Biological Assessment of Potential Effects on Listed Fishes from the Emergency Drought 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
BMPs	best management practices
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
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
CPTs	cone penetrometer tests
CVP/SWP	Central Valley Project/State Water Project
CVTRT	Central Valley Technical Review Team
CWT	coded-wire tag
dB re: 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
NOX	oxides of nitrogen
O2	oxygen
OMR	Old and Middle River flows
PAHs	poly aromatic hydrocarbons
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
YOY	young of the year
μPa	micropascal

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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), proposes to install an emergency, temporary rock barrier across a Delta channel. DWR seeks to install a single emergency salinity barrier across West False River in May, to be removed six months later, in November. State and federal water and wildlife officials, working as a Real-Time Drought Operations Management Team, have determined that the barrier would help deter the tidal push of saltwater from San Francisco Bay into the central Delta. The emergency drought barrier (EDB) would be essentially a pile of basketball-size rocks across the 800-foot-wide channel. Keeping saltwater from the central Delta is a priority, as a large portion of the state's freshwater supplies travel through this part of the Delta. The barrier would help prevent saltwater contamination of water supplies used by people who live in the Delta; Contra Costa, Alameda, and Santa Clara counties; and the 25 million people who rely on the Delta-based federal and state water projects for at least some of their supplies.

Water quality conditions in the Sacramento-San Joaquin River Delta (Delta) during 2014 were difficult to control as a result of persistent drought conditions, and put municipal, industrial, and agricultural water supplies at risk. The brackish conditions also were degrading habitat for threatened and endangered fish dependent on the Delta. In response to the statewide drought conditions, the U.S. Department of Agriculture identified 57 counties in California, including Sacramento, Solano, and San Joaquin counties, as eligible for natural disaster assistance, including funding for emergency watershed protection and water assistance for rural communities (USDA, 2014). This announcement came in the spring of 2014, following President Obama's earlier announcement of an administration-wide drought response in February 2014.

In addition, on January 17, 2014, California's Governor Edmund G. Brown Jr. signed a proclamation declaring a State of Emergency, prompted by record dry conditions and projections that 2014 would be the driest year on record (see http://gov.ca.gov/news.php?id=18368). The proclamation found that the lack of precipitation is beyond the ability of local authorities to address, placing the safety of people and property existing within California in peril because of water shortage from persistent drought conditions. Governor Brown issued a number of directives calling for immediate action to implement conservation programs, secure water supplies for at-risk communities, and protect critical environmental resources. A Proclamation of a Continued State of Emergency was issued on April 25, 2014, and an Executive Order was issued on December 22, 2014 extending the waiver of the California Environmental Quality Act (CEQA) and Water Code Section 13247 in paragraph 9 of the January 17, 2014 Proclamation, and paragraph 19 of the April 25, 2014 Proclamation through May 31, 2016.

An Executive Order issued on April 1, 2015 extended the orders and provisions in the January 17, 2014 and April 25, 2014 Proclamations and Executive Orders B-26-14 and B-28-14 and added several modifications, discussed in the following paragraph. Many of the actions in the drought proclamation are being undertaken by DWR and its various federal, state, and local partners. These actions include temporary modifications of requirements included in the State Water Resources Control Board's (SWRCB) Revised Decision 1641 (D-1641) to meet water quality objectives in the Water Quality Control Plan for the Bay-Delta, including increased flexibility for water transfers, regulating diversions, and Delta Cross Channel (DCC) gate operations. The drought proclamation also directed DWR to take other necessary actions to protect water quality and water supply in the Delta, including installation of temporary barriers or temporary water supply connections as needed, and coordination with the California Department of Fish and Wildlife (CDFW) to minimize impacts on affected aquatic species. The 2015 Executive Order suspends Division 13 (commencing with Section 21000) of the Public Resources Code (related to the CEQA) and regulations adopted pursuant to that Division, as well as Section 13247 (related to compliance with approved or adopted water quality control plans) and Chapter 3 of Part 3 (commencing with Section 85225 related to preparing a written certification of consistency with the Delta Plan) of the Water Code. The Executive Order also calls for DWR to exercise any authority vested in the Central Valley Flood Protection Board to enable the quick installation of the emergency drought barriers, and authorizes the Director of DWR to request that the Secretary of the Army, on the recommendation of the Chief of Engineers of the Army Corps of Engineers, grant permission required pursuant to Section 14 of the Rivers and Harbors Act of 1899.

Setting precedent for the proposed project, several rock barriers were installed at Delta locations during 1976 and 1977 to help mitigate drought conditions. In 1976, one rock barrier was installed at Sutter Slough to help meet water quality criteria and allow for conserving additional water in upstream reservoirs. A second barrier was installed at Old River at its divergence from the San Joaquin River (often referred to as head of Old River) to protect fishery resources by keeping special-status fish in the San Joaquin River, thereby reducing entrainment risk at Central Valley Project/State Water Project (CVP/SWP) export facilities in the South Delta. In 1977, as drought conditions continued, rock barriers were installed at six different locations in the Delta. In addition, control facilities were built at two additional locations. The six rock barrier locations constructed in 1977 included Old River east of Clifton Court, San Joaquin River near Mossdale, Rock Slough, Indian Slough, Dutch Slough, and the head of Old River.

The "Interagency 2015 Drought Strategy for the Central Valley Project and State Water Project" (2015 Drought Strategy), released as a working draft on December 12, 2014, was developed by Bureau of Reclamation (Reclamation), DWR, U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), and CDFW includes several core principles for CVP and SWP operations, one of which is to control salt water intrusion in the Delta. Installation of temporary rock barriers is considered in the 2015 Drought Strategy. With the current proposed project, one temporary rock barrier would be installed in May and June of 2015.

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;
- Emergency Drought Barrier 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. Note that the latter only includes effects related to Emergency Drought Barrier (EDB) operations, limited to the presence of the West False River barrier (e.g., in terms of changing hydrodynamics, water quality, and as structure for predatory fishes). The installation and operation of the EDB would be done within the broader framework of drought contingency planning through multi-agency collaboration between DWR, Reclamation, SWRCB, NMFS, USFWS, and CDFW. As such, the EDB would be installed and operated in order to meet water quality and outflow objectives described inD-1641.

Currently, D-1641 has been temporarily modified through a Temporary Urgency Change Petiton (TUCP) filed with the SWRCB on March 24, 2015, and subsequent Order issued on Apri 6, 2015, by the SWRCB Executive Director.There are no additional water quality or Delta outflow modifications proposed as a result of installation of the emergency drought barrier. The USFWS, NMFS, and CDFW provided consultation on the TUCP and current water operations are consistent with their findings.

A number of different sources were used in preparing this document. Because of the similarity of a number of aspects of the proposed project to the South Delta Temporary Barriers Project (TBP), some of the information found in this document was 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 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.

- This BA was prepared to respond to agency comments on the previous version and provide several updates to the project description.

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, and also includes information for consultation regarding essential fish habitat (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 EDB.

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 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.

Emergency Drought Barrier Project Description

Purpose

Basic Project Purpose

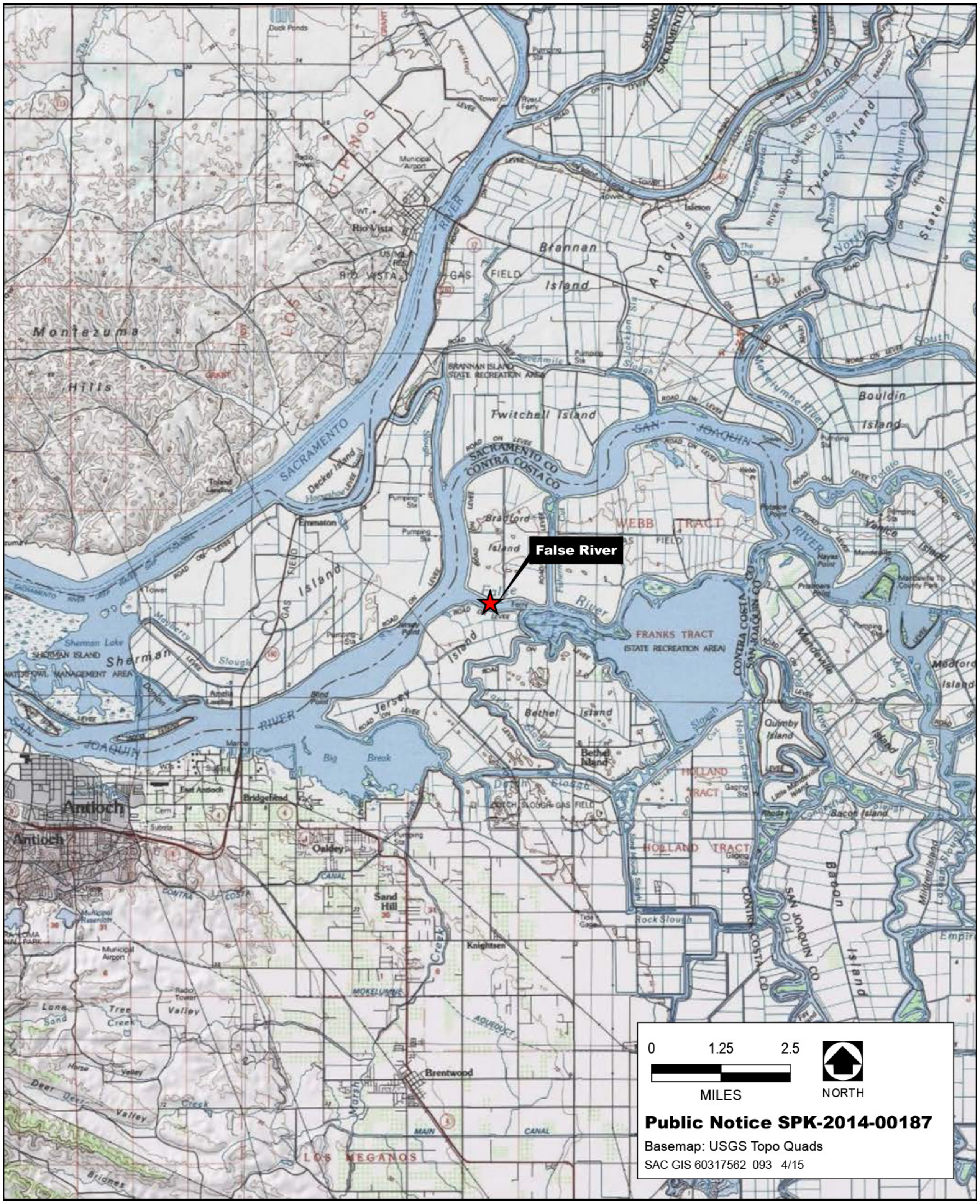
The purpose of the proposed EDB is to control saltwater intrusion into the Delta with reduced reservoir releases while continuing to meet federal and state regulatory requirements.

Overall Project Purpose

Constructing the emergency temporary rock barrier provides a method of controlling saltwater intrusion into the Delta, as well as potentially conserving cold water reservoir storage to protect habitat for sensitive aquatic species. In addition, the EDB purpose would maintain water quality standards set by the SWRCB to help ensure water is drinkable by 25 million Californians and usable by farms that are reliant upon this source.

Project Location

The temporary rock barrier would be installed at West False River. The general location of the site is shown in Figures 1 and 2, and the specific location is shown in Figure 3. Photographs of the levee banks at the project site are presented in Figure 4.

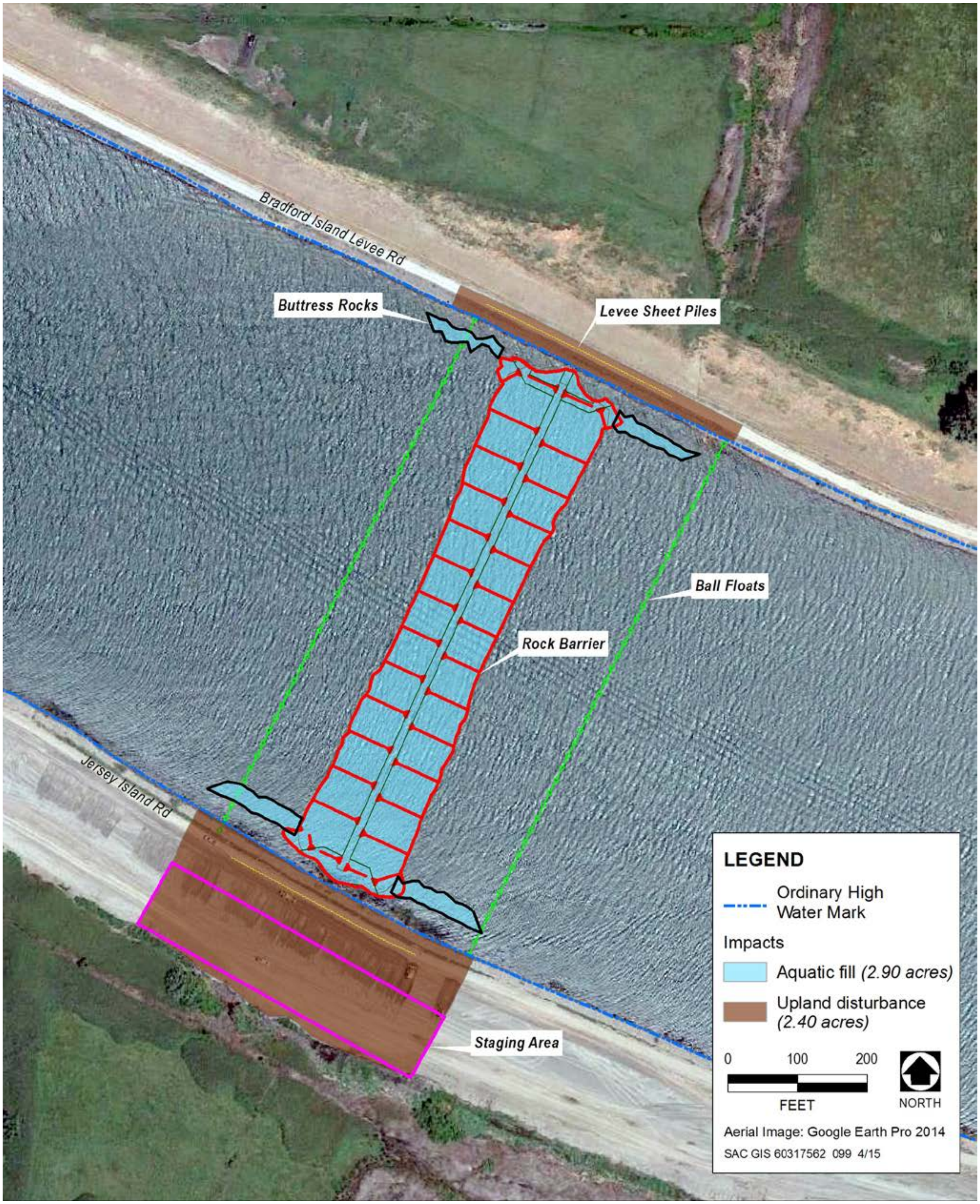


Source: DWR 2015, AECOM 2015

Figure 1. Location of Proposed Emergency Drought Barrier

Source: DWR 2015, AECOM 2015

Figure 2. Aerial View of the Proposed Emergency Drought Barrier Location



Source: DWR 2015, AECOM 2015

Figure 3. Aerial View of the Project Site

Figure 4. West False River South Levee (top), North Levee (middle), and North Levee at USGS Gaging Station East of the Barrier Site (bottom)

The project site is located approximately 0.4 mile east of the confluence with the San Joaquin River, between Jersey and Bradford Islands in Contra Costa County, and is about 4.8 miles northeast of Oakley. The banks of the project site are existing rock-lined levees (Figure 4).

General Design and Installation Concepts

A rock (rip-rap) barrier weir structure would be installed at the West False River site. The structure would be a trapezoid-shaped rock barrier with a wide base tapering up to a 12-foot-wide top width set perpendicular to the channel alignment. It would have transitions to the levees with 75-foot-long sheet pile walls supported by king piles and buttressed with rock, because the levees are weak due to peat soil foundations. To address existing erosion of the waterside levee toe on both Jersey and Bradford islands, DWR will place rock fill, approximately 0.25 acres and approximately 4,500 cubic yards, along the levee toe for a distance of 225 feet upstream and downstream from the center line of the barrier (approximately 125 feet from the ends of the barrier rock placement). This fill must be placed prior to installing the sheet pile wall to prevent sloughing of the levee when the piles are driven. Because this fill is necessary for levee stability, the rock will remain in place. Construction of the barrier may include land-based staging of equipment and materials. Temporary rights for construction of the barrier may be obtained before securing the necessary permanent easement rights required for those portions of the piping preventers, sheet pile walls, king piles, and rock abutments that would be permanent installations. This applies to the following APNs:

- APN 027-010-005-0 (Contra Costa County)
- APN 026-040-005-6 (Contra Costa County)

Temporary access rights for construction inspection and fence installation purposes would be required from the following APNs on Bradford Island:

- APN 026-040-003-1 (Contra Costa County)
- APN 026-050-006-1 (Contra Costa County)
- APN 026-050-018-6 (Contra Costa County)
- APN 026-050-024-4 (Contra Costa County)

The temporary rock barrier would be installed during May and June. The construction period would be approximately 30 to 60 days. Barrier removal may require approximately 45 to 60 days, with removal commencing on or near October 1. The temporary rock barrier would be removed entirely no later than November 15, before the rainy season when freshwater runoff typically occurs and flood risk increases.

Tidal flows would be the main factor influencing water quality conditions at the West False River barrier. 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 barrier site, 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.

Solar-powered monitoring instruments would be placed at appropriate locations upstream and downstream of the site and would monitor parameters like dissolved oxygen, turbidity, salinity as measured by electrical conductivity (EC), river stage, and flow velocity.

Appropriate navigation signage would be installed at the emergency drought barrier site and would comply with navigation requirements established by the U.S. Aids to Navigation System and the California Waterway Marker system, as appropriate. Signs would be posted at upstream and downstream entrances to each waterway or other key locations, informing boaters of the restricted access. A Notice to Mariners would include information on the location, date, and duration of channel closure. Signs would be posted on each side of each barrier, float lines with orange ball floats would be located across the width of the channels to deter boaters from approaching the barrier, and solar-powered warning buoys with flashing lights would be present on the barrier crest to prevent accidents during nighttime hours. Additional information regarding navigational issues is provided "Structural Components."

Structural Components

The emergency drought barrier located at West False River 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) (Figure 3). The top of the structure would be at an elevation of 7 feet above sea level across the entire crest. The barrier would include two king pile-supported sheet pile walls extending out from each levee into the channel for a distance of 75 feet. The sheet piles/king piles are required because the levees are weak at this location as they are on peat soils and placing a large volume of rock directly on the levees would cause stress. The walls would be buttressed on both sides with rock that will not be removed this year. After removal of the temporary rock structure, the sheet pile abutments and associated rock placed in order to achieve smooth transitions around the sheet pile abutments will remain in place for possible future use during the declared drought. Removal of the abutments and rock associated with the emergency drought barrier would occur no later than at the end of the term of the CDFW Lake and Streambed Alteration Agreement issued for this project. The permanent rock placed to stabilize the toe of the levee will remain. Inspection of the rock would compare actual conditions with as-constructed plans and/or bathymetric survey data. The results of the inspections and any bathymetric survey data collected would be made available to the Local Maintaining Agency (LMA). Any necessary repairs of the rock would be made using land or water-based construction equipment during summer and fall (July through October) when special-status species are less likely to be affected. DWR would assure that this rock is maintained and either contract with the LMA or use DWR resources or contractors to repair and or replace the transition rock as needed.

In addition to the temporary barrier installation, repair of the undercut toe of the levee is required for a distance of 225 feet from the center line of the barrier upstream and downstream (approximately 125 feet from the ends of the barrier rock placement). The repair includes placement of rockfill within the undercut toe of the levee and this rock will remain in place as a permanent repair.

The piles to be installed would include in total:

- Eight 36-inch-diameter king piles (barrier abutments)

- About 70 sheet piles (barrier abutments), or about 35 pairs of sheet piles totaling approximately 160 wall feet (including approximately 5 feet on either side that would be in the levee)
- Four 24-inch steel pipe piles (float line attachment, i.e., two piles upstream and downstream of the barrier)
- Twelve permanent 12-inch steel pipe piles (monitoring equipment)

In addition to river sheet piles, approximately 300 feet of sheet piles would be installed through the levee to a depth of approximately 35 feet and parallel to the channel to prevent water piping from the river. These piping preventer sheet piles would be set into the tops of the levees on each side of the barrier and would remain in place for possible future use. The 12-inch steel pipe piles proposed for monitoring equipment will remain in place for future use. The coordinates of the proposed 12-inch steel pipe piles are listed in Table 2 and shown in Figure 5.

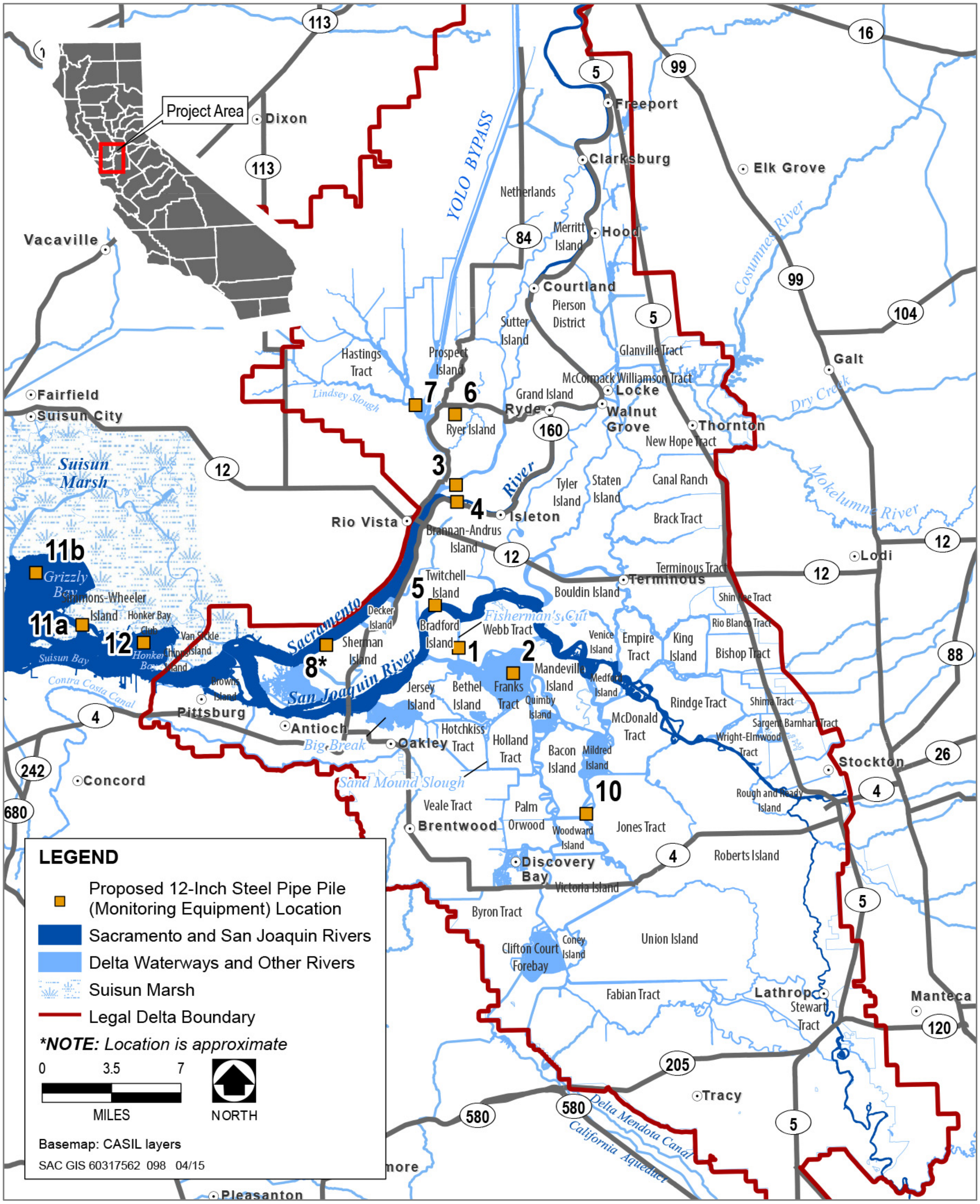
Table 2. Coordinates of the Proposed 12-Inch Steel Pipe Piles

No.	Station Name	Latitude	Longitude
1	Fisherman's Cut near Franks Tract	38.065600°	-121.647900°
2	Franks Tract (Mid Tract)	38.046417°	-121.598100°
3	Steamboat Slough	38.184550°	-121.648067°
4	Sacramento River near Steamboat Slough	38.172167°	-121.647350°
5	San Joaquin River at Twitchell Island	38.096900°	-121.669100°
6	Miner Slough near Cache Slough	38.236033°	-121.666072°
7	Liberty Island	38.243183°	-121.684600°
8	Sacramento River near Sherman Lake[1]	38.068933°	-121.770250°
9	Old River	37.968600°	-121.574236°
10	Middle River	37.942967°	-121.532266°
11a	Cutoff Slough near Ryer Island[2]	38.085783°	-121.995833°
11b	Grizzly Bay[2]	38.124250°	-122.038117°
12	Honker Bay	38.072400°	-121.939200°

Notes:
1. This location is an approximation and may be moved slightly.
2. DWR will need only one station at either Cutoff Slough near Ryer Island or Grizzly Bay but not both.

Source: DWR 2015

No boat passage is provided around the barrier because of safety concerns and because alternative routes (Fisherman's Cut or False River east for vessel traffic between the South Delta to the San Joaquin River; and the Main San Joaquin River for vessel traffic between the Antioch and the eastern Delta) are available. No fish passage is provided because migrating fish would use the adjacent San Joaquin River, Fisherman's Cut, or Dutch Slough, where their access is not restricted.



Source: DWR, adapted by AECOM 2015

Figure 5. Locations of the Proposed 12-Inch Steel Pipe Piles

Project Construction

Construction Schedule

In-water construction would begin no sooner than May 4, with full barrier closure on or near approximately 30 to 60 days after starting work. Landside work would begin no sooner than May 1. Removal would take approximately 45 to 60 days, with full removal by November 15. Removal activities would begin prior to October 1. Construction would require approximately 10 to 30 workers. DWR assumes that the contractor could conduct daytime and nighttime construction activities for installation of the rock barrier and would conduct daytime and nighttime construction activities for removal of the barrier.

Construction Practices

Notices of construction would be posted at local marinas and in the Local Notice to Mariners. Navigational markers would be used to prevent boaters from entering the immediate construction area, and speed limits would be posted. Safe vessel passage procedures would be coordinated with the U.S. Coast Guard District 11 and California Department of Parks and Recreation Division of Boating and Waterways. An educational program would be implemented to inform boaters of the purpose of the proposed project and the expected duration of installation activities. The program would include notices in local newspapers and boater publications as appropriate; notices also would be posted at local marinas and boat launches and on the proposed project website.

Approximately 92,500 cubic yards of rock would be required to construct the emergency drought barrier located at West False River (including approximately 25,000 cubic yards that would remain around the sheet piles and on the adjacent levee). Clean, unwashed rock would be used. The rock source would likely be one or more existing quarries, near San Rafael. All rock, gravel, and structures would be transported to and constructed at the project site in May and June of 2015. The methodology described herein is general. Although construction activities would primarily be situated in water, the contractors would also work from the levees. Vehicle access to the site would be via Jersey Island Road.

The contractors would mobilize construction equipment and crew. DWR would utilize multiple barges with excavators and work boats which would be transported on water to the project site. An excavator or other small earthwork equipment would be needed on each side of the levees to aid with the installation of the sheet pile walls. The contractors would install construction trailers on the levee nearby.

Barges powered by tugs would be used to transport rock from quarries and/or other loading bulkheads or material transfer points to the barrier site. The barge would be appropriately sized based on the depth of the channel where the rock would be placed. The contractors would use excavators, dozers, and loaders to move/push the rock from transportation barges into the channel. The contractors would shape/contour the rock barrier by using a barge-mounted crane with a clamshell or barge-mounted excavator from material barges. The contractors may use a dump scow to transport the rock and place it in the channel. Some of the existing rock slope protection would need to be temporarily removed in order to construct the abutments; however, no channel dredging or excavation in the levee profiles would be required. To prevent riverbed scour, the contractor would be required to place rock in horizontal layers and to prevent levee scour and the final lifts of rock would be placed on the barrier starting from the levees toward the center of the channel. During final rock placements and closure, excavators would be place rock from the top of the barrier.

Minimal vegetation and clearing would be required on the levees prior to the installation of sheet piles. This would be accomplished by a dozer or backhoe and hand clearing.

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.

The sheet and king piles are anticipated to be installed by an appropriately-sized vibratory hammer, which appears to be feasible given the anticipated ground conditions and modest pile penetration of 20 feet to 50 feet in the ground. Vibratory penetration rates are normally limited to 20 inches per minute (per North American Sheet Piling Associations – Best Practices, www.nasspa.com), which would result in the following vibration times per pile assuming normal driving conditions:

- 20-foot ground penetration: 12 minutes
- 50-foot ground penetration: 30 minutes

Due to uncertainties of the ground conditions and the possibility of encountering dense soil layers and/or obstructions such as left-in-place rip-rap on the existing levee side slopes, a larger impact hammer would be available as a contingency measure, in the event unexpected difficult driving is encountered. The impact hammer would only be used if the vibratory hammer cannot reach design tip elevation of the pilings. In the absence of detailed geotechnical information, it is not known whether an impact hammer would be required, and the exact location and timing of its use. If piles are driven by impact hammers in water deeper than 3.3 feet, a bubble curtain would be employed if underwater noise exceeds pre-established levels (peak pressure levels or cumulative sound exposure level) that would indicate potential injury to fish.

Construction equipment would be placed within the staging area (approximately 1.03 acres) adjacent to Jersey Island Road (i.e., left bank). A complete list of construction equipment anticipated to be used is provided in Table 3.

Facilities Removal

All rock, gravel, and structures would be removed from the project site in fall, with the exception of the sheet pile abutments. The methodology described herein is general. Although removal activities would primarily be situated in water, the contractors would also work from the levees.

First, the contractors would mobilize construction equipment and crew. DWR would utilize multiple barges with excavators and work boats which would be transported on water to the barrier site. In water work would occur on one side of the barrier–either upstream or downstream of the barrier–in the direction of where the contractors would ship the rock.

Table 3. Anticipated Construction Equipment

Type of Equipment	Maximum Number	Type of Equipment	Maximum Number	Type of Equipment	Maximum Number
Place Rock					
Tug/barge	8	Dozer	1	Rock haul/dump truck	4
Crane	2	Loader	4	Conveyor	3
Work boat	2				
Drive Piles					
Tug/barge	2	Skid steer loader	1	Crane	1
Crane	2	Off-road crane	1	Pickup	4
Work boat	2	Service truck	1	Air compressor	1
Grader	1	Off-road fork lift	2	Power generator	1
Compactor	1				
Removal					
Tug/barge	8	Excavator	3	Front-end loader	2
Long-reach excavator	3	Dump truck	4	Grader	1
Work boat	2	Dozer	1		

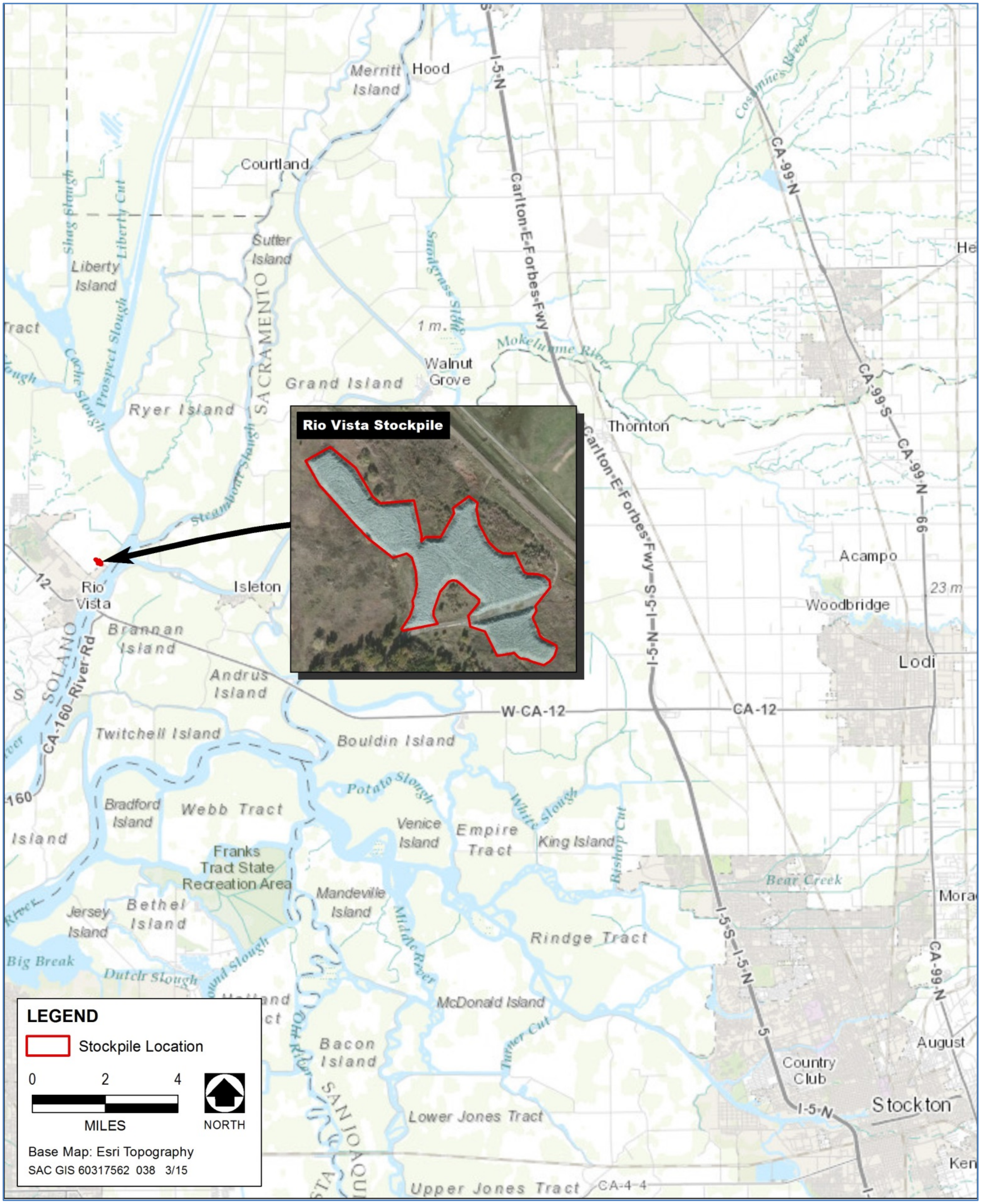
Next, the contractors would strategically place the barges adjacent to the barrier in order to excavate the rock. Rock would be excavated using cranes with clam-shell buckets, and/or excavators from one barge and placed onto another barge where it would be transported to an approved off-loading site. Given the volume of rock, DWR anticipates that excavation would occur continuously (i.e., 24 hours per day, 7 days per week). To prevent levee scour, rock removal will start from the center of the channel and work outward. Excavation would occur from the top of the barrier down to the streambed to approximate pre-project contours. DWR would restore the levee geometry to ensure compliance with any local maintaining agency, Central Valley Flood Protection Board, or USACE requirements.

Lastly, the rock would be shipped on a barge from the project site to be off-loaded onto dump trucks using excavators and loaders. The contractors would haul the rock to the Rio Vista stockpile location (outside of waters of the U.S.), which is depicted in Figure 6.

DWR would monitor downstream water quality for parameters, including turbidity, identified in the Emergency Drought Barriers Water Quality Monitoring Plan, during the excavation process. Bathymetric surveys would be completed after emergency drought barrier removal to confirm that the rock is removed.

Site Restoration

Disturbed areas would be restored after initial construction and after the EDB is removed. The affected areas would be restored to approximate pre-project conditions.



Source: DWR, adapted by AECOM 2014

Figure 6. Stockpile Location

Operations and Maintenance

There are no operational features associated with the proposed barrier. Given the temporary nature of the EDB, maintenance during the time the barrier is installed would be minimal or nonexistent. DWR would inform the permitting fish agencies (CDFW, USFWS, and NMFS) if any major maintenance activities are required during the period of operation (estimated to be June through October).

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 footprints. Whereas the near-field effects of the EDB are very limited in extent (i.e., the footprints of the barrier and its environs), the far-field effects of the West False River barrier potentially are broad because of the barrier's influence on water quality and 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).

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).

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: High; Medium; 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)

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

Year	Population Estimate[a]	5-Year Moving Average of Population Estimate	Cohort Replacement Rate[b]	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

Year	Population Estimate[a]	5-Year Moving Average of Population Estimate	Cohort Replacement Rate[b]	5-Year Moving Average of Cohort Replacement Rate	NMFS –Calculated Juvenile Production Estimate (JPE)[c]
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

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

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)

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.

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 has been consistently below 15 percent.

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 7). 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.

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 6). 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).

Table 6. 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

Each month is divided into two half-month cells; shading is given as H = High, M = Medium, L = Low, – = no shading.

(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: ■ = High ■ = Medium ■ = 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)

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 6). 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 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 6). 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 7). 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 7). 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).

Table 7. 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
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

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
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	9,680	2,825	6,855	10,634	1.26	2.77	13,531	1.31	2.47
Median	12,163	3,657	9,228	9,068	0.81	1.98	13,054	0.84	1.52
Average[c]	14,219	3,591	10,628	9,972	1.77	1.74	13,644	1.47	1.42
Last 10[d]	13,269	2,281	10,989	12,069	1.70	1.41	14,784	1.53	1.27
Last 6[e]	12,027	2,579	9,448	9,117	2.36	1.39	11,166	2.11	1.28
Last 3[f]	18,542	3,619	14,923	9,690	4.36	2.25	12,154	3.79	2.04

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)

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 Attachment A of Murillo and Cowin (2015).

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 7). 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 2.77 in 2014. As mentioned previously, greater escapement occurred in the tributaries in 2012-2014, with 5-year means of around 8,500 to 10,600 fish (Table 7). 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.

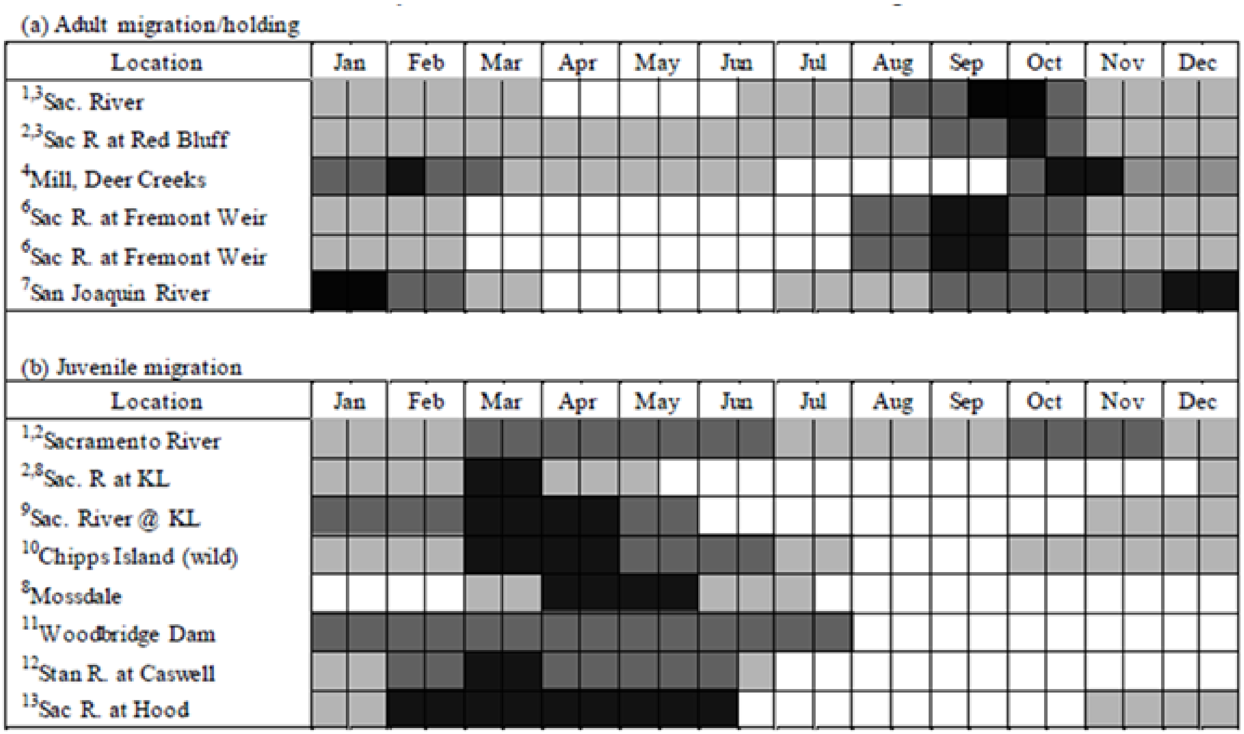
Central Valley Steelhead

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.

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

Region Life Stage:	Average Annual Frequency (%) 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**

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

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.

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 EDB site footprints; however, the EDB do have the potential to affect the Sacramento River during their 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).

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, augmented with recent information from the Biological Review for Endangered Species Act Compliance associated with the March 24, 2015, request for modification of the revised order that approved a temporary urgency change in license and permit terms and conditions requiring compliance with Delta water quality objectives in response to drought conditions (Murillo and Cowin 2015). The Action Area for the construction, operation, and removal of the EDB 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

General

CVP and SWP salvage records and northern and central Delta fish monitoring data indicate that juvenile spring-run Chinook salmon 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 earliest proposed EDB construction period (commencing in May), historical monitoring data suggest that approximately 1 percent of the annual spring-run juvenile population may move into the waterways within the Delta (Table 11). Therefore prior to the proposed EDB operation period (which could be as long as early June through the end of October), nearly all of the annual juvenile spring-run Chinook salmon population would be anticipated to have moved into and through the Delta.

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 EDB operational period.

During the potential EDB construction (as early as May) and operational period (early June to October), it is estimated that much of the remainder of the adult escapement would move upriver through the Delta. The removal period of the EDB (commencing in fall, with full removal by November 15) 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.

ESA Compliance Biological Review (March 2015)

In addition to above general account of the species' status in the action area, the following account of Central Valley spring-run Chinook salmon status is adapted from the recent Biological Review for Endangered Species Act Compliance submitted to NMFS and USFWS and provided as Attachment A to the March 24, 2015, request for modification of the revised order (dated March 5, 2015) that approved a temporary urgency change in license and permit terms and conditions requiring compliance with Delta water quality objectives in response to drought conditions (Murillo and Cowin 2015; and references therein). It focuses on the status of the species as of March 2015 to provide context for the potential for effects of modified SWP/CVP operations during April-September 2015, and therefore is very relevant as status information for the EDB.

The 2014 spawning run of spring-run Chinook Salmon returning to the upper Sacramento River Basin was lower in four of seven locations compared to the 2013 escapement, with markedly lower escapement observed in Clear Creek, Butte Creek, and Feather River Hatchery. Spawning of spring-run Chinook salmon in the Sacramento River Basin occurs approximately from mid-August through mid-October, peaking in September. In 2014, this peak in spawning activity corresponded with the high Sacramento River temperatures downstream of Keswick Dam resulting in an elevated potential for high egg and alevin mortality. It is believed that spring-run Chinook salmon eggs in the Sacramento River underwent significant, and potentially complete mortality due to high water temperature downstream of Keswick Dam starting in mid- August when water temperatures downstream of Keswick Dam exceeded 56^{o}F in water year 2014. Spring-run Chinook Salmon eggs spawned in the tributaries to the Sacramento River may also have experienced warmer temperatures in 2014 due to low flows through late October, as well as scouring or sedimentation during rain events from late October through December.

