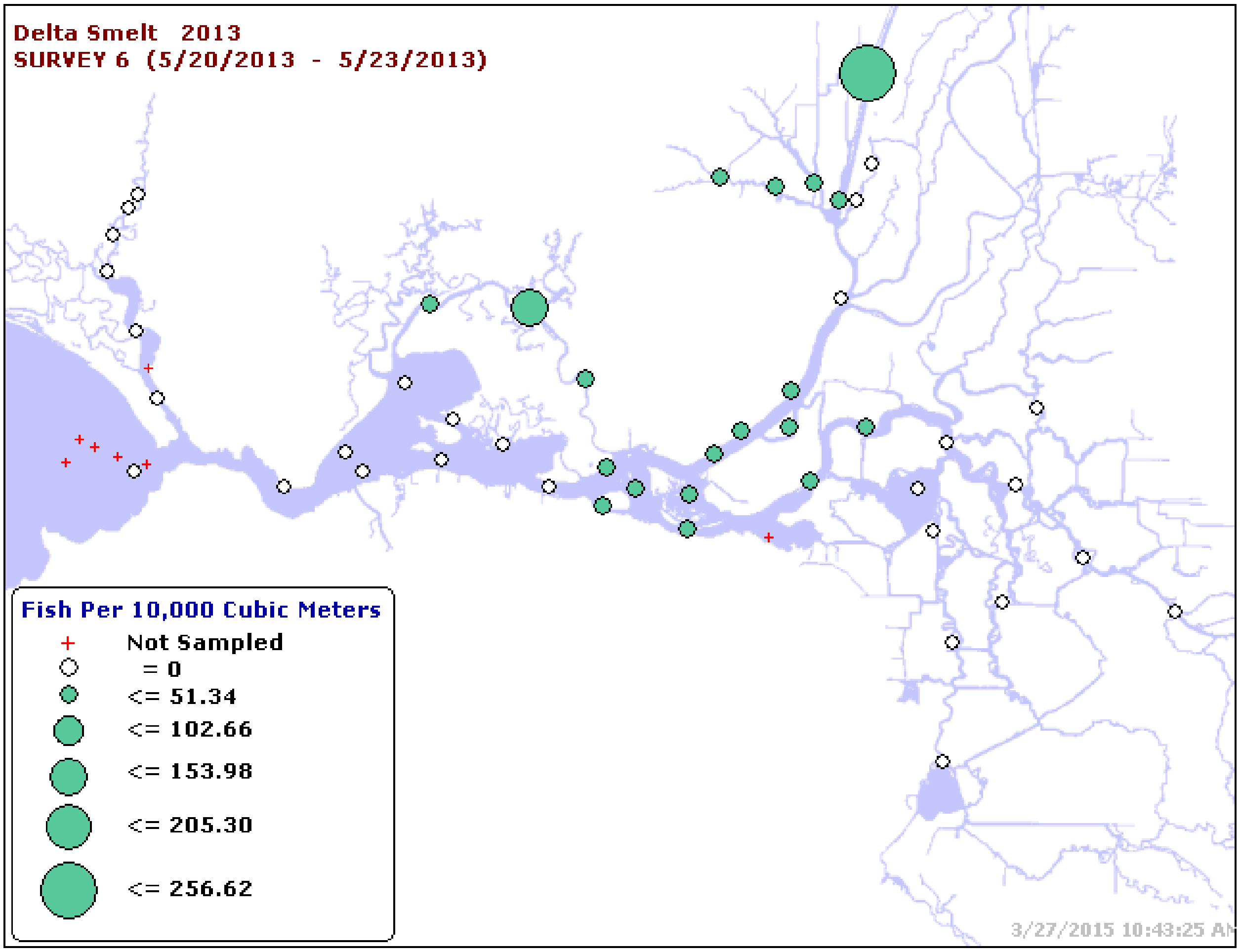
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C33. Density of Delta Smelt from 20-mm Survey 4, 2013.



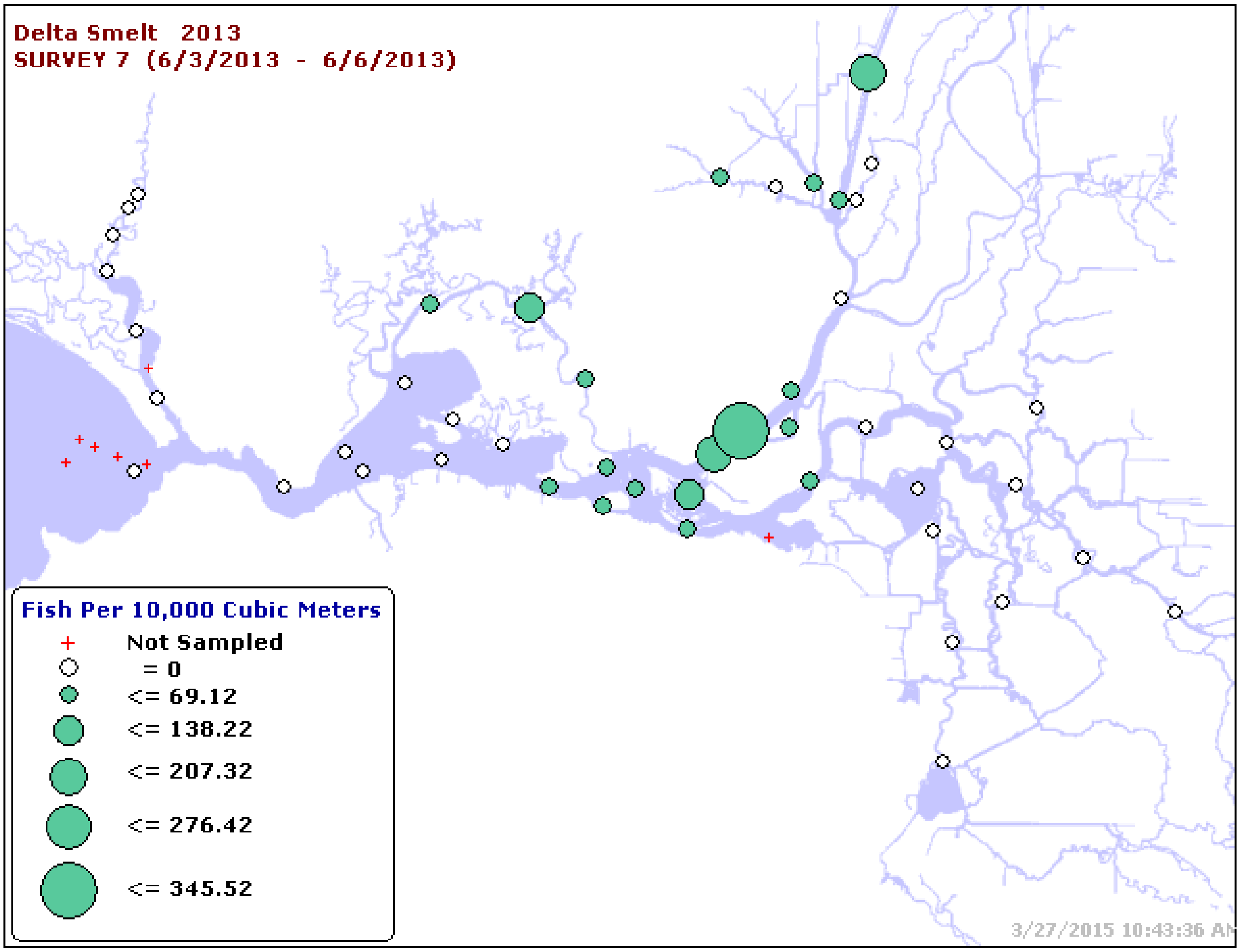
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C34. Density of Delta Smelt from 20-mm Survey 5, 2013.