Juvenile spring-run Chinook salmon begin emigration from Clear Creek soon after emergence, with passage near the mouth peaking in November through December and continuing to around May. For brood year 2014, extremely few juvenile spring-run Chinook Salmon were observed migrating downstream past RBDD during high winter flows, when spring-run Chinook salmon originating from the upper Sacramento River, Clear Creek, and other northern tributaries are typically observed to outmigrate. As of March 11, 2015, only 35,435 brood year 2014 spring-run Chinook salmon were estimated to have passed Red Bluff Diversion Dam, and these low RBDD passage estimates are a concern. A second pulse of juvenile spring-run Chinook Salmon typically migrate past RBDD in the springtime. However, this second pulse appears to positively bias estimates of spring-run Chinook passage due to the presence of millions of unmarked fall-run Chinook salmon hatchery fish released from the Coleman National Fish Hatchery on Battle Creek. These hatchery production fish typically overlap with the spring-run Chinook salmon category based on the length-at-date run assignments.

In fall 2014, yearling spring-run Chinook salmon from Mill and Deer creeks experienced flow and temperature conditions typically associated with the outmigration of this life history expression from these tributaries. Although not currently monitored with RSTs, these tributaries have experienced flows exceeding "First Alert" thresholds identified in the NMFS (2009) Biological Opinion Action IV.1.2. Recent analyses of multiple years of RST data have determined that 99% of outmigrating yearlings are captured at flows greater than 95 cfs.

Spring-run young-of-the-year (YOY) sized Chinook salmon juveniles have been observed at the Tisdale Weir and Knights Landing RSTs since early December 2014. Likewise, juvenile YOY spring-run Chinook have been observed in the catch from multiple Delta beach seine regions, and in the standard trawling and special drought monitoring trawling surveys, including those in the Central Delta. Monitoring data suggest that the majority of surviving brood year 2014 natural-origin YOY juveniles are currently residing in the Delta, downstream of Knights Landing. No yearling spring-run Chinook Salmon have been caught in 2014 Delta monitoring, however, yearling spring-run observations are expected to be rare because of their relatively large size and strong swimming ability (associated with gear avoidance), and relatively low densities relative to YOY. The majority of YOY, yearling, and surrogate (hatchery late fall) spring-run are currently rearing in the Delta. This estimate is based on the best professional judgment of the biologists participating on the Delta Operations for Salmonids and Sturgeon (DOSS) work team. No natural or hatchery origin spring-run Chinook salmon have been salvaged at the fish collection facilities as of March 15, 2015.[1]

Most Recent Delta Information

The DOSS team meeting for April 21, 2015, estimated the current distribution of listed juvenile salmonids. The DOSS estimates for spring-run Chinook salmon were:

- Young-of-the-year: approximately 40% are in the Delta, approximately 60% have exited the Delta past Chipps Island;
- Yearlings: more than 95% have exited the Delta past Chipps Island, with migration generally complete except for a few stragglers.

Sacramento River Winter-Run Chinook Salmon

General

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

[1] Subsequent to the ESA Compliance Biological Review, spring-run-sized Chinook salmon were salvaged at the CVP on March 30, April 5, April 6, and April 9.

between 1999 and 2009 at the south Delta fish salvage facilities, juvenile Sacramento River winter-run Chinook salmon 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 enter the Delta during the proposed EDB construction window (beginning as early as May). The proposed EDB operational period (which could stretch from early June to October), would be almost entirely outside the juvenile winter-run population migration period, as would the EDB removal period (October/November).

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 construction period occurring as early as May, approximately 17.5 percent of the adult winter-run spawning population may pass through the Delta (based on half of the 35% total historically reaching Red Bluff Diversion Dam in the months of April and May; Table 12). During the proposed EDB operation period (which could extend from early June to October), a relatively low proportion of the adult spawning population (15%, based on RBDD data for half of May and June-November) would be anticipated to move through the Delta. The removal phase of the project (October/November 2014) would be outside the migration period of winter-run Chinook salmon adults (Table 12).

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).

ESA Compliance Biological Review (March 2015)

In addition to above general account of the species' status in the action area, the following account of Sacramento River winter-run Chinook salmon status is adapted from the recent Biological Review for Endangered Species Act Compliance submitted to NMFS and USFWS and provided as Attachment A to the March 24, 2015, request for modification of the revised order (dated March 5, 2015) that approved a temporary urgency change in license and permit terms and conditions requiring compliance with Delta water quality objectives in response to drought conditions (Murillo and Cowin 2015; and references therein). As noted above for spring-run Chinook salmon, the account below focuses on the status of the species as of March 2015 to provide context for the potential for effects of modified SWP/CVP operations during April-September 2015, and therefore is very relevant as status information for the EDB.

A small number of winter-run Chinook Salmon (n=3,015; 90% CI=2,741-3,290) returned to spawn in the upper Sacramento River in 2014. Of these 3,105 winter-run Chinook, 388 were collected at the Keswick trap for broodstock at Livingston Stone National Fish Hatchery. Assuming that 3-year old fish make up the majority of each spawning cohort,returning adults in 2014 were produced by a much smaller spawning escapement in 2011 (i.e., 827 adult spawners). The effects of limited cold water storage and loss of temperature control out of Keswick Dam from mid-August through the fall of 2014 led to substantial egg and fry mortality. The mortality associated with this loss of temperature control was estimated to have affected up to 95% of the brood year 2014 eggs and fry. The average egg to fry mortality for brood year 2007-2012 was estimated to be 69% based on female escapement, fecundity, and the RBDD juvenile production index. As of March 11, 2015, approximately 408,704 juvenile winter-run Chinook Salmon were estimated to have migrated past the Red Bluff Diversion Dam (RBDD). The rotary screw traps at RBDD were operated for just 8 of 31 days during December 2014, a period when the Sacramento River flows and turbidity levels were at their highest. Very few natural-origin juvenile winter-run Chinook Salmon are hypothesized to remain upstream of the Delta and these are anticipated to migrate into the Delta and lower Sacramento River by the end of April based upon historical RBDD passage data. Monitoring data throughout the Sacramento River suggest that the majority of salmonids, including natural-origin juvenile winter-run Chinook Salmon are currently residing in the Lower Sacramento River and Delta. Detections of winter-run sized juveniles in the Chipps Island trawl monitoring have been low, but trending upwards, indicating that while few have migrated out of the Delta at this time, outmigration to the ocean is increasing. During April, the seaward migration of juvenile winter-run Chinook salmon is likely to be completed due to changes in photoperiod and temperature, which stimulate smoltification and migratory behavior in these rearing fishes. Historical patterns indicate that the majority of out-migration typically occurs in March and is not complete until early spring. Discussions by the Delta Operations for Salmonids and Sturgeon (DOSS) team have estimated on March 17 that for the natural origin winter-run juveniles greater than 85% were rearing in the Delta, less than 15% had exited the Delta, and "few remaining stragglers" had yet to enter the Delta. A low level of salvage of winter-run sized juveniles has occurred during the winter, with a cumulative loss of 102 natural-origin winter-run sized juvenile Chinook as of March 20, 2015. This may be due to several factors, acting individually or in concert, including low population numbers, low exports, and low survival.

The entire production population of hatchery-origin winter-run Chinook Salmon were released into the upper Sacramento River in Redding from February 4-6, 2015. This segment of the winter-run population, which was released concurrently with a storm pulse, began entering the North Delta within a week after release based on monitoring data, coded wire tag recoveries, and acoustic tag detections. Detection of acoustic tags and recoveries of CWT tags have in occurred at the Sacramento I-80 receiver, in the Knights Landing rotary screw traps (RSTs), the Sacramento regional beach seines, and the Sacramento trawls occurring near Sherwood Harbor on the Sacramento River. Discussions by the DOSS team have estimated passage into the Delta to be approximately 70-85% for the hatchery winter-run Chinook salmon. A subset of this release group from LSNFH was tagged with JSAT acoustic telemetry tags (n=500) and provided another means to track the downstream migration of the hatchery-origin winter-run juveniles, in addition to the standard river, Delta, and salvage fish monitoring efforts already in place. As of March 16, 2015, approximately 27.8% of the acoustic tagged hatchery winter-run were observed to have entered the Delta at the I-80/50 bridge in Sacramento, based on at least 2 detections of each tag by the array on the bridge abutments. If only single detections are used (which could include some false positives), the percentage of the tagged hatchery fish reaching the North Delta is 39.2%. It is worth noting that the Tisdale Weir did overtop immediately following the release of these fish and adipose fin-clipped juvenile salmonids (indicative of hatchery fish which includes both winter-run Chinook Salmon released from LSNFH and late-fall Chinook salmon concurrently released from the Coleman National Fish Hatchery [CNFH]) were rescued from the downstream apron of the weir. This observation suggests that some proportion of the hatchery release groups from both the LSNFH and CNFH releases entered the Sutter Basin and took that route downstream. As of March 20, 2015, the total observed loss of hatchery winter-run, confirmed by CWT, at the salvage facilities is 8.40. The DOSS estimates for the hatchery winter-run Chinook and the detected passage of the telemetry tagged differ considerably, which could result from, in part, detections probabilities being reduced due to high turbidity and flows, differential migration rates or holding patterns.

Most Recent Delta Information

The DOSS team meeting for April 21, 2015, estimated the current distribution of listed juvenile salmonids. The DOSS estimates for winter-run Chinook salmon were:

- Young-of-the-year (naturally produced): approximately 10% are in the Delta, approximately 90% have exited the Delta past Chipps Island;

- Young-of-the-year (hatchery-produced): approximately 10% are in the Delta, approximately 90% have exited the Delta past Chipps Island.

Central Valley Steelhead

General

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 EDB (full removal of West False River barrier by November 15). 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 numbers 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 EDB installation (i.e., beginning in May). The proposed EDB operation period could extend from early June to October, during which time only a very low proportion of the juvenile steelhead population would be expected to enter the Delta (Table 11).

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 EDB for adult steelhead moving upstream to spawn several months later if construction occurred in the earliest proposed month (May); construction later in summer (e.g., July) would increase the potential for overlap. 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 EDB construction period. It is expected that more kelts would be observed earlier in the construction period because the timing of spawning in the Sacramento River basin generally would precede the earliest potential construction period in May (Figure 28 in NMFS 2014). A significant proportion of adult steelhead upstream migrants could encounter the EDB during the operational period (which could comprise early June-October). Adult steelhead also are likely to be present in appreciable numbers in the Delta during EDB removal in October/November.

ESA Compliance Biological Review (March 2015)

In addition to above general account of the species' status in the action area, the following account of Central Valley steelhead status is adapted from the recent Biological Review for Endangered Species Act Compliance submitted to NMFS and USFWS and provided as Attachment A to the March 24, 2015, request for modification of the revised order (dated March 5, 2015) that approved a temporary urgency change in license and permit terms and conditions requiring compliance with Delta water quality objectives in response to drought conditions (Murillo and Cowin 2015; and references therein). As noted above for spring-run and winter-run Chinook salmon, the account below focuses on the status of the species as of March 2015 to provide context for the potential for effects of modified SWP/CVP operations during April-September 2015, and therefore is very relevant as status information for the EDB.

Information on steelhead in the Delta is extremely limited. Steelhead smolts are seldom recovered in Sacramento River and Delta fish monitoring efforts due to sampling biases related to their large size and swimming ability. False negatives (i.e., zero catches when the target species is present) are more likely with steelhead smolts than smaller older juvenile Chinook salmon, but historic data can be assessed to consider their typical periodicity in Delta monitoring efforts. From 1998 to 2011, temporal observations of wild steelhead juveniles (n=2,137) collected in Delta monitoring efforts occurred less than 10% of the time in January, >30% of the time during February, and >20% of the time during March.

The temporal occurrence of Central Valley steelhead near and within the Delta is informed by recovery of natural steelhead in various monitoring surveys. For WY2015 (as of March 9, 2015), 36 adipose-clipped steelhead and no unmarked steelhead were recovered in various beach seine and trawling efforts in the Delta and Lower San Joaquin River. Of these, one marked steelhead was observed in the Chipps Island mid-water trawl (228-mm clipped fish on 3/2/15) and three marked steelhead were observed (one each) at Sacramento beach seine monitoring locations: Miller Park (300-mm acoustic tagged fish on 12/8/14); Sherwood Harbor (178-mm clipped fish on 2/17/15); and Verona (203-mm clipped fish on 2/17/15). Additionally, marked steelhead were observed at three Kodiak trawling locations including: Jersey Point (four clipped fish from 2/28/15-2/20/15), Prisoner's Point (fourteen clipped fish from 2/12/15-3/3/15), and Sherwood Harbor (fourteen clipped fish; one on 1/23/15 and thirteen from 2/9/15-2/20/15). No outmigrating steelhead have been observed in the Mossdale trawl yet; however, historic data indicate that most steelhead are recorded at this location during April and May. Adipose clipped steelhead from Coleman National Fish Hatchery and Feather River Hatchery, are considered ESA listed Central Valley steelhead. No steelhead have been released from Nimbus Fish Hatchery to date in 2015. These fish were released in-river in May 2014 and marked with a secondary mark of a clipped pelvic fin. Fish monitoring at Mossdale on the lower San Joaquin River also encounters steelhead entering the Delta, and based on thise information it is likely steelhead may still be migrating into the Delta from the San Joaquin in April and early May.

An expanded salvage of 22 natural origin and 450 adipose-clipped steelhead have been estimated at the state and federal fish collection facilities at the South Delta CVP/SWP export pumps. Of these, all 22 natural origin and 382 adipose-clipped fish were salvaged at the SWP and no natural origin and 68 adipose-clipped fish were salvaged at the CVP fish collection facilities. Most steelhead have been salvaged during the past month. The high ratio of clipped to unclipped steelhead (17:1) likely indicates a low abundance of naturally-produced steelhead compared to the number of hatchery steelhead.

Most Recent Delta Information

The DOSS team meeting for April 21, 2015, estimated the current distribution of listed juvenile salmonids. The DOSS estimates for steelhead were:

- Sacramento River steelhead (naturally produced): there are limited catch data with which to judge the distribution;
- San Joaquin River steelhead: based on historical monitoring and this year's specific monitoring, approximately 25% are in the Delta, and approximately 70% have exited the Delta past Chipps Island, with 5% remaining upstream of the Delta.

Southern DPS of North American Green Sturgeon

General

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 EDB, 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 EDB (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 will be present in the Action Area during EDB 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 upstream migrants generally would avoid EDB operations (early June to October) and, allowing for travel time from the Delta to spawning grounds, a portion of the population may pass through the Delta during construction in May 2014. The acoustic data suggest perhaps 15-20% of spawners may move through the Delta in May, and may experience effects of construction during this month given the earliest proposed construction start dates of May 4. 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 EDB during construction, operation, or removal.

ESA Compliance Biological Review (March 2015)

In addition to above general account of the species' status in the action area, the following account of green sturgeon status is adapted from the recent Biological Review for Endangered Species Act Compliance submitted to NMFS and USFWS and provided as Attachment A to the March 24, 2015, request for modification of the revised order (dated March 5, 2015) that approved a temporary urgency change in license and permit terms and conditions requiring compliance with Delta water quality objectives in response to drought conditions (Murillo and Cowin 2015; and references therein). As noted above for spring-run and winter-run Chinook salmon and Central Valley steelhead, the account below focuses on the status of the species as of March 2015 to provide context for the potential for effects of modified SWP/CVP operations during April-September 2015, and therefore is very relevant as status information for the EDB.

Information on green sturgeon is extremely limited. Adult green sturgeon will migrate into the upper Sacramento River through the Delta in March and April. Last year, a review of telemetric data found 26 tagged green sturgeon entered the San Francisco Bay with only half migrating upstream of RBDD. Already in 2015, one acoustically tagged adult was recorded migrating past Sacramento this winter and based on typical migration rates, has likely reached Red Bluff. Adult green sturgeon have been observed to overwinter in the Sacramento River, and a number of tagged 2014 adults appeared to still be present in the upper Sacramento River as of January, 2015, but it is unknown if they remained in this area during the past two months. Also, adult green sturgeon exit through the Lower Sacramento River during the summer and fall following their spawning, then return to SF Bay throughout this period also. Green sturgeon exit the San Francisco Bay late in the summer through the winter.

Spawning typically occurs from April through July. Spawning in the upper Sacramento River was documented during 2014 and associated larval green sturgeon were observed at RBDD during the summer of 2014 (n=316). This was greater than the long-term average of 186 fishes, but less than the highest number observed (i.e., >3,500 in 2011). At RBDD, two juvenile green sturgeon were also observed in the fall of 2014, but no additional fish were recorded as of March 12, 2015. At GCID, ten juvenile green sturgeon (TL= 110-285) were observed from September through October 2014 and no additional fish have been recorded as of March 9, 2015. Brood year 2014 juvenile green sturgeon have likely migrated downstream from their natal spawning areas and are overwintering in the Lower Sacramento River and Delta.

Green sturgeon observations are extremely rare in the Delta, primarily related to the use of monitoring gear types that are not designed to sample the benthic habitats where green sturgeon are most likely to be found if they are present. Although the lower Sacramento and Delta fish monitoring surveys do not target benthic environments, they have captured juvenile green sturgeon in the past, but none have been observed in these surveys in recent years including during 2011 when high numbers were observed migrating downstream past RBDD. One dead green sturgeon (FL= 670mm) was removed from the SWP Fish Facility on February 9, 2015. In 2011, over a thousand juvenile green sturgeons were enumerated at RBDD and none were observed in Delta or Bay fish monitoring. While this absence in the monitoring may suggest no impact from Delta Cross Channel operations or outflow operations, it may also suggest the recruitment of juveniles may be limited before the species reaches one year old due to habitat, predation, or multiple stressors; which is a phenomenon that has been observed in other North American sturgeon species. More monitoring needs to be conducted in order to reduce this uncertainty.

Delta Smelt

General

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 2009. 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. 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, delta smelt probably are likely to occur near the West False River barrier. 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 West False River barrier 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).

ESA Compliance Biological Review (March 2015)

In addition to above general account of the species' status in the action area, the following account of delta smelt status is adapted from the recent Biological Review for Endangered Species Act Compliance submitted to NMFS and USFWS and provided as Attachment A to the March 24, 2015, request for modification of the revised order (dated March 5, 2015) that approved a temporary urgency change in license and permit terms and conditions requiring compliance with Delta water quality objectives in response to drought conditions (Murillo and Cowin 2015; and references therein). As noted for the other species covered in this BA, the account below focuses on the status of the species as of March 2015 to provide context for the potential for effects of modified SWP/CVP operations during April-September 2015, and therefore is very relevant as status information for the EDB.

As California enters a fourth year of drought, abundance of delta smelt has continued to decline. The 2014 Fall Midwater Trawl (FMWT) annual index for delta smelt was 9, which is the lowest reported fall index since the beginning of this survey in 1967, and approximately one half of the previous lowest index values of 17 (2009) and 18 (2013). The third Spring Kodiak Trawl (SKT) survey for March 9 – 12, 2015 yielded six adult Delta Smelt, a record low number for March and a number that has only occurred over the period of record at this level once before in May surveys, when catches typically tail off because of postspawn mortality. These winter survey results provide additional evidence that the delta smelt population is likely at an all-time low. The recent catch data also indicate most adult delta smelt may be in the Sacramento River and outside the influence of the south Delta export facilities.

Drought-Related Impacts

Research presented at the Interagency Ecological Program (IEP) workshop (March 18-20, 2015) showed that 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.

Salvage

The estimated cumulative season total for adult delta smelt salvage is 68. No salvage has been reported since February 21st. The State Water Project (SWP) and Central Valley Project (CVP) initiated larval fish monitoring on March 2nd and February 24th, respectively. The frequency of larval fish samples at the CVP has been reduced at times due to heavy debris load in the salvage collections. Regardless, no larval delta smelt have been reported at either facility to date. However, pre-screen loss of all life stages (e.g., predation) may decouple entrainment at low densities so that fish entrained at low densities are not observed in salvage. This is further supported by regular presence of adult delta smelt at Jersey Point and Prisoners Point surveys for most of the winter that indicates likely presence of larvae in the central Delta in spring. Daily "early-warning" sampling resumed during the week of February 2nd at Jersey Point and Prisoners Point in anticipation of storm conditions. Weekly sampling resumed the week of March 9th and no adult Delta Smelt have been caught at Jersey Point since March 16th (when one individual was caught) and no Delta Smelt have been caught at Prisoners Point since February 15th.

The 3-station average water temperature threshold of 12°C (Action 3 of the USFWS 2008 SWP/CVP Biological Opinion) was first exceeded on February 2nd and was reported on March 15th to be 17.8°C. This suggests delta smelt spawning has occurred early this year. On March 16th, the Smelt Working Group (SWG) suggested the most likely reason for steep decline in catch of delta smelt in the third SKT survey was that fish may not have survived after a first spawn or they could have been avoiding the gear. This hypothesis is partly supported by poor condition of the few mature fish caught in the third SKT survey. Hatching will likely continue over the next few weeks, although the peak of the spawning season has likely passed. As water temperatures rise, larvae are beginning to recruit to juvenile size, and a broader distribution in the central Delta may become evident by way of larval field surveys. Intermittent salvage of adult Delta Smelt indicates the likely presence of larvae in the central and southern Delta within the vicinity of the SWP and CVP pumps. Those larval and juvenile Delta Smelt hatching in the central and southern Delta are vulnerable to entrainment; however, exports are currently at minimum levels, resulting in favorable Old and Middle River (OMR) flows. A temperature off-ramp occurs when water temperature at Clifton Court Forebay reaches 25°C for three consecutive days. This off-ramp typically occurs in late June or early July, although present unseasonably warm water temperatures may suggest an earlier temperature off-ramp (the calendar-based off-ramp is June 30th).

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[2]). 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

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

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 (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 2015

The environmental baseline in the Action Area was described previously in general terms, with additional species-specific context from the Biological Review for Endangered Species Act Compliance provided to NMFS and USFWS and as Attachment A in the March 24, 2015, request for modification of the revised order that approved a temporary urgency change in license and permit terms and conditions requiring compliance with Delta water quality objectives in response to drought conditions (Murillo and Cowin 2015). Drought conditions in 2014 and 2015 have necessitated management actions that require special consideration in the environmental baseline. These factors are summarized below.

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.

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 documentstates:

> 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[3], 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 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

[3] The Interagency 2015 Drought Strategy was written when barriers in Sutter and Steamboat sloughs also were considered in addition to the West False River barrier described in this BA.

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).

Effects Assessment

This section describes the potential effects of implementing the EDB on the species and habitats listed in Table 1. The assessment is divided into construction and removal effects and operations effects. Some operations effects are analyzed using outputs of DSM2-HYDRO and DSM2-QUAL modeling based on simulated hydrology[4]. The scenarios compared (no EDB and EDB) are very similar in Delta inflow, Delta outflow, and other operational features (e.g., south Delta exports); the scenarios are intended to illustrate differences in Delta conditions because of the EDB operations (which is limited to the presence of the West False River barrier) and not because of changes in SWP/CVP operations that

[4] The details of this simulated hydrology are provided in Appendix C.

could arise because of drought operations (e.g., differences in south Delta exports between EDB and no-EDB situations). Operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015) . The TUCP proposal includes both flow and water quality components. Further details of the main features of these scenarios are provided in Appendix C. Currently, D-1641 has been temporarily modified through a TUCP filed with the SWRCB on March 24, 2015, and subsequent Order issued on Apri 6, 2015, by the SWRCB Executive Director. There are no additional water quality or Delta outflow modifications proposed as a result of installation of the emergency drought barrier. The USFWS, NMFS, and CDFW provided consultation on the TUCP and current water operations are consistent with their findings.

Construction and Removal Effects on Fish

Chinook Salmon and Central Valley Steelhead

As noted in the Environmental Baseline description, historic data suggest that only a very limited proportion of the juvenile populations of Central Valley spring-run and Sacramento River winter-run Chinook salmon and Central Valley steelhead would overlap with the EDB construction (earliest start date: May 4), operation (early June-October) and removal (September/October/November) periods (Table 11). Also as described in the Environmental Baseline section, a portion of the adult spring-run Chinook salmon population may migrate upstream through the Delta towards spawning areas during the construction and operation of the EDB (Table 12), whereas a very small proportion of adult winter-run Chinook salmon would be expected to do so. 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 would be more likely to coincide with construction of the EDB if construction began later in summer (e.g., in July) than if it began in spring (e.g., May), whereas the upstream migration would be likely to coincide with barrier operations (early June-October) and removal (September/October/November).

As noted in the Project Description, most materials needed for the construction of the West False River barrier would be brought to the site by barge; the exceptions include the installation of portions of the king piles and sheet piles. Additionally, minimal vegetation and clearing would be required on the levees prior to placement of rock or the installation of sheet piles. The more substantial of these land-based activities generates noise that could potentially disturb fish in the immediate area. The placement of rock below the waterline also generates noise as well as creates a physical disturbance that may harass, injure, kill or displace juvenile and adult salmonids. Displaced juvenile fish may become more prone to predation in areas away from the zone of disturbance if water levels are relatively low because of the drought conditions. Rock placement in the river channels causes increased turbulence and turbidity in the water column. The increased turbidity levels associated with construction may negatively impact juvenile fishes temporarily through reduced availability of food, reduced feeding efficiency, and exposure to potentially toxic sediment released into the water column. These potential effects would be limited because they are temporary, only a relatively small area of the subject channel is disturbed or affected by construction (although much of the width of the channels could be affected by noise from rock placement during construction), most fish are expected to move away from the area of disturbance, and DWR will employ a number of conservation measures intended to minimize the extent of take (see Conservation Measures section).

Pile driving will be used in the construction of the West False River barrier, as noted in the Project Description. High levels of underwater noise from pile driving can adversely affect some fish species[5], as discussed by NMFS and others (Hastings and Popper 2005; Popper et al. 2006; Carlson et al. 2007; NMFS 2008a). To the extent possible, the EDB will use a vibratory hammer to install the sheet pile dikes and king piles (wall) at the West False River barrier; however, impact driving may be necessary for some pile driving. Vibratory hammers are generally much quieter than impact hammers and are routinely used on smaller piles (ICF Jones & Stokes and Illingworth & Rodkin 2009). 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). Although these criteria were specific to impact or percussive pile driving, they have served as a general guideline for noise thresholds for the onset of physical injury in fish exposed to the impact sound associated with pile driving (NMFS 2008a).

Pile driving at the West False River barrier site would occur over a several-day period in order to install the two sheet pile walls and associated eight king piles. A vibratory hammer would be used for the sheet and king pile driving, which is quieter than impact driving (ICF Jones & Stokes and Illingworth & Rodkin 2009). Vibratory driving appears to be feasible given the anticipated ground conditions and modest pile penetration of 20-50 feet into the ground (Broadbaek, pers. comm.). Vibratory penetration rates are normally limited to 20 inches per minute (per North American Sheet Piling Associations – Best Practices, www.nasspa.com), which would result in the following maximum vibration times per pile assuming normal driving conditions:

- 20-ft ground penetration: 12 minutes

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[5] 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).

- 50-ft ground penetration: 30 minutes

Because of uncertainties in ground conditions and the possibility of encountering dense soil layers or obstructions such as left-in-place rip-rap on the existing levee side slopes, a larger impact hammer would be used as a contingency measure, in the event that unexpected harder driving is encountered. The impact hammer would only be used if the vibratory hammer cannot reach the design tip elevation of the pilings.

Although peak sound levels of vibratory hammers can be substantially less than those produced by impact hammers, the total energy imparted can be comparable to impact driving because the vibratory hammer operates continuously and requires more time to install the pile (ICF Jones & Stokes and Illingworth & Rodkin 2009). Sound levels during vibratory pile driving were measured at the City of Stockton Downtown Marina (ENTRIX 2008). Peak sound pressure levels ranged from 184 to 202 dB, while accumulated SELs ranged from 181 to 195 dB, as measured at 10 m from the pile and mid-water depth (approximately 2 to 3 m below the water surface). The duration of pile driving ranged from approximately 6 to 12 minutes, with periods of 11 to 71 minutes between pile driving (Power Engineering and City of Stockton 2008). The peak sound pressure levels were below recommended levels, while the accumulated SELs slightly exceeded the recommended criteria by 8 dB. During the 5-week period of observing each pile installation at the City of Stockton Downtown Marina, technicians did not observe effects on salmonids or other species related to the pile installations.

Appendix A presents an analysis for potential pile driving effects for the EDB, including barrier piles (i.e., king piles and sheet piles) at the West False River site, float line piles upstream and downstream of the West False River site, and water quality equipment monitoring piles. This analysis examined various potential scenarios for the duration of pile driving, given lack of exact knowledge about the number of piles to be driven per day. The analysis suggested that the potential zone of effect (i.e., the zone within which there is potential for take through physical injury or harassment causing displacement) for vibratory pile driving of barrier piles could extend almost 500 meters upstream and downstream from the site of pile driving at the West False River barrier[6]; the zone of effect for impact driving varied broadly depending on the number of strikes necessary for pile driving (maximum of 1,000 meters for many strikes per day). As described in the Conservation Measures section, vibratory pile driving would be used whenever possible, and driving would be halted should daily cumulative SEL at 10 meters exceed the greatest values estimated from the pile driving effects analysis, i.e., 214 dB for vibratory driving and 218 dB for impact driving. Pile driving for the float line piles at the West False River barrier would affect an area within the area of impact of the barrier piles. Pile driving for the water quality monitoring piles would be expected to affect a very small area (e.g., < 10 m distance to 183-dB physical injury threshold, for 720 seconds) at the locations where the piles would be driven.

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[6] This distance is based on sound pressure criteria for effects on fishes that were adopted for impact driving; as noted in Appendix A, suggested criteria for vibratory driving would give a shorter distance to sound pressure thresholds and therefore a smaller zone of impact.

The use of vibratory driving whenever possible, the adoption of attenuation measures for any impact driving (i.e., bubble curtains; see Conservation Measures), combined with sound monitoring to limit pile driving should thresholds be exceeded, are intended to minimize the potential for take of listed fish species during pile driving.

Anticipated responses of any fish within the work area may be more likely to be behavioral in nature (e.g., startle response and avoidance), although these would diminish with distance from the construction sites. 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.

Overall, it is anticipated that the potential adverse effects of EDB 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 take place when very few individuals of the listed juvenile salmonids would be expected to occur in the Action Area;
- the effects would be temporary (total construction period of around 30-60 days at all sites and total removal period of around 45-60 days);
- pile driving on each day at the West False River barrier would be limited not to exceed NMFS-established thresholds for injury to fishes, and would be undertaken with a vibratory pile driver to the extent possible, with any necessary impact driving incorporating bubble curtains to attenuate noise effects (see Conservation Measures section);
- pile driving for water quality monitoring equipment would be very limited in duration and area affected and would be undertaken with a vibratory pile driver;
- 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),[7] suggesting that the area of construction effects from rock placement

[7] 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[8]);

- the effects of noise on fish would likely 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 are expected to move away from the area of disturbance, and the tidal/riverine nature of the action area would facilitate fish movement because of water flow;
- DWR would employ a number of conservation measures to limit the potential for take (see Conservation Measures section).

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 EDB. 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 nearly 80% of green sturgeon reach their spawning grounds in the upper Sacramento River by the end of April, and nearly 100% do so by the end of May (Woodbury pers. comm.). Therefore, construction could have some overlap with adult upstream migration, and this overlap may be greater if construction began in the spring (earliest proposed construction date: May 4) than in early summer. 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 EDB construction, operation, and removal.

The effects on green sturgeon of construction and removal activities associated with the EDB would be similar to those described previously for Chinook salmon and steelhead. In summary, those green sturgeon juveniles and sub-adults that do enter the project area during potential construction and removal periods are likely to experience increased turbidity and sediment-associated toxicant levels,

[8] In addition to rock placement during construction, rock placement may occur at the permanent abutments should annual inspections show displacement of rocks from these structures; however, there are expected to be no adverse effects from these rock placements on listed salmonids because the work would be of limited extent and would occur during the summer in-water work window (see Conservation Measures).

noise, and potential harassment by construction and removal activities. However, adverse effects are expected to have a limited negative impact on green sturgeon for the reasons previously described for salmonid species.

Delta Smelt

Based on historic patterns, migrating and spawning adult delta smelt may be present in the Action Area during the construction of the West False River barrier because construction activities beginning as early as May would 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). However, as described in the Environmental Baseline section related to the ESA Compliance Biological Review, the peak of spawning appeared to have already passed in March 2015 and declines in March catch in the Spring Kodiak Trawl were suggested by the Smelt Working Group to possibly be caused by post-spawn mortality (or gear avoidance). Only one adult delta smelt was caught in the early April Spring Kodiak Trawl survey (in the Sacramento River Deep Water Ship Channel), which may reflect the very low abundance of delta smelt generally as well as post-spawn mortality, following the Smelt Working Group logic from the March survey. 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) 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 West False River barrier site, where the habitat consists of primarily steep-sloped, riprapped banks (see Figure 4). Therefore, although in-water nighttime construction activities at the West False River barrier 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 peak of the spawning season appeared to be in March (as reflected in capture of only one adult fish during the Spring Kodiak Trawl survey in April), and because the hypothesized preferred spawning habitat is limited or absent in the area. Construction later in the year (e.g., summer) would avoid effects to adult delta smelt.

Occurrence of early life stages of the subsequent generation of delta smelt (larvae and early juveniles) near the West False River barrier during EDB construction could occur 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 adults, construction later in the year would tend to lessen the likelihood of overlap with delta smelt early life stages. Removal of the West False River barrier (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 installation of the EDB 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 and any pile driving that would occur (primarily at the West False River barrier, with the potential for minor effects from pile driving for installation of water quality monitoring equipment at the twelve locations described in the project description). As described in Appendix A and discussed further above for juvenile salmonids, vibratory pile driving has the potential to affect fishes up to 500 meters upstream and downstream from the construction area of the West False River barrier. Delta smelt moving away from the zone of effect may become more prone to predation in areas away from the zone of disturbance. Additionally, the increased turbidity levels associated with construction may negatively impact delta smelt temporarily through reduced availability of food, reduced feeding efficiency, and exposure to toxic sediments released into the water column. Removal of the EDB in September/October/November could also affect delta smelt occurring near the West False River barrier; their likelihood of presence near the barrier would depend on the environmental conditions (principally water temperature, salinity, and turbidity).

The construction and removal of the EDB 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 (total construction period of around 30-60 days and total removal period of around 45-60 days);
- pile driving on each day at the West False River barrier would be limited not to exceed NMFS-established thresholds for injury to fishes, and would be undertaken with a vibratory pile driver to the extent possible, with any necessary impact driving incorporating bubble curtains and other conservation measures to attenuate noise effects (see Conservation Measures section);
- pile driving for water quality monitoring equipment would be very limited in duration and area affected and would be undertaken with a vibratory pile driver;
- 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)[9], suggesting that the area of construction effects from rock placement

[9] 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/($10^{[\text{149dB – pressure threshold in dB}]/15 \text{ (i.e., the assumed attenuation coefficient)}}$)) 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)[10];

- the effects of noise on fish would likely 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);
- the spawning period appears to have largely been completed and there is little to no hypothesized preferred spawning habitat for adult delta smelt;
- juvenile and adult delta smelt are 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 disturbance than juvenile and adult delta smelt);
- DWR would employ a number of conservation measures to limit the potential for take (see Conservation Measures section).

Operations Effects on Fish

As described in the Introduction, the present analysis of EDB operations is limited to potential general effects from the presence of the West False River barrier. Changes to SWP/CVP operations because of the EDB and resulting potential effects on listed fishes would be analyzed separately from this BA by Reclamation/DWR within the scope of Biological Reviews for drought operational planning and consistency with ESA section 7. However, there are no additional water quality or Delta outflow modifications proposed as a result of installation of the emergency drought barrier. Therefore, water operations are consistent with the TUCP filed March 24, 2015, with the SWRCB.

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) and discusses the potential far-field effects generally in comparison to baseline conditions with no barrier present; both scenarios were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). The general far-field effects of the barrier on hydrodynamics and water quality are illustrated using various modeling data; more specific analyses would be conducted by DWR and Reclamation in conjunction with the aforementioned Biological Reviews for ESA compliance.

[10] As noted for juvenile salmonids, in addition to rock placement during construction, rock placement may occur at the permanent abutments should annual inspections show displacement of rocks from these structures (see Conservation Measures); however, there are expected to be no adverse effects from these rock placements on delta smelt because the work would be of limited extent and would occur during the summer in-water work window.

Chinook Salmon and Central Valley Steelhead

As outlined in the Project Description, operation of the EDB would commence following construction which, given the May 4 earliest construction start date, would result in operations in early June; operations would continue until barrier removal commences before October 1. As described in the Environmental Baseline section, historic data suggest that this timeframe has minimal overlap with the occurrence of juvenile listed salmonids from the Sacramento River basin (Table 11). In addition, some listed adult Chinook salmon 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).

Operational effects of the EDB are discussed in relation to hydrodynamic effects, water quality effects, and near-field predation effects.

Hydrodynamic Effects

For the few juvenile salmonids (Central Valley spring-run Chinook salmon, Sacramento River winter-run Chinook salmon, and Central Valley steelhead) expected to enter the Action Area during EDB operations, there would be altered flow routing in the lower Sacramento River leading to changes in seaward migration pathways. The location of the West False River barrier in relation to the main adult migratory pathways suggests limited potential for effect. There may be changes to juvenile salmonid entrainment susceptibility at the South Delta export facilities because of changes in tidal hydraulics in the lower San Joaquin River caused by the West False River barrier. Each of these mechanisms is discussed separately.

Juvenile Migration Pathways

The analysis of EDB operational effects on juvenile migration pathways presented in this section is of greatest relevance to EDB operations commencing in June; as described above and in the Environmental Baseline section, should operations commence later than June (e.g., July), it is anticipated that essentially all listed juvenile salmonids will have left the project area and would not be susceptible to changes in migration pathways.

Studies of acoustically tagged late fall-run Chinook salmon smolts have shown that these fish generally enter divergences in similar or slightly lower proportion as the proportion of flow entering the divergences (Perry et al. 2010; Cavallo et al. 2015; Perry et al. 2015). These studies also have shown that there is a lower probability of survival for fish taking the Georgiana Slough or DCC pathways to Chipps Island than for fish taking the Sacramento River or Steamboat Slough pathways; Sutter Slough survival generally is intermediate (Table 13). Rescaling survival for each release event to the maximum observed in each event (last column of Table 13) for the events in which Sutter and Steamboat slough survival pathways were separately estimated shows that with the DCC open, the mean survival in the Steamboat Slough and Sacramento River pathways was greatest, and on average was nearly double that of the Sutter Slough pathway; survival down the Georgiana Slough pathway was slightly less than that of the Sutter Slough pathway, and the DCC pathway had by far the lowest survival (Table 14). With the DCC closed, there was much less difference between the Sutter Slough and Sacramento River/Steamboat Slough pathways, while survival down the Georgiana Slough pathway was considerably lower than all of the other pathways. These results generally were consistent with the results for late-fall run Chinook salmon and steelhead observed by Singer et al. (2013), although these authors did not separate survival in the Sutter/Steamboat pathways or Georgiana Slough/DCC pathways (Table 15).

Actions undertaken as a result of drought operations planning could influence potential outcomes of EDB operations in relation to juvenile salmonid migration pathways. For example, the 2015 Drought Strategy included the potential for implementation of a DCC gate operations trigger matrix accompanying modifications in operations of the DCC gates from those specified in the NMFS (2009) SWP/CVP Biological Opinion or D-1641; these modifications may result in the DCC gates being open more frequently than otherwise would occur. As noted above, opening of the DCC gates would expose a greater number of listed juvenile salmonids to the low-survival, interior Delta migration pathway. This and other potential actions could influence the effects of the EDB on listed juvenile salmonid survival down migration pathways, although as noted above, even the earliest operational period of the EDB would be largely outside the downstream migration period of Central Valley spring-run Chinook salmon, Sacramento River winter-run Chinook salmon, and Central Valley steelhead.

The West False River barrier would increase the tidal flow entering the north Delta, with the result that a slightly lower proportion of Sacramento River flow would enter Sutter and Steamboat sloughs than with no EDB: for the month of June, the mean proportion of tidally averaged mean daily flow[11] was 0.32 with no EDB and 0.30 with the EDB (Figure 7). In addition, the increased tidal influence would result in a slightly greater proportion of flow entering the DCC and Georgiana Slough than with no EDB; for the month of June, the mean proportion of tidally averaged mean daily flow was 0.63 with no EDB and 0.66 with the EDB (Figure 8). To illustrate the potential effects of such changes on overall through-Delta survival of Sacramento River-origin juvenile salmonids, the relative survival values presented in Table 14 were related to the proportion of daily mean flow that would pass through each migration pathway (Sutter Slough, Steamboat Slough, Sacramento River main stem, DCC, and Georgiana Slough), making the simplifying assumption of fish moving proportionally with flow splits. Overall survival was calculated from the mean survival down all pathways weighted by the proportion of flow moving through each pathway.

It is important to note that this analysis is intended to be illustrative of potential differences between scenarios and not predictive. There are a number of uncertainties because the survival data used to develop the survival estimates differ in a number of respects from the situation to which they are being applied, e.g., season (winter vs. spring), race of salmon (late fall-run vs. winter-run and spring-run), and origin of salmon (hatchery vs. wild). These caveats aside, it is assumed the available data provide at least a relative sense of potential differences between scenarios. In addition, given that steelhead also seem to exhibit differences in pathway-specific survival similar to those of juvenile Chinook salmon (Singer et al. 2013), the results may be indicative of effects on juvenile Central Valley steelhead.

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[11] The tidally averaged mean daily flow was calculated from the DSM2-HYDRO data based on the following steps: 1) calculate the hourly arithmetic mean flow from the 15-minute outputs; 2) calculate a 25-hour centered moving average hourly flow from the hourly arithmetic mean flow; 3) calculate a daily mean of the 25-hour-centered-moving-average hourly flows. This procedure was applied to derive all tidally averaged mean daily flows discussed in this BA.