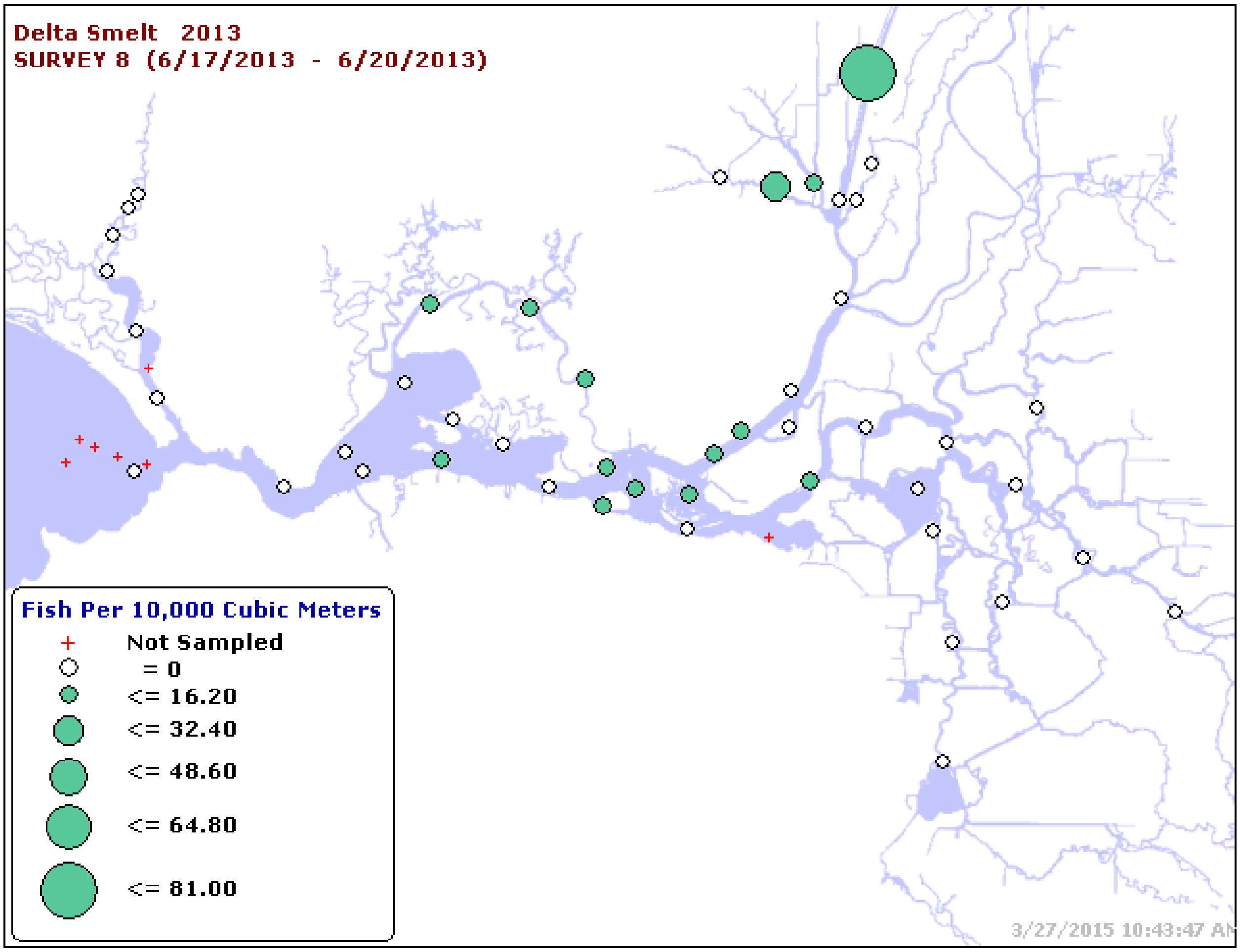
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C35. Density of Delta Smelt from 20-mm Survey 6, 2013.



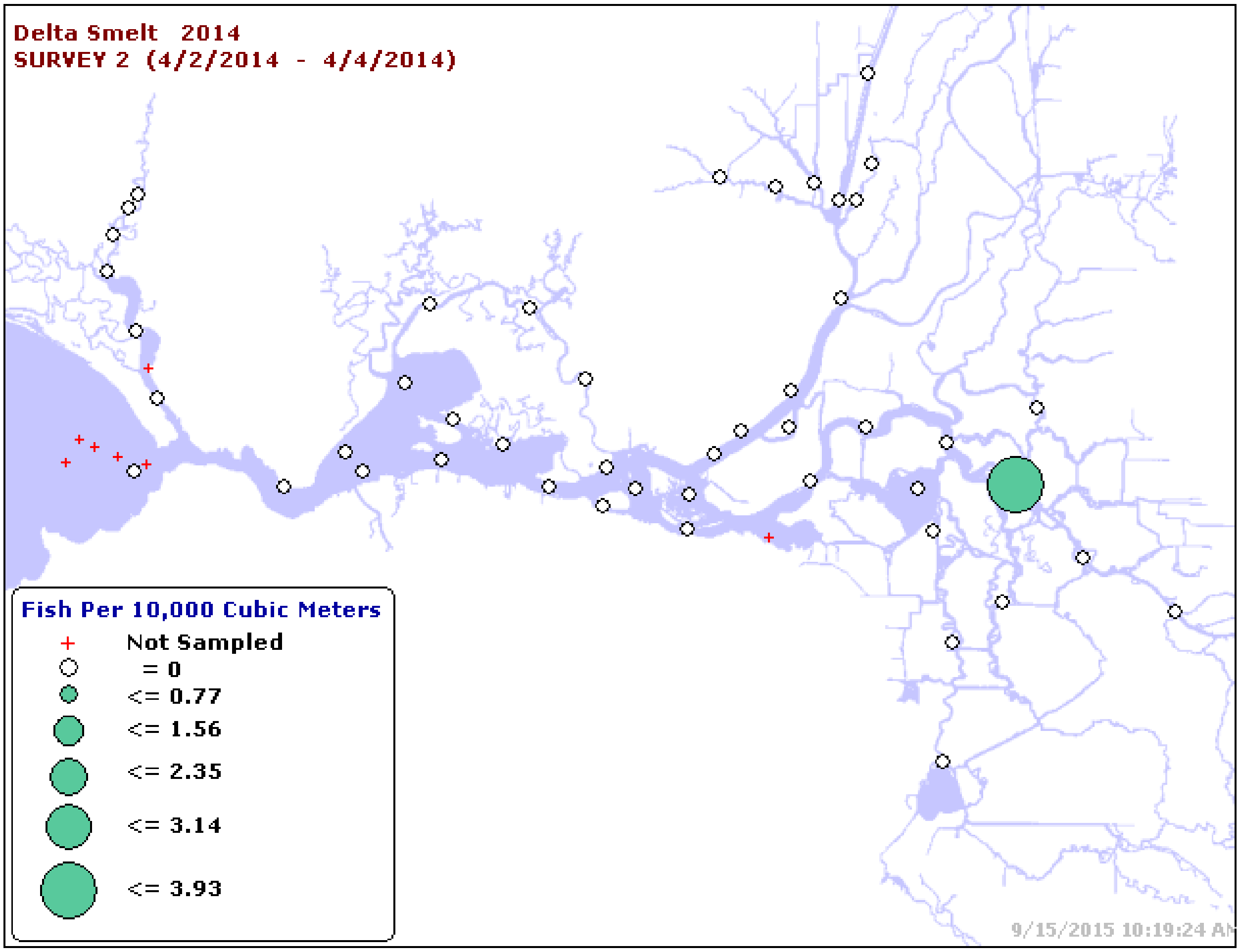
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C36. Density of Delta Smelt from 20-mm Survey 7, 2013.



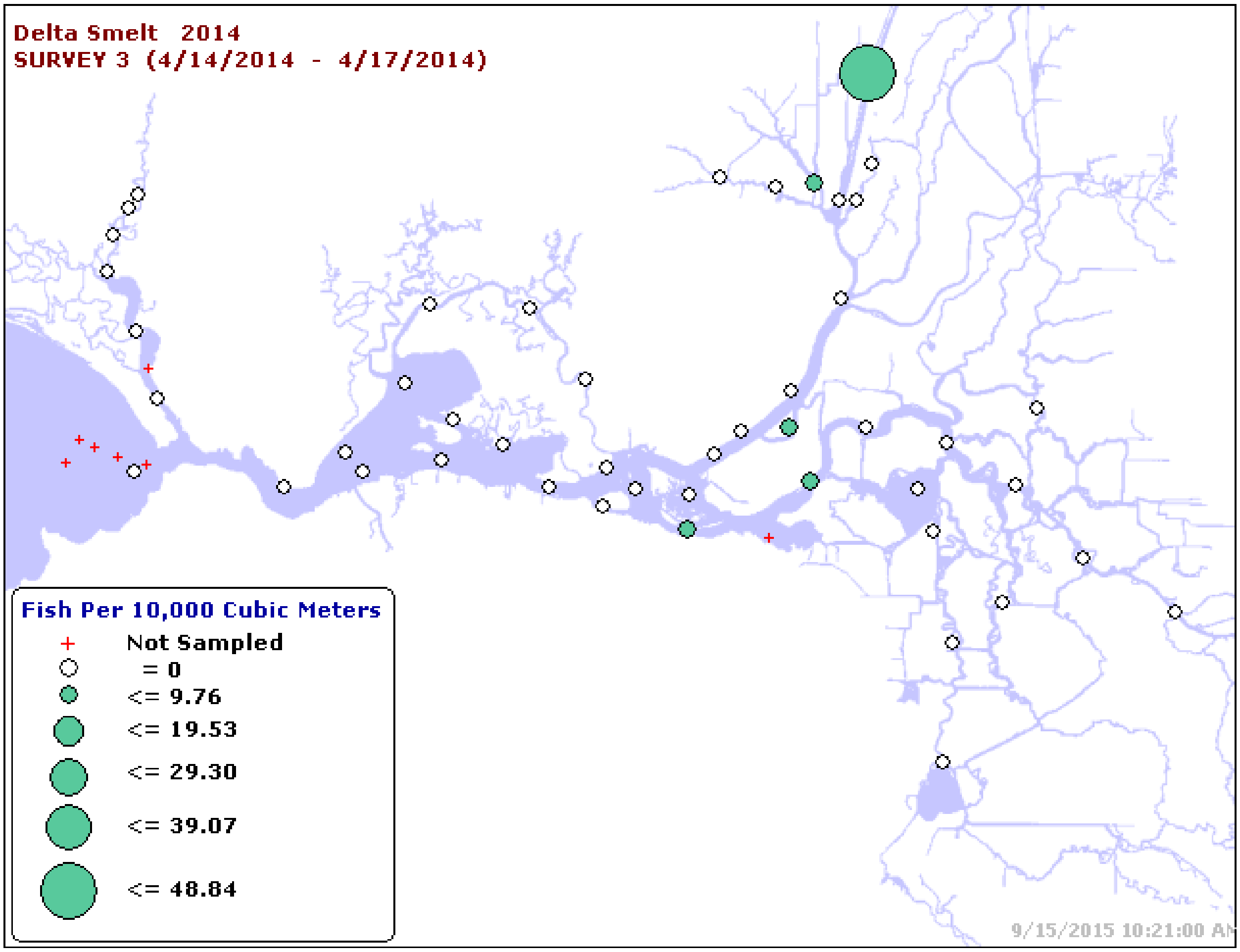
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C37. Density of Delta Smelt from 20-mm Survey 8, 2013.



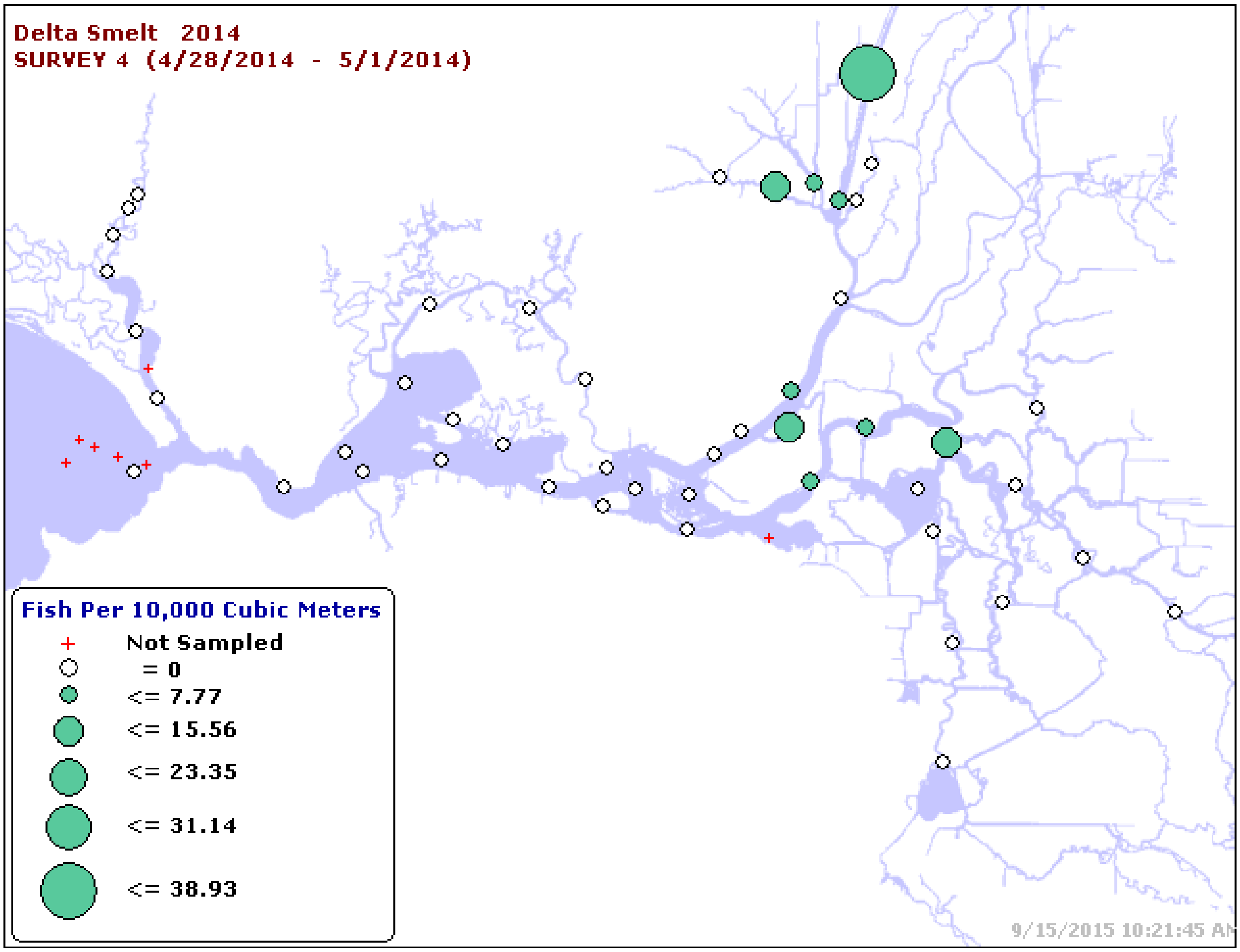
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C38. Density of Delta Smelt from 20-mm Survey 2, 2014.