Table 13. Survival to Chipps Island and Migration Pathway Use By Acoustically Tagged Late Fall-Run Chinook Salmon Juveniles

Source	Migration pathway, release date	Survival	SE	Pathway use	SE	Proportion of max. survival by release
Perry et al. (2010)	Sac. R., 12/5/06	0.443	0.146	0.352	0.066	1.000
Perry et al. (2010)	Sutter/Steamboat Sl., 12/5/06	0.263	0.112	0.296	0.062	0.594
Perry et al. (2010)	DCC, 12/5/06	0.332	0.152	0.235	0.059	0.749
Perry et al. (2010)	Geo. Sl., 12/5/06	0.332	0.179	0.117	0.045	0.749
Perry et al. (2010)	Sac. R., 1/17/07	0.564	0.086	0.498	0.060	1.000
Perry et al. (2010)	Sutter/Steamboat Sl., 1/17/07	0.561	0.092	0.414	0.059	0.995
Perry et al. (2010)	DCC, 1/17/07	NA	NA	0.000	0.000	NA
Perry et al. (2010)	Geo. Sl., 1/17/07	0.543	0.200	0.088	0.034	0.963
Perry(2010)	Sac. R., 12/07	0.283	0.054	0.387	0.044	1.000
Perry(2010)	Sutter/Steamboat Sl., 12/07	0.136	0.039	0.345	0.042	
Perry(2010)	Sutter Sl., 12/07	0.107	0.037	0.230	0.037	0.378
Perry(2010)	Steamboat Sl., 12/07	0.193	0.060	0.115	0.028	0.682
Perry(2010)	DCC, 12/07	0.041	0.021	0.117	0.029	0.145
Perry(2010)	Geo. Sl., 12/07	0.087	0.028	0.150	0.033	0.307
Perry(2010)	Sac. R., 1/08	0.244	0.048	0.490	0.048	0.853
Perry(2010)	Sutter/Steamboat Sl., 1/08	0.245	0.059	0.198	0.037	
Perry(2010)	Sutter Sl., 1/08	0.192	0.070	0.086	0.026	0.671
Perry(2010)	Steamboat Sl., 1/08	0.286	0.070	0.112	0.029	1.000
Perry(2010)	DCC, 1/08	NA	NA	0.000	0.000	NA
Perry(2010)	Geo. Sl., 1/08	0.086	0.023	0.311	0.045	0.301
Perry(2010)	Sac. R., 12/08	0.448	0.053	0.392	0.040	0.709
Perry(2010)	Sutter/Steamboat Sl., 12/08	0.394	0.056	0.321	0.037	
Perry(2010)	Sutter Sl., 12/08	0.281	0.061	0.217	0.033	0.445

Source	Migration pathway, release date	Survival	SE	Pathway use	SE	Proportion of max. survival by release
Perry(2010)	Steamboat Sl., 12/08	0.632	0.059	0.104	0.025	1.000
Perry(2010)	DCC, 12/08	0.117	0.048	0.224	0.045	0.185
Perry(2010)	Geo. Sl., 12/08	0.315	0.054	0.164	0.164	0.498
Perry(2010)	Sac. R., 1/09	0.398	0.051	0.459	0.043	0.913
Perry(2010)	Sutter/Steamboat Sl., 1/09	0.432	0.067	0.253	0.036	
Perry(2010)	Sutter Sl., 1/09	0.426	0.086	0.096	0.024	0.977
Perry(2010)	Steamboat Sl., 1/09	0.436	0.075	0.158	0.030	1.000
Perry(2010)	DCC, 1/09	NA	NA	0.000	0.000	NA
Perry(2010)	Geo. Sl., 1/09	0.163	0.033	0.288	0.040	0.374
Perry et al. (2012)	Sac. R., 12/2-5/09	0.584	0.057	0.512	0.048	0.954
Perry et al. (2012)	Sutter/Steamboat Sl., 12/2-5/09	0.446	0.076	0.223	0.039	
Perry et al. (2012)	Sutter Sl., 12/2-5/09	0.336	0.090	0.134	0.032	0.549
Perry et al. (2012)	Steamboat Sl., 12/2-5/09	0.612	0.077	0.089	0.027	1.000
Perry et al. (2012)	DCC, 12/2-5/09	0.236	0.080	0.038	0.019	0.386
Perry et al. (2012)	Geo. Sl., 12/2-5/09	0.248	0.047	0.227	0.041	0.405
Perry et al. (2012)	Sac. R., 12/16-19/09	0.510	0.059	0.392	0.045	1.000
Perry et al. (2012)	Sutter/Steamboat Sl., 12/16-19/09	0.345	0.061	0.319	0.043	
Perry et al. (2012)	Sutter Sl., 12/16-19/09	0.302	0.065	0.243	0.044	0.592
Perry et al. (2012)	Steamboat Sl., 12/16-19/09	0.483	0.087	0.076	0.028	0.947
Perry et al. (2012)	DCC, 12/16-19/09	NA	NA	0.000	0.000	NA
Perry et al. (2012)	Geo. Sl., 12/16-19/09	0.223	0.040	0.289	0.042	0.437
Perry et al. (2012)	Sac. R., 1/31/10	0.485	0.059	0.449	0.045	0.951
Perry et al. (2012)	Sutter/Steamboat Sl., 1/31/10	0.468	0.062	0.447	0.049	
Perry et al. (2012)	Sutter Sl., 1/31/10	0.432	0.079	0.242	0.091	0.847
Perry et al. (2012)	Steamboat Sl., 1/31/10	0.510	0.084	0.205	0.085	1.000

Source	Migration pathway, release date	Survival	SE	Pathway use	SE	Proportion of max. survival by release
Perry et al. (2012)	DCC, 1/31/10	NA	NA	0.000	0.000	NA
Perry et al. (2012)	Geo. Sl., 1/31/10	0.179	0.074	0.104	0.022	0.351
Perry et al. (2012)	Sac. R., 2/5/10	0.577	0.043	0.600	0.038	0.937
Perry et al. (2012)	Sutter/Steamboat Sl., 2/5/10	0.550	0.061	0.221	0.030	
Perry et al. (2012)	Sutter Sl., 2/5/10	0.508	0.076	0.135	0.027	0.825
Perry et al. (2012)	Steamboat Sl., 2/5/10	0.616	0.071	0.086	0.022	1.000
Perry et al. (2012)	DCC, 2/5/10	NA	NA	0.000	0.000	NA
Perry et al. (2012)	Geo. Sl., 2/5/10	0.314	0.075	0.179	0.030	0.510

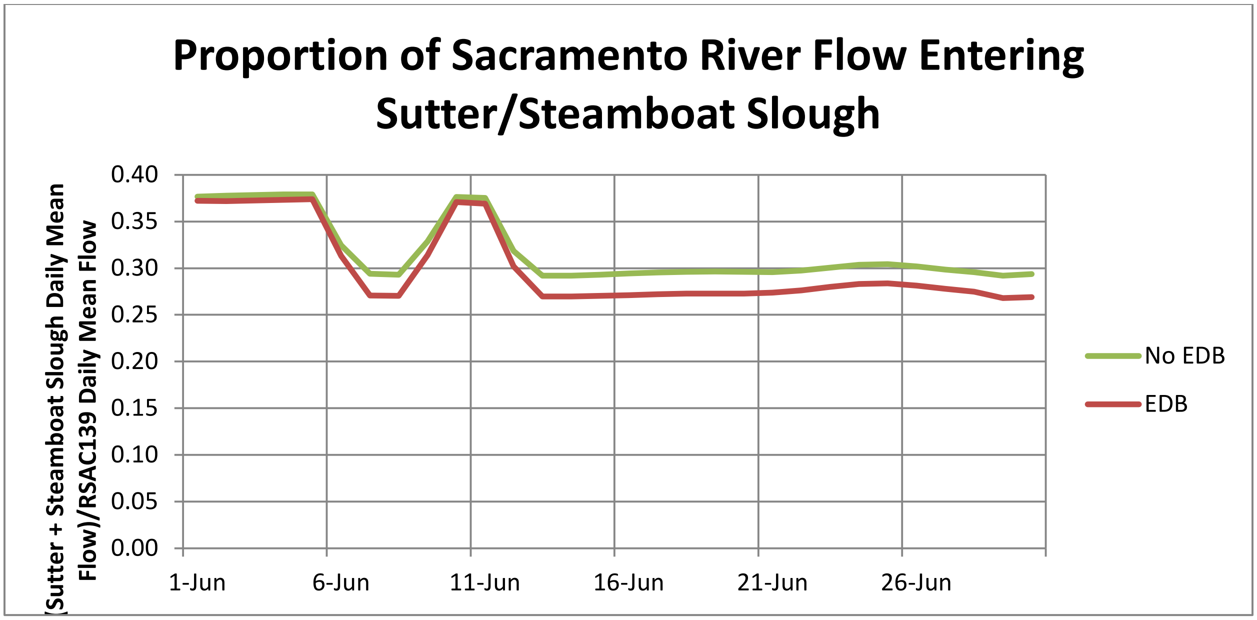
Table 14. Mean Proportion of Maximum Pathway Survival By Acoustically Tagged Late Fall-Run Chinook Salmon Juveniles, Based on Release Events For Which Sutter and Steamboat Slough Survival Were Calculated Separately

Pathway	DCC Open (N = 3)	DCC Closed (N = 5)
Sac R.	0.888	0.931
Sutter Sl.	0.457	0.782
Steamboat Sl.	0.894	0.989
DCC	0.239	NA
Geo Sl.	0.404	0.395
Source: Data in Table 12		

Table 15. Proportional Survival and Pathway Use of Acoustically Tagged Steelhead and Late Fall-Run Chinook Salmon[a]

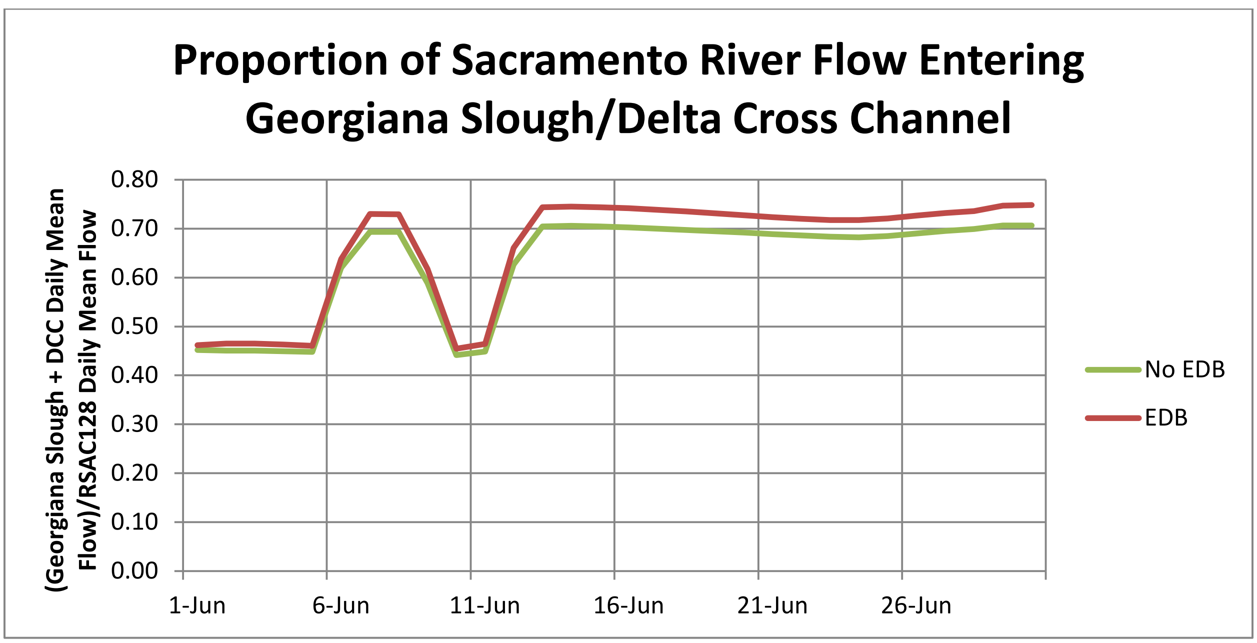
Pathway		Steelhead		Chinook Salmon	
		2009	2010	2009	2010
Sutter/Steamboat[b]	Proportion using pathway	0.23	0.29	0.21	0.32
	Survival to ocean	0.10	0.30	0.30	0.31
Interior Delta[c]	Proportion using pathway	0.17	0.19	0.15	0.14
	Survival to ocean	0.19	0.10	0.09	0.16
Mainstem Sacramento River[d]	Proportion using pathway	0.60	0.52	0.64	0.54
	Survival to ocean	0.25	0.33	0.20	0.26

[a] Reported by Singer et al. (2013).
[b] Originally called West Delta by Singer et al. (2013).
[c] Originally called East Delta (i.e., Georgiana Slough and DCC).
[d] Originally called Mainstem.



Source: Tu, pers. comm. Note: Scenarios include no EDB and EDB (West False River Barrier). Delta operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). EDB assumed installed June 1, removed October 31.

Figure 7. Proportion of Tidally Averaged Sacramento River Flow Entering Sutter Slough and Steamboat Slough, Based on Simulated Hydrology and Delta Cross Channel Operated Per D-1641.



Source: Tu, pers. comm. Note: Scenarios include no EDB and EDB (West False River Barrier). Delta operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). EDB assumed installed June 1, removed October 31.

Figure 8. Proportion of Tidally Averaged Sacramento River Flow Entering the Delta Cross Channel and Georgiana Slough, Based on Simulated Hydrology and Delta Cross Channel Operated Per D-1641.

The analysis illustrated that the calculated relative survival with no EDB (mean: 0.58; range 0.52-0.76) was marginally greater than with the EDB (mean: 0.56; range 0.50-0.75) (Figure 9).

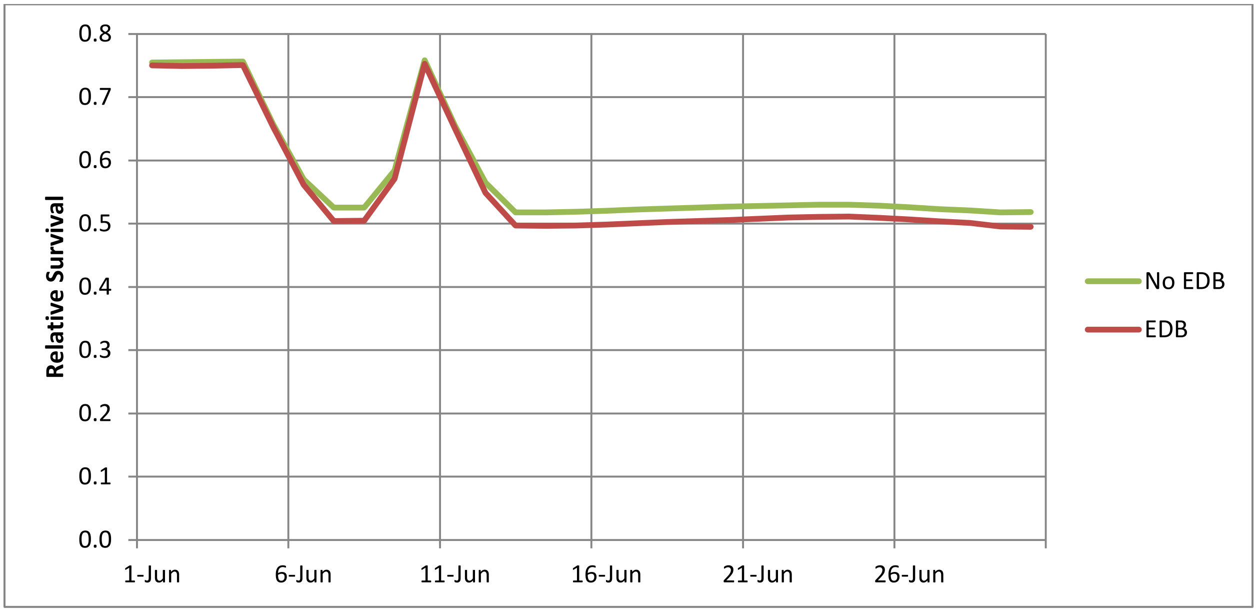
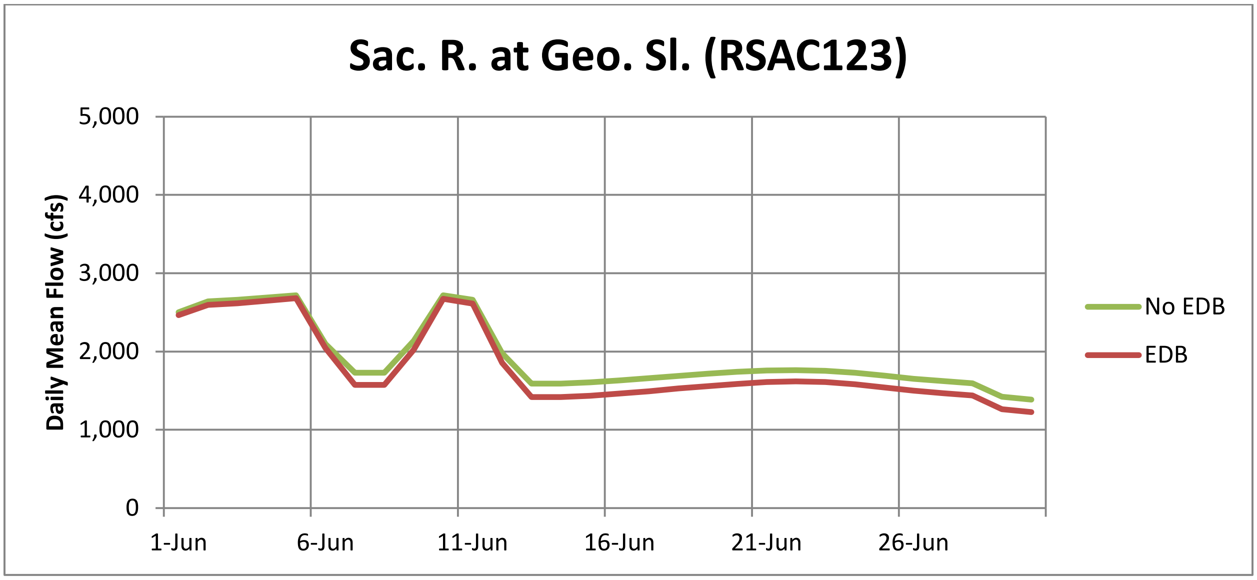


Figure 9. Relative Survival of Chinook Salmon Juveniles For Emergency Drought Barrier (EDB at West False River) and No EDB, Based on Application of Calculated Flow Splits to Survival Results from Perry (2010), Perry et al. (2010), and Perry et al. (2012).

Overall, these results suggested that operation of the West False River barrier could result in a marginally lower relative survival of Chinook salmon juveniles than with no EDB. This analysis only includes the effects of the West False River barrier in terms of changing the probability that a migrating salmonid juvenile would take a particular pathway, i.e., because of changing flow splits. Changes in flow could also affect survival probability within individual reaches, e.g., by changing residence time and velocity, which could affect probability of predation. For example, Perry (2010; see his Figures 5.7 and 5.8) found evidence of the probability of survival along the main stem Sacramento River from Georgiana Slough/DCC to Chipps Island increasing with increasing flow. DSM2-HYDRO modeling including DCC operated per D-1641,[12] showed that the tidally averaged daily mean flow in the Sacramento River at Georgiana Slough would be slightly lower under EDB (daily mean: 1,804 cfs) than a case without EDB (daily mean: 1,929 cfs) (Figure 10). This reflects the presence of the West False River barrier. Applying Perry's (2010) flow-survival relationship (Perry pers. comm.) to these mean flows gave a very slightly lower survival probability with the EDB (0.407) compared to no EDB (0.411). For any juvenile salmonids entering Sutter and Steamboat sloughs, the slightly reduced net downstream flow in these channels caused by the West False River barrier may increase travel time and therefore increase predation risk; Perry (2010) also found a significant flow-survival relationship for these channels. However, the difference in June tidally averaged mean daily flow was very small (Sutter Slough: 1,549 cfs with no EDB vs. 1,474 cfs with the

[12] Discussion of the simulated operations is provided in Appendix C.

EDB; Steamboat Slough: 1,001 cfs with no EDB vs. 935 cfs with the EDB) and so the difference in flow-related survival would be expected to be very small as well. As described in the Hydrodynamic Effects on delta smelt presented later herein, the West False River barrier would block one of the main potential entry points towards the south Delta export facilities and would slightly increase net flows in the San Joaquin River at Jersey Point, both of which may slightly reduce the risk of entrainment for fish in this area. However, regardless of whether the West False River barrier is installed or not, the potential for entrainment would be closely monitored by the Delta Operations for Salmonids and Sturgeon group (as a requirement of the SWP/CVP BiOp) and exports would be adjusted accordingly, so there would be likely to be little difference in entrainment loss between EDB and no EDB scenarios.



Source: Tu, pers. comm. Note: Scenarios include no EDB and EDB (West False River Barrier). Delta operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). EDB assumed installed June 1, removed October 31.

Figure 10. Tidally Averaged Mean Daily Flow in the Sacramento River at Georgiana Slough from June 1 to June 30, from DSM2-HYDRO Modeling, Based on Simulated Hydrology and Delta Cross Channel Operated Per D-1641.

Although these results were specific to modeling based on the simulated hydrology discussed in Appendix C that assumed barrier operation beginning on June 1 (with DCC operations per D-1641), the general patterns are of relevance to any juvenile salmonids migrating through the Action Area during the proposed operational period of the EDB (June-October).

Adult Migration Pathways

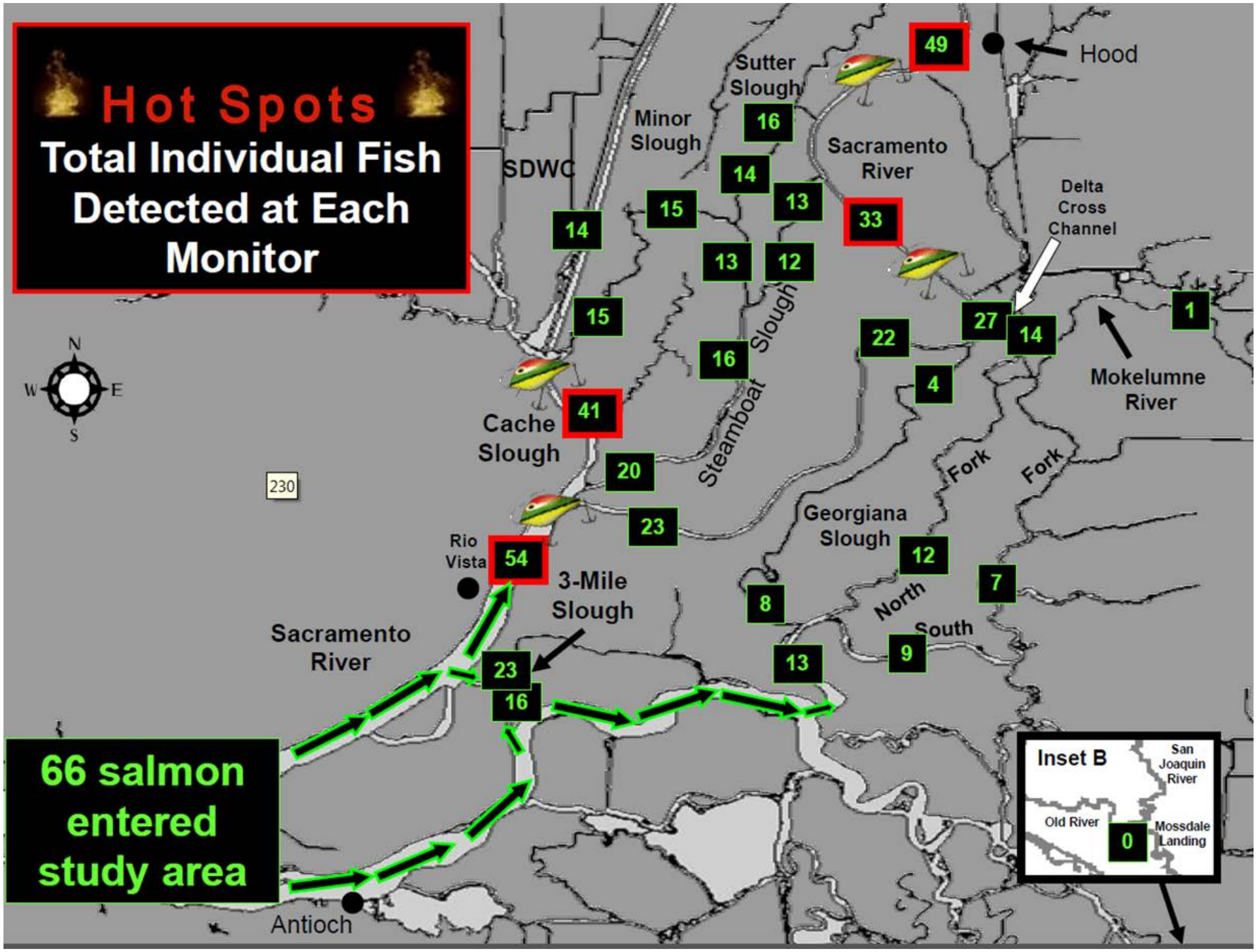
Adult Central Valley spring-run Chinook salmon, Sacramento River winter-run Chinook salmon, and Central Valley steelhead would be unlikely to experience migratory delays because of the operation of the EDB. There are few data assessing migratory pathways taken by adult salmonids through the Delta. Stein and Cuetara (2004) discussed the results of a preliminary study in which adult Chinook salmon were tagged during October-November 2003 to assess the effects of the Suisun Marsh Salinity Control gates (see Vincik 2013 for more details) and to examine passage through different pathways within the Delta. Of 66 adult Chinook salmon entering the Delta, a large proportion entered the Cache Slough complex, possibly because of the greater channel cross-section and tidal flows entering that area, relative to the main stem Sacramento River (Figure 11). Stein and Cuetara (2004) noted that many fish entering the Cache Slough complex subsequently returned to Rio Vista. Presumably similar migratory behavior may occur in Central Valley steelhead. Based on the limit observations from Stein and Cuetara (2004), adult salmonids returning to natal spawning grounds in the Sacramento River region would be unlikely to encounter the West False River barrier because they primarily would use the main stem Sacramento River pathway (leading to Cache Slough and the north Delta), or secondarily would be likely to use the mainstem San Joaquin River pathway. Central Valley steelhead from the San Joaquin River basin could encounter the West False River barrier (although there would be little to no flow- or odor-based cues coming from the pathway because flows in West False River would be very low because of the barrier), but would not have to return far (0.4 miles) to the main stem San Joaquin River.

Water Quality Effects

The EDB would be unlikely to result in water quality effects that would affected listed juvenile salmonids as the main effect would be to slightly alter the salinity field, as discussed further below for delta smelt.

Near-Field Predation Effects

Predatory fish may congregate below manmade barriers in rivers to feed on prey passing through the barriers. For example, Tucker et al. (1998) described the problem of relatively high predation of juvenile Chinook salmon below RBDD on the Sacramento River. Predatory fish (e.g., largemouth bass [*Micropterus salmoides*]) fitted with acoustic tags have been shown to associate with the head of Old River barrier that was installed in 2012 (DWR unpublished data), and predation rates of acoustically tagged Chinook salmon juveniles at or near the barrier were high. Also within the Delta, Sabal (2014) showed that striped bass congregated below Woodbridge Irrigation District Dam (Mokelumne River) at higher densities than at other anthropogenically altered sites in the lower Mokelumne River (which in turn had greater densities of striped bass than natural sites); the per capita consumption of juvenile Chinook salmon at the dam was also higher than at other areas.



Source: Stein and Cuetara (2004).

Figure 11. Number of Individual Acoustically Adult Chinook Salmon Detected at Hydrophones Deployed During October-November 2003

However, the West False River barrier is not on the main migration route for Central Valley spring-run Chinook salmon, Sacramento River winter-run Chinook salmon, and Central Valley steelhead originating in the Sacramento River watershed that may enter Sutter/Miner and Steamboat sloughs or remain in the mainstem Sacramento River without entering the interior Delta through the DCC or Georgiana Slough. In addition, even those individuals moving along the main stem San Joaquin River may be unlikely to enter False River because of the greatly reduced tidal flows caused by the presence of the barrier. The West False River barrier location is more likely to be encountered by some Central Valley steelhead emigrating from the San Joaquin River watershed but in contrast to the references cited above in relation to barriers with culverts or dams with passage facilities, the West False River barrier would not have culverts and therefore there would be no predation risk to fish passing through culverts. Near-field predation risk would be greater because of structure-associated predatory fishes. The barrier and its associated structures may provide perching habitat for predatory diving birds such as cormorants, which could increase predation risk for any juvenile salmonids occurring near the West False River barrier.

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 West False River barrier 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.

The abutments (sheet piles and king piles) at the West False River barrier would be left in place. As noted in the Project Description, the sheet piles would extend approximately 75 feet from the levee into the river channel; installation of rock transitions would be done to limit the potential for creation of hydrodynamic eddies that could form ambush habitat for predatory fishes, although some enhanced level of predation on juvenile salmonids that is attributable to the presence of the remaining structures could still occur.

Southern DPS of North American Green Sturgeon

The Southern DPS of North American green sturgeon could be affected by similar operational effects of the EDB as noted for listed salmonids, i.e., hydrodynamic effects (including blockage of migratory pathways), water quality effects, and near-field predation effects. Of the potential effects noted for salmonids, blockage of migratory pathways may be the most likely to give adverse effects because juvenile and sub-adult green sturgeon are relatively large and presumably are less susceptible to predation than juvenile salmonids. The longest potential EDB operational period (early June-October) would be expected to generally avoid much of the spring upstream migration period of adult green sturgeon (see sections discussing Environmental Baseline and Construction and Removal Effects on Fish) and, as noted for adult salmonids above, the West False River barrier location is well away from the main migratory pathways leading to spawning grounds in the Sacramento River. Juvenile green sturgeon occur year-round in the Delta and therefore could encounter the barrier during operations, with some potential for delay if seeking to reach a particular destination (e.g., downstream portions of the Delta, during outmigration to the ocean) that was blocked by the barrier, which would require seeking an alternative, unobstructed pathway.

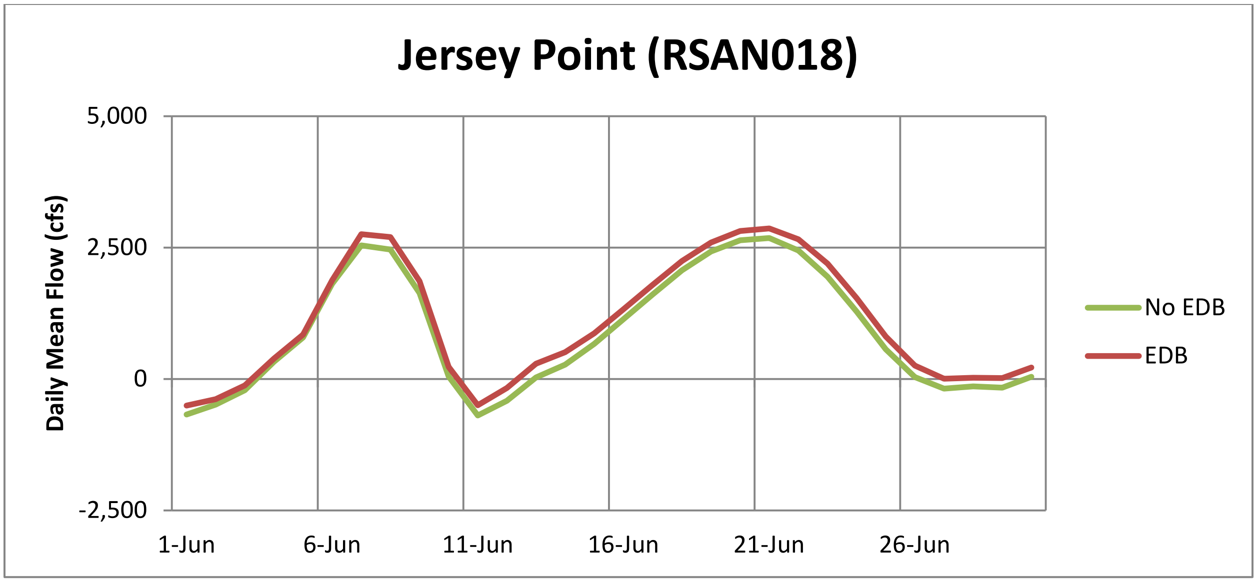
Delta Smelt

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 delta smelt would have less potential to occur near the West False River barrier during EDB operations (which may cover the early June-October period). In general, some delta smelt would be expected to occur near to the West False River barrier 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. Because of low inflow conditions, the low-salinity zone that is occupied by delta smelt would be further upstream in summer/fall of 2015 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.

Hydrodynamic Effects

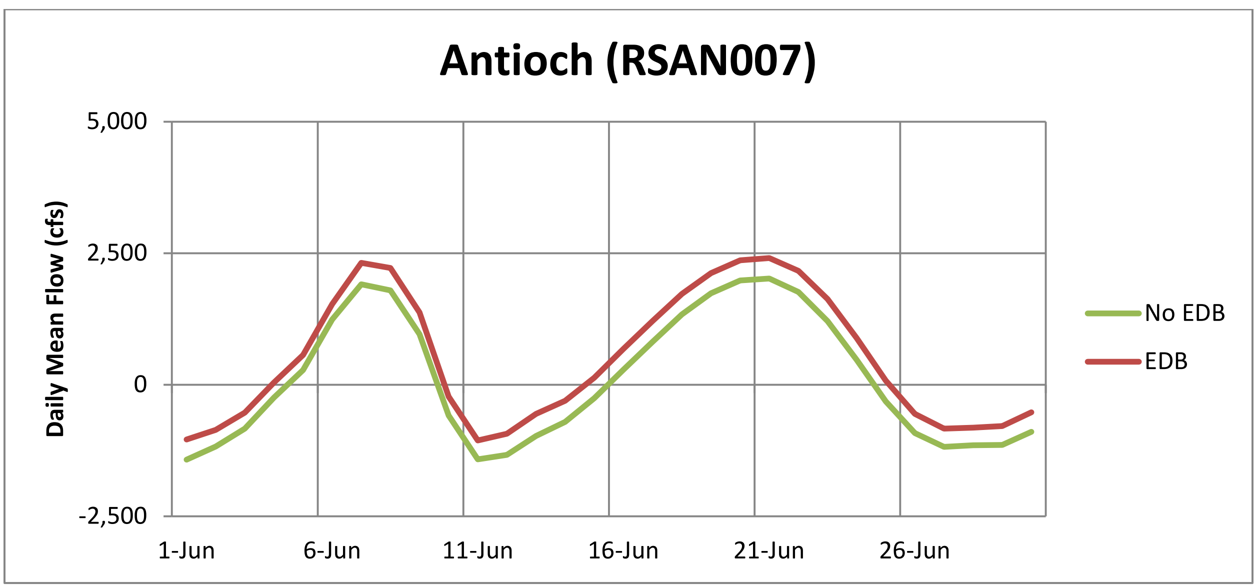
Operations of the EDB (i.e., the presence of the West False River barrier) have the potential to change the likelihood of entrainment toward the south Delta export facilities of delta smelt larvae/juveniles occurring in the lower San Joaquin River compared to the situation without the EDB. The West False River barrier would essentially eliminate the potential for delta smelt to move from the lower San Joaquin River through False River and Franks Tract into Old River. Modeling based on simulated hydrology[13] suggested that the net flows in the San Joaquin River at Jersey Point would not differ greatly between EDB and no-EDB scenarios: the tidally averaged daily mean flow for June with the EDB was 1,065 cfs, compared to 882 cfs without the EDB (Figure 12). Similarly, the operation (presence) of the West False River barrier would increase the net positive flow downstream in the lower San Joaquin River at Antioch (Figure 13).

[13] The simulated hydrology discussed in this BA assumed the EDB to be installed on June 1 and is useful for illustrating the general effects of the EDB in relation to a no-EDB scenario; the EDB and no-EDB scenarios were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). See Appendix C for further description.



Source: Tu, pers. comm. Note: Scenarios include no EDB and EDB (West False River Barrier). Delta operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). EDB assumed installed June 1, removed October 31.

Figure 12. Tidally Averaged Mean Daily Flow at Jersey Point from June 1 to June 30, from DSM2-HYDRO Modeling, Based on Simulated Hydrology and Delta Cross Channel Operated Per D-1641.



Source: Tu, pers. comm. Note: Scenarios include no EDB and EDB (West False River Barrier). Delta operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). EDB assumed installed June 1, removed October 31.

Figure 13. Tidally Averaged Mean Daily Flow at Antioch from June 1 to June 30, from DSM2-HYDRO Modeling, Based on Simulated Hydrology and Delta Cross Channel Operated Per D-1641.

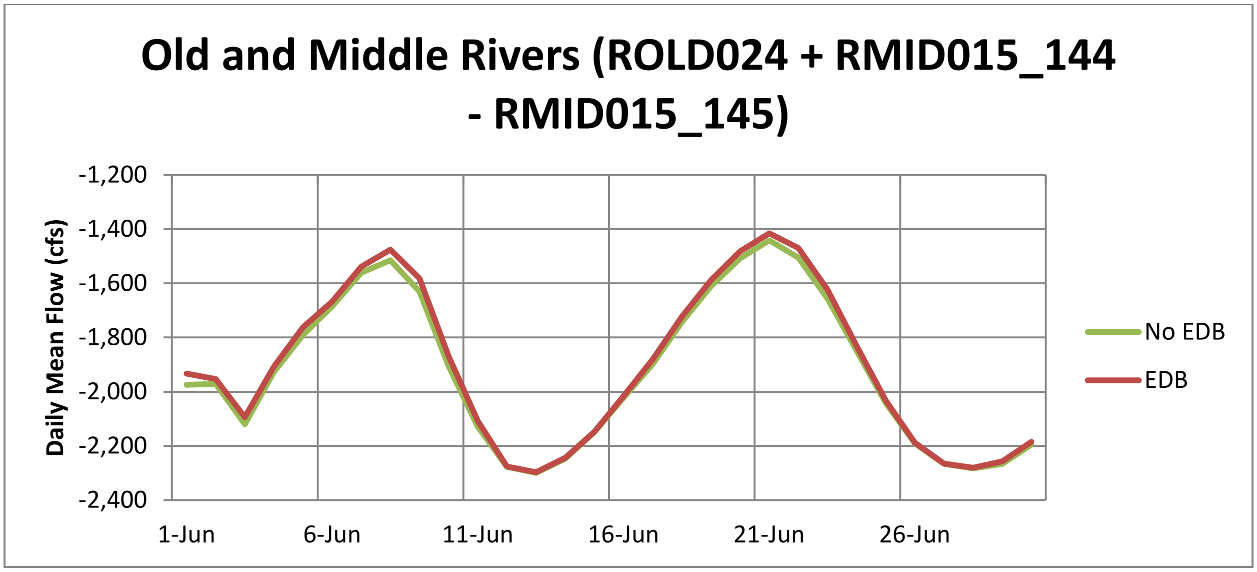
As noted above, installation of the West False River barrier would have the potential to reduce entrainment of delta smelt in the lower San Joaquin River into Franks Tract and Old River (and ultimately the SWP/CVP south Delta export facilities) by blocking off one of the main points of entry into the south Delta. However, seepage flow between the rocks of the barrier has the potential to result in impingement of small delta smelt (e.g., larvae and early juveniles) occurring in the area. Analyses presented in Appendix B based on DSM2-HYDRO modeling for the simulated hydrology were used to assess the potential for seepage flow through the West False River barrier. This suggested that the seepage flow would be very low (median of 0 cfs, range from -84 cfs to just under 370 cfs, for the June 1-30 period; Table B3 in Appendix B) and that therefore there would be low risk to delta smelt from impingement because this flow is very low compared to nearby tidal flow at Jersey Point (median of around 12,000 cfs, range -149,000 to 132,000 cfs). Without the EDB, median flow in False River was 5,600 cfs (range -37,500 to 36,000 cfs), indicating that a substantial portion of the San Joaquin River flood tide (upstream) flows are diverted into Franks Tract.

Operation of the West False River barrier could trap delta smelt that are present upstream of the barrier (e.g., in the Franks Tract area). With the EDB changing hydrodynamics in the central and south Delta, OMR flows become slightly less negative in the modeling based on the simulated hydrology (Figure 14), which is a function of differences in hydrodynamics caused by the West False River barrier (and not because less exports occurred under the EDB scenario). The West False River barrier changes the San Joaquin River flood tide pathway into Franks Tract, and moves the tidal connection about 20 kilometers upstream to the mouth of Old River. These hydrodynamic changes in the tidal elevations and corresponding tidal flows in the San Joaquin River, Franks Tract, and Old and Middle River channels also would slightly shift the distribution of the OMR flows. The tidally averaged mean daily flows for June of the simulated hydrology were 1,922 cfs for the no-EDB scenario and 1,903 cfs for the EDB scenario (Figure 14). Regardless of whether the West False River barrier is installed or not, the potential for entrainment would be closely monitored by the Smelt Working Group (as a requirement of the SWP/CVP BiOp) and exports would be adjusted accordingly, so there would be likely to be little difference in entrainment loss between EDB and no-EDB scenarios.

The fate of delta smelt found southeast of the West False River barrier may well be entrainment at the south Delta export facilities regardless of the presence of the barrier, based on simulated fates of neutrally buoyant particles (Kimmerer and Nobriga 2008).

Water Quality Effects

DSM2-QUAL modeling provides some perspective on potential effects in relation to changes in salinity (expressed as electrical conductivity, EC) that could affect delta smelt. As noted previously, the modeling discussed here was based on the simulated hydrology (see Appendix C) that represents the 99% exceedance hydrology with March 24 TUCP modifications, but the maximum salinity patterns are uncertain as they are dependent on actual outflow. The discussion below summarizes differences in mean daily conductivity at various locations.

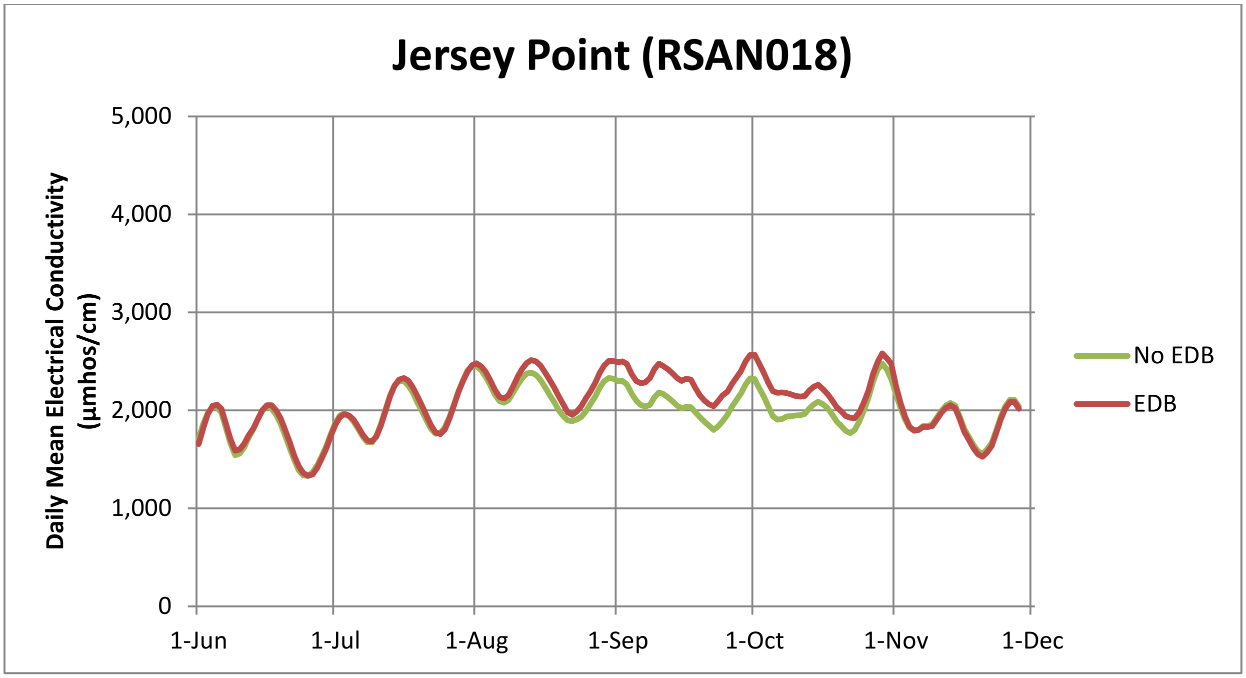


Source: Tu, pers. comm. Note: Scenarios include no EDB and EDB (West False River Barrier). Delta operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). EDB assumed installed June 1, removed October 31.

Figure 14. Tidally Averaged Mean Daily Flow at Old and Middle Rivers from June 1 to June 30, from DSM2-HYDRO Modeling, Based on Simulated Hydrology and Delta Cross Channel Operated Per D-1641.

Based on the DSM2-QUAL modeling using the simulated hydrology, conductivity on the lower San Joaquin River at Jersey Point during June 1 to October 31[14] generally was very similar with the EDB and with no EDB (Figure 15). The West False River Barrier would eliminate the seawater intrusion pathway into False River and Franks Tract, so the salinity at Jersey Point would remain in the San Joaquin River, possibly slightly increasing EC at and upstream of Jersey Point, as reflected in the slightly greater EC at Jersey Point during August to October (Figure 15).

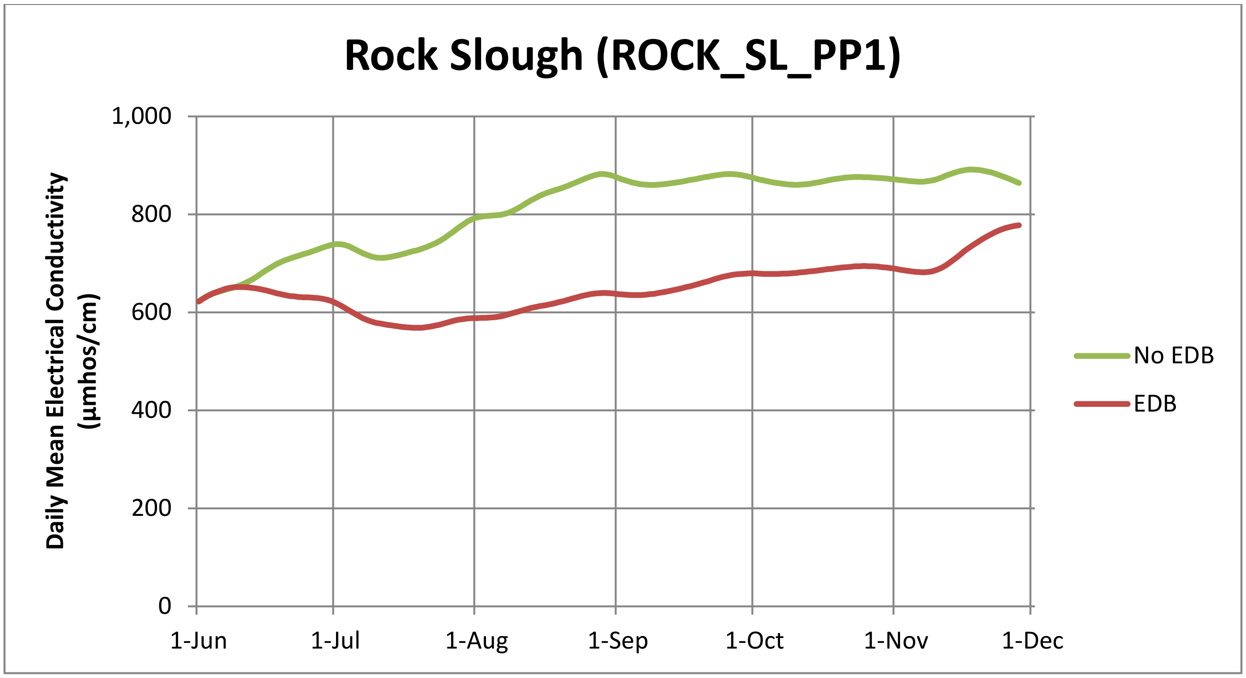
[14] This period was chosen to align with the operation period of the EDB; note that the scenarios modeled here assumed the West False River barrier commencing operations on June 1, with removal on October 31. As described in the Project Description of this BA, it is proposed that the West False River barrier would be removed by November 15.



Source: Tu, pers. comm. Note: Scenarios include no EDB and EDB (West False River Barrier). Delta operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). EDB assumed installed June 1, removed October 31.

Figure 15. Mean Daily Electrical Conductivity at Jersey Point from June 1 to November 30, from DSM2-QUAL Modeling, Based on Simulated Hydrology and Delta Cross Channel Operated Per D-1641.

With the EDB, conductivity would be lower along the water supply channels (e.g., Old River, Middle River and Rock Slough [Figure 16]) that are important for some water users, including in-Delta diversions, south Delta exports, and diversions by Contra Costa Water District. Although the barrier at West False River would prevent most tidal flow from entering False River and therefore tidal flow would tend to move further upstream on the lower San Joaquin River, the modeling suggests that the seawater intrusion reaching the water intakes at Rock Slough and farther upstream on Old River (i.e., CCWD, SWP, CVP) would be appreciably reduced (Figure 16). From these data it is inferred that there would be little effect from changes in conductivity in the lower San Joaquin River from the EDB on delta smelt, particularly in light of the relatively low occurrence of delta smelt in this area during the summer (Merz et al. 2011; see discussion above) and the range of conductivities that delta smelt inhabit (see below).

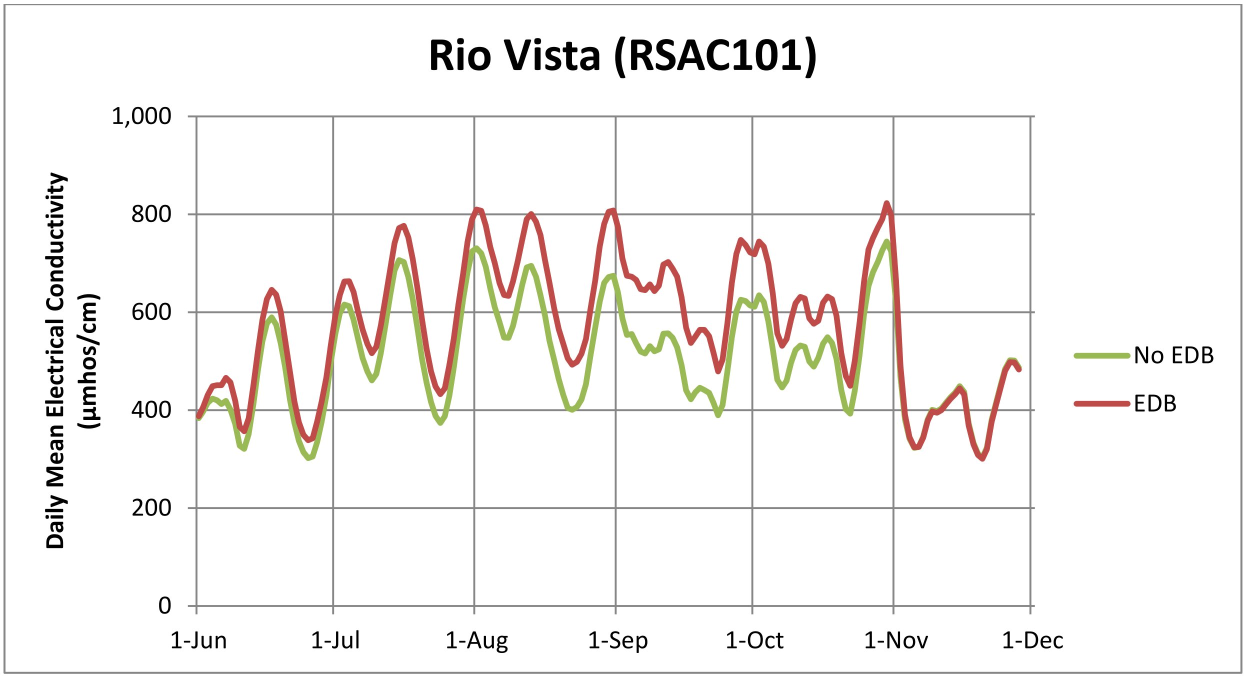


Source: Tu, pers. comm. Note: Scenarios include no EDB and EDB (West False River Barrier). Delta operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). EDB assumed installed June 1, removed October 31.

Figure 16. Mean Daily Electrical Conductivity at Rock Slough from June 1 to November 30, from DSM2-QUAL Modeling, Based on Simulated Hydrology and Delta Cross Channel Operated Per D-1641.

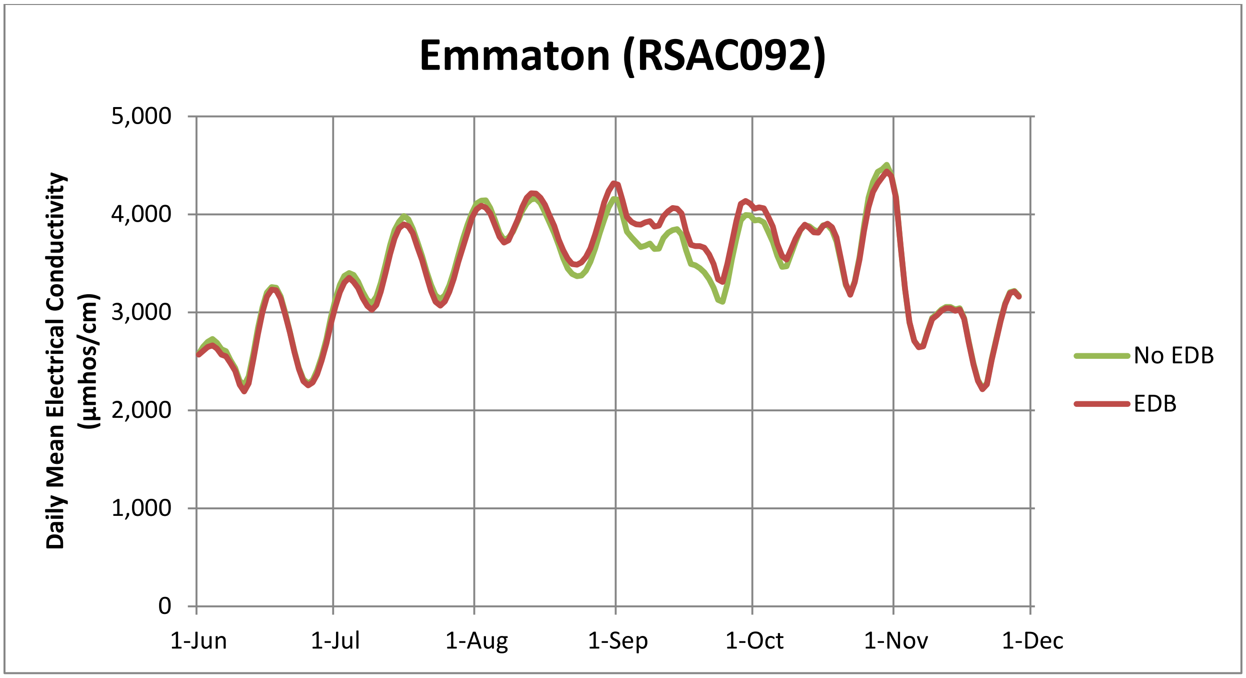
The EDB would result in slightly higher conductivity occurring further upstream on the lower Sacramento River. The DSM2-QUAL modeling based on the simulated hydrology indicated that from June 1 to October 31 the median daily conductivity at Rio Vista with the EDB would be about 75 µmhos/cm higher than with no EDB (Figure 17). At Emmaton, conductivity also would be slightly (again, around 75 µmhos/cm) higher with EDB compared to no EDB, but with median EC of about 3,500 µmhos/cm this would be a very small effect. (Figure 18). The salinity in the lower Sacramento River and lower San Joaquin River (Emmaton and Jersey Point) generally are controlled by the Delta outflow, which for the modeling included in this BA was slightly greater (200-300 cfs) under the no-EDB scenario than the EDB scenario in August/September (see Table C1 in Appendix C).

Greater conductivity further upstream on the lower Sacramento River (above Emmaton) could result in the delta smelt population that resides in the low salinity zone moving further upstream on the lower Sacramento River than would be the case without the EDB operating. This could result in a slightly smaller area of abiotic habitat, given the general decrease in habitat with movement upstream of the low-salinity zone (Feyrer et al. 2007). As Sommer and Mejia (2013: 8) noted, however, delta smelt are not confined to a narrow salinity range and occur from fresh water to relatively high salinity, even though the center of distribution is consistently associated with X2 (Sommer et al. 2011). Nobriga et al. (2008) found that the probability of occurrence of delta smelt was highest at low conductivity (1,000-5,000 µmhos/cm), and declined at higher conductivity (Figure 19); conductivity estimates for the simulated hydrology at Rio Vista were less than this range more for both the EDB scenario and for the no-EDB scenario (Figure 17), whereas at Emmaton conductivity for both the EDB scenario and the no-EDB scenario generally were within this range (Figure 18).



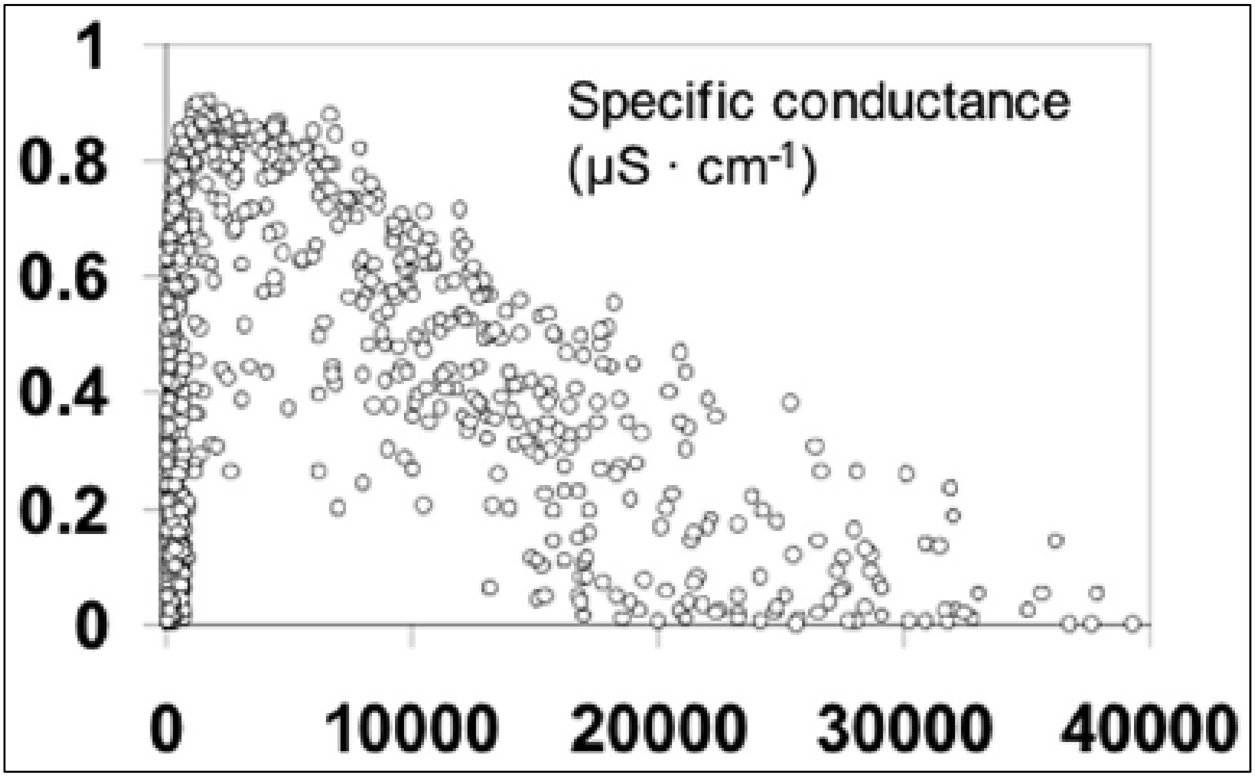
Source: Tu, pers. comm. Note: Scenarios include no EDB and EDB (West False River Barrier). Delta operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). EDB assumed installed June 1, removed October 31

Figure 17. Mean Daily Electrical Conductivity at Rio Vista from June 1 to November 30, from DSM2-QUAL Modeling, Based on Simulated Hydrology and Delta Cross Channel Operated Per D-1641.



Source: Tu, pers. comm. Note: Scenarios include no EDB and EDB (West False River Barrier). Delta operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). EDB assumed installed June 1, removed October 31

Figure 18. Mean Daily Electrical Conductivity at Emmaton from June 1 to November 30, from DSM2-QUAL Modeling, Based on Simulated Hydrology and Delta Cross Channel Operated Per D-1641.



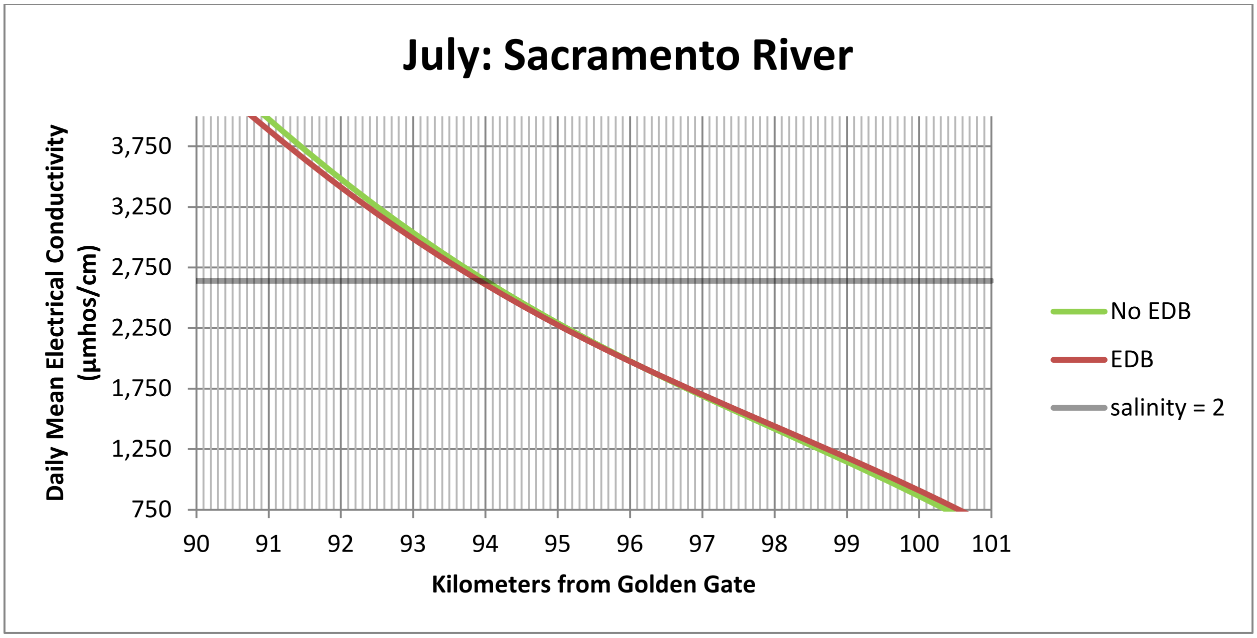
Source: Nobriga et al. (2008).

Figure 19. Predicted Capture Probability of Delta Smelt Juveniles in 1974-2004 July Summer Townet Surveys From Generalized Additive Modeling In Relation to Specific Conductance, With Scatter Depicting Variation Caused by Secchi Depth and Water Temperature.

The DSM2-QUAL data from Mallard Island (75 km from the Golden Gate), Collinsville (81 km), Emmaton (92 km), and Rio Vista (101 km) can be used to interpolate the approximate location of EC of 2,640 µmhos/cm (i.e., salinity = 2), i.e., the approximate X2 on the lower Sacramento River. During July to October, the mean monthly X2 was approximately 93.9-94.8 km with no EDB, compared to 94.0-95.0 km with the EDB (Figures 20-23). The greatest upstream shift in mean X2 with the EDB was 0.5 km, in September (Figure 22). This suggests the potential for some movement upstream of the portion of the delta smelt population residing in the low-salinity zone and a slightly smaller extent of abiotic habitat. Note that the difference between the no-EDB and EDB scenarios is partly because of greater Delta outflow (reflecting greater Sacramento River inflow) with no EDB, caused by the need to maintain salinity standards in the lower San Joaquin River.

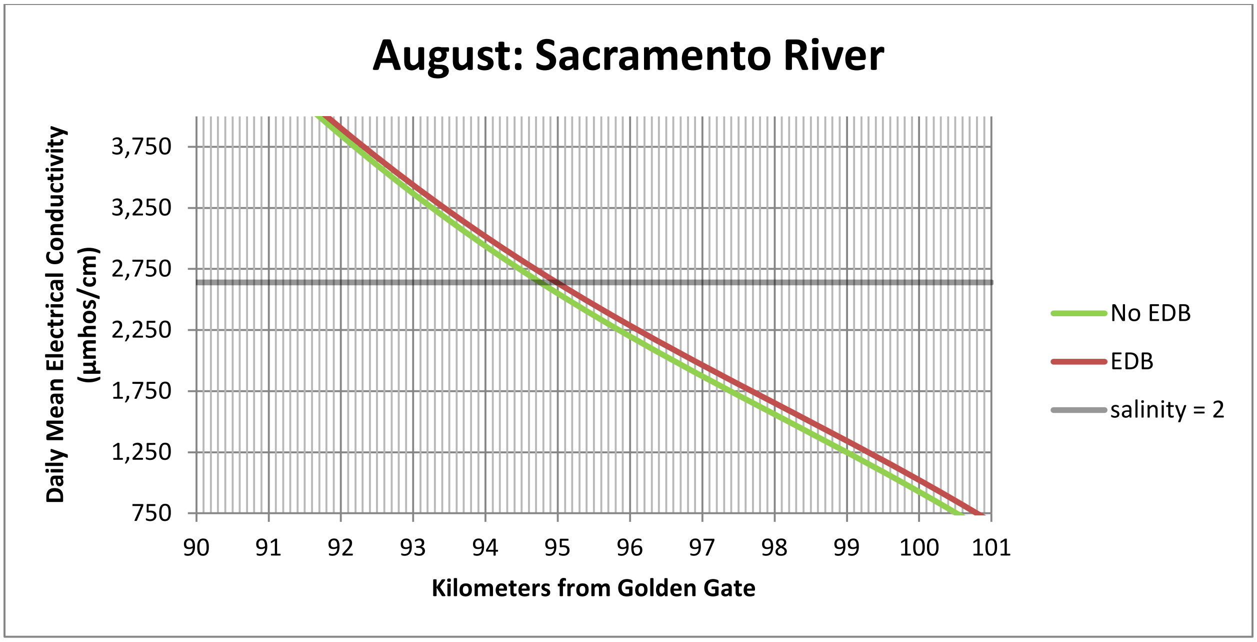
Conductivity at locations further downstream (e.g., Collinsville and Mallard Island) would be only minimally affected by the EDB (Figures 24 and 25).

Water quality within the Cache Slough complex is of particular interest because of that area's importance to delta smelt as year-round habitat (Sommer and Mejia 2013). Based on the simulated hydrology (see summary in Appendix C), conductivity for June 1-October 31 was relatively low for the EDB and no-EDB scenarios at Cache Slough at Ryer Island (Figure 26) and at Barker Slough (Figure 27), with only slightly greater conductivity under the EDB scenario.



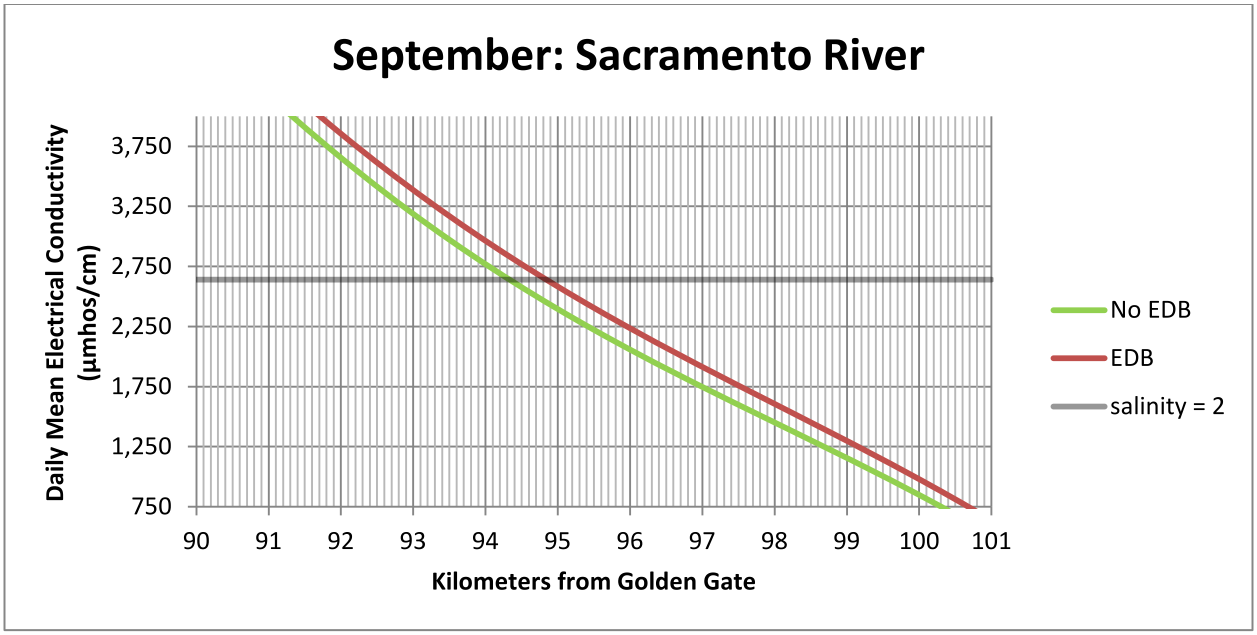
Source: Tu, pers. comm. Note: The plot is based on interpolation of mean daily electrical conductivity at Mallard Island (75 km), Collinsville (81 km), Emmaton (92 km), and Rio Vista (101 km), and focuses on a portion of the full range in order to show the approximate location of salinity = 2 (i.e., X2). Scenarios include no EDB and EDB (West False River Barrier). Delta operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). EDB assumed installed June 1, removed October 31.

Figure 20. Mean Daily Electrical Conductivity By River Kilometer in July, from DSM2-HYDRO Modeling, Based on Simulated Hydrology and Delta Cross Channel Operated Per D-1641.



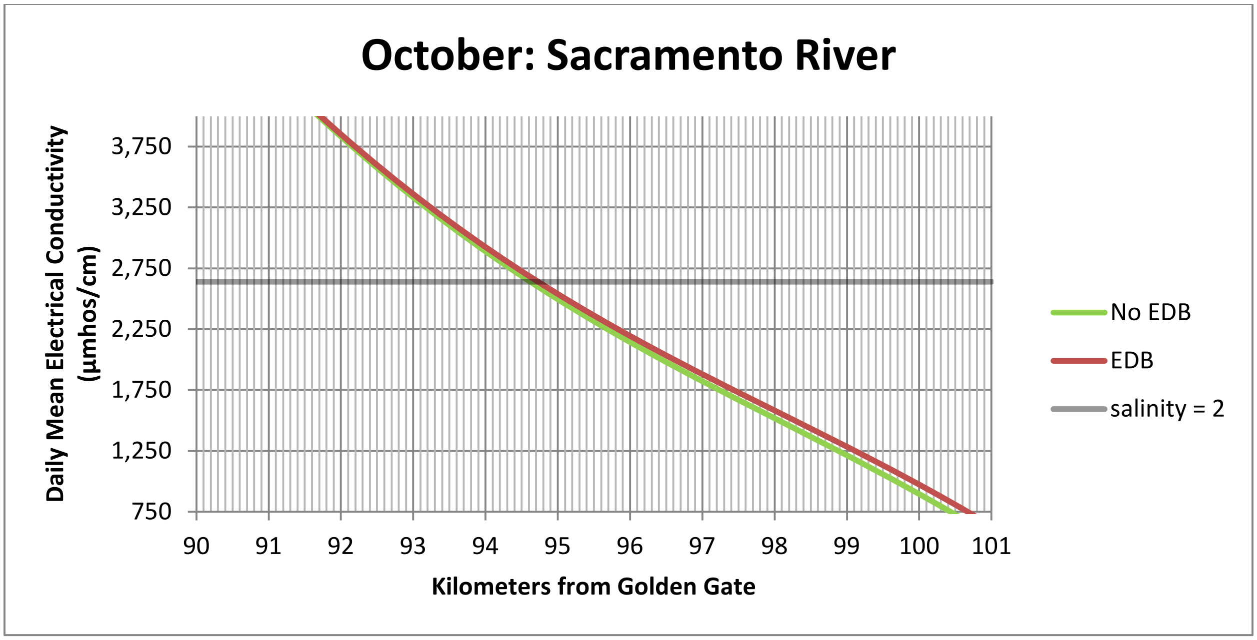
Source: Tu, pers. comm. Note: The plot is based on interpolation of mean daily electrical conductivity at Mallard Island (75 km), Collinsville (81 km), Emmaton (92 km), and Rio Vista (101 km), and focuses on a portion of the full range in order to show the approximate location of salinity = 2 (i.e., X2). Scenarios include no EDB and EDB (West False River Barrier). Delta operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). EDB assumed installed June 1, removed October 31.

Figure 21. Mean Daily Electrical Conductivity By River Kilometer in August, from DSM2-HYDRO Modeling, Based on Simulated Hydrology and Delta Cross Channel Operated Per D-1641.



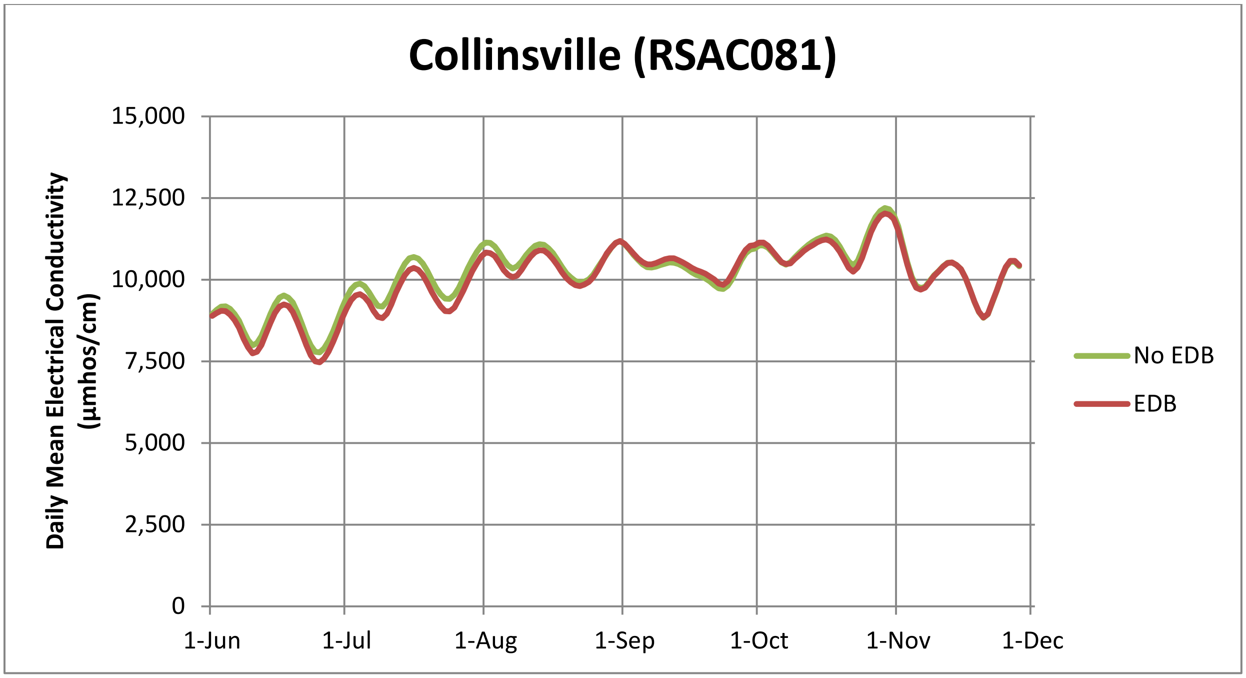
Source: Tu, pers. comm. Note: The plot is based on interpolation of mean daily electrical conductivity at Mallard Island (75 km), Collinsville (81 km), Emmaton (92 km), and Rio Vista (101 km), and focuses on a portion of the full range in order to show the approximate location of salinity = 2 (i.e., X2). Scenarios include no EDB and EDB (West False River Barrier). Delta operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). EDB assumed installed June 1, removed October 31.

Figure 22. Mean Daily Electrical Conductivity By River Kilometer in September, from DSM2-HYDRO Modeling, Based on Simulated Hydrology and Delta Cross Channel Operated Per D-1641.



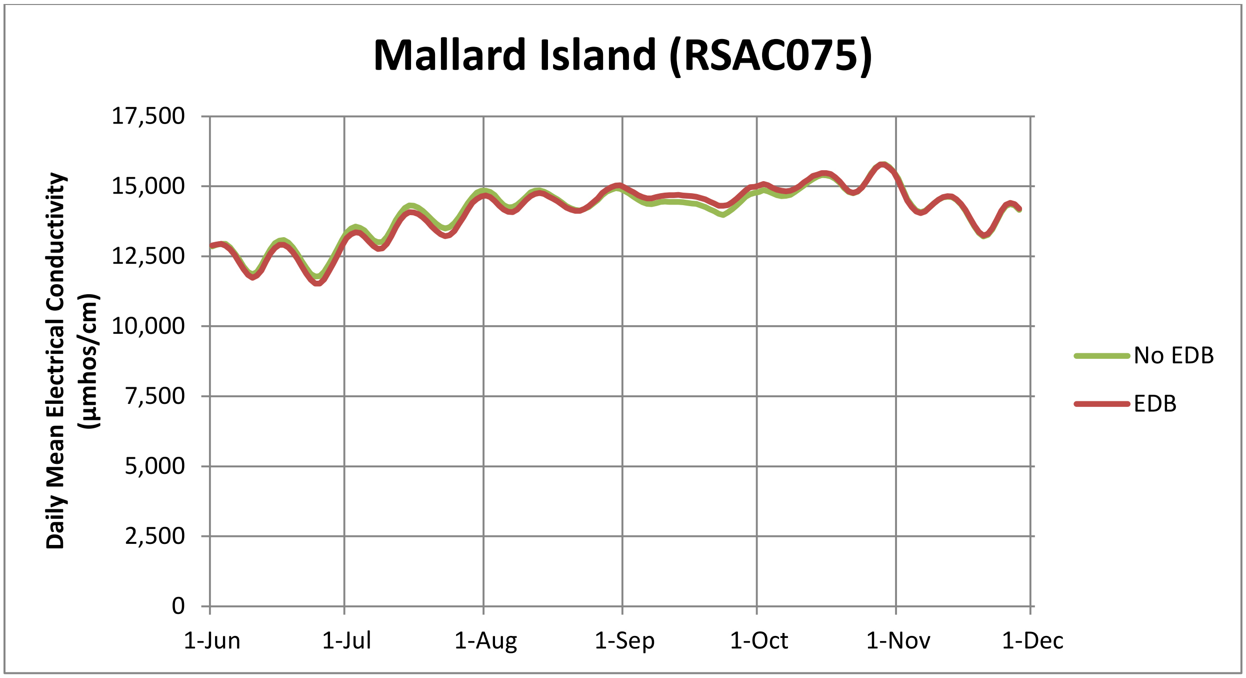
Source: Tu, pers. comm. Note: The plot is based on interpolation of mean daily electrical conductivity at Mallard Island (75 km), Collinsville (81 km), Emmaton (92 km), and Rio Vista (101 km), and focuses on a portion of the full range in order to show the approximate location of salinity = 2 (i.e., X2). Scenarios include no EDB and EDB (West False River Barrier). Delta operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). EDB assumed installed June 1, removed October 31.

Figure 23. Mean Daily Electrical Conductivity By River Kilometer in October, from DSM2-HYDRO Modeling, Based on Simulated Hydrology and Delta Cross Channel Operated Per D-1641.



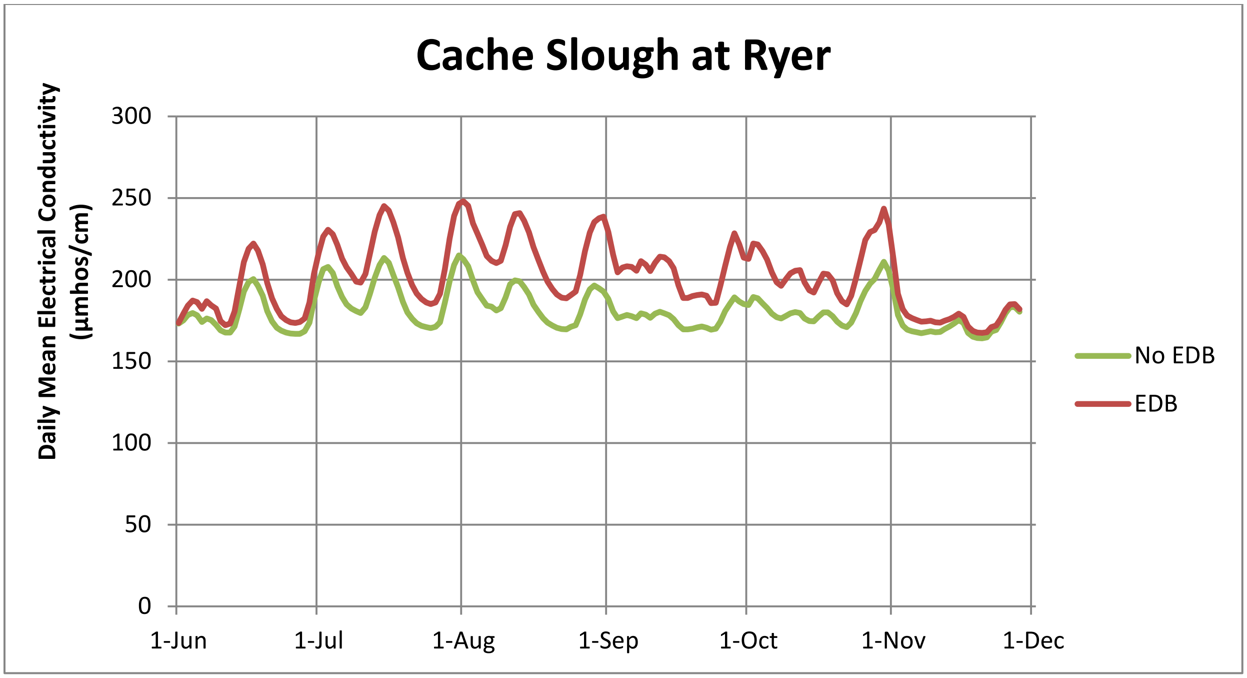
Source: Tu, pers. comm. Note: Scenarios include no EDB and EDB (West False River Barrier). Delta operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). EDB assumed installed June 1, removed October 31.

Figure 24. Mean Daily Electrical Conductivity at Collinsville from June 1 to November 30, from DSM2-HYDRO Modeling, Based on Simulated Hydrology and Delta Cross Channel Operated Per D-1641.



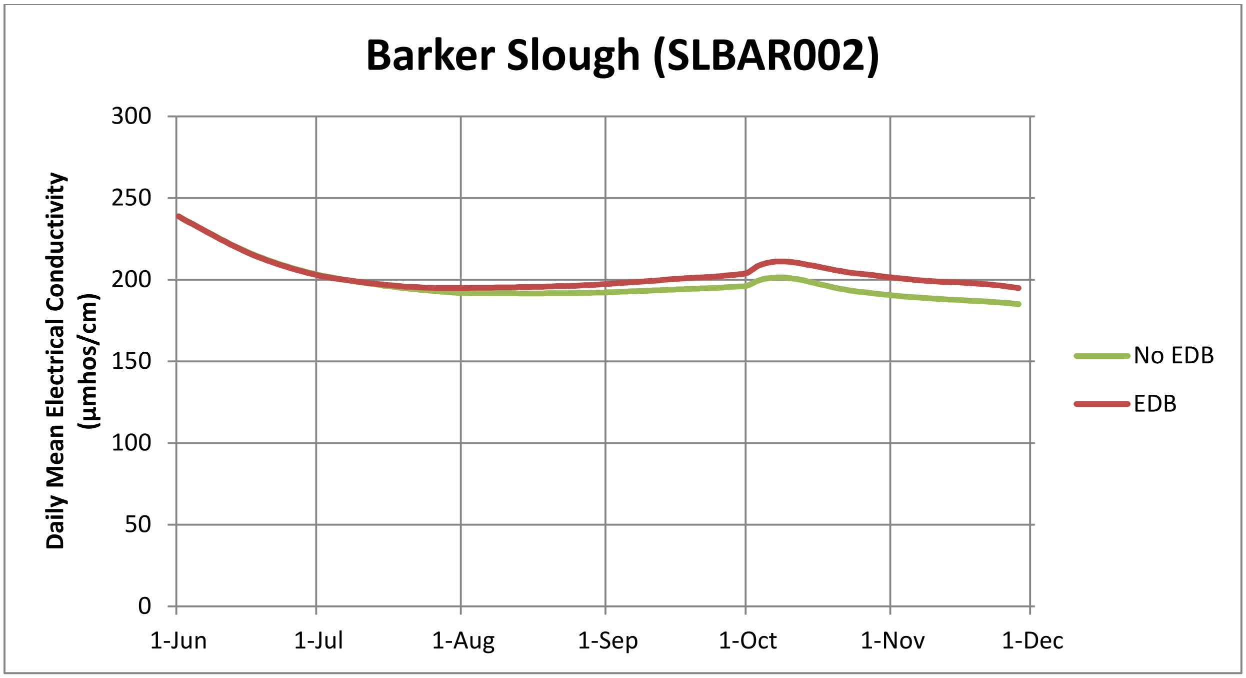
Source: Tu, pers. comm. Note: Scenarios include no EDB and EDB (West False River Barrier). Delta operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). EDB assumed installed June 1, removed October 31.

Figure 25. Mean Daily Electrical Conductivity at Mallard Island from June 1 to November 30, from DSM2-QUAL Modeling, Based on Simulated Hydrology and Delta Cross Channel Operated Per D-1641.



Source: Tu, pers. comm. Note: Scenarios include no EDB and EDB (West False River Barrier). Delta operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). EDB assumed installed June 1, removed October 31.

Figure 26. Mean Daily Electrical Conductivity at Cache Slough at Ryer Island from June 1 to November 30, from DSM2-QUAL Modeling, Based on Simulated Hydrology and Delta Cross Channel Operated Per D-1641.



Source: Tu, pers. comm. Note: Scenarios include no EDB and EDB (West False River Barrier). Delta operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015). EDB assumed installed June 1, removed October 31.

Figure 27. Mean Daily Electrical Conductivity at Barker Slough from June 1 to November 30, from DSM2-QUAL Modeling, Based on Simulated Hydrology and Delta Cross Channel Operated Per D-1641.

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 West False River barrier.

As described in the Conservation Measures section and for juvenile salmonids above, 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 West False River barrier 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 (sheet piles and king piles) at the West False River barrier would be left in place. As noted in the Project Description and as described for juvenile salmonids above, the sheet piles would extend approximately 75 feet from the levee into the river channel; installation of rock transitions would be done to limit the potential for creation of hydrodynamic eddies that could form ambush habitat for predatory fishes, although some enhanced level of predation on delta smelt could still occur (primarily to adults moving into nearshore areas to spawn, or to avoid ebb tides during upstream spawning migration), which would be attributable to the presence of the remaining structures.

Emergency Implementation Earlier Than Proposed Dates

As outlined in the Project Description, the EDB is proposed for construction no earlier than May 4. However, it is possible that emergency implementation earlier than the proposed dates may be necessary. This section discusses potential effects of emergency implementation earlier than the proposed dates.