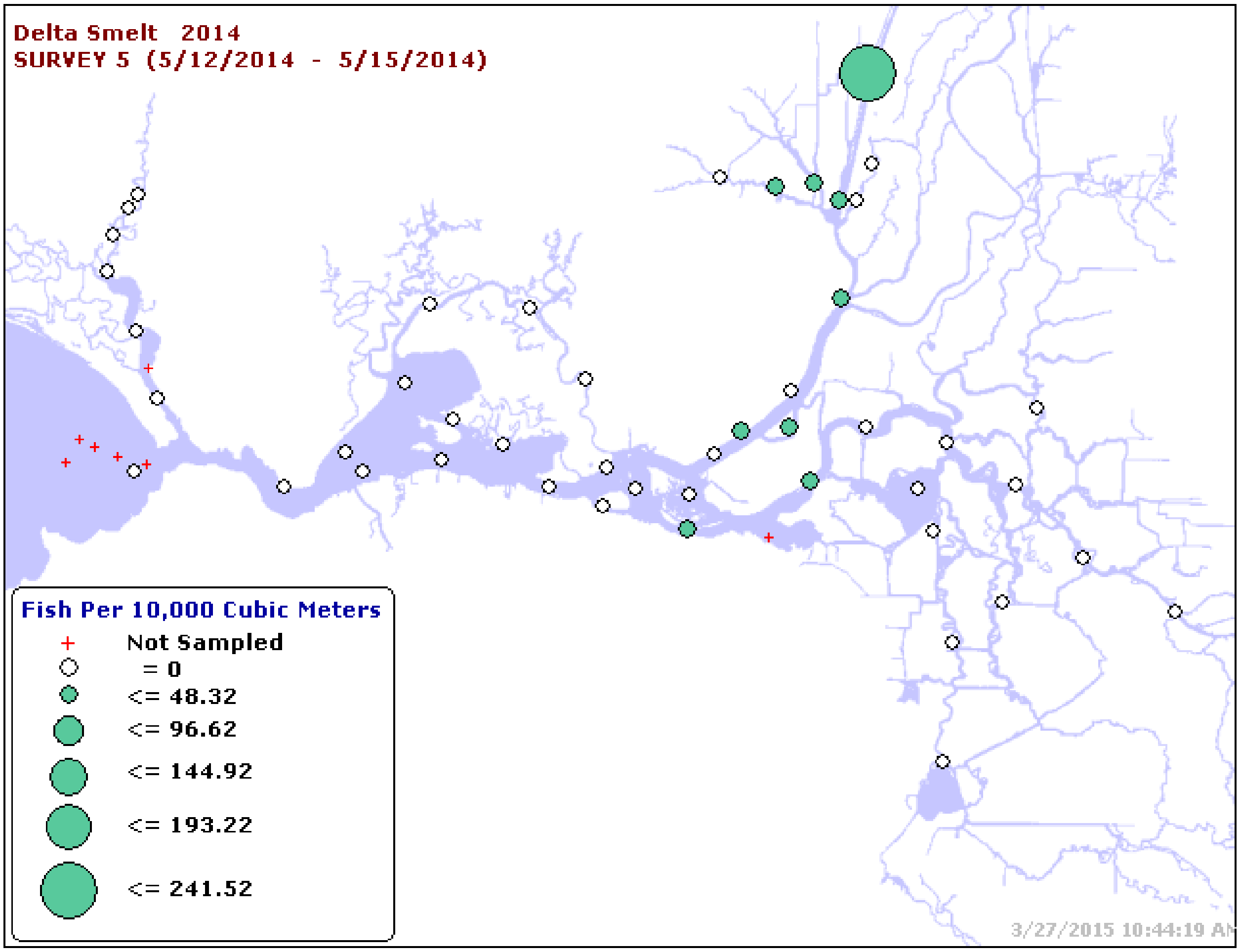
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C39. Density of Delta Smelt from 20-mm Survey 3, 2014.



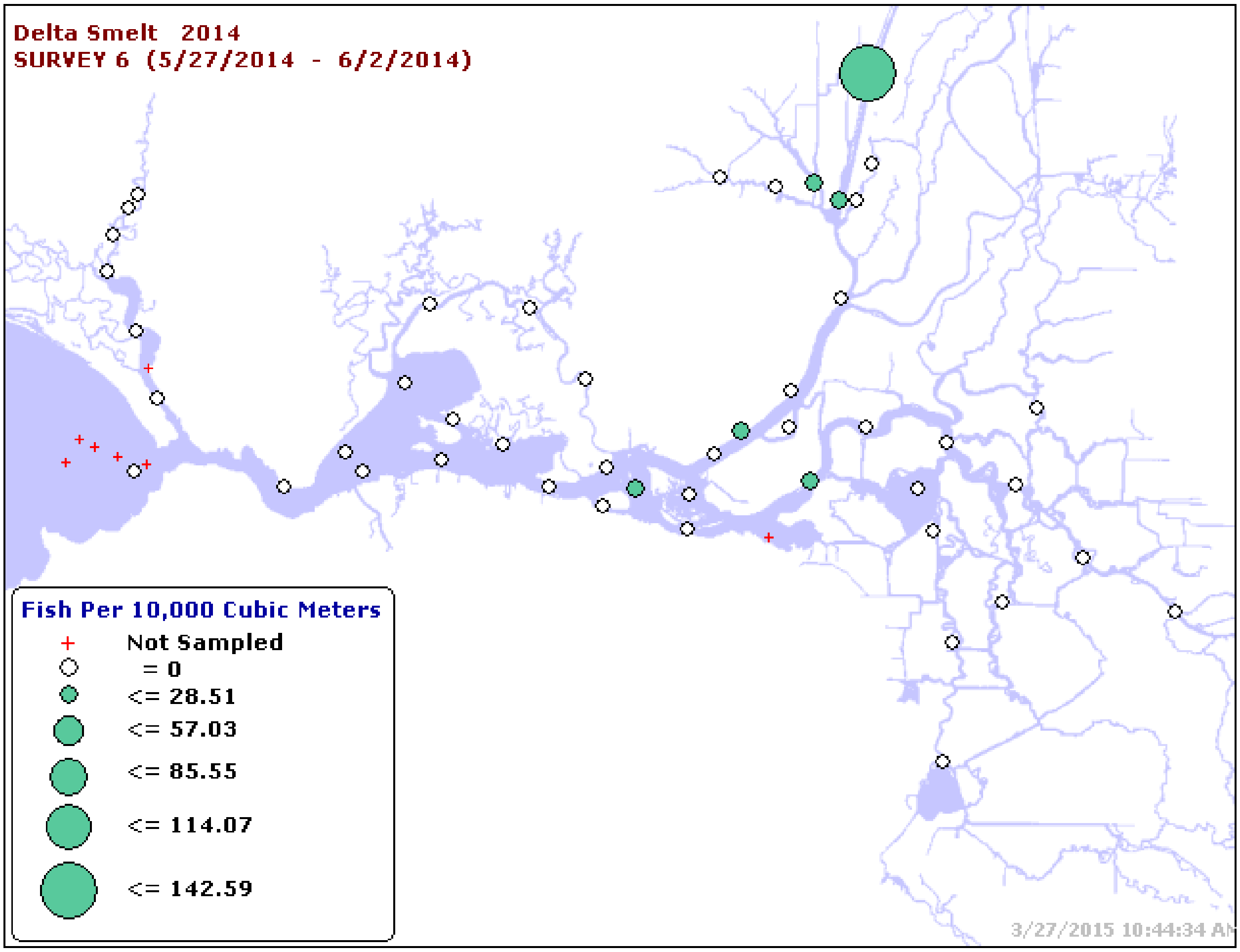
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C40. Density of Delta Smelt from 20-mm Survey 4, 2014.



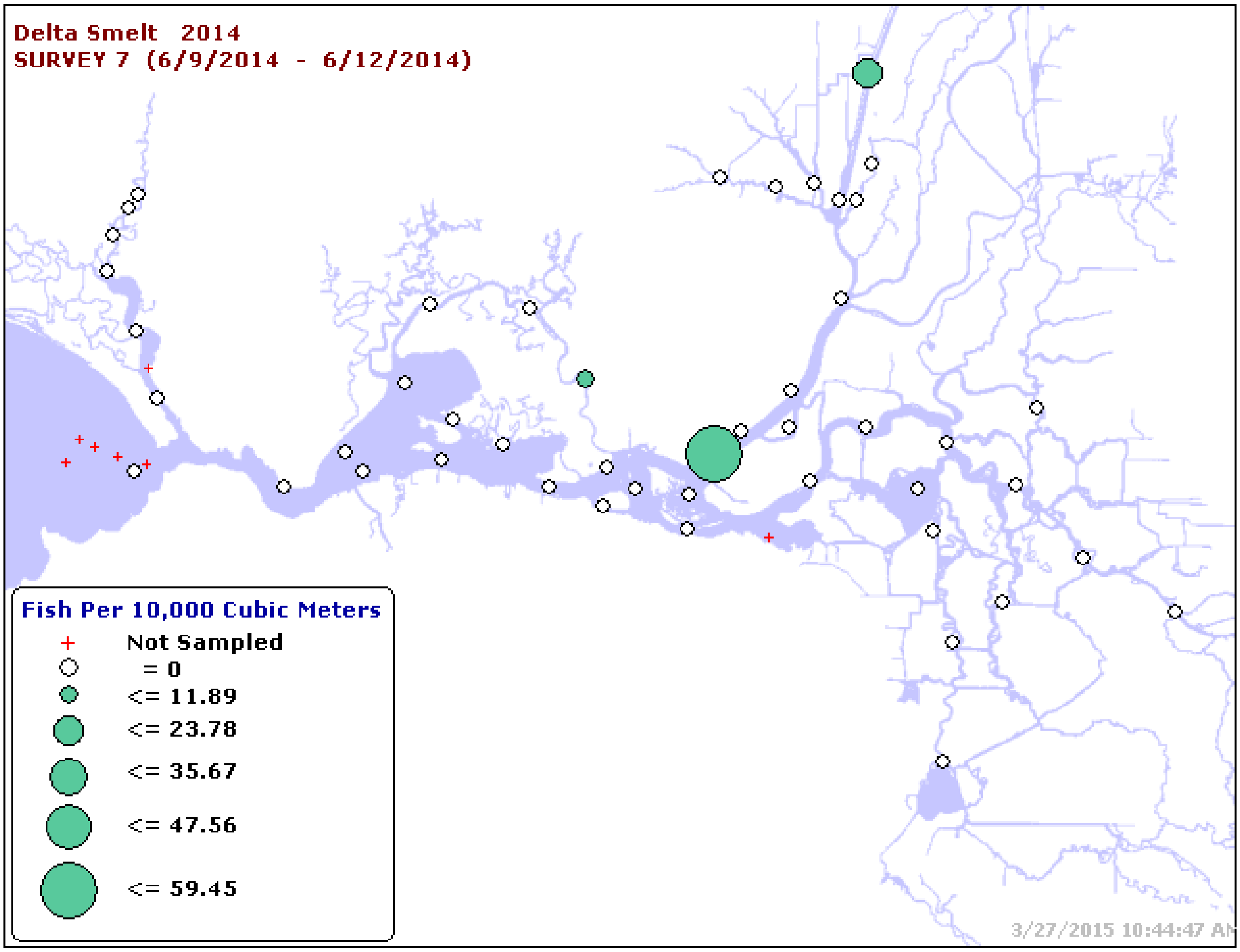
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C41. Density of Delta Smelt from 20-mm Survey 5, 2014.