NMFS-Managed Species

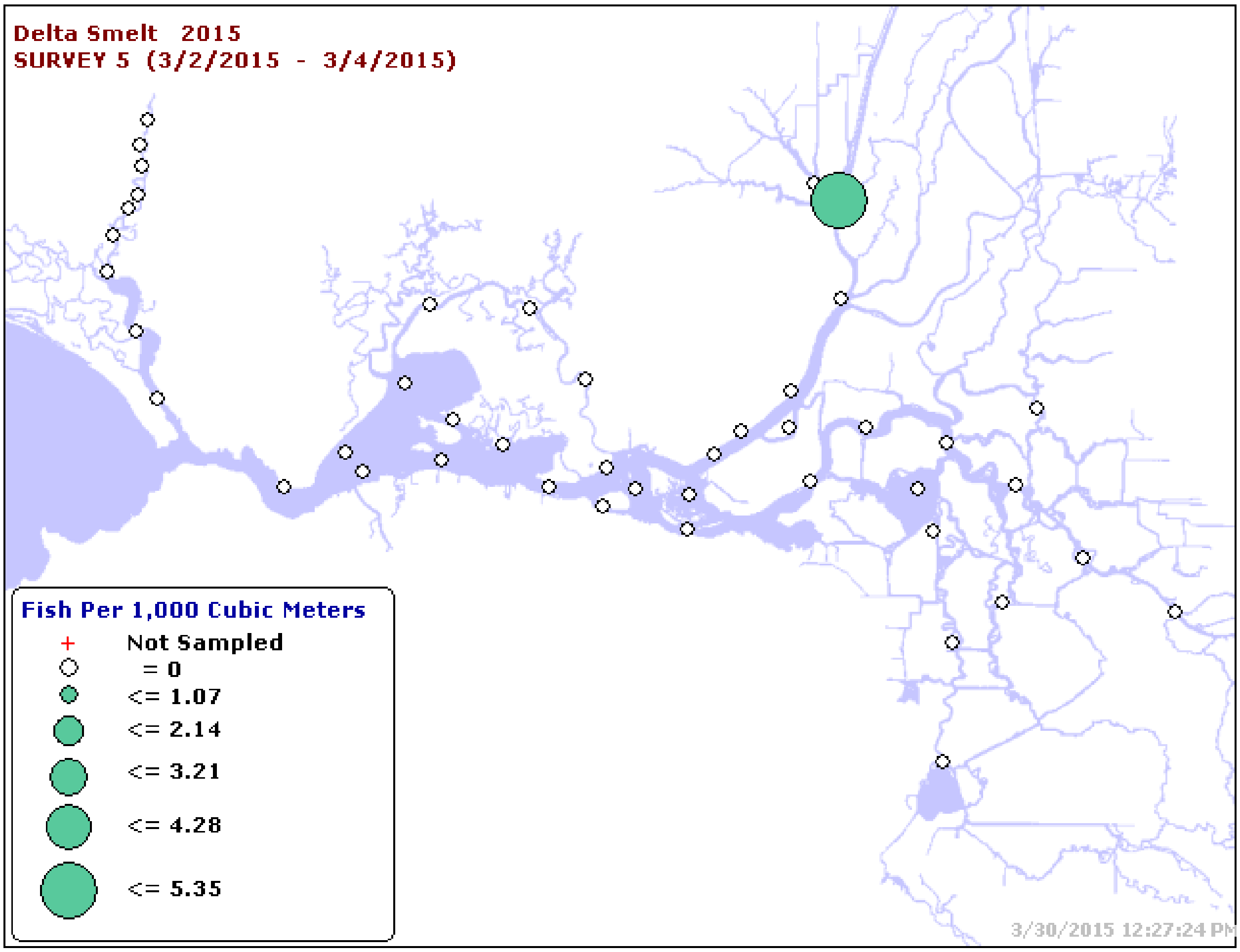
Should the EDB require emergency implementation earlier than the proposed dates described in the Project Description (i.e., construction beginning no earlier than May 4), the potential for adverse effects to NMFS-managed species would increase. This is because, in general, there would be greater overlap with the temporal occurrence of these species in the Delta, which is greater in late winter/early spring:

- Sacramento River winter-run Chinook salmon
  - Juvenile greatest abundance is in January-March (Table 4 and Table 11)
  - Adult greatest abundance is in February-April (Table 4 and Table 12)
- Central Valley spring-run Chinook salmon
  - Juvenile greatest abundance is in March-April (Table 6 and Table 11)
  - Adult greatest abundance is in April-June (Table 6)
- Central Valley steelhead
  - Juvenile greatest abundance is in March-April (Table 8 and Table 11)
  - Adult greatest abundance is in September/October, and there would be few individuals expected to be encountered after February/March (Table 8)
- Southern DPS of green sturgeon
  - Juveniles are present year-round (Table 9)
  - Adult greatest abundance is in March-April (Woodbury pers. comm.)

Implementation of the EDB earlier than May therefore would have the potential to affect a greater proportion of the NMFS-managed species occurring in the Delta, through the construction and operational effects previously discussed.

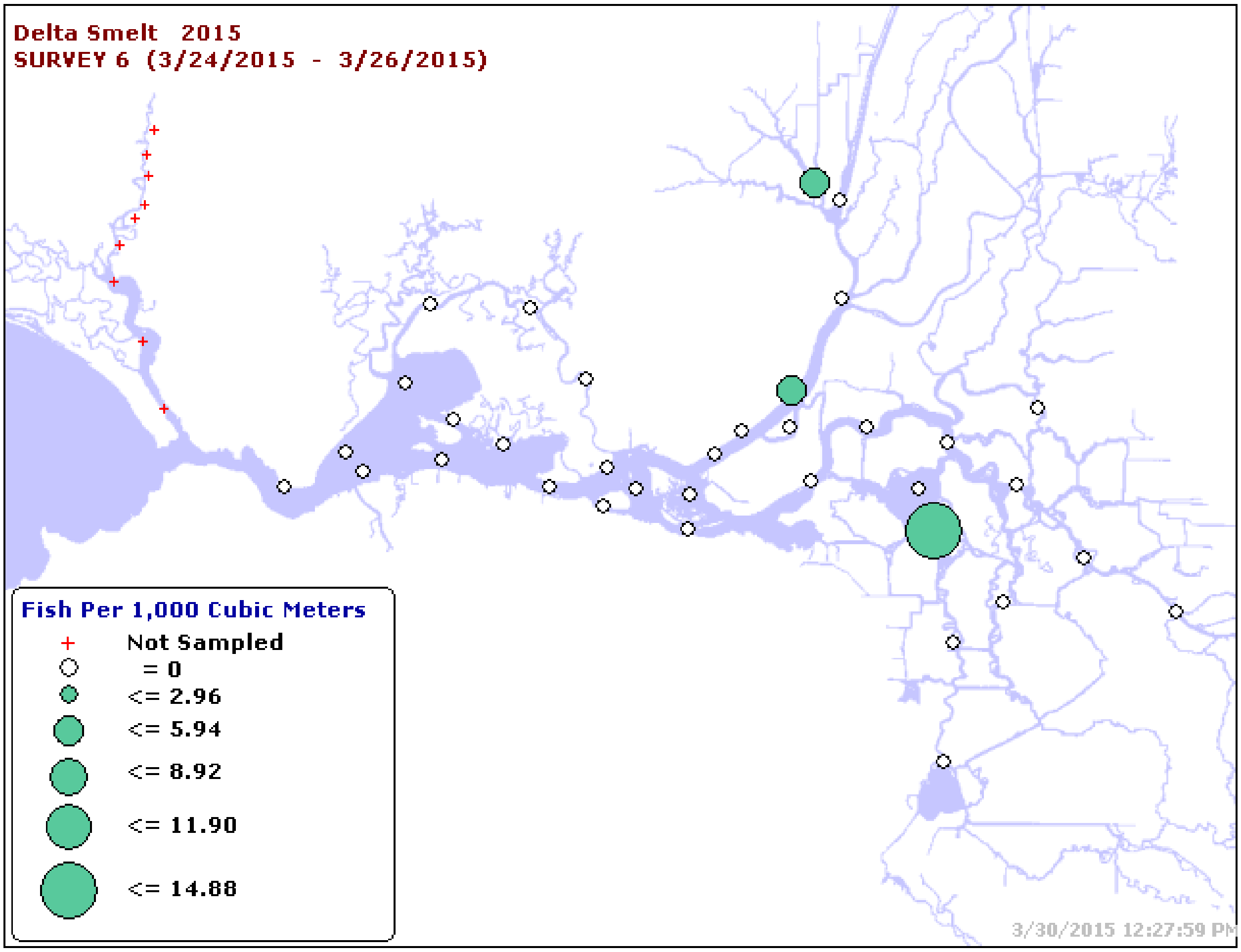
Delta Smelt

As with NMFS-managed species, the potential for effects on delta smelt from the EDB generally would be expected to increase with emergency implementation of the EDB earlier than the dates proposed in the Project Description (i.e., construction beginning no earlier than May 4). In 2015, delta smelt larvae first were collected during survey 5 (March 2-4) of the Smelt Larva Survey (Figure 28) in the lower portion of the Sacramento Deep Water Ship Channel. During survey 6 (March 24-26), collections of larvae were made in Cache Slough, the lower Sacramento River,and lower Old River near Franks Tract (Figure 29). Early juvenile delta smelt tend to move downstream towards the low salinity zone and would be expected to be further upstream earlier in their lives (Dege and Brown 2004). Earlier implementation of the EDB therefore would have greater potential to affect delta smelt as described above in the the sections discussing Construction and Removal Effects on Fish and Operations Effects on Fish.



Source: http://www.dfg.ca.gov/delta/data/sls/CPUE_Map.asp

Figure 28. Larval Delta Smelt Density from Smelt Larva Survey 5 of 2015.



Source: http://www.dfg.ca.gov/delta/data/sls/CPUE_Map.asp

Figure 29. Larval Delta Smelt Density from Smelt Larva Survey 6 of 2015.

Removal of West False River Barrier Later Than Proposed Date

As noted in the Project Description, the West False River Barrier is proposed to be fully removed by November 15. However, the size of the barrier and the logistical challenges its removal presents could result in removal extending beyond November 15, up to November 30. This section discusses potential effects of removal of the West False River Barrier later than the proposed date.

NMFS-Managed Species

In general, the potential for adverse effects to NMFS-managed species from removal-related disturbance would somewhat increase with later removal of the West False River Barrier. This is because there would be greater overlap with the temporal occurrence of these species in the Delta, which becomes more frequent as temperatures cool:

- Sacramento River winter-run Chinook salmon
    - Juvenile abundance tends to increase greatly in December, with a small proportion of fish occurring in November (Table 4 and Table 11)
    - Adult occurrence in the Sacramento River begins in November/December (Table 4 and Table 12)
- Central Valley spring-run Chinook salmon
    - Juvenile greatest abundance in the lower Sacramento River begins to increase greatly in December (Table 6)
- Central Valley steelhead
    - Juvenile abundance begins to increase in October-January, with greatest abundance in spring (Table 8 and Table 11)
    - Adult greatest abundance generally has passed by mid-November for the Sacramento River, but greatest abundance is in December-January for the San Joaquin River (Table 8)
- Southern DPS of green sturgeon
    - Juveniles are present year-round (Table 9)
    - Adult greatest abundance is in March-April (Woodbury pers. comm.), with removal at any time in November expected to coincide with only low abundance of adults (Table 9)

Removal of the EDB by November 30 therefore generally would have the potential to affect a somewhat greater proportion of the NMFS-managed species occurring in the Delta than removal by November 15.

Delta Smelt

As with NMFS-managed species, the potential for effects on delta smelt from removal of the West False River barrier generally would be expected to increase somewhat with removal by November 30 compared to removal by November 15. As the water in the Delta cools, it would be expected that delta smelt would find a greater extent of habitat more hospitable and therefore to have more potential to occur in the West False River barrier area. However, the onset of greatest upstream migration at this time of year is associated with major increases in turbidity from seasonal rainfall, particularly first flush events in early winter (Sommer et al. 2011). Full removal of the West False River barrier later than November 15 and as late as November 30 would increase the likelihood of overlapping such events. Note, however, that removal of the barrier is proposed for completion in November to reduce the risk of overlap with major precipitation events in order to minimize flooding risks. In general, later removal therefore would somewhat increase the potential to affect delta smelt by the mechanisms described above in the the sections discussing Construction and Removal Effects on Fish.

Effects on Critical Habitat

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

The West False River barrier would have an aquatic footprint of 2.90 acres. The duration of the physical "smothering" of the channel bottom by the rocks of the barrier would be approximately three to four months or less, depending on construction and removal dates, except for 1.00 acres that would be permanently filled. Disturbance of the channel substrate due to the installation and removal of the EDB, 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 EDB would affect salmonids migrating through the Action Area. As previously described, the hydrodynamic effects of the West False River barrier could affect the migration success of a small proportion of the juvenile Chinook salmon and steelhead out-migrant populations from the Sacramento River watershed by slightly increasing the likelihood of entering the interior Delta through Georgiana Slough and the DCC, and by slightly reducing the net flow in the lower Sacramento River and Sutter/Steamboat sloughs. As described previously, the EDB also would create an impediment to free movement of fish within False River (e.g., for adult salmonids), as well as potentially attracting predatory fish and creating areas that enhance the foraging success of predatory fishes on juvenile salmonids passing through the reaches affected by the placement of the barrier. These effects, although periodic and very small, 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) were spilled or entered the river. These potential effects would be minimal because they would be temporary. DWR will 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 will also describe procedures for minimization of effects from vessel traffic collision with the West False River barrier once installed. Additionally, DWR will 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 EDB project 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 EDB would disturb and reduce benthic habitat in the area occupied by the West False River 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, and potentially water quality, would be affected by construction and removal of the EDB. River flow and salinity would not be affected by the construction of the EDB, 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 installed would be limited to the footprint area of the West False River barrier. Approximately 2.90 acres of delta smelt critical habitat, in the form of physical habitat, would be adversely affected by the EDB. Additionally, construction activities could potentially impair water quality if hazardous chemicals (e.g., fuels and petroleum-based lubricants) or other construction materials are spilled or enter the waterways near the EDB. This risk is limited to the construction period and is not likely to occur because of the proposed conservation measures, including a spill prevention and control plan to ensure avoidance of any accidental spills or releases. As such, it is anticipated that there would be minimal, if any, effects on the water PCE from construction and removal activities. As noted above for salmonids, the spill prevention plan also will include procedures for minimizing the effects of any vessel collisions with the West False River barrier once installed.

As described in the Operations Effects on Fish section, barrier operation would result in salinity moving marginally further upstream on the lower Sacramento River. This change could lessen the quantity of abiotic habitat available for delta smelt in the lower Sacramento River and Sacramento-San Joaquin Rivers confluence area, but the effect would be very small.

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 EDB would be implemented.

Chinook Salmon EFH

The effects of the proposed action on salmonid habitat have been 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 were it to begin in May (Table 11). A minor proportion of downstream-migrating fall-run Chinook juveniles could be exposed to the tail end of the EDB operational period in October, and could also be exposed to EDB removal in September/October/November (Table 11). Late fall-run Chinook salmon compose a much smaller proportion of the two runs making up the ESU and juveniles tend to peak in downstream migration during October (Moyle et al. 2008), coinciding with the period of EDB 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). EDB construction would be expected to have some overlap with the early portion of the adult fall-run Chinook salmon upstream migration only if the construction began in summer (e.g., in July), whereas construction at the earliest proposed date (May 4) would result in less potential for effect. EDB operations (potentially stretching from early June to October) would be expected to appreciably overlap fall-run Chinook salmon upstream migration and would have the potential for effects to EFH discussed previously under Adult Migration Pathways in the Hydrodynamic Effects assessment for Chinook salmon and Central Valley steelhead. 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 the EDB operational period in October and during removal effects in September/October/November; nearly 40% of the population passes above RBDD in October and November. It is not anticipated that there would be any effects to late fall-run Chinook salmon adults from EDB construction activities.

Starry Flounder and Northern Anchovy EFH

Installation and operation of the EDB may 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 EDB 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 has been collected from this sampling program 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 West False River barrier.

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

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 EDB.

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 EDB would be unlikely to measurably change the dilution of any contaminants that are discharged into Delta waterways because changes in diluting flows would be very small (e.g., marginally less Sacramento River flow entering Sutter and Steamboat sloughs).

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 proposed project to assist with avoiding and minimizing potential environmental impacts from the proposed project, including those to the listed fishes included in this BA.

Prepare and Implement an Erosion Control Plan

An Erosion Control Plan will be prepared before 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. If 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 uses be notified immediately of any substantial spill or release.

Implement Bay Area Air Quality Management District Basic and Enhanced Construction Emission Control Practices to Reduce Fugitive Dust

The construction contractor will implement the following applicable basic and enhanced control measures recommended by the Bay Area Air Quality Management District (BAAQMD) to reduce construction-related fugitive dust during site grading at the West False River project site (BAAQMD 2010):

- All exposed surfaces (e.g., parking areas, staging areas, soil piles, graded areas, and unpaved access roads) will be watered two times per day, as necessary to control fugitive dust.
- All haul trucks transporting soil, sand, or other loose material off-site will be covered.
- All visible mud or dirt track-out onto adjacent public roads will be removed using wet power vacuum street sweepers at least once per day. The use of dry power sweeping will be prohibited.
- All vehicle speeds on unpaved roads will be limited to 15 miles per hour.
- All construction equipment will be maintained and properly tuned in accordance with manufacturer's specifications. All equipment will be checked by a certified mechanic and will be determined to be running in proper condition before operation.
- A publicly visible sign with the telephone number and person to contact at the lead agency (i.e., DWR) regarding dust complaints will be posted at the construction sites. The person identified as the contact will respond and take corrective action within 48 hours. The air district's phone number also will be visible, to ensure compliance with applicable regulations.
- Idling time of diesel-powered construction equipment will be no more than 5 minutes.
- All contractors will be required to use equipment that meets the California Air Resources Board's most recent certification standard for off-road heavy-duty diesel engines.

In addition, the construction contractor will implement the following applicable enhanced measures to reduce operation-related diesel particulate matter:

- Acceptable options for reducing emissions may include use of late model engines, low-emission diesel products, alternative fuels, engine retrofit technology, after-treatment products, and other options as they become available.

Reduce Construction-Related Emissions from Off-Road Equipment and Heavy-Duty Vehicles

The following measure from the BAAQMD's Additional Construction Mitigation Measures will be implemented during construction at the West False River project site (BAAQMD 2010):

- All contractors will be required to use equipment that meet California Air Resources Board's most recent certification standard for off-road heavy duty diesel engines.

Fuel Tugboats/Barges with Renewable Diesel Fuel

All tugboats/barges will be fueled using renewable diesel fuel. The fuel provider could include, but is not limited to Golden Gate Petroleum. However, all renewable diesel fuel used from other providers will achieve a similar emissions reduction potential to Golden Gate Petroleum renewable diesel. In the case that renewable diesel cannot be used for tugboats/barges for logistic reasons, this will be recorded in the bi-weekly construction reports, and incorporated into the final emissions and mitigation fee calculations.

Use Construction Monitoring and BAAQMD Carl Moyer Program or Another Verifiable Offset Program to Offset Regional Off-Site Emissions

DWR and/or its contractor will monitor construction activities throughout construction of the barrier. Construction activities data will be collected, emissions associated with construction activities will be calculated, and these data will be reported to the BAAQMD. The specifics of construction monitoring and reporting will be determined in consultation with BAAQMD. Construction activities data will include, but are not limited to the following items:

1. Tugboats/Barges
    a. Distance traveled by tugboats/barges separated by “loaded” travel and “unloaded” travel.
    b. Horsepower of tugboats and auxiliary engines
    c. Idling time of tugboats/barges
    d. Fuel use and fuel type
2. Construction Equipment
    a. Equipment type and number of pieces
    b. Horsepower
    c. Hours of actual operation
3. Haul Trucks (heavy-duty trucks)
    a. Number of heavy-duty haul truck trips
    b. Total trip distance for haul truck trips
4. Construction Workers
    a. Number of construction workers per day

BAAQMD will collect the construction activity and emissions reports for record keeping and monitoring purposes. Following completion (i.e., removal of the barrier) of the proposed project, the final construction emissions will be evaluated to calculate the total offset mitigation fee based on actual construction activities. DWR will work in coordination with BAAQMD to assess the specific mechanisms associated with construction monitoring, emission calculations, and payment logistics.

DWR will use BAAQMD’s Carl Moyer Program (CMP) or another verifiable program to offset the proposed project’s reactive organic gases, oxides of nitrogen (NO_X), and particulate matter emissions that exceed the BAAQMD 2010 threshold as determined through the construction monitoring program described above. DWR may achieve the required offset through any combination of the following:

- Reduce on-site emission sources and implement offset actions (i.e., construction or operational changes to site-specific emissions).
- Implement offset emissions and programs available within Contra Costa County and the San Francisco Bay Area Air Basin (SFBAAB).
- Submit payment to BAAQMD on a per ton of NO_X amount (i.e., dollars per ton of NO_X to offset) for emission reduction projects that will be funded by BAAQMD. The price of NO_X emission offsets will be determined by BAAQMD on an annual basis. The types of projects that will be funded by BAAQMD can include:
  - Projects within the Contra Costa County and/or the SFBAAB that are eligible for funding under the CMP guidelines, which are real, surplus, quantifiable, and enforceable.
  - Projects to replace older, high-emitting construction equipment operating in Contra Costa County and/or the SFBAAB with newer, cleaner, retrofitted, or more efficient equipment.

Conform to Best Management Practices (BMPs) for Construction and Maintenance Activities to Reduce Greenhouse Gas Emissions that are Contained in the Climate Action Plan Phase I: Greenhouse Gas Emissions Reduction Plan Implementation Procedures (DWR 2012)

DWR will implement the following measures for the proposed project:

Pre-Construction and Final Design BMPs

1. Evaluate project characteristics, including location, project work flow, site conditions, and equipment performance requirements, to determine whether specifications of the use of equipment with repowered engines, electric drive trains, or other high efficiency technologies are appropriate and feasible for the project or specific elements of the proposed project.
2. Evaluate the feasibility and efficacy of performing on-site material hauling with trucks equipped with on-road engines.
3. Ensure that all feasible avenues have been explored for providing an electrical service drop to the construction site for temporary construction power. When generators must be used, use alternative fuels, such as propane or solar, to power generators to the maximum extent feasible.
4. Limit deliveries of materials and equipment to the construction sites to off-peak traffic congestion hours.

Construction BMPs

5. Minimize idling time by requiring that construction equipment be shut down after 5 minutes when not in use, as required by the State airborne toxics control measure in Section 2485 of Title 13 in the California Code of Regulations. Provide clear signage that posts this requirement for construction workers at the entrances to construction sites and provide a plan for the enforcement of this requirement

6. Maintain all construction equipment in proper working condition and perform all preventative maintenance. Required maintenance will include compliance with all manufacturer's recommendations, proper upkeep and replacement of filters and mufflers, and maintenance of all engine and emissions systems in proper operating condition.

7. Implement a tire inflation program at construction sites to ensure that equipment tires are correctly inflated. Check tire inflation when equipment arrives on-site and every 2 weeks for equipment that remains on-site. Check vehicles used for hauling materials off-site weekly for correct tire inflation.

8. Develop a project-specific ride share program to encourage carpools, shuttle vans, transit passes, and/or secure bicycle parking for construction worker commutes.

9. Reduce electricity use in temporary construction offices by using high efficiency lighting and requiring that heating and cooling units be Energy Star compliant. Require that all contractors develop and implement procedures for turning off computers, lights, air conditioners, heaters, and other equipment each day at close of business.

10. For deliveries to construction sites where the haul distance exceeds 100 miles and a heavy-duty class 7 or class 8 semi-truck or 53-foot or longer box-type trailer is used for hauling, a SmartWay2 certified truck will be used to the maximum extent feasible.

11. Develop a project-specific construction debris recycling and diversion program to achieve a documented 50 percent diversion of construction waste.

12. Evaluate the feasibility of restricting all material hauling on public roadways to off-peak traffic congestion hours. During construction scheduling and execution, minimize, to the extent possible, uses of public roadways that will increase traffic congestion.

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 (MBTA). 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 EDB 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 during barrier installation and removal and monitor pile driving activities. The qualifications of the biologist(s) will be presented to the permitting agencies for review and approval prior to project activities at the project site. The complete set of permitting documents will be onsite after construction begins. 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 documents (BOs, CESA ITP). If the biologist(s) exercise(s) 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. Compared to the standard impact driving method, vibratory driving substantially reduces the distance that noise exceeds NMFS thresholds, thereby substantially reducing or avoiding 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. Monitoring of underwater sound generated by the vibratory 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 as calculated in the effects analysis (i.e., 214 decibels [dB] cumulative sound exposure level [SEL] at approximately 33 feet [10 meters], for each day of 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.

If impact driving is necessary, bubble curtains will be employed to attenuate noise. As noted above for vibratory driving, monitoring of underwater sound generated by impact driving will be conducted to verify that sound level criteria are not being exceeded as calculated in the effects analysis (i.e., 218 dB cumulative SEL at approximately 33 feet [10 meters], for each day of 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.

Should EDB installation occur in summer (e.g., July), DWR will confer with the permitting fish agencies regarding the need for sound monitoring and restrictions on pile driving during a period in which few listed fishes would be likely to be exposed to excessive sound levels.

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 emergency drought barrier, to advise boaters about the presence of the emergency drought 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. 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 State Water Resources Control Board and permitting fish agencies to determine the most appropriate BMPs to minimize turbidity impacts to the maximum extent feasible.

Develop a Water Quality Monitoring Plan to Monitor Water Quality

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 by using solar-powered monitoring instruments. DWR proposes to install twelve permanent water quality and/or flow monitoring stations. DWR would install the stations at strategic locations from Middle River in the south to Liberty Island in the north and Grizzly Bay or Cutoff Slough in the west. In addition to the new permanent stations, DWR may assess monitoring data from existing and recently updgraded stations throughout the Delta.

The stations will be used to 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 new monitoring sites and augmentation of existing 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.

Return Disturbed Areas to Pre-Project Conditions And Conserve Habitat

DWR and its construction contractors will strive to limit vegetation removal during project-related construction activities. Immediately following barrier removal, DWR will restore habitat to approximate pre-project conditions using native vegetation only. DWR will mitigate through an approved mitigation bank for impacts on shallow water habitat at a 3:1 ratio for permanent impacts and a 1:1 ratio for temporary impacts.

Limit Land-Based Access Routes and Construction Area

The number of land-based access routes and each 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.

Work with North Delta Water Agency to Minimize Salinity Changes for Water Users within the Agency's Boundaries

DWR will reach agreement with North Delta Water Agency to ensure that any salinity increases remain below the State Water Resources Control Board limits set in Water Rights Decision 1641 as amended. DWR remains committed to fulfilling its commitments in the 1981 Contract between State of California Department of Water Resources and North Delta Water Agency for the Assurance of a Dependable Water Supply of Suitable Quality.

Conduct Scour Monitoring

Prior to installation of the emergency drought barrier, DWR will use low-level aerial surveys to conduct aerial video and photo documentation of the existing conditions, critical channels, and levees (mainly at Fisherman's Cut and Dutch Slough). Similar flights would also be conducted following barrier removal. Aerial video and photo documentation both before barrier installation and after barrier removal would be compared. Bathymetric surveys will also be conducted prior to installation of the barrier and after removal and the results will be compared. Although damage to levees or property is not anticipated based on the expected worse case velocities, DWR will be responsible for repairing any damage documented and verified through the pre- and post-construction surveys.

Maintain Sheet Piles and Rock Fill

DWR will assure that the sheet piles and rock fill are maintained. DWR will either contract with the Local Maintaining Agency (LMA) or use DWR resources or contractors to repair and or replace the transition rock as needed. If DWR determines that they are no longer functional or a safety issue is identified with the sheet piles that cannot be mitigated through other means, they will be removed either by cutting them off with a torch or driving them into the grade. If removal is needed, DWR will coordinate with the LMA on a removal plan.

Inspections of the sheet piles and rock will compare actual conditions with as constructed plans and/or bathymetric survey data. The results of the inspections and any bathymetric survey data collected will be made available to the LMAs. Any necessary repairs of the rock will be made using land or water-based construction equipment during summer and fall (July through October) when special-status species are less likely to be affected.

If maintenance or removal of the sheet piles or rock fill is deemed necessary, DWR or the LMA will seek authorization from the applicable resources agencies (i.e., USACE, USFWS, NMFS, and CDFW).

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 water hyacinth, Brazilian elodea (*Egeria Densa*) or other invasive water weeds covered by the control program in the vicinity of the barrier while the barrier is in place. As needed, the Division of Boating and Waterways will conduct herbicide treatments to control water hyacinth that may result from in changes flow from installation of the barrier. DWR will coordinate with the Division of Boating and Waterways on removal strategies for water hyacinth or other covered invasive water weeds as necessary to assure that the barrier does not exacerbate current aquatic invasive weed problems.

Coordinate Traffic Management Plans with Contra Costa County

DWR will coordinate a traffic management plans with Contra Costa County for construction traffic and haul routes. DWR will document pre- and post-construction haul route conditions, if applicable, and will repair any documented pavement damage from heavy equipment.

Minimize Impacts to Ferry Service

If needed, DWR will work with the Delta Ferry Authority to implement solutions to minimize impacts to ferry service as a result of installation of the barrier should changes in water flow or growth of aquatic weeds become an issue for normal ferry operations. Coordination will occur during construction, while the barrier is in place, and during removal activities.

Conclusions

ESA-Listed Fish and Critical Habitat

It is concluded that the Emergency Drought Barrier Project will have adverse effects on all of the ESA-listed fish species occurring in the Action Area, and will adversely modify the critical habitat for the species with designated critical habitat in False River (Table 16).

Implementation of the above conservation measures will avoid or minimize adverse effects to the maximum extent practicable. The Emergency Drought Barrier Project would not jeopardize the continued existence of the ESA-listed species occurring in the Action Area.

Table 16. Effects Determinations on ESA-Listed Fishes and Critical Habitat From the Emergency Drought 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 Modify
North American green sturgeon designated critical habitat	X	May Affect, Likely to Adversely Modify
Delta smelt designated critical habitat	X	May Affect, Likely to Adversely Modify

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 Emergency Drought Barrier Project will have an adverse effect on EFH for Chinook salmon, starry flounder, and northern anchovy. Implementation of the above conservation measures will avoid or minimize adverse effects to the maximum extent practicable.

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Appendix A
Pile Driving Effects Analysis

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As described in the Emergency Drought Barrier Project Description section of this BA, the Emergency Drought Barrier project involves pile driving at the West False River barrier site in order to install two king pile-supported sheet pile walls extending 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'. In addition to the barrier piles, steel pipe piles would be driven for attachment of water quality monitoring instruments and float lines.

Pile driving would be conducted with a vibratory driver to the extent possible, with impact driving only used if vibratory driving is not possible. As described in the Conservation Measures section of this BA, attenuation (bubble curtains) would be provided should impact driving be necessary.

As described further below, this appendix uses the NMFS calculator workbook (BA_NMFSpileDrivCalcs.xls[15]), together with project-specific details for number and types of piles, in order to illustrate the potential pile driving-related effects of the EDB. Assumptions regarding potential noise from pile driving were derived from data collated in Appendix I of ICF Jones & Stokes and Illingworth & Rodkin (2009), as originally published by Illingworth & Rodkin (2007).

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)[16] 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

Note that the interim criteria adopted by the Fisheries Hydroacoustic Working Group (2008) are most relevant to impact pile driving, rather than the vibratory technique to be used to install the barrier at the West False River site. Recently proposed criteria suggest higher threshold levels that are specifically related to effects caused by vibratory hammers (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

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

[16] 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

Assumptions and Inputs for the Pile Driving Calculator Workbook

Barrier Piles

The following assumptions and inputs were developed for the pile driving associated with the West False River barrier. The West False River barrier would include eight 36-inch-diameter king piles (four per bank of the river). The approximate substrate depths (in feet) of the piles going from left to right are 50, 40, 25, and 20 (left bank); and 20, 30, 45, and 50 (right bank). Based on these estimates, a single value of 30 feet was used to simplify the calculations of pile driving effects. Sheet piles would be driven to somewhat shallower substrate depths than king piles; a mean value of 25 feet was assumed. Given 160 wall feet of sheet piles to be installed, this equates to approximately 35 pairs of sheet piles for both banks of the barrier (70 sheet piles total).

As described in the main body of the BA, vibratory driving penetration rates are normally limited to 20 inches per minute (i.e., 1.67 feet/minute, per North American Sheet Piling Associations – Best Practices, www.nasspa.com). Therefore the time to install the required number of piles would be as follows:

- Sheet piles: (70 piles) * (25-foot depth/pile)/(1.67-foot penetration depth/minute) = 1,050 minutes = 63,000 seconds;
- King piles: (8 piles) * (30-foot depth/pile) /(1.67-foot penetration depth/minute) = 144 minutes = 8,640 seconds.

Given the soft soil conditions typical of the Delta, faster driving rates may be possible, so the present analysis may provide a conservative estimate of driving time.

The NMFS pile driving calculator workbook was developed for impact driving as it requires an estimate of the number of strikes and the sound pressure associated with each strike. However, it is possible to use the workbook to make estimates for vibratory driving given sound pressure data that are representative of each second of driving (with each second representing a ‘strike’ for purposes of filling in the input to the workbook), and an estimate of the duration of vibratory driving. Estimates of sound pressure of vibratory driving for this BA were taken from the California

Department of Transportation's Compendium of Pile Driving Sound Data (Illingworth & Rodkin 2007: Table 1.2-2) as follows, based on the most comparable available data:

- King piles (Data from 36-inch steel pipe pile – loudest)
  - Peak pressure: 185 dB
  - RMS (Root mean square pressure, 35-millisecond average impulse level): 175 dB
  - SEL (Accumulated sound exposure level for 1 second of continuous driving): 175 dB
- Sheet piles (Data from 24-inch AZ steel sheet pile – loudest)
  - Peak pressure: 182 dB
  - RMS: 165 dB
  - SEL: 165 dB

These values were entered into the NMFS calculator workbook, with calculations made separately for sheet piles and king piles. Vibratory pile driving is likely to require several days for completion; therefore in addition to calculations based on all piles being installed on a single day, calculations also were made for piles being installed over two and four days to illustrate the range of potential acoustic effects. Note that the analysis did not attempt to account for the different locations of the piles across the river cross-section. Note also that the analysis was conducted under the assumption of stationary fish which, given the tidal nature of False River, may not represent back and forth movement of fish through the area of potential effect. The NMFS calculator workbook's default transmission loss constant of 15 was assumed in the analyses.

As noted in the project description, impact pile driving would only be used should vibratory driving be unsuccessful. A limited set of calculations were made to illustrate the potential area of effect from impact pile driving, assuming bubble curtains were used for attenuation (as is proposed in the Conservation Measures). Per ICF Jones & Stokes and Illingworth & Rodkin (2009: 4-10), it was assumed that bubble curtains would attenuate each of the acoustic metrics by 10 dB. Sound pressure data to illustrate impact driving potential effects were taken from Illingworth & Rodkin (2007: Table 1.2-1) as follows:

- King piles (Data from 36-inch steel pipe pile)
  - Peak pressure: 210 dB (assumed attenuated to 200 dB)
  - RMS: 193 dB (assumed attenuated to 183 dB)
  - SEL: 183 dB (assumed attenuated to 173 dB)
- Sheet piles (Data from 24-inch AZ steel sheet pile)
  - Peak pressure: 205 dB (assumed attenuated to 195 dB)
  - RMS: 190 dB (assumed attenuated to 180 dB)
  - SEL: 180 dB (assumed attenuated to 170 dB)

For each pile type, calculations were made to illustrate the effects of 10 impact strikes per pile and 100 strikes per pile (i.e., 80 and 800 strikes for king piles and 700 and 7,000 strikes for sheet piles).

The Excel workbook used for the barrier pile driving calculations is provided as an attachment to this BA (file BA_NMFSpileDrivCalcs_EDB_03312014.xls). This workbook has the following spreadsheets within it:

- Sheet 'intro': basic description provided by NMFS
- Sheet 'source': summary of information used in the analysis
- Sheet 'Calc_king_piles_1d_vib': calculations for vibratory driving of all king piles in one day
- Sheet 'Calc_king_piles_2d_vib': calculations for vibratory driving of all king piles in two days
- Sheet 'Calc_king_piles_4d_vib': calculations for vibratory driving of all king piles in four days
- Sheet 'Calc_sheet_piles_1d_vib': calculations for vibratory driving of all sheet piles in one day
- Sheet 'Calc_sheet_pile_2d_vib': calculations for vibratory driving of all sheet piles in two days
- Sheet 'Calc_sheet_pile_4d_vib': calculations for vibratory driving of all sheet piles in four days
- Sheet 'Calc_king_piles_80_str_imp_att': calculations for impact driving of all king piles with 10 strikes per pile (80 strikes total, all assumed to be in one day, with 10 dB of attenuation from bubble curtains)
- Sheet 'Calc_king_piles_800_str_imp_att': calculations for impact driving of all king piles with 100 strikes per pile (800 strikes total, all assumed to be in one day, with 10 dB of attenuation from bubble curtains)
- Sheet 'Calc_sheet_piles_700_str_imp_att': calculations for impact driving of all sheet piles with 10 strikes per pile (700 strikes total, all assumed to be in one day, with 10 dB of attenuation from bubble curtains)
- Sheet 'Calc_sheet_piles_7000_str_imp_att': calculations for impact driving of all sheet piles with 100 strikes per pile (7,000 strikes total, all assumed to be in one day, with 10 dB of attenuation from bubble curtains)

Monitoring and Float Line Piles

As described in the project description and in the Conservation Measures section, six 12-inch steel pipe piles would be installed at various locations to support water quality monitoring equipment (i.e., water quality monitoring and/or flow monitoring stations at the twelve locations described in the project description). As with barrier piles described above, these piles would be installed with a vibratory pile driver. For the purposes of this analysis it was assumed that each pile would be driven

20 feet into the substrate and therefore would require 720 seconds of driving time. The potential effects of driving each pile were assessed as above for the barrier piles, but with the following sound pressure assumptions from Illingworth & Rodkin (2007: Table 1.2-2) for 12-inch steel pipe piles:

- Peak pressure: 171 dB
- RMS: 155 dB
- SEL: 155 dB

Float lines to warn boaters of the West False River barrier would be installed upstream and downstream of the barrier. These float lines each would have two 24-inch steel pipe piles. For each of these piles, the same drive time assumption (720 seconds) as for monitoring piles was used, in combination with sound pressure data for the most comparable piles from Illingworth & Rodkin (2007: Table 1.2-2), i.e., typical sound pressure levels for 36-inch steel pipe piles:

- Peak pressure: 180 dB
- RMS: 170 dB
- SEL: 170 dB

The Excel workbook used for the pile driving calculations for the monitoring and float line piles is provided as an attachment to this BA (file BA_NMFSpileDrivCalcs_EDB_extra_piles_04022014.xls). This workbook has the following spreadsheets within it:

- Sheet 'intro': basic description provided by NMFS

- Sheet 'source': summary of information used in the analysis

- Sheet 'Calc_12_inch_piles': calculations for vibratory driving of each 12-inch steel pipe pile for holding monitoring equipment

- Sheet 'Calc_24_inch_piles': calculations for vibratory driving of each 24-inch steel pipe pile for support of float lines

Results

Barrier Piles

For vibratory driving, the estimated cumulative SEL at 10 meters ranged from 207 to 214 dB (Table A1). The 206-dB peak for onset of physical injury was not reached for either pile type. The distance to the cumulative SEL required for onset of physical injury for fish ≥ 2 g ranged from 100 m (sheet piles, regardless of number of days taken to install) to 464 m (king piles, all piles installed in one day). For fish < 2 g, the 183-dB onset of physical injury threshold was 100 m for sheet piles and 464 m for king piles; these same distances applied to the distances for changes in behavior (Table A1). Overall, this analysis suggested that there would be potential for take of fishes from king pile driving that would extend up to almost 500 m from the location of pile driving, i.e., across the full width of

False River and upstream and downstream. Note, however, that based on criteria for vibratory driving (Hastings 2010, see above), this distance would be less.

Table A1. Results of Applying NMFS Pile Driving Calculator Workbook to Vibratory Driving for West False River Barrier Construction

Pile Type	Number of Piles	Number of Days Taken to Install	Driving Duration Per Day (Seconds)	Cumulative SEL (dB) at 10 Meters	Distance (Meters) to Threshold			
					Onset of Physical Injury			Behavior
					Peak (206 dB)	Cumulative SEL (dB) Fish ≥ 2 grams (187 dB)	Cumulative SEL (dB) Fish < 2 grams (183 dB)	RMS (150 dB)
King	8	1	8,640	214	0	464	464	464
King	8	2	4,320	211	0	420	464	464
King	8	4	2,160	208	0	265	464	464
Sheet	70	1	63,000	213	0	100	100	100
Sheet	70	2	31,500	210	0	100	100	100
Sheet	70	4	15,750	207	0	100	100	100

The illustrative analysis for impact pile driving with attenuation estimated that the cumulative SEL at 10 m ranged from 202 dB (king piles, 80 strikes per day) to 218 dB (sheet piles, 7,000 strikes per day) (Table A2). Distances to the onset of physical injury based on peak sound pressure of 206 dB were 2 m for sheet piles and 4 m for king piles). Based on cumulative SEL, the onset of physical injury thresholds for fish ≥ 2 g ranged from 100 m (king piles, 80 strikes) to 1,000 m (sheet piles, 7,000 strikes); the distances for fish < 2 g ranged from 100 m (king piles, 80 strikes) to 1,000 m (sheet piles, 7,000 strikes). Distances to the 150-dB threshold distance for behavioral changes were 215 m for sheet piles and 341 m for king piles (Table A2). The largest distances from this analysis (1,000 m for 7,000 sheet pile strikes) were approximately double those from the analysis of vibratory driving presented above. The 7,000-strikes scenario probably represents a very high extent of single-day pile driving.

Table A2. Results of Applying NMFS Pile Driving Calculator Workbook to Impact Driving for West False River Barrier Construction

Pile Type	Number of Piles	Driving Duration Per Day (Number of Strikes)	Cumulative SEL (dB) at 10 Meters	Distance (Meters) to Threshold			
				Onset of Physical Injury			Behavior
				Peak (206 dB)	Cumulative SEL (dB) Fish ≥ 2 grams (187 dB)	Cumulative SEL (dB) Fish < 2 grams (183 dB)	RMS (150 dB)
King	8	80	202	4	100	186	341
King	8	800	212	4	466	862	341
Sheet	70	700	208	2	269	497	215
Sheet	70	7,000	218	2	1,000	1,000	215

Monitoring and Float Line Piles

For each 12-inch steel pipe monitoring pile, the cumulative SEL at 10 meters was estimated to be 184 dB, and the distance to thresholds of cumulative SEL leading to physical injury were 6-11 m depending on fish size (Table A3). The threshold distance for behavior changes was just over 20 m.

For the 24-inch steel pipe float line piles, the 10-m cumulative SEL was just under 200 dB and distance to the threshold for physical injury for larger fish (≥ 2 g) was around 60 m, compared to around 110 m for smaller fish < 2 g (Table A3). The distance to threshold for changes in behavior was 215 m.

As noted above for barrier piles, these criteria were provisionally adopted for impact driving and more recently proposed criteria for vibratory driving (Hastings 2010) suggest higher thresholds may be appropriate, which would reduce the distances to the thresholds estimated in Table A3.

Table A3. Results of Applying NMFS Pile Driving Calculator Workbook to Vibratory Driving for Monitoring and Float Line Piles

Pile Type	Driving Duration Per Pile (Seconds)	Cumulative SEL (dB) at 10 Meters	Distance (Meters) to Threshold: Onset of Physical Injury: Peak (206 dB)	Onset of Physical Injury: Cumulative SEL (dB): Fish ≥ 2 grams (187 dB)	Onset of Physical Injury: Cumulative SEL (dB): Fish < 2 grams (183 dB)	Behavior: RMS (150 dB)
Monitoring	720	184	0	6	11	22
Float Line	720	199	0	59	109	215

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Appendix B
Seepage Flow Between Barrier Rocks

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The West False River barrier would be constructed of rock and therefore would be somewhat permeable to flow. This seepage flow could result in impingement of small fishes such as delta smelt larvae on the rocks of the barrier because of flow seeping between the rocks. This appendix provides estimates of flow seeping between barrier rocks to inform the effects analysis on listed fishes. The DSM2-HYDRO modeling used in this appendix was based on simulated hydrology (which assumed EDB installation on June 1), described further in Appendix C.