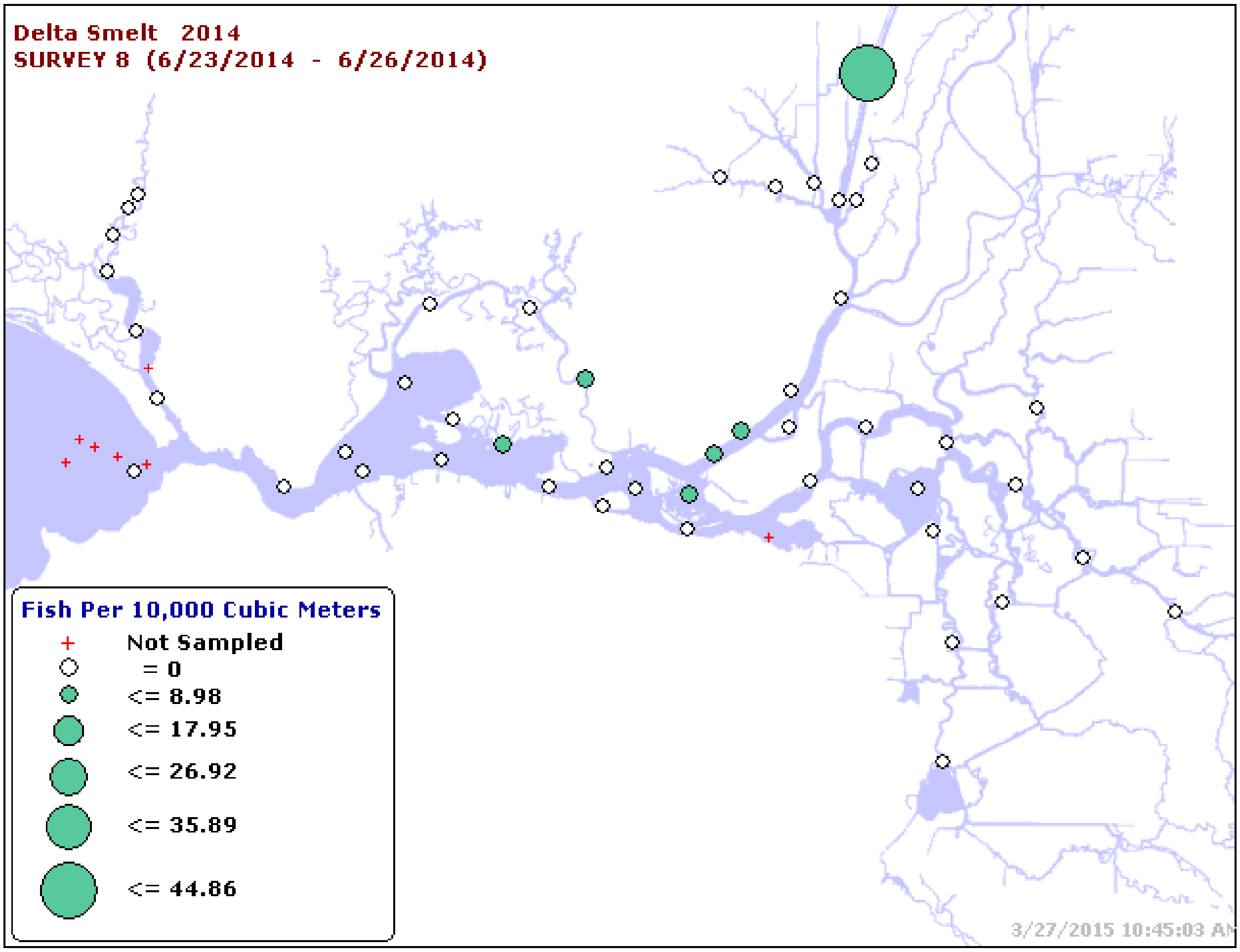
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C42. Density of Delta Smelt from 20-mm Survey 6, 2014.



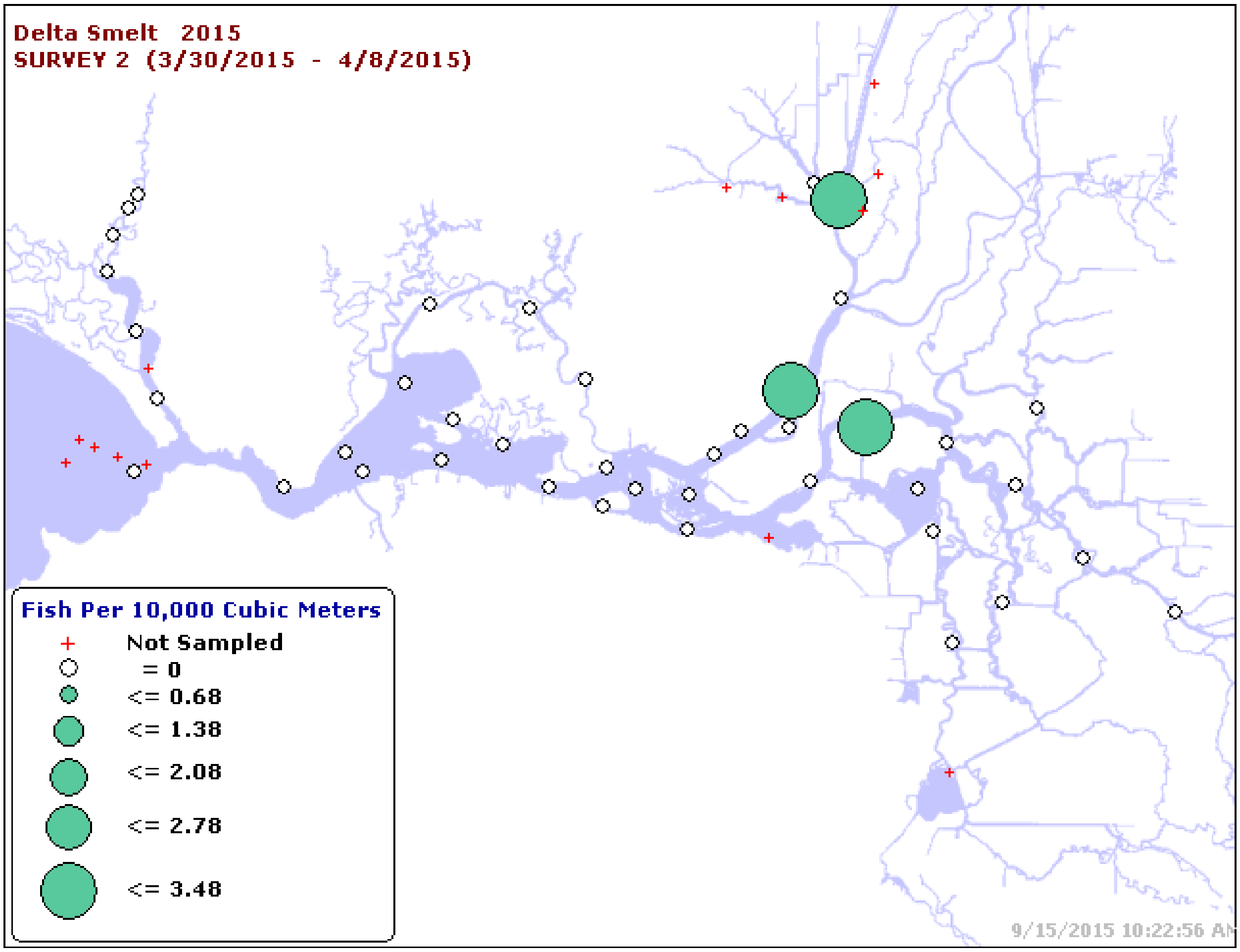
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C43. Density of Delta Smelt from 20-mm Survey 7, 2014.