The analysis of flow seeping between barrier rocks focuses on DSM2-HYDRO results for June, as it is during this month that there is likely to be more potential for the early life stages of delta smelt to encounter the West False River barrier. There has been no field study of the amount of seepage flow that occurs through temporary rock barriers of the type proposed under the EDB, e.g., during the South Delta Temporary Barriers Project. Preliminary calculations by Hultgren-Tullis Engineers estimated hydraulic permeability for various diameters of rock fill (based on D_{10}, the diameter at which 10% of a sample's mass is comprised of smaller particles). Hultgren-Tullis Engineers also estimated flow rates through the previously proposed barriers to be constructed at Sutter and Steamboat sloughs, for a head difference of one foot (Table B1). A general relationship between D_{10} and seepage flow can be derived from these data (Figure B1).

Table B1. Estimates of Hydraulic Permeability and Through-Barrier Seepage Flow At a One-Foot Head Difference at the Previously Proposed Sutter and Steamboat Slough Barriers

D_{10} (inches)	Hydraulic Permeability (ft/s)	Seepage Flow (cfs)
0.5	1.5	100
3.3	11	700
3.7	13	800
7	22	1,300
7.9	24	1,400
9	27	1,600

Source: Hultgren, pers. comm.

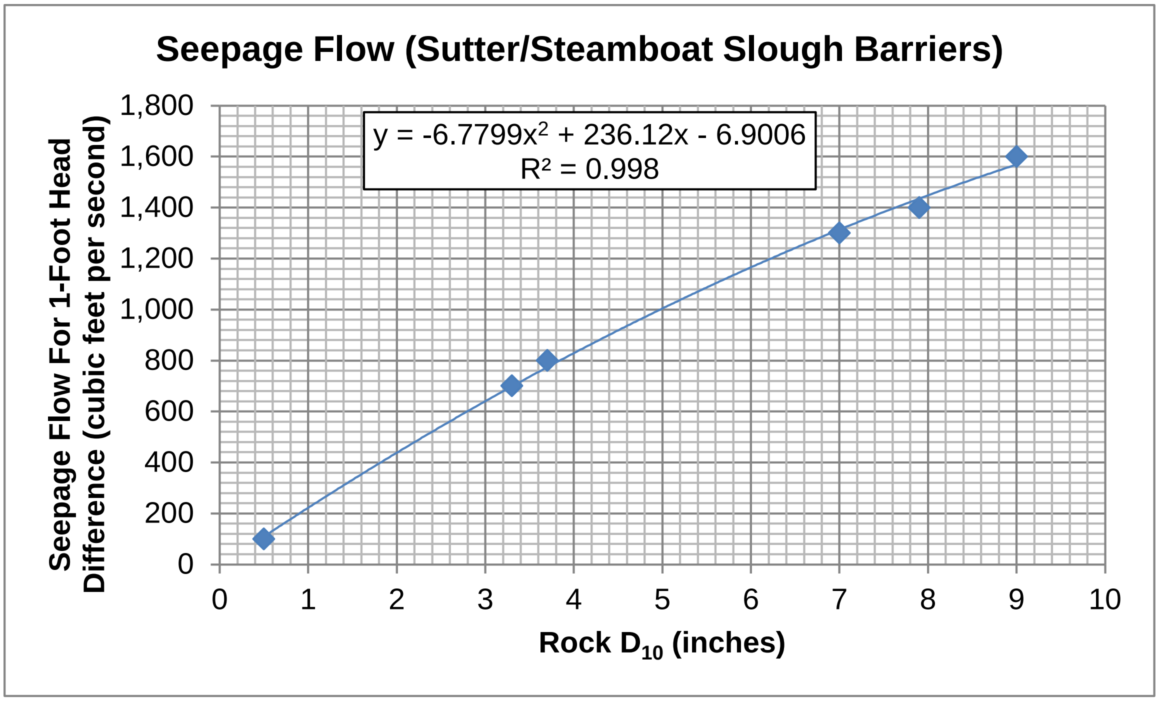

Figure B1. Relationship Between Rock D_{10} and Estimated Seepage Flow at the Previously Proposed Sutter and Steamboat Slough Barriers, For One-Foot Head Difference

The proposed West False River barrier would be constructed based on the specifications given in Table B2, which shows that the cumulative percentage rock size expressed as percent passing. Applying the midpoint of the range of each percent passing for each rock size category gives the relationship shown in Figure B2; from this relationship the estimated D_{10} for the West False River barrier is 0.55 inches.

Table B2. Rock Specifications for Proposed West False River 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

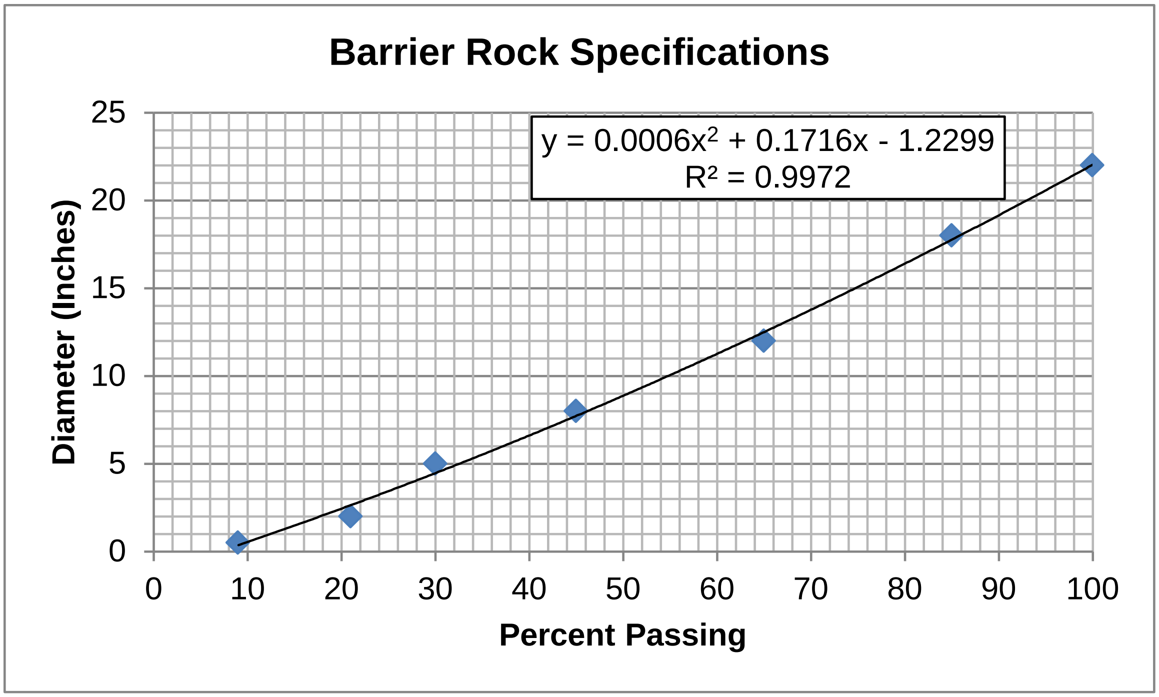

Figure B2. Relationship Between Percent Passing and Rock Diameter for Rock To be Used for the Proposed West False River Barrier

Estimates for seepage flow through the West False River barrier were made for the head differences estimated by DSM2-HYDRO modeling (June 1-30, based on the simulated hydrology discussed in Appendix C), assuming a D_{10} of 0.55 inches. Seepage flow at a given head difference can be assumed to be directly proportional to the values derived for a one-foot head difference (Hultgren pers. comm.); for example, seepage flow with a one-foot head difference at a D_{10} of 0.5 inches is 100 cfs (Table B1), and so seepage flow with a 0.5-foot head difference would be 50 cfs.

For a given head difference, more seepage flow would pass through the West False River barrier than through the previously proposed Sutter or Steamboat slough barriers. The West False River barrier has a cross-sectional area (approximately 15,000 ft^2) that is around five times greater than the previously proposed Sutter and Steamboat slough barriers (approximately 3,000 ft^2 each). The West False River barrier sectional width (i.e., distance between the upstream and downstream edges of the barrier) at mid-depth is approximately double that of the previously proposed Sutter and Steamboat Slough barriers, which means that the flow has to travel further to seep through the barrier. Therefore a factor of 2.5 (i.e., 5/2) was applied to the relationship between head difference and seepage flow (Figure B1).

The analysis suggested that, based on the percentiles of head difference at the West False River barrier from DSM2-HYDRO modeling, there would be very little seepage flow through the barrier: for June 1-30, the median seepage flow was 0 cfs and the range was from a minimum of -84 cfs to a maximum of nearly 380 cfs (Table B3). These very small estimates are because of the small head differences, reflecting the influence of the tide on water surface elevation throughout this area.

For perspective on potential impingement risk to delta smelt larvae by the rocks of the West False River barrier, the estimated seepage flow can be considered in the context of flow in the San Joaquin River at Jersey Point. The DSM2-HYDRO modeling data indicate that the median Jersey Point 15-minute flow during June 1-30 was just over 12,000 cfs and that the tidal flows ranged from around -149,000 to nearly 132,000 cfs. Therefore only a very small percentage of the tidal flow would have the potential to pass through the West False River barrier, which may be indicative of relatively low impingement risk for delta smelt larvae. Note also that much of the same water would pass back and forth through the barrier on flood and ebb tides, possibly limiting the number of delta smelt encountering the barrier. It is emphasized that these seepage flows are based on theoretical calculations and have not been examined in the field.

Table B3. Estimated Seepage Flow Through the Proposed West False River Barrier, For Head Differences Estimated from DSM2-HYDRO Modeling (June 1-June 30 Estimates for Simulated Hydrology)

Percentile	Head Difference (ft)	Seepage Flow (cfs)
0	-0.3	-84
10	0.0	-2
20	0.0	-1
30	0.0	-1
40	0.0	0
50	0.0	0
60	0.0	1
70	0.0	1
80	0.0	1
90	0.0	2
100	1.3	379

Appendix C
Summary of Simulated Hydrology Used for the DSM2 Tidal Flows and Salinity Modeling

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This appendix describes the features of the simulated hydrology used to inform the effects assessment on listed fishes. This simulated hydrology, including Delta SWP/CVP operations, is useful in terms of illustrating the basic effects of the EDB on variables of importance to listed fishes such as channel flows and salinity. The simulated hydrology used in this BA included scenarios with no EDB and EDB (West False River barrier). Operations were based on the 99% exceedance forecast and were consistent with the March 24, 2015, TUCP modification petition for Bay-Delta standards (Murillo and Cowin 2015).[17] The TUCP proposal includes both flow and water quality components. The minimum outflow was enforced as a lower bound; sufficient supplemental flow was provided for each case (no EDB and EDB) to conform with water quality objectives as modified in the petition. As noted elsewhere in this BA, changes to SWP/CVP operations because of the EDB and resulting potential effects on listed fishes would be analyzed separately from this BA and in greater depth by Reclamation/DWR within the scope of Biological Reviews for drought operational planning and consistency with ESA section 7 (e.g., TUCP modification requests; see Appendix A of Murillo and Cowin [2015], for example). These Biological Reviews compare the effects of changes in SWP/CVP operations (e.g., modification of D-1641 standards) to baseline conditions with unmodified D-1641 standards.

As noted above, the simulated hydrology for the DSM2-HYDRO and DSM2-QUAL modeling used for this biological assessment was based on the 99% exceedance forecast, applying D-1641 flow and water quality standards with adjustments as necessary to reflect the March 24, 2015, TUCP modification petition (Murillo and Cowin 2015). The West False River barrier was assumed to be installed on June 1 and removed on October 31. The modeled location of the barrier was the closest available DSM2 node in False River (node 44), which is about 0.4 miles downstream of the proposed barrier location.

The simulated hydrology included operation of the Delta Cross Channel per D-1641 except in the fall when there is concern about meeting Rio Vista flow requirements, for which it was assumed that the Delta Cross Channel was closed 35% of the time in September, 40% of the time in October, and 80% in November (Figure C1). Operation of the Suisun Marsh Salinity Control Gates (Figure C2) assumed the following:

- Boat lock
  - Open: January 1 to May 30
  - Closed: June 1 to December 30
- Flashboards
  - Open: June 1 to September 2
  - Closed: January 1 to May 30; September 3 to December 30

[17] The only exception was that the modeled Delta outflow in April (mean = 3,790 cfs; Table C1) was slightly lower than the TUCP modification request (4,000 cfs).

- Radial gates
    - January 1 to May 30 and after October 1: closed when the velocity immediately downstream of the radial gates is >0.1 ft/s during flood tide; open when the stage difference (upstream minus downstream) at the gates is >0.3 ft
    - June 1 to September 30: closed

Implementation of the south Delta Temporary Barriers Project assumed the following installation and removal dates:

- Head of Old River: Installed April 19, removed June 8;
- Middle River: Installed May 16, removed November 29;
- Old River at Tracy: Installed June 2, removed November 29;
- Grant Line Canal: Installed June 10, removed November 29.

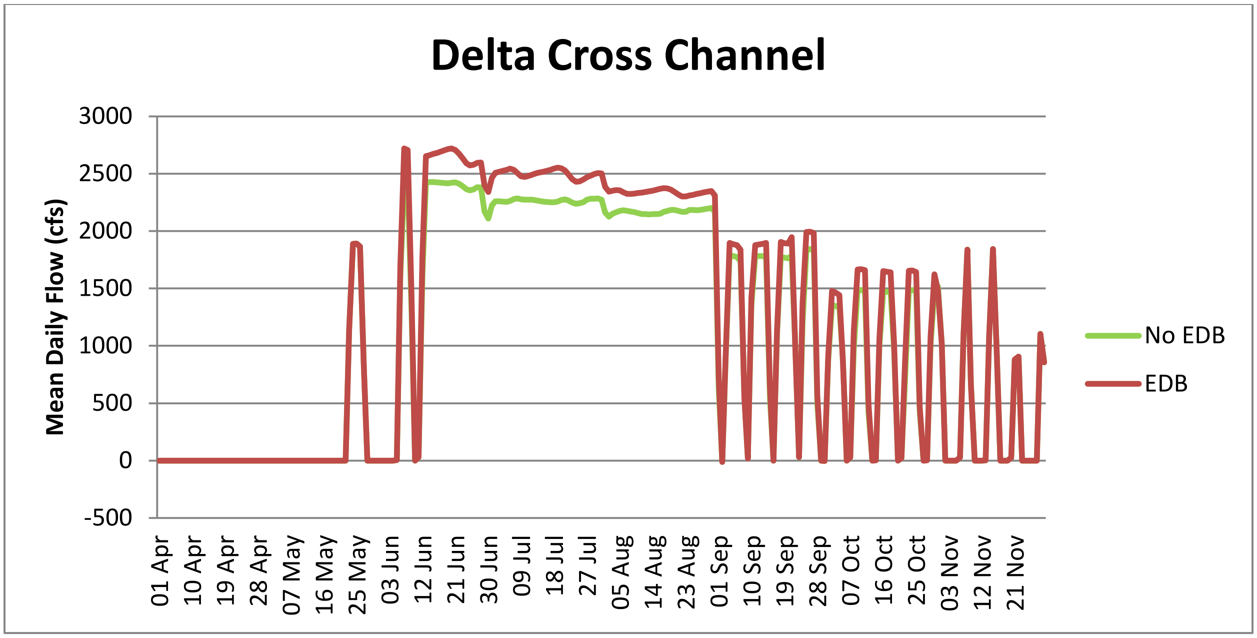
Mean monthly flows for the simulated hydrology are summarized in Table C1. The flows differ only in that Sacramento River inflows (at Freeport) for the no EDB scenario were somewhat greater than the EDB scenario during the summer in order to meet water quality standards, with the result that Delta outflow was around 200-300 cfs greater with the no EDB scenario in August and September.

As described in the subsection of the Environmental Baseline section that discusses Environmental Baseline Conditions Specific to Drought Years (main body of this BA), Temporary Urgency Change Petition Orders and modifications influence potential Delta outflow and therefore salinity conditions. The DSM2 modeling of the EDB shown in the Operations Effects on Fish section provides a reliable comparison of potential Delta flows and Delta salinity within critical habitat for listed fishes. As noted elsewhere in this BA, specific changes to SWP/CVP operations that could result from EDB implementation would be analyzed by Reclamation/DWR during biological reviews for TUCP modifications and consistency with ESA Section 7.

Table C1. Mean Monthly Flow (Cubic Feet Per Second) At Several Key Locations For the DSM2 Modeling Associated with the Emergency Drought Barrier Project, Together with Net Delta Outflow Index

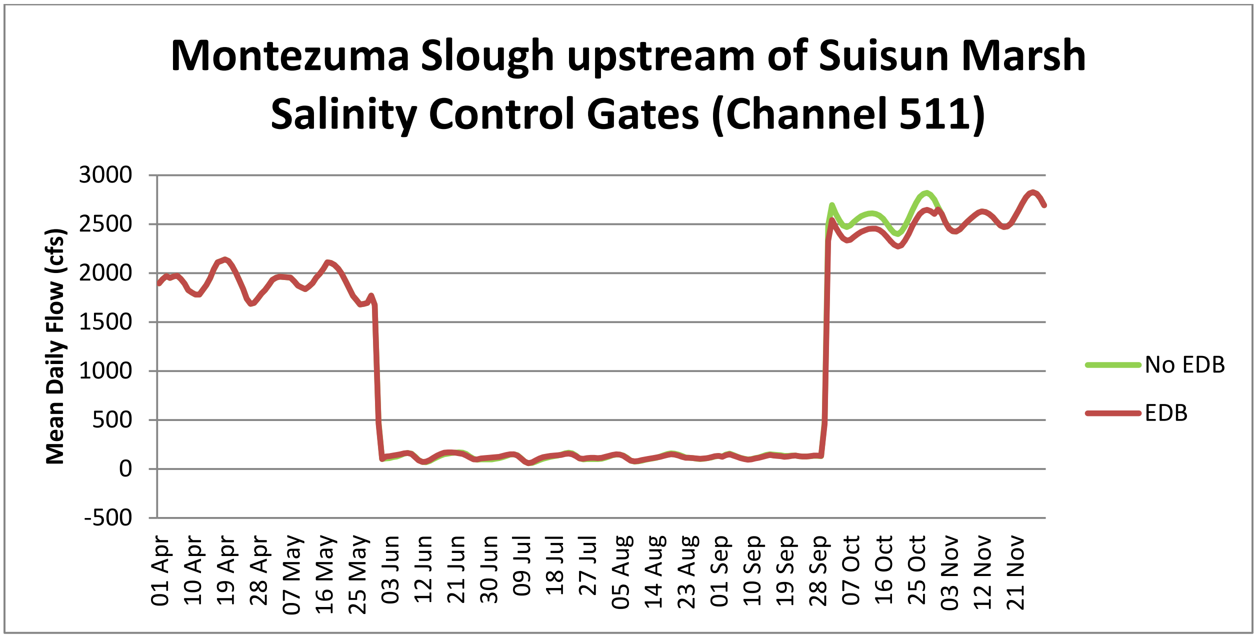
Month	Sacramento River at Freeport (cfs)		San Joaquin River at Vernalis (cfs)		Delta Consumptive Use (cfs)		SWP Exports (cfs)		CVP Exports (cfs)		Net Delta Outflow Index (cfs)	
	No EDB	EDB	No EDB	EDB	No EDB	EDB	No EDB	EDB	No EDB	EDB	No EDB	EDB
April	5,265	5,265	605	605	1,446	1,446	581	581	555	555	3,790	3,790
May	6,660	6,660	310	310	2,260	2,260	683	683	537	537	4,000	4,000
June	8,148	8,149	202	202	3,698	3,698	1,043	1,034	555	555	3,934	3,933
July	7,677	7,659	195	195	4,341	4,341	1,082	1,074	537	537	3,016	3,000
August	7,333	7,109	195	195	3,772	3,772	1,061	1,051	537	537	3,226	3,000
September	6,227	5,979	202	202	2,538	2,538	917	908	555	555	3,336	3,091
October	5,305	5,290	244	244	1,447	1,447	704	699	537	537	3,443	3,429
November	6,621	6,621	955	955	756	756	299	299	554	554	4,773	4,773

Source: Tu (pers. comm.), Ateljevich (pers. comm.). Notes: Mean monthly flows were for DSM2 channels labeled RSAC155 (Sacramento River), RSAN112 (San Joaquin River), CHSWP003 (SWP exports), CVP (CVP exports), as well as the Net Delta Outflow Index.



Source: Tu (pers. comm.).

Figure C1. Tidally Averaged Mean Daily Flow in the Delta Cross Channel for the Simulated Hydrology.



Source: Tu (pers. comm.).

Figure C2. Tidally Averaged Mean Daily Flow in Montezuma Slough upstream of the Suisun Marsh Salinity Control Gates for the Simulated Hydrology.

Appendix D
20-mm Survey and Summer Townet Survey Data of Delta Smelt Distribution

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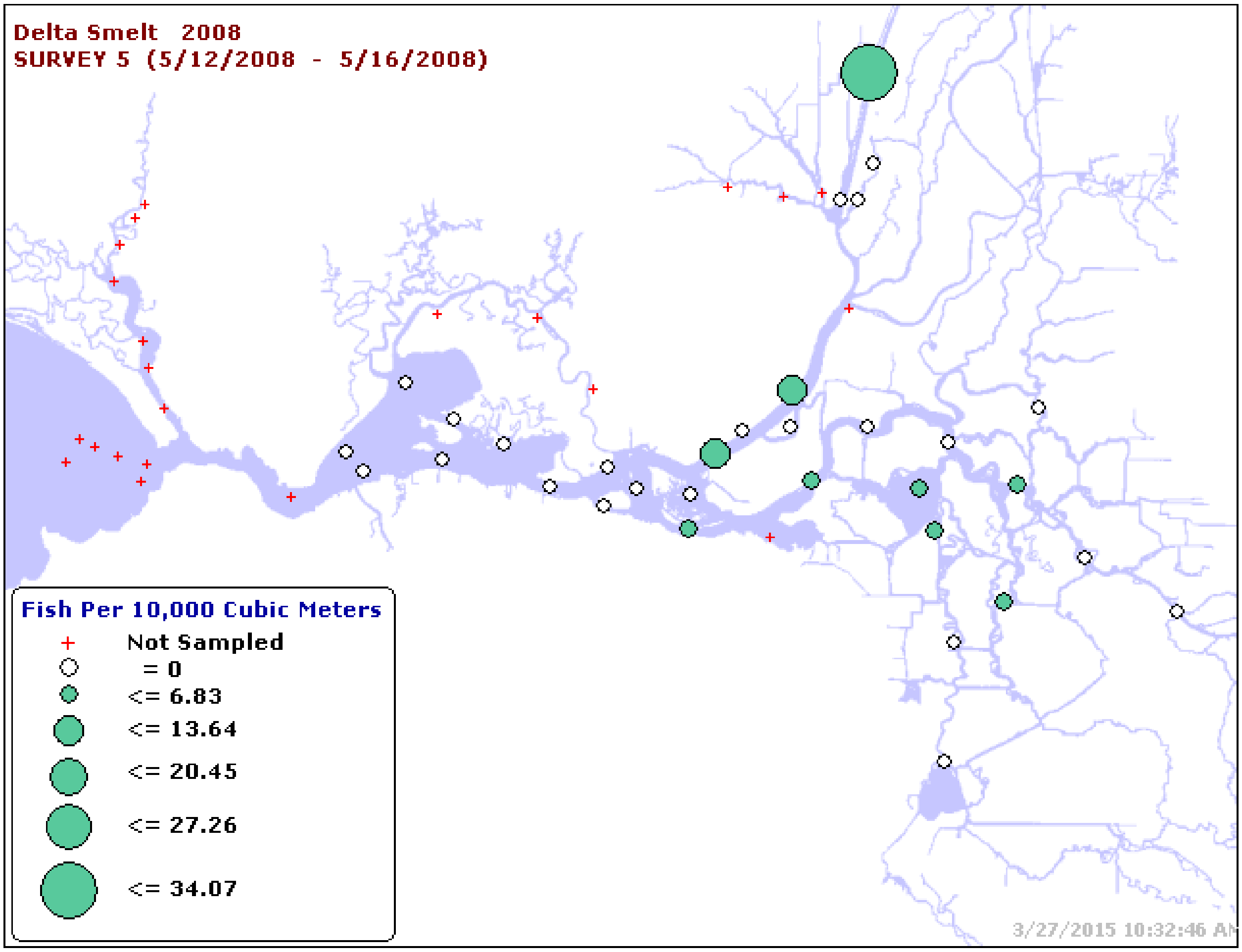
This appendix provides distribution data for larval, early juvenile, and juvenile delta smelt from the ongoing 20-mm Survey and the Summer Townet Survey.

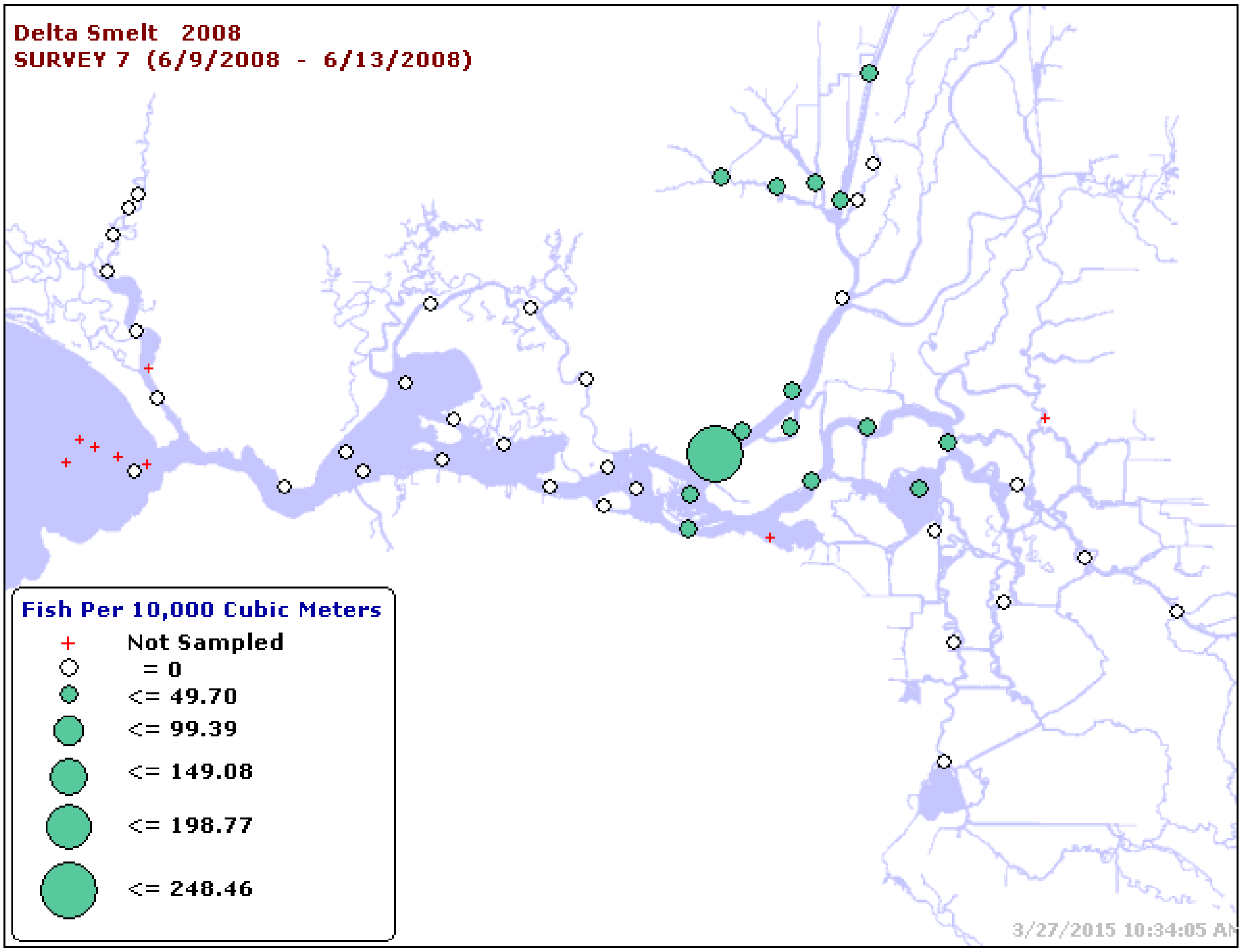
20-mm Survey

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 West False River barrier in more than 50% of the May-July 20-mm surveys from 2008 to 2014 (Figures D1-D27).



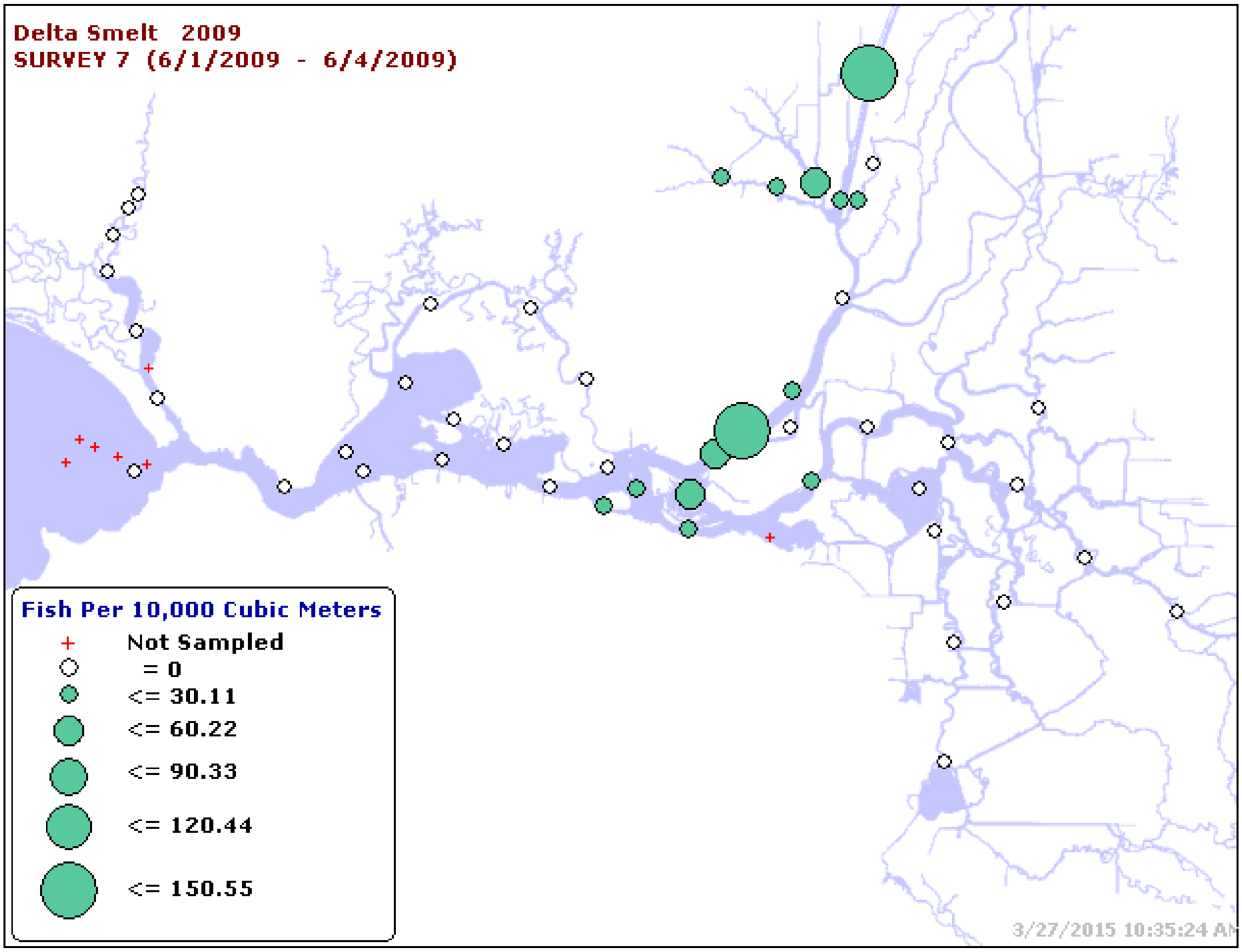
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D1. Density of Delta Smelt from 20-mm Survey 5, 2008.



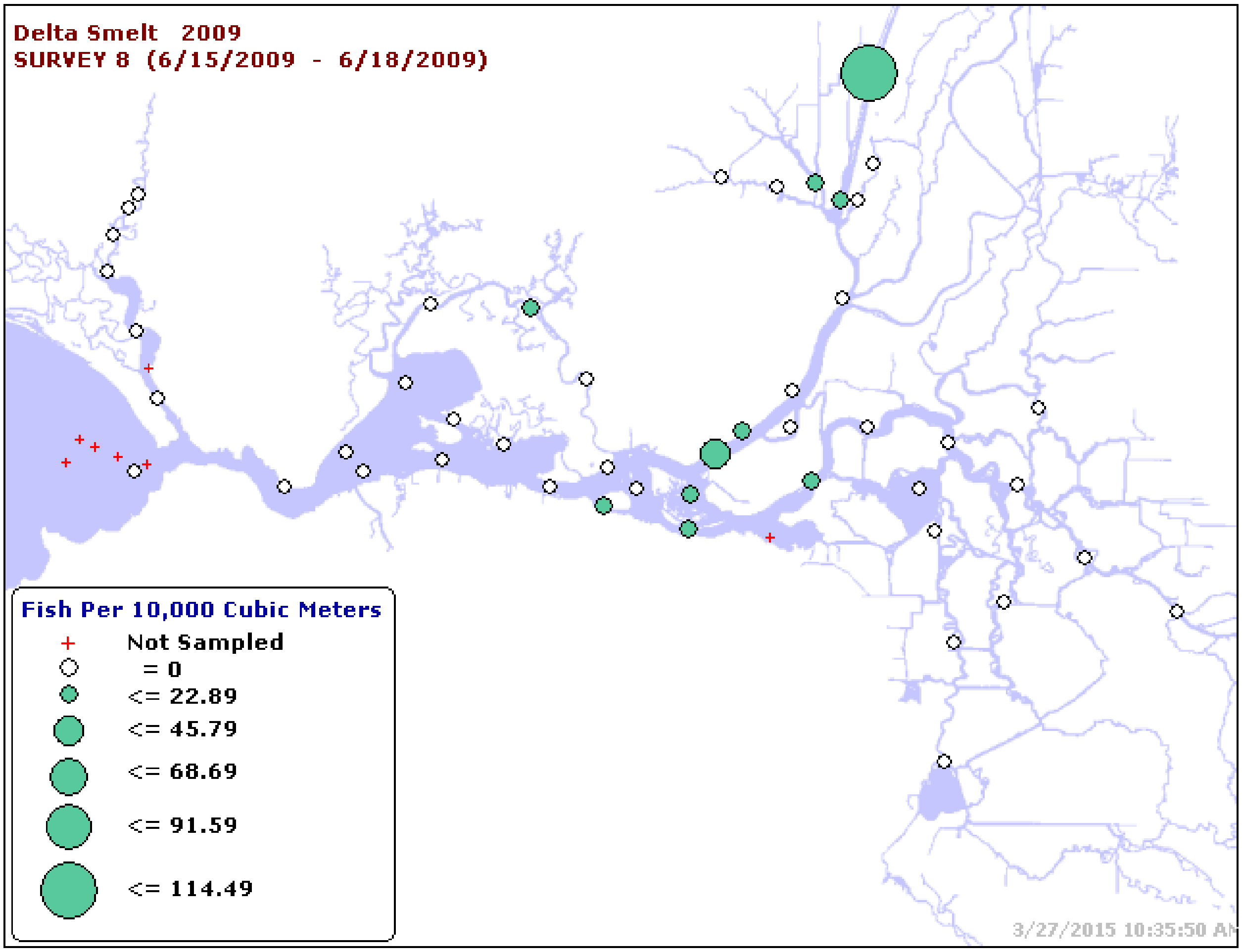
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D2. Density of Delta Smelt from 20-mm Survey 7, 2008.



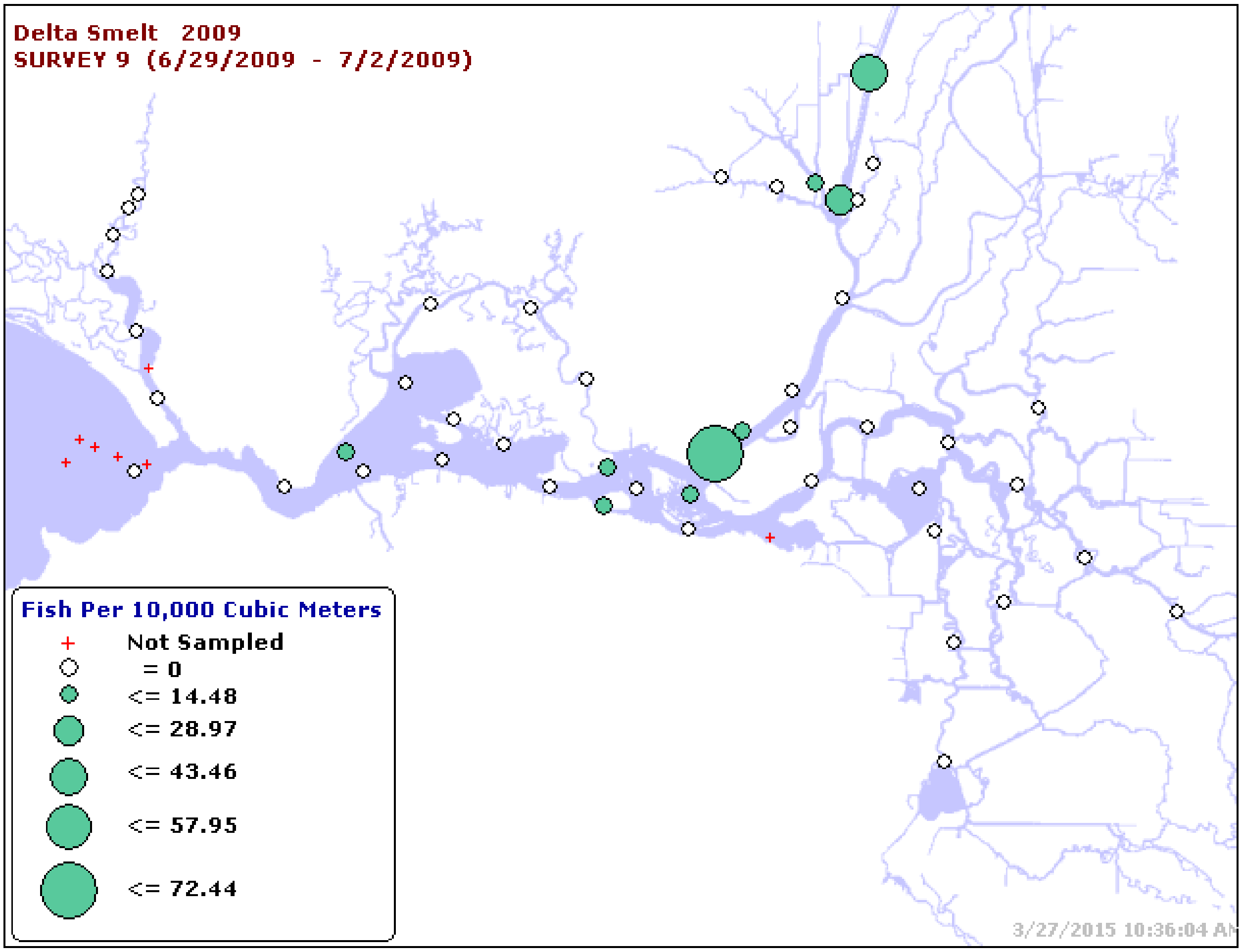
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D3. Density of Delta Smelt from 20-mm Survey 7, 2009.



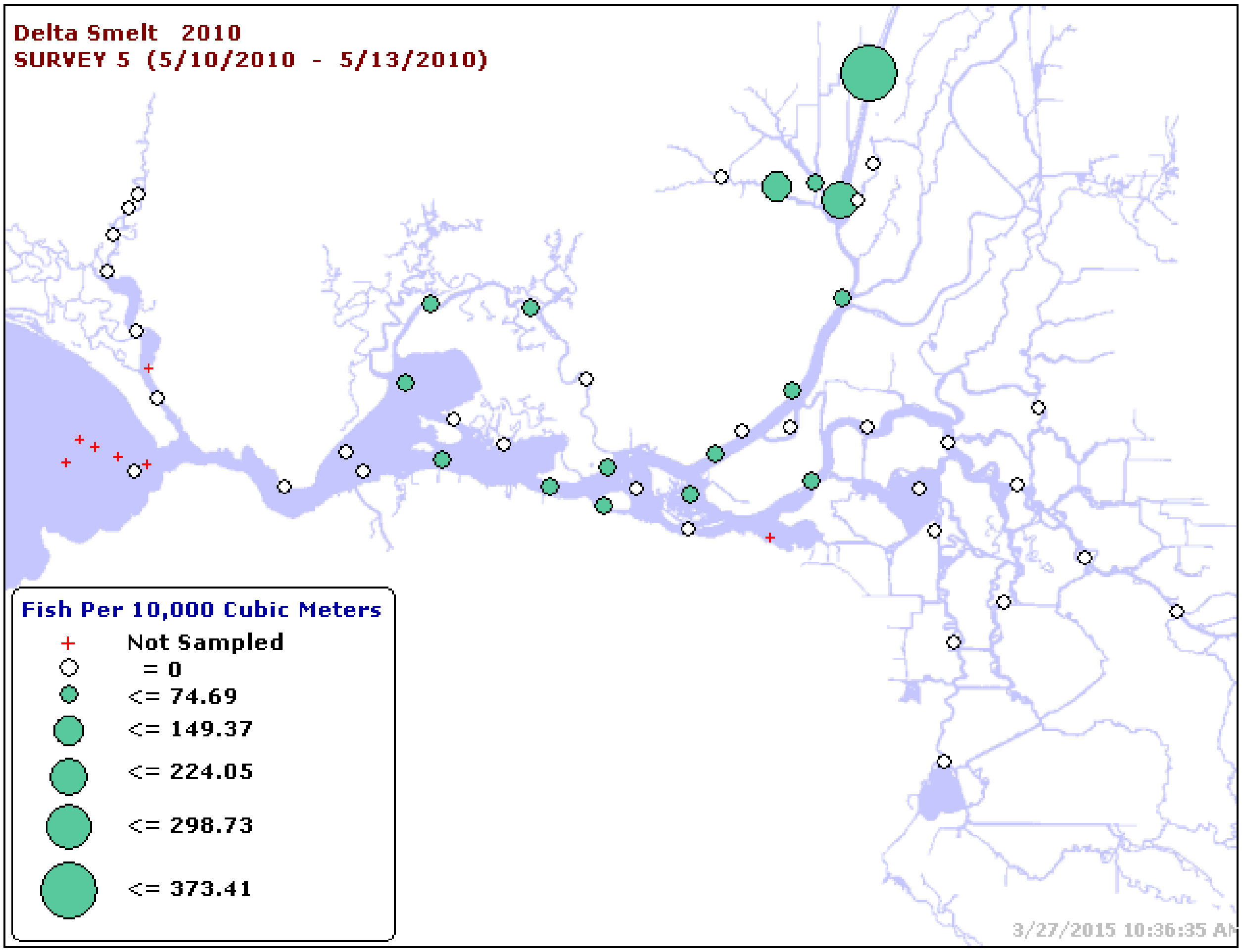
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D4. Density of Delta Smelt from 20-mm Survey 8, 2009.



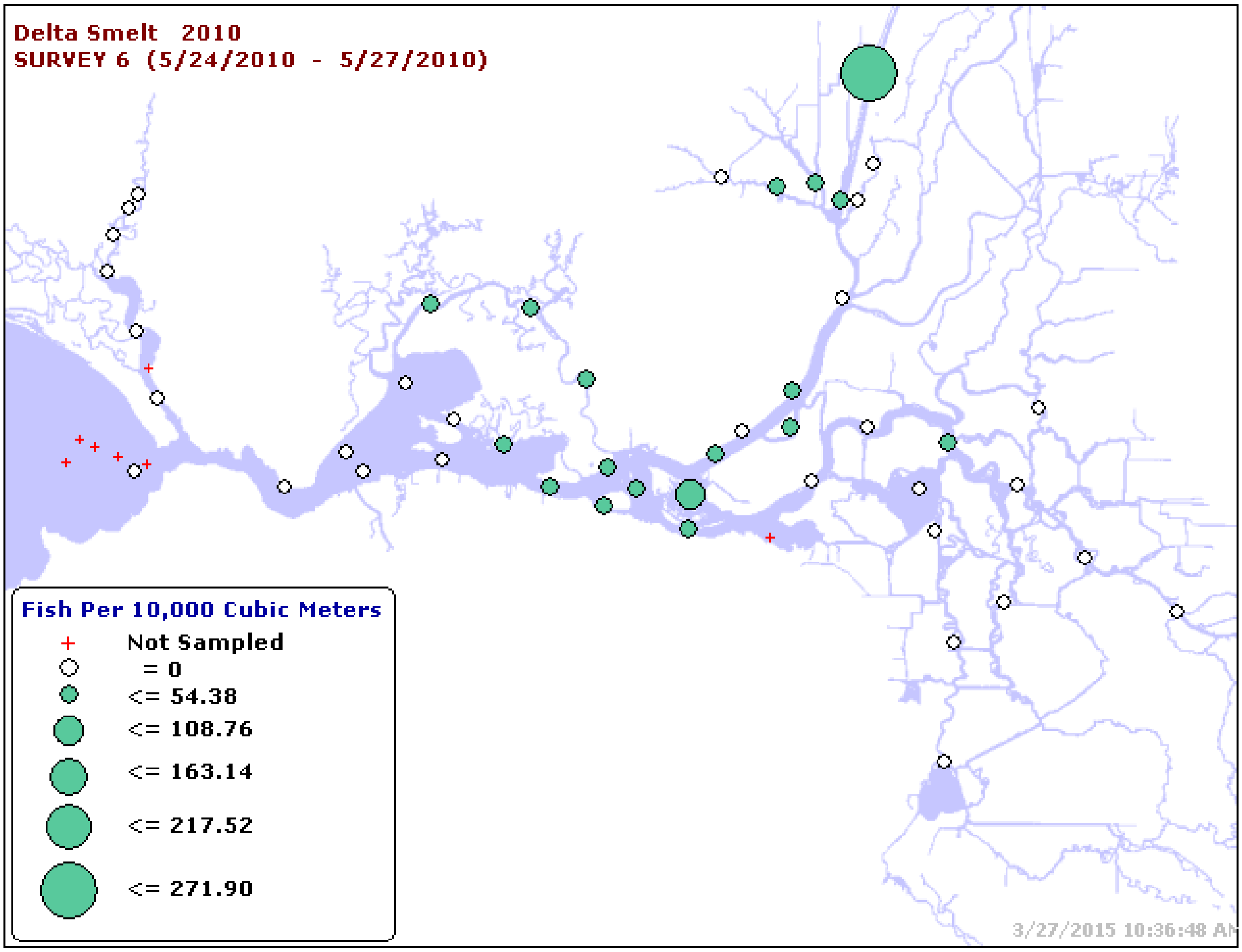
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D5. Density of Delta Smelt from 20-mm Survey 9, 2009.



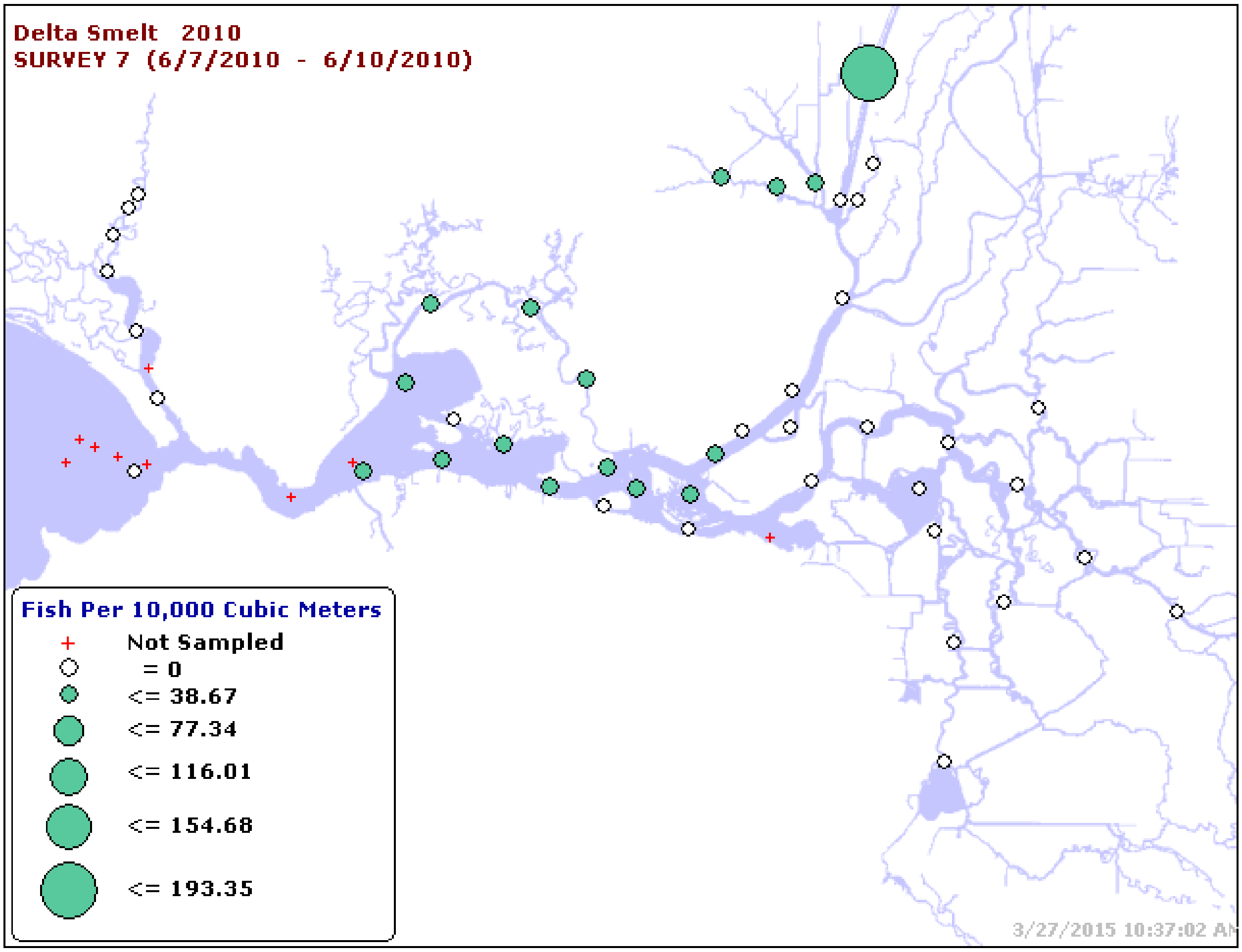
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D6. Density of Delta Smelt from 20-mm Survey 5, 2010.



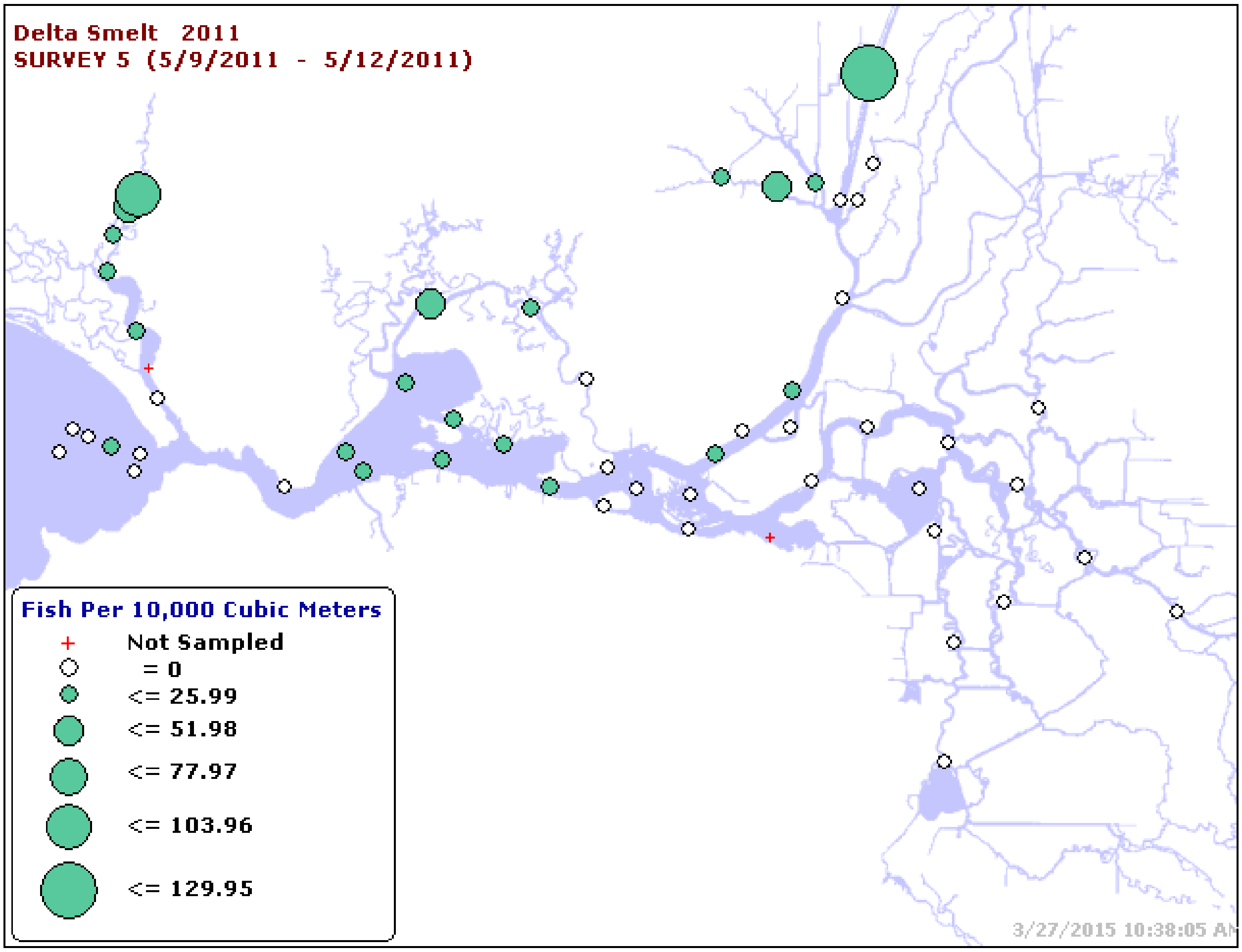
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D7. Density of Delta Smelt from 20-mm Survey 6, 2010.



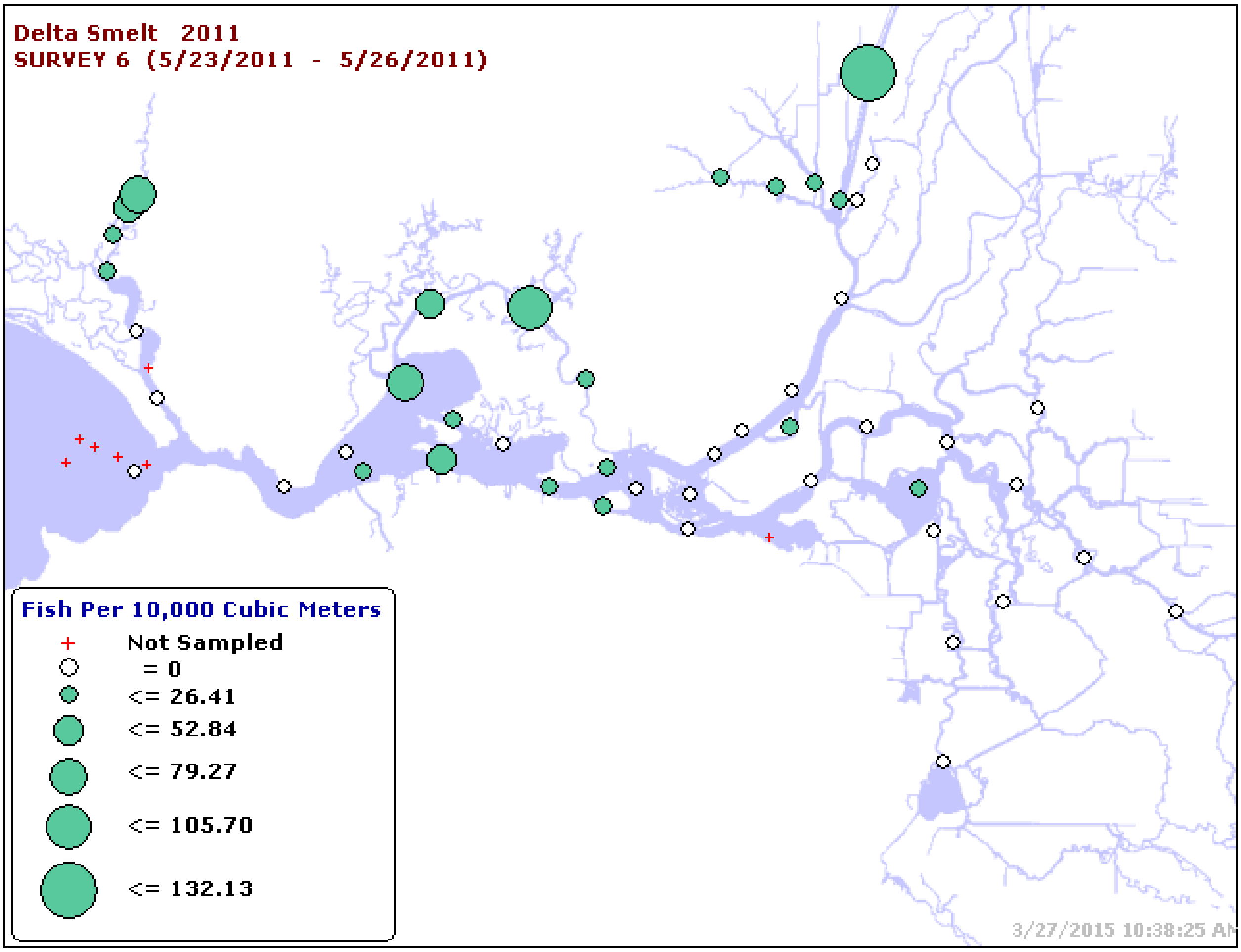
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D8. Density of Delta Smelt from 20-mm Survey 7, 2010.



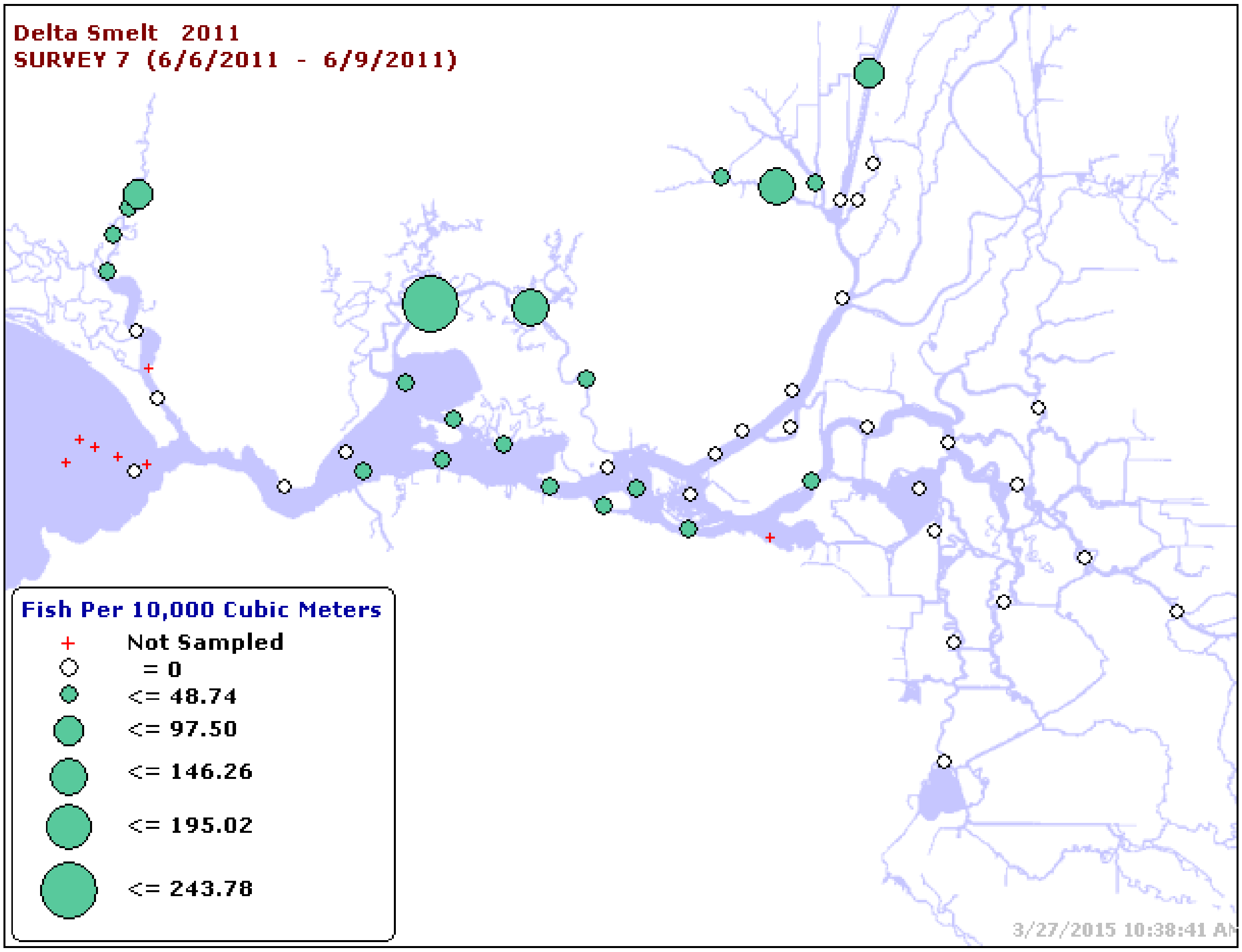
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D9. Density of Delta Smelt from 20-mm Survey 5, 2011.



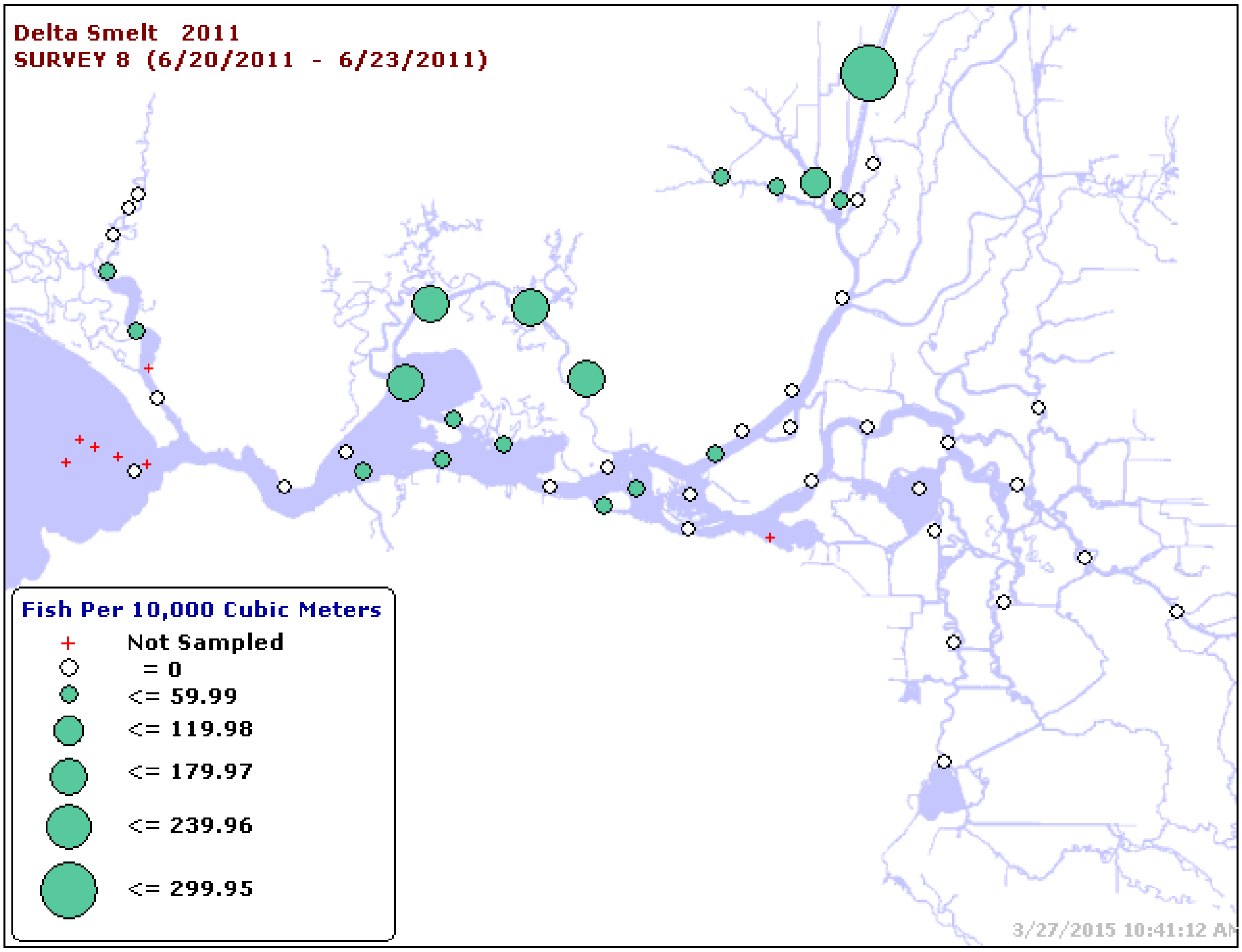
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D10. Density of Delta Smelt from 20-mm Survey 6, 2011.



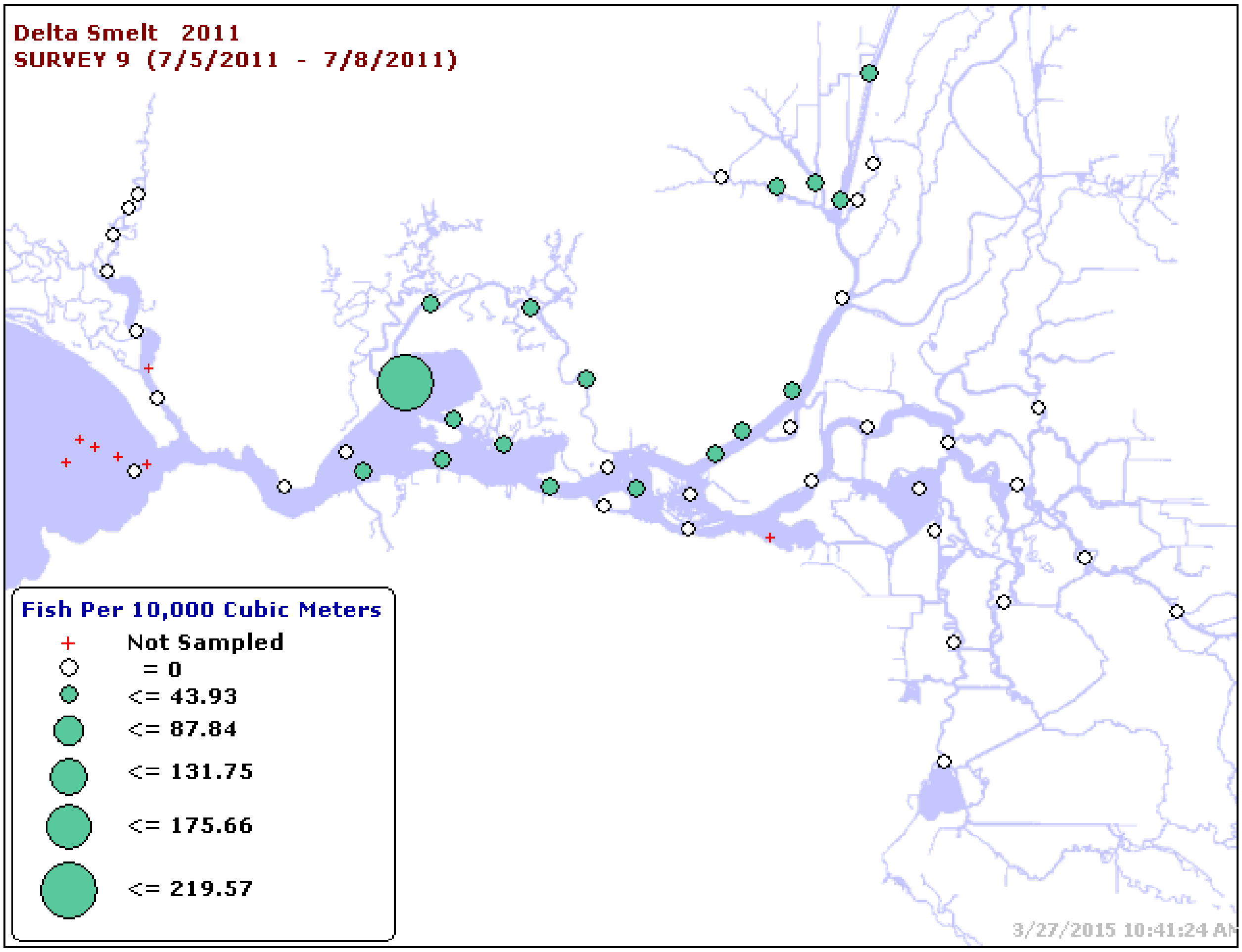
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D11. Density of Delta Smelt from 20-mm Survey 7, 2011.



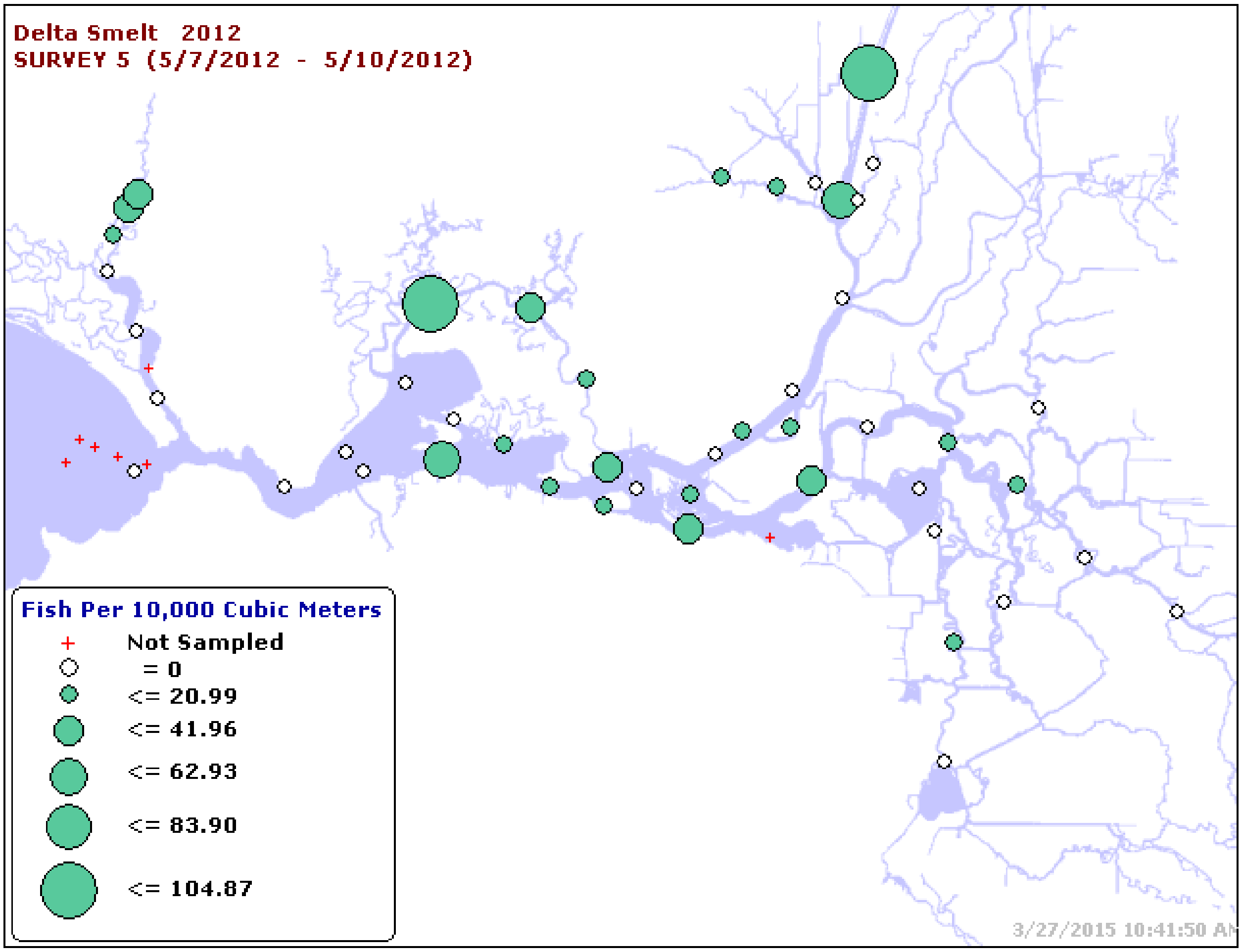
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D12. Density of Delta Smelt from 20-mm Survey 8, 2011.



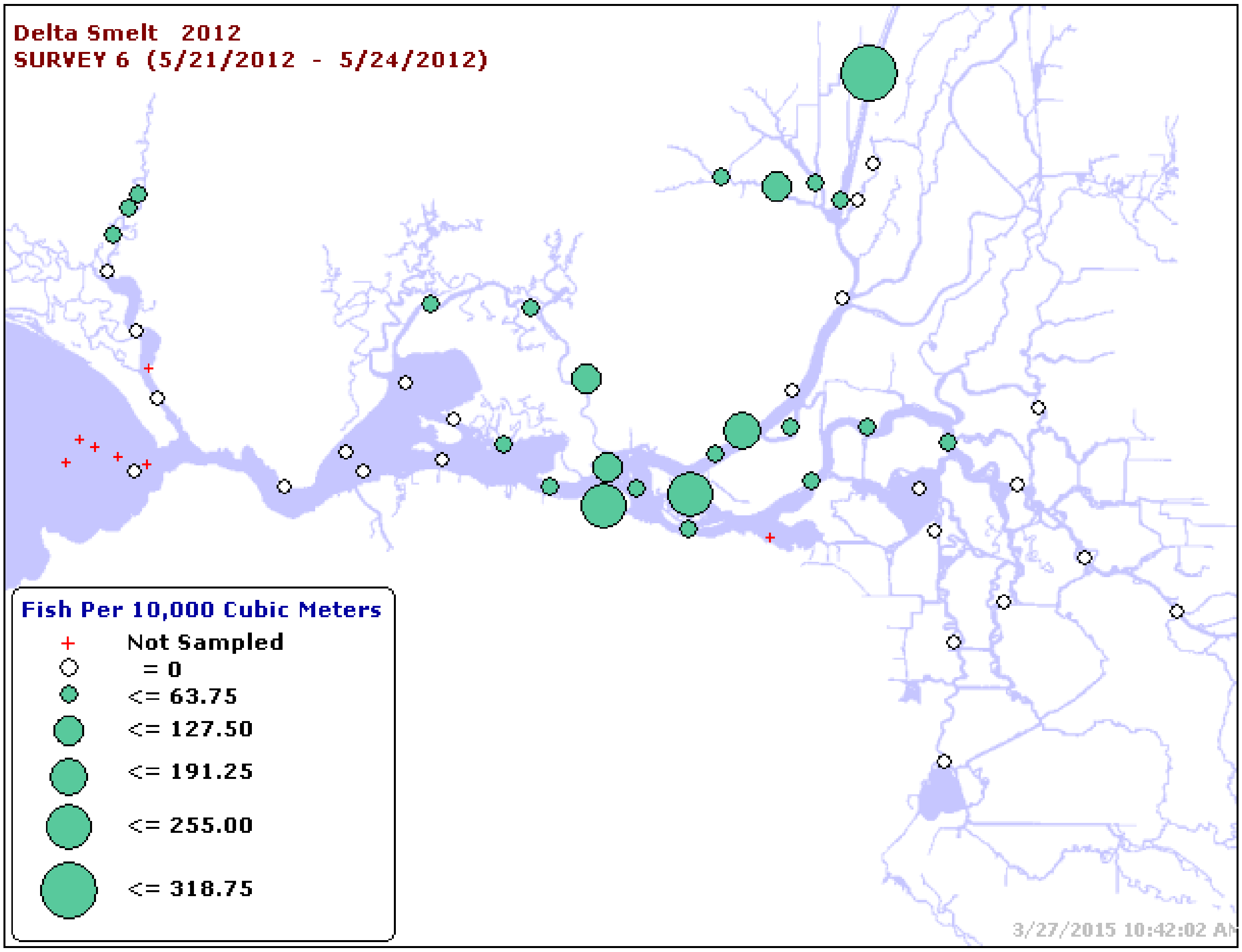
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D13. Density of Delta Smelt from 20-mm Survey 9, 2011.



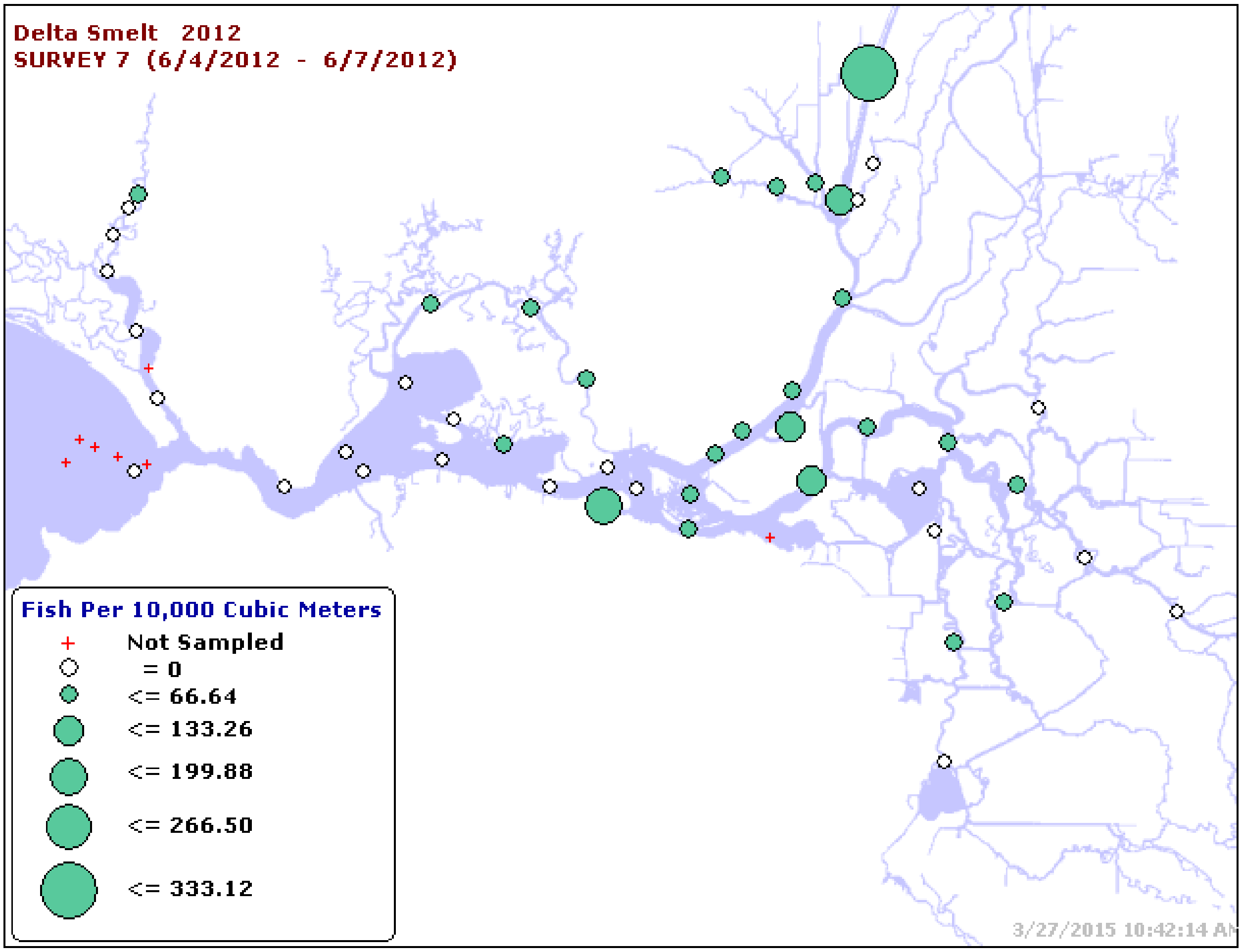
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D14. Density of Delta Smelt from 20-mm Survey 5, 2012.



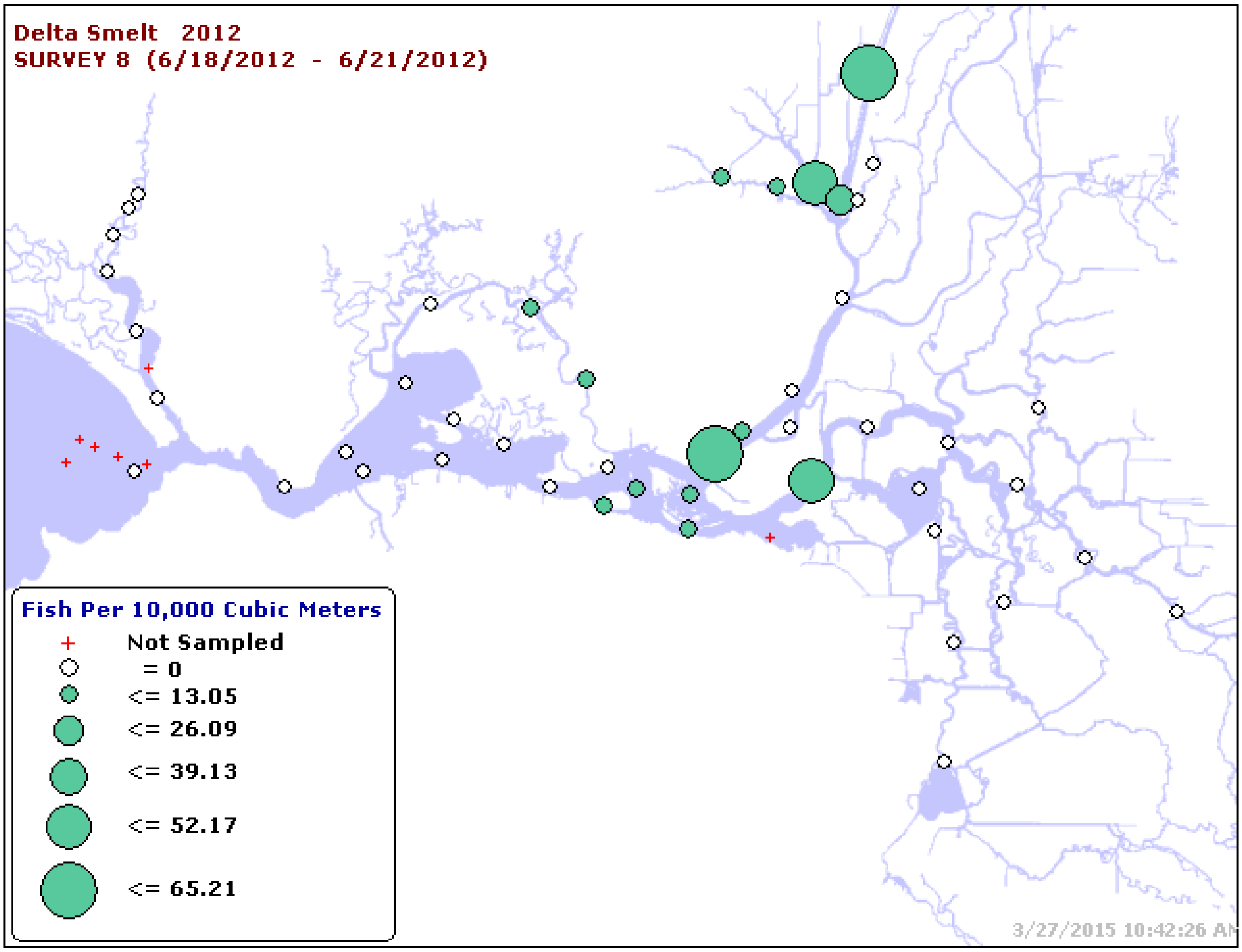
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D15. Density of Delta Smelt from 20-mm Survey 6, 2012.



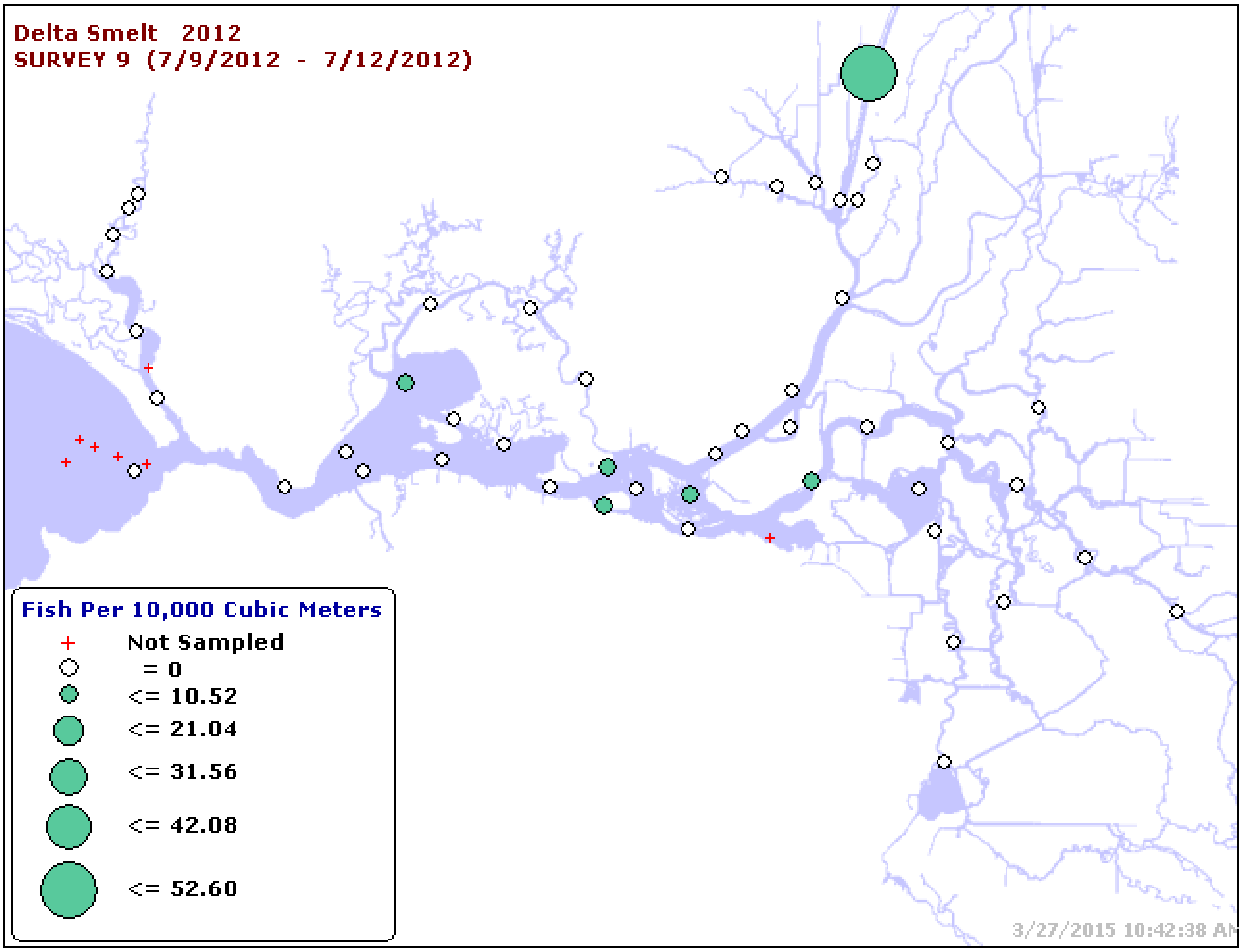
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D16. Density of Delta Smelt from 20-mm Survey 7, 2012.