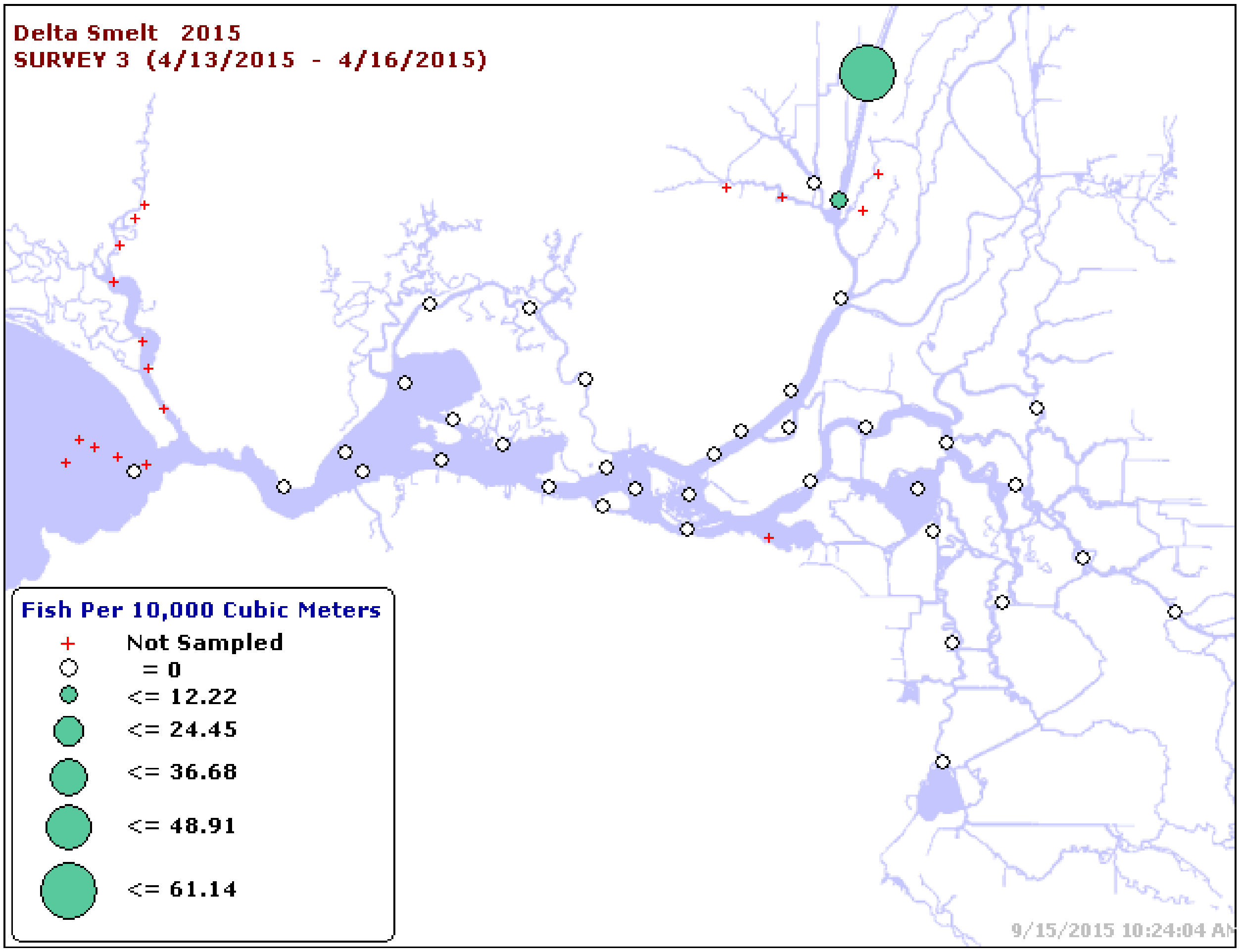
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure C44. Density of Delta Smelt from 20-mm Survey 8, 2014.



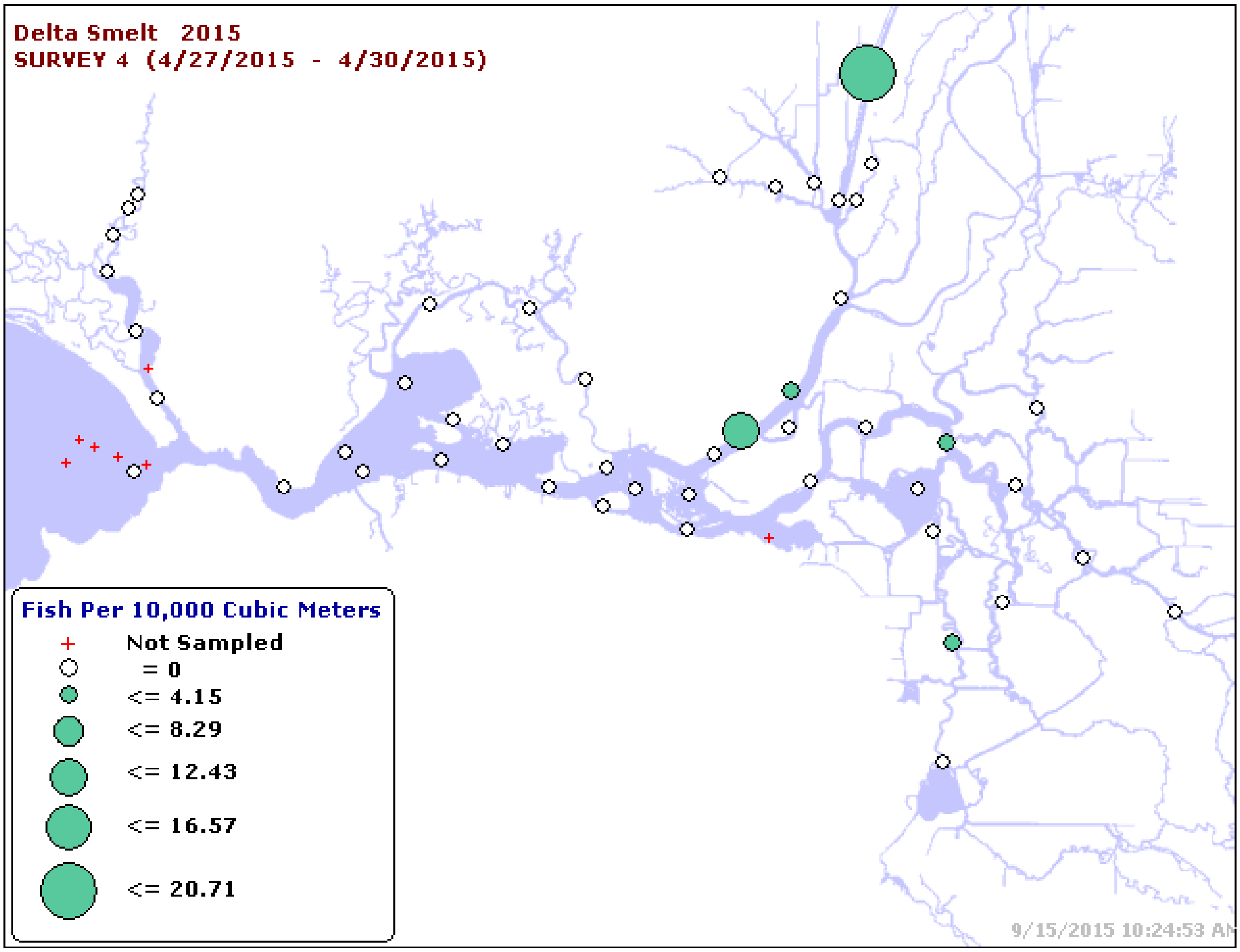
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C45. Density of Delta Smelt from 20-mm Survey 2, 2015.



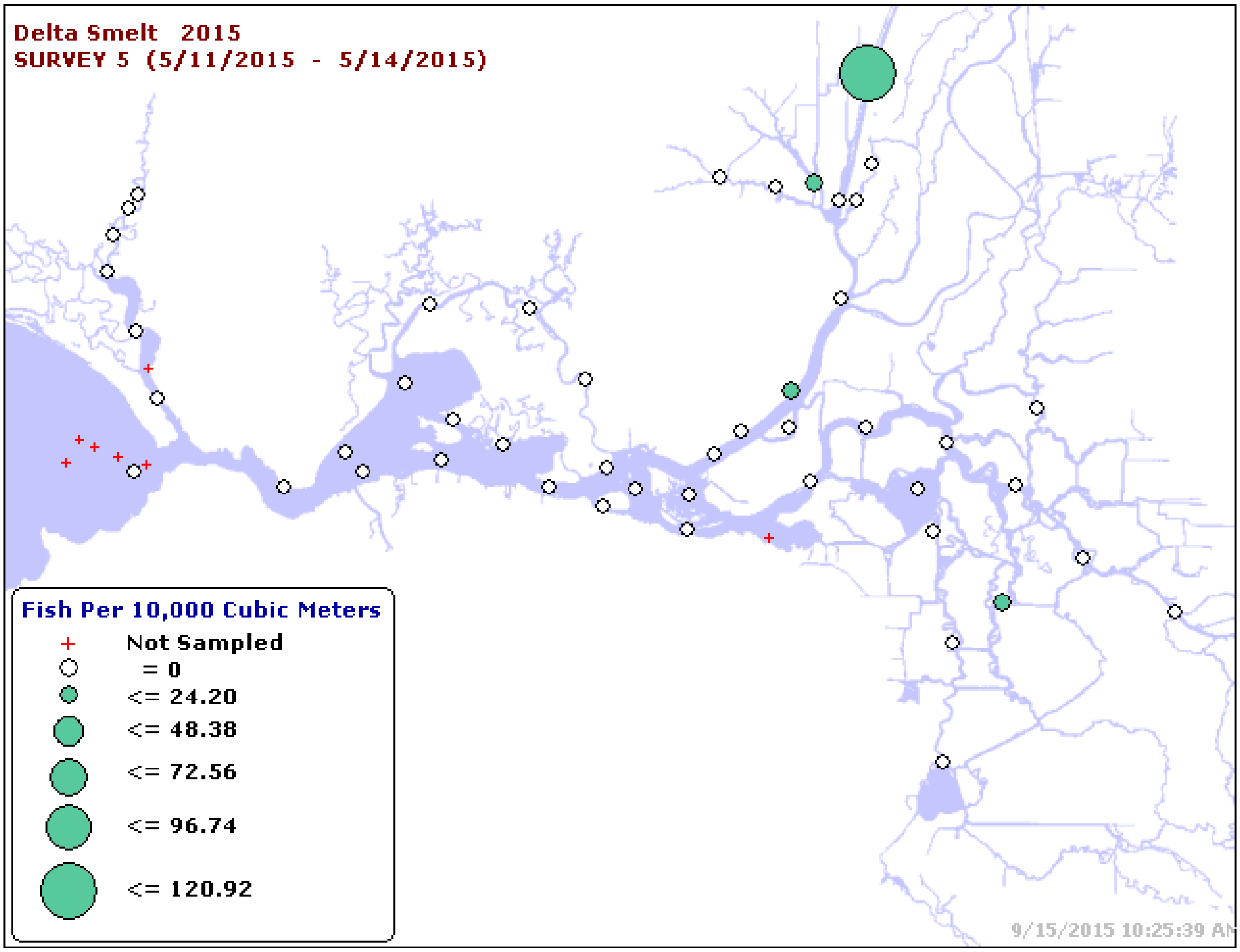
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C46. Density of Delta Smelt from 20-mm Survey 3, 2015.



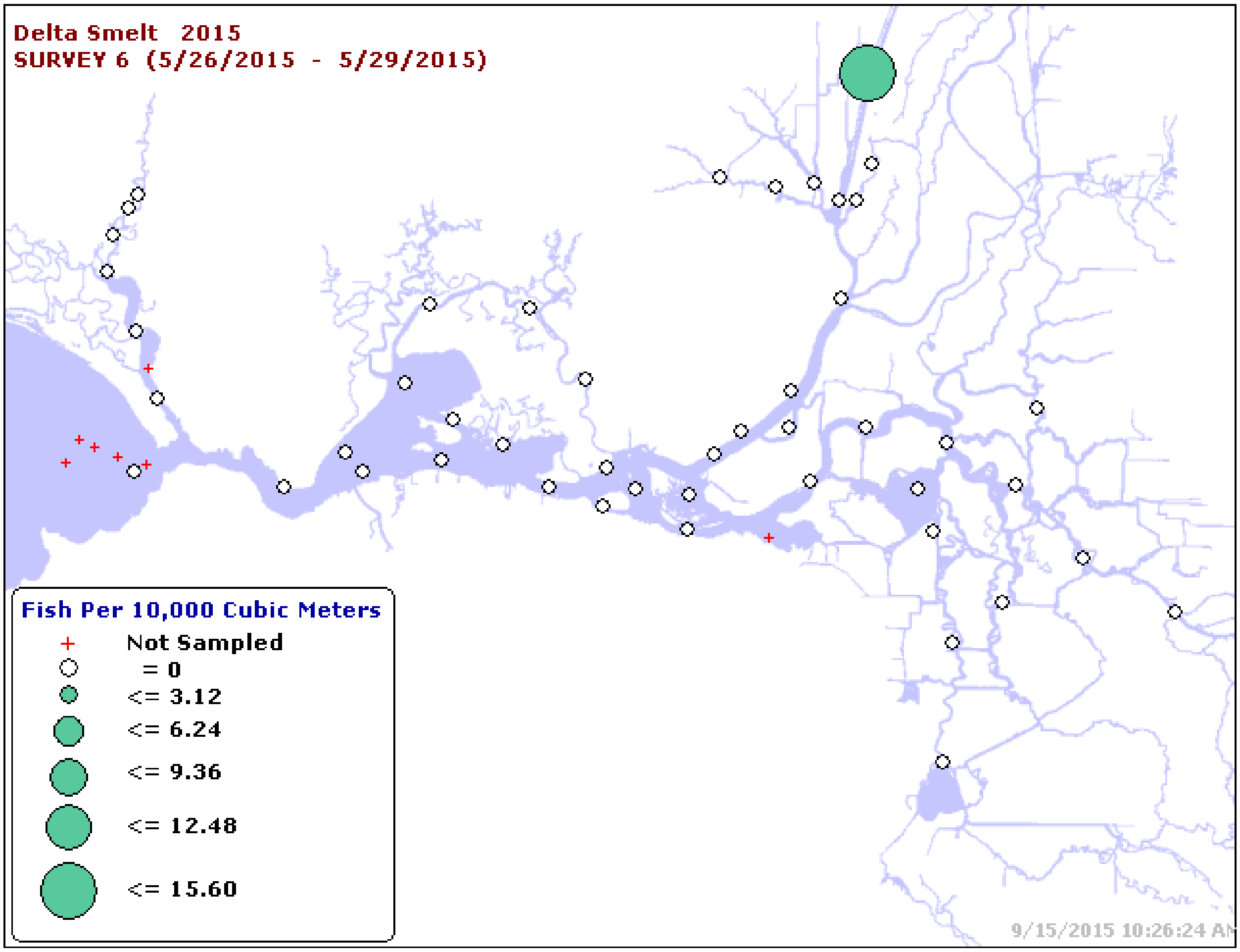
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C47. Density of Delta Smelt from 20-mm Survey 4, 2015.



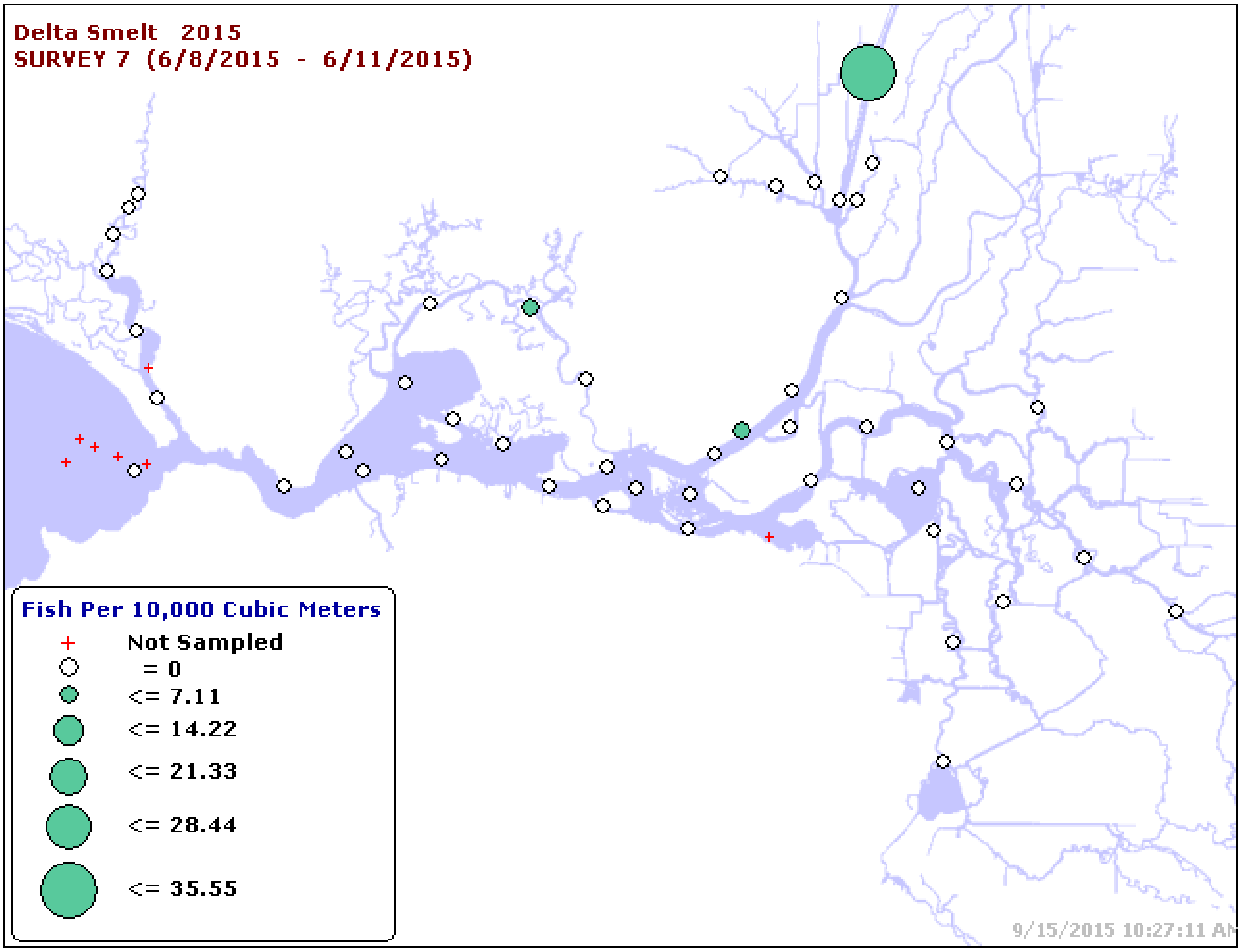
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C48. Density of Delta Smelt from 20-mm Survey 5, 2015.



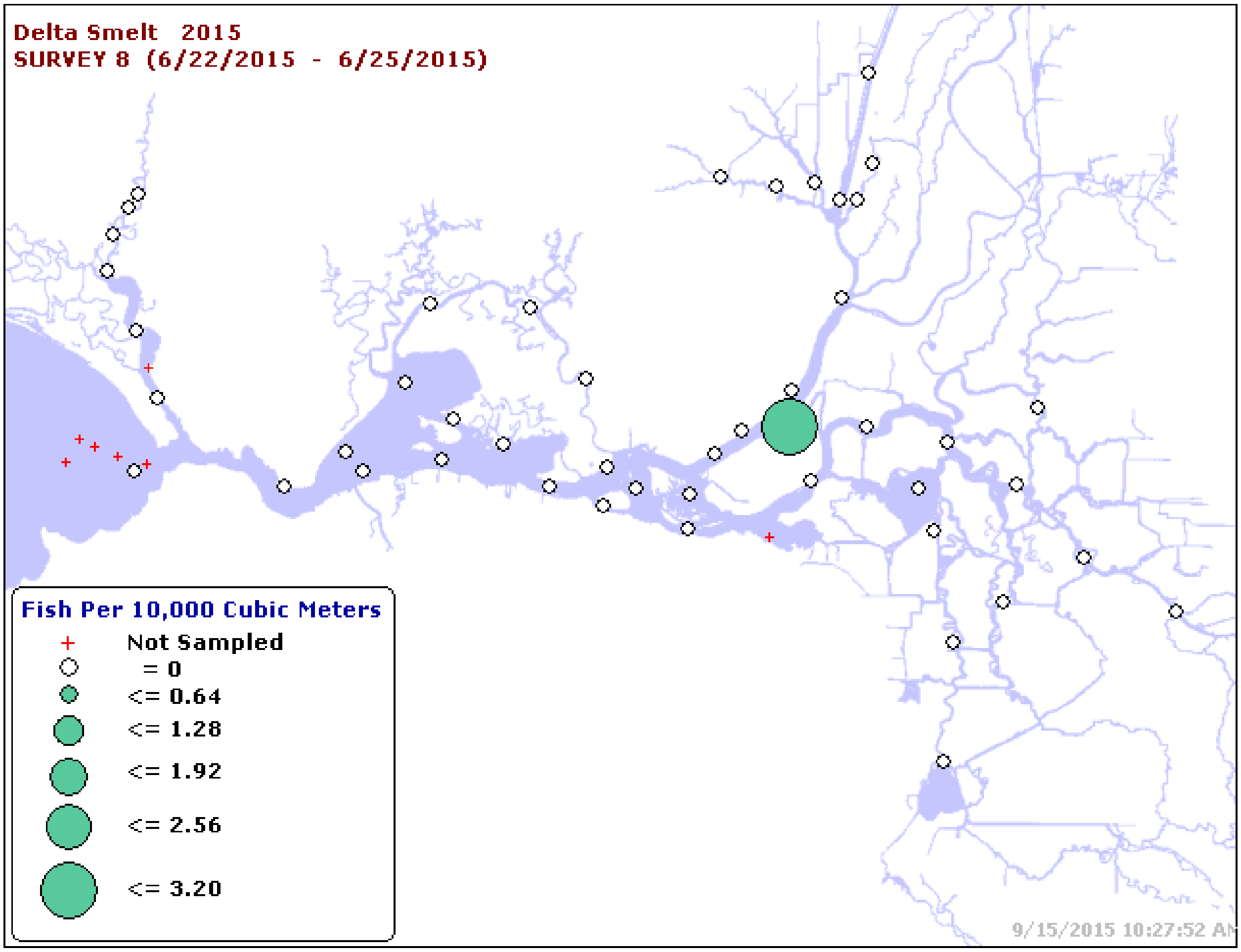
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C49. Density of Delta Smelt from 20-mm Survey 6, 2015.



Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C50. Density of Delta Smelt from 20-mm Survey 7, 2015.



Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: September 15, 2015.

Figure C51. Density of Delta Smelt from 20-mm Survey 8, 2015.

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