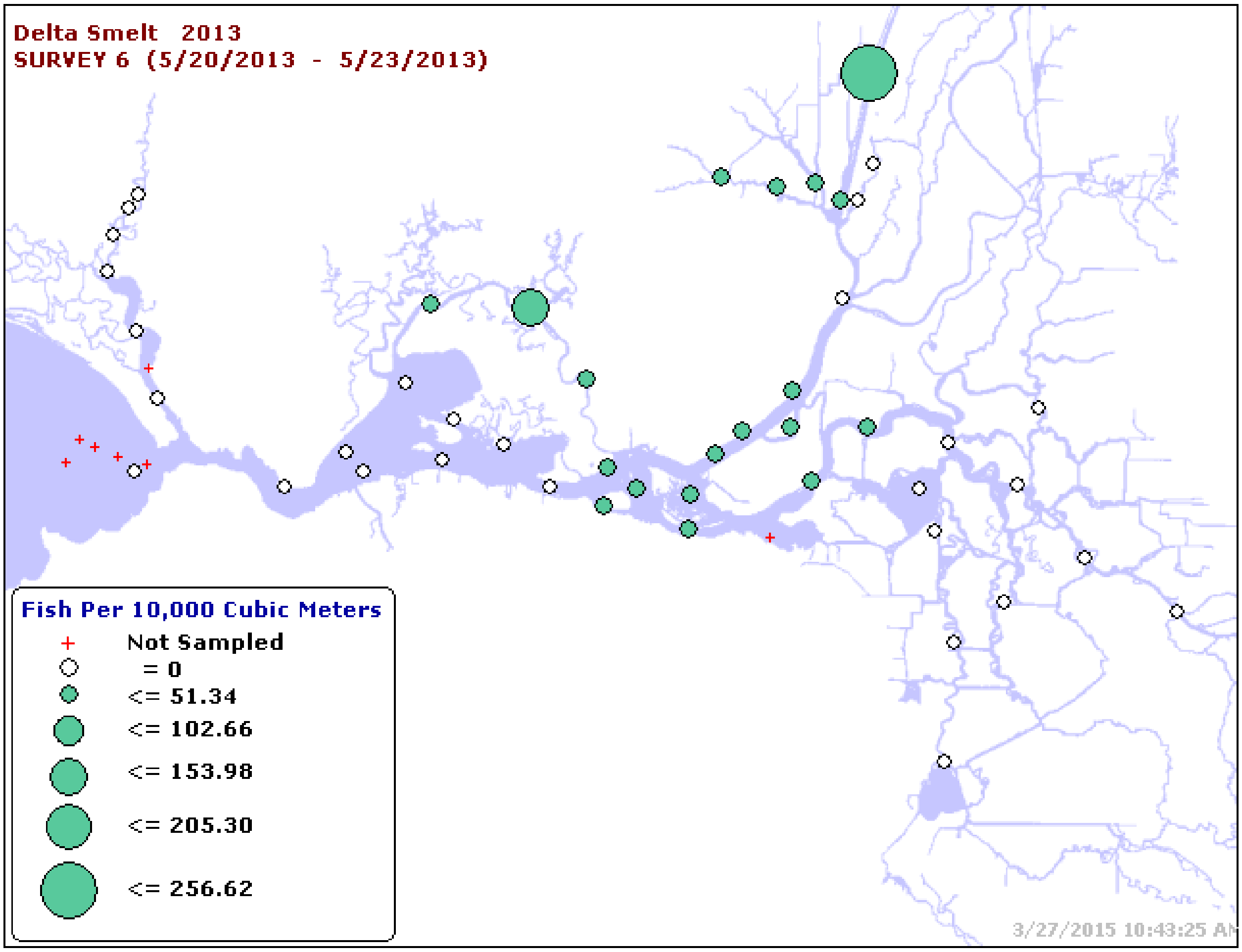
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D17. Density of Delta Smelt from 20-mm Survey 8, 2012.



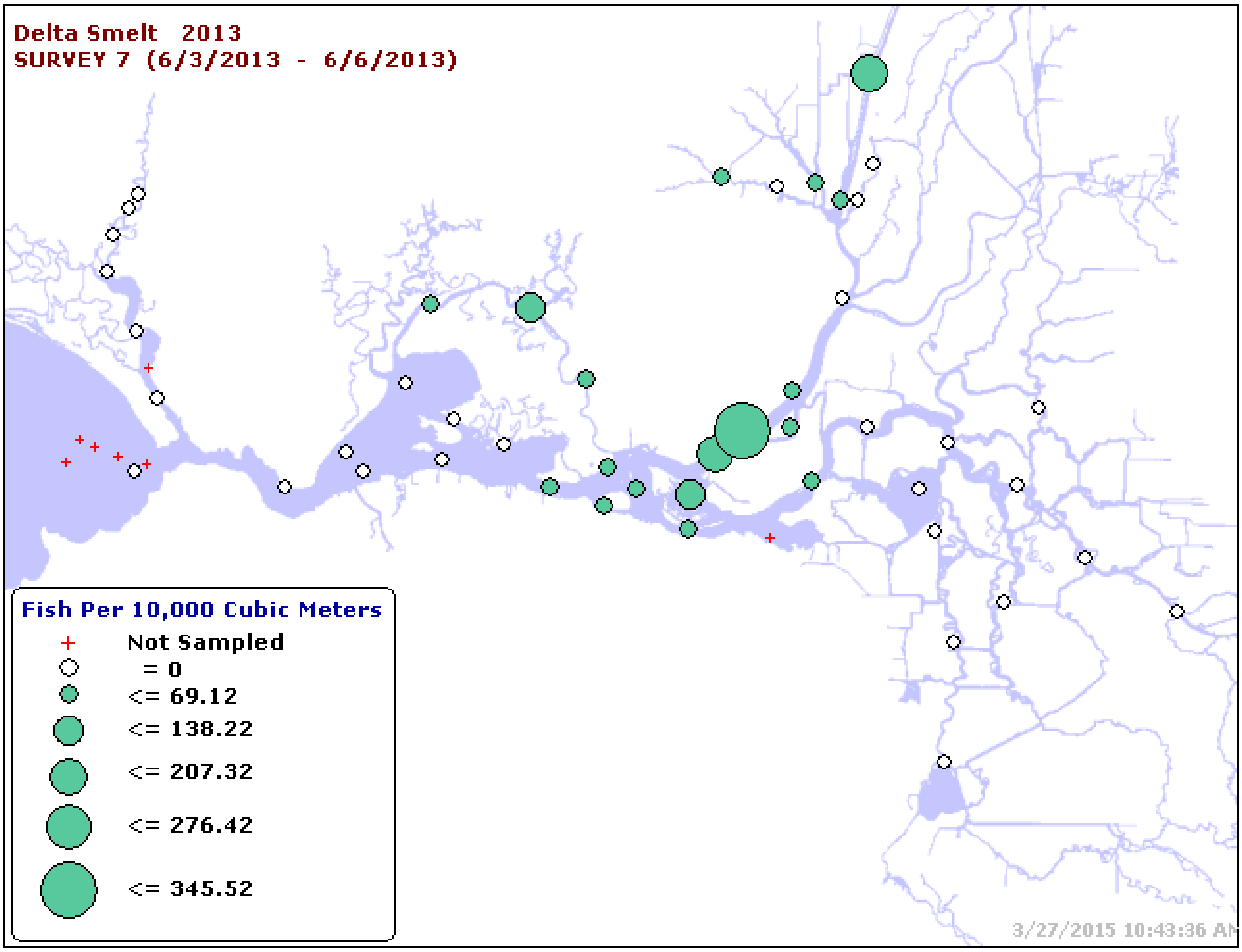
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D18. Density of Delta Smelt from 20-mm Survey 9, 2012.



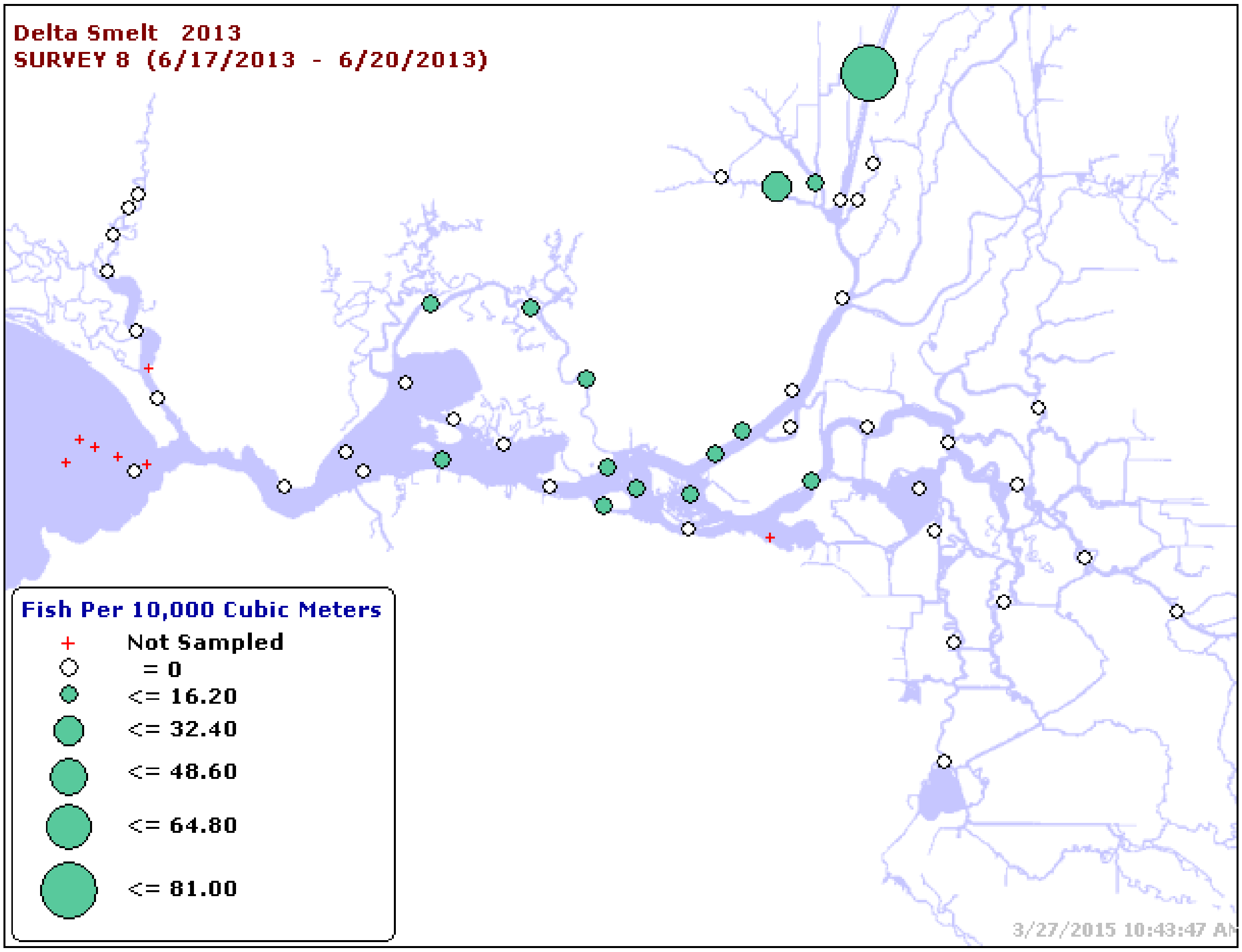
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D19. Density of Delta Smelt from 20-mm Survey 6, 2013.



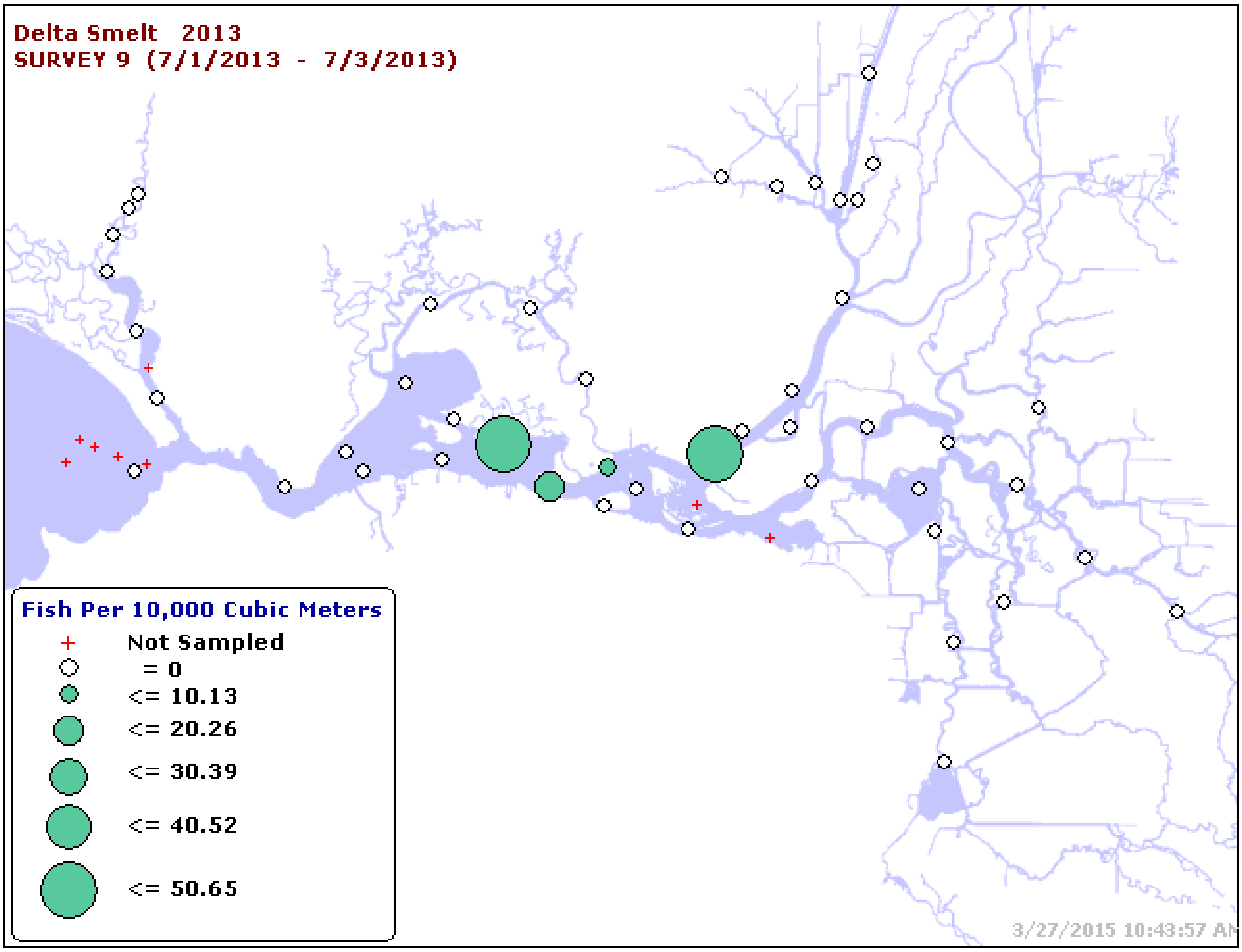
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D20. Density of Delta Smelt from 20-mm Survey 7, 2013.



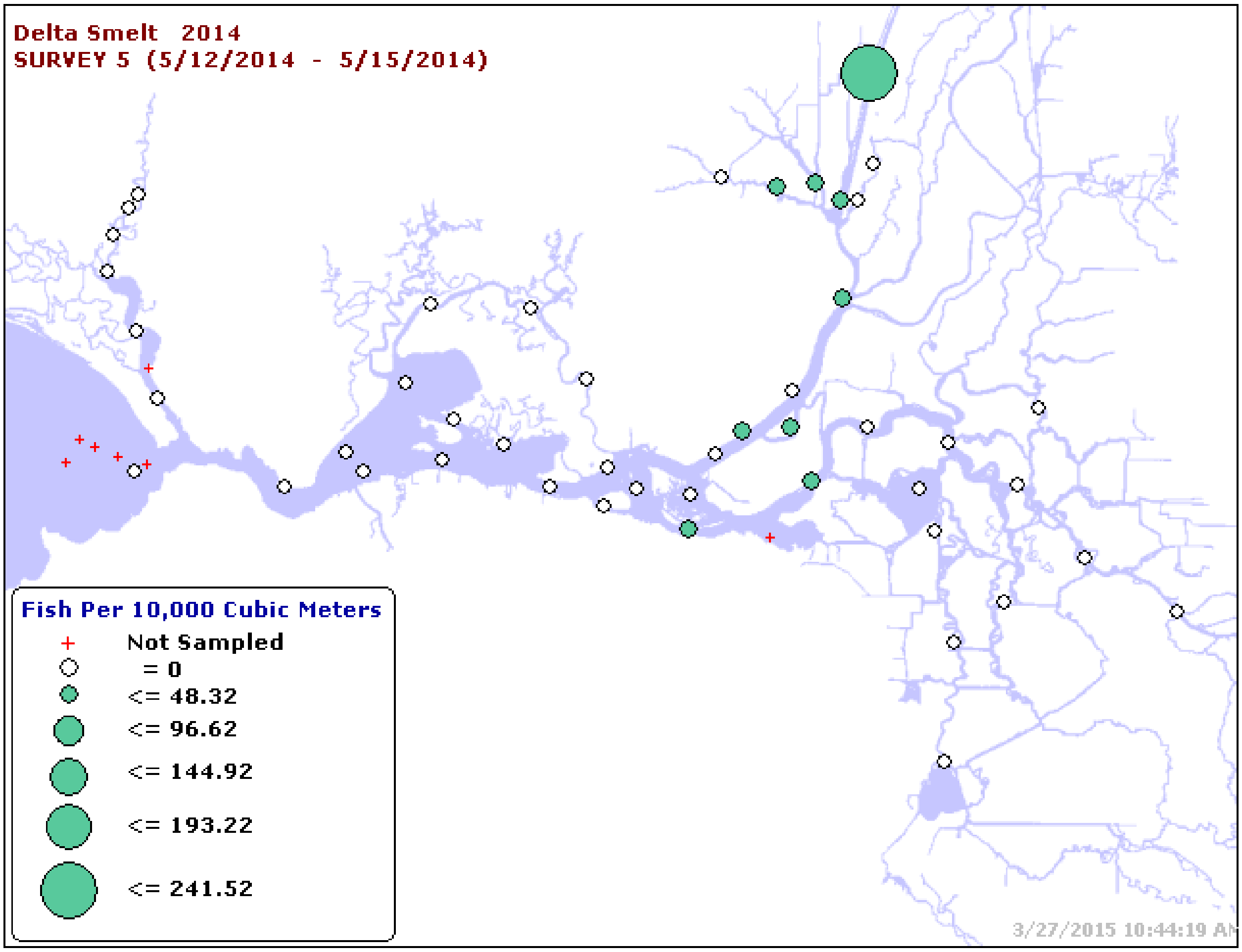
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D21. Density of Delta Smelt from 20-mm Survey 8, 2013.



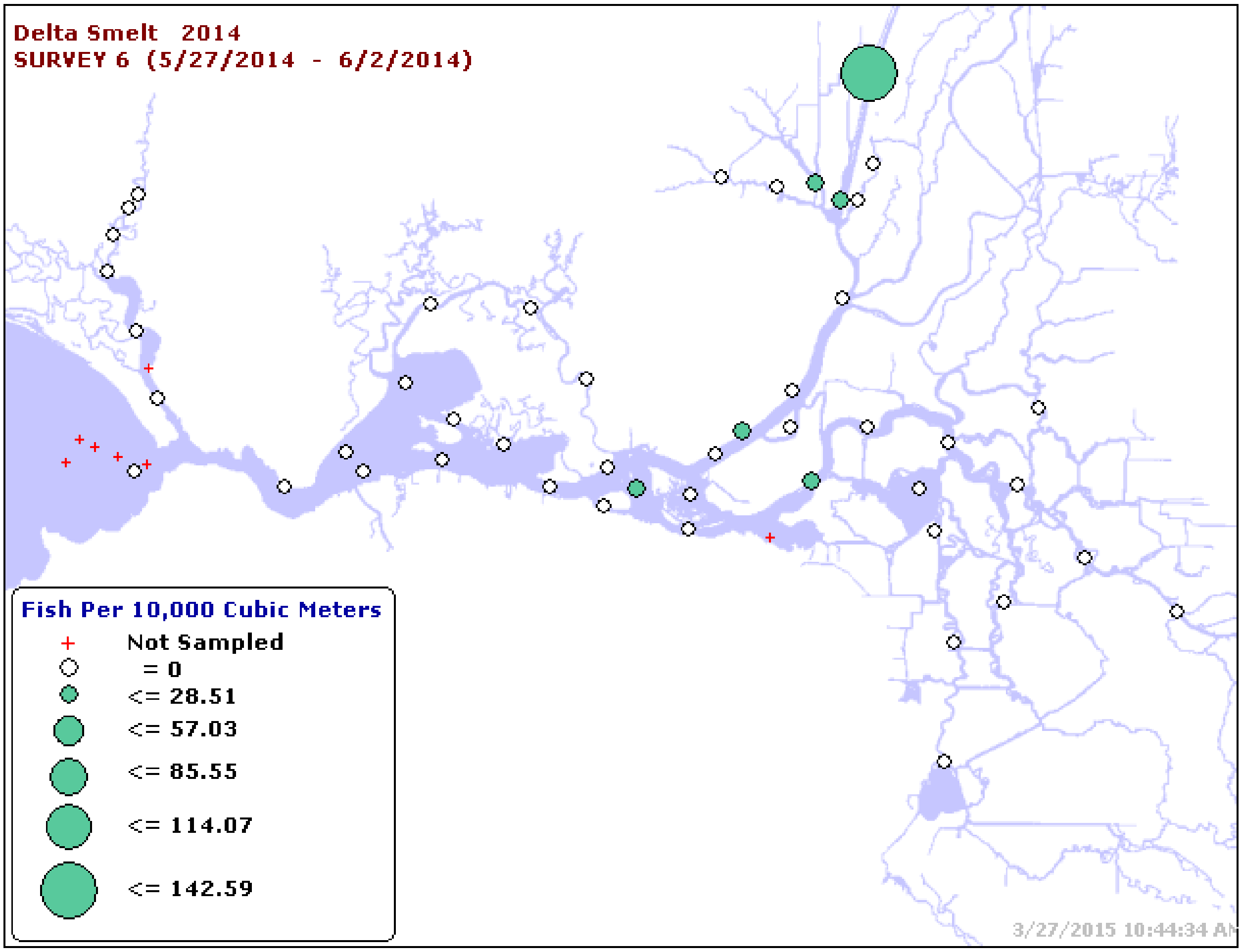
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D22. Density of Delta Smelt from 20-mm Survey 9, 2013.



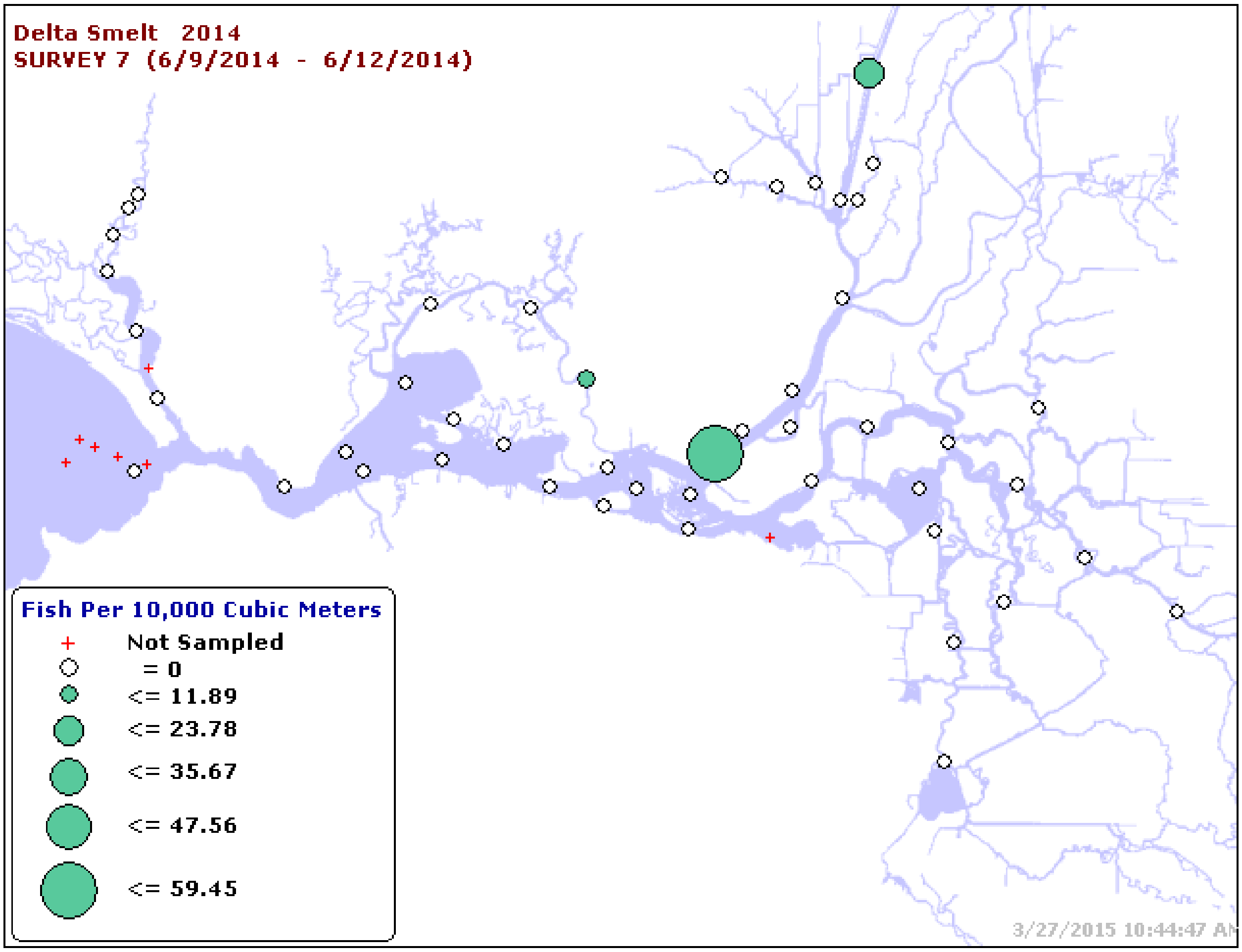
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D23. Density of Delta Smelt from 20-mm Survey 5, 2014.



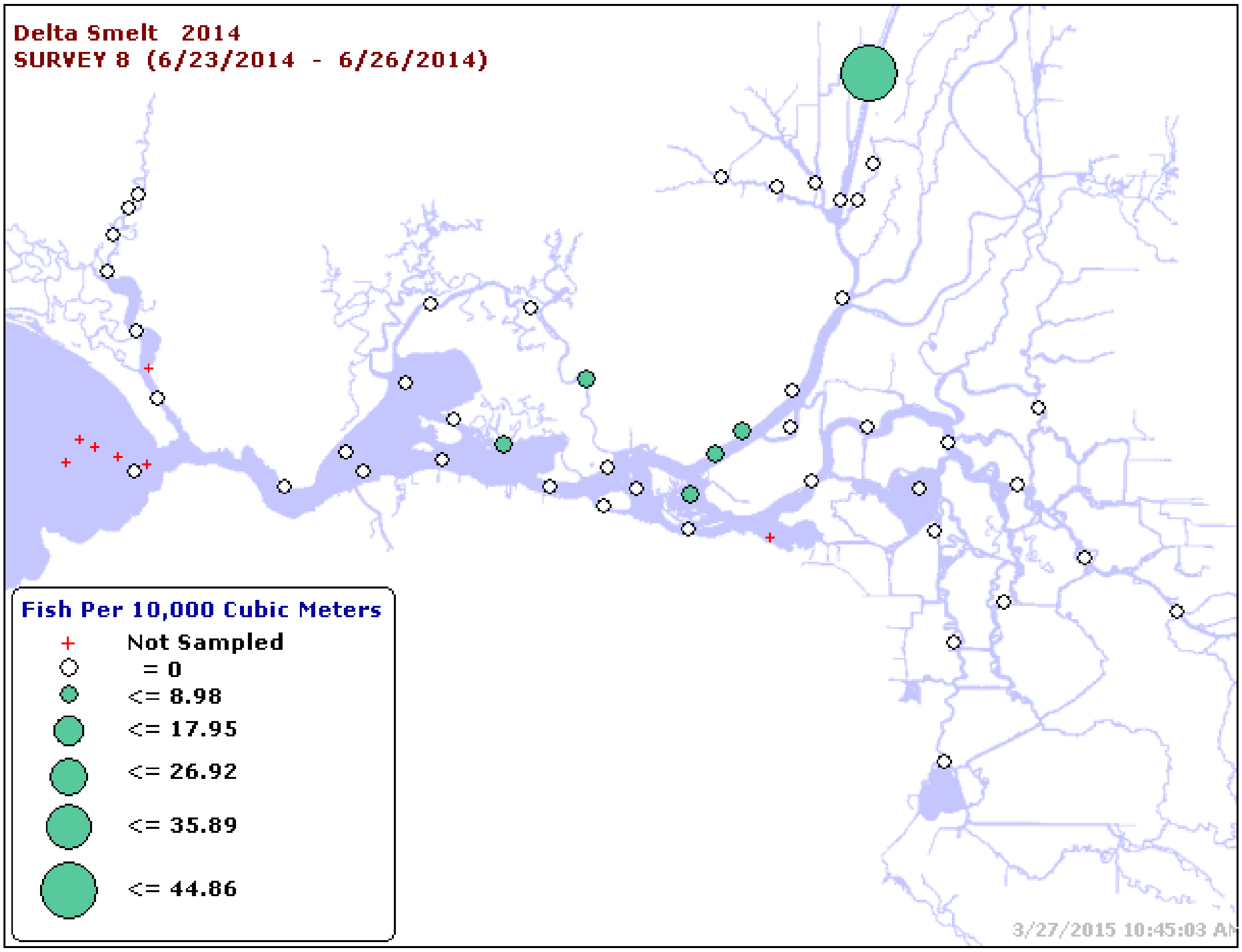
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D24. Density of Delta Smelt from 20-mm Survey 6, 2014.



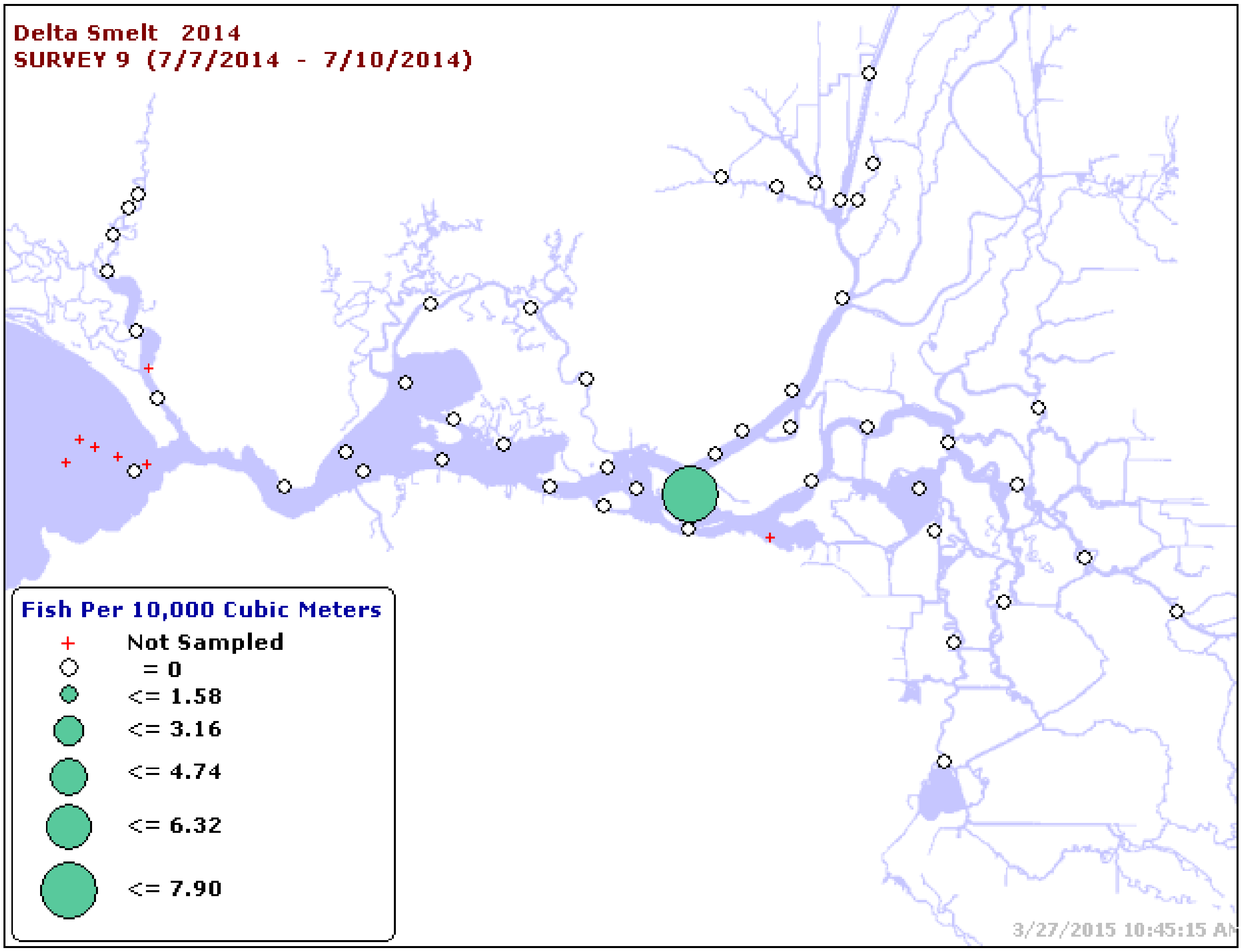
Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D25. 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 D26. Density of Delta Smelt from 20-mm Survey 8, 2014.

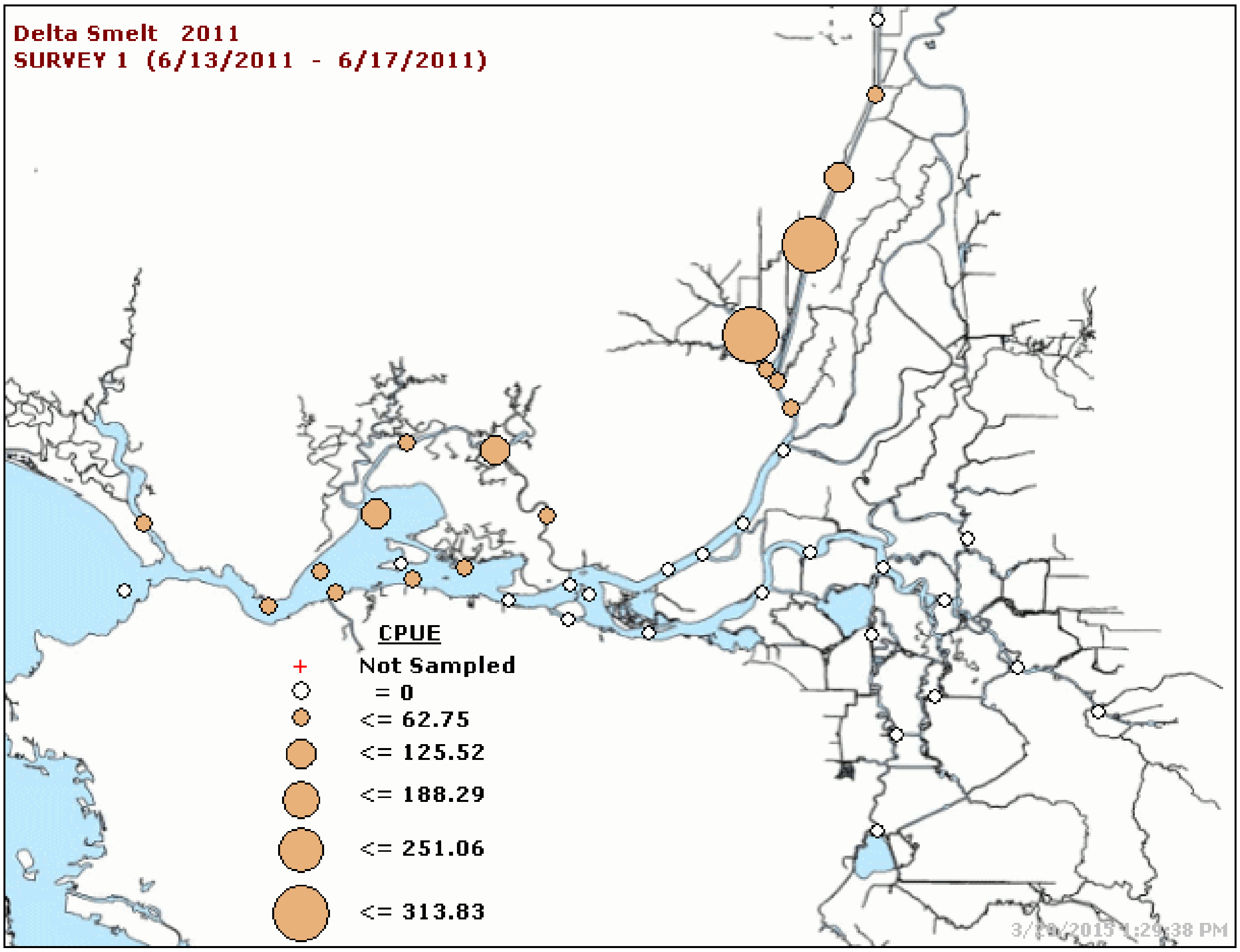


Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: March 27, 2015.

Figure D27. Density of Delta Smelt from 20-mm Survey 9, 2014.

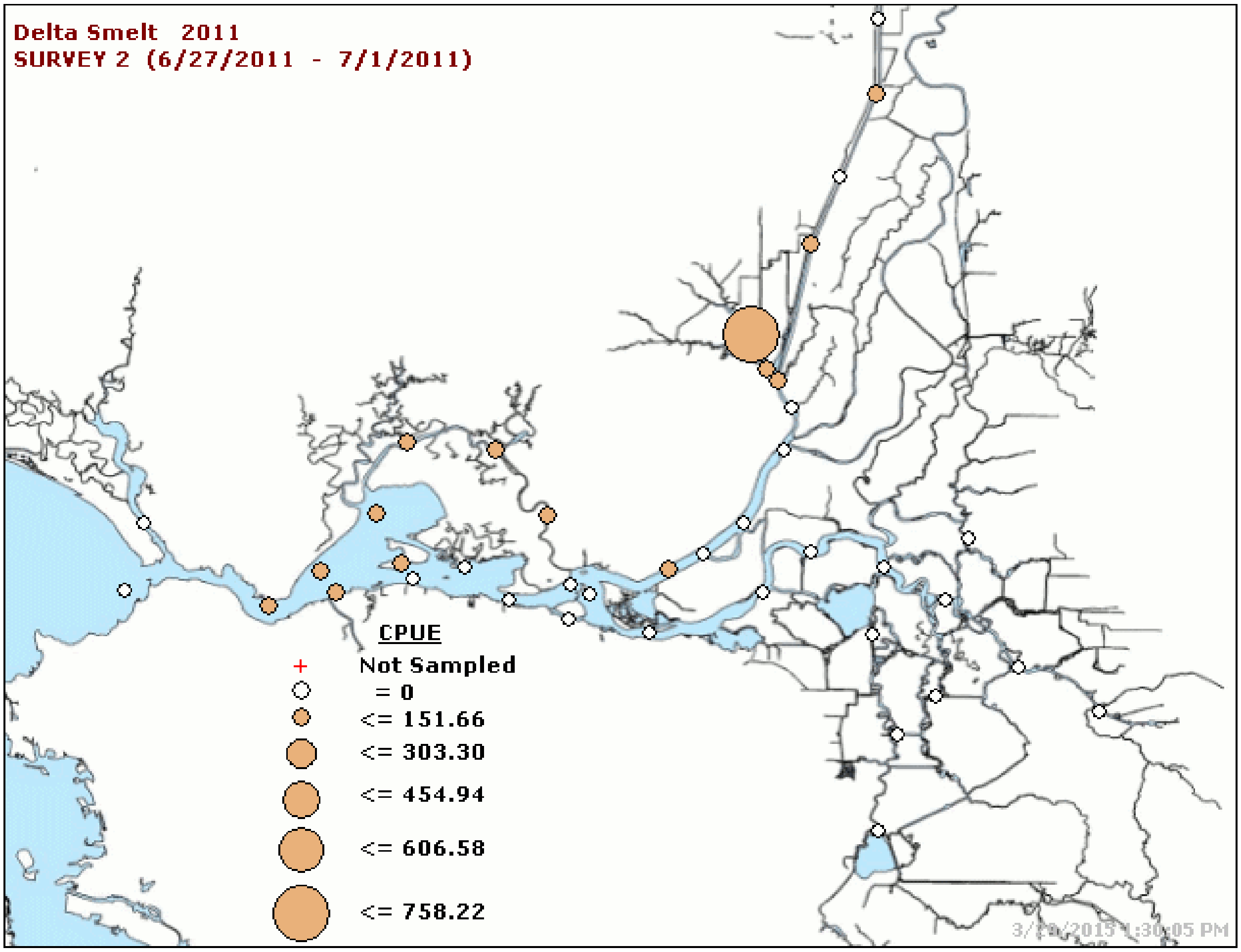
Summer Townet Survey

The Summer Townet Survey samples in June-August. Since 2011, the Summer Townet Survey has sampled several additional stations in the Cache Slough and Sacramento Deep Water Ship Channel (see, for example, Figure D28). Although this survey does not sample within False River, it samples close to this location. Delta smelt occurred infrequently in the San Joaquin River near the proposed West False River barrier (Figures D28-D51). Relatively high densities of delta smelt generally occurred in Cache Slough above the confluence with the Sacramento Deep Water Ship Channel, and in the Ship Channel itself, as well as in the lower Sacramento River, West Delta, and Suisun Bay (Figures D28-D51).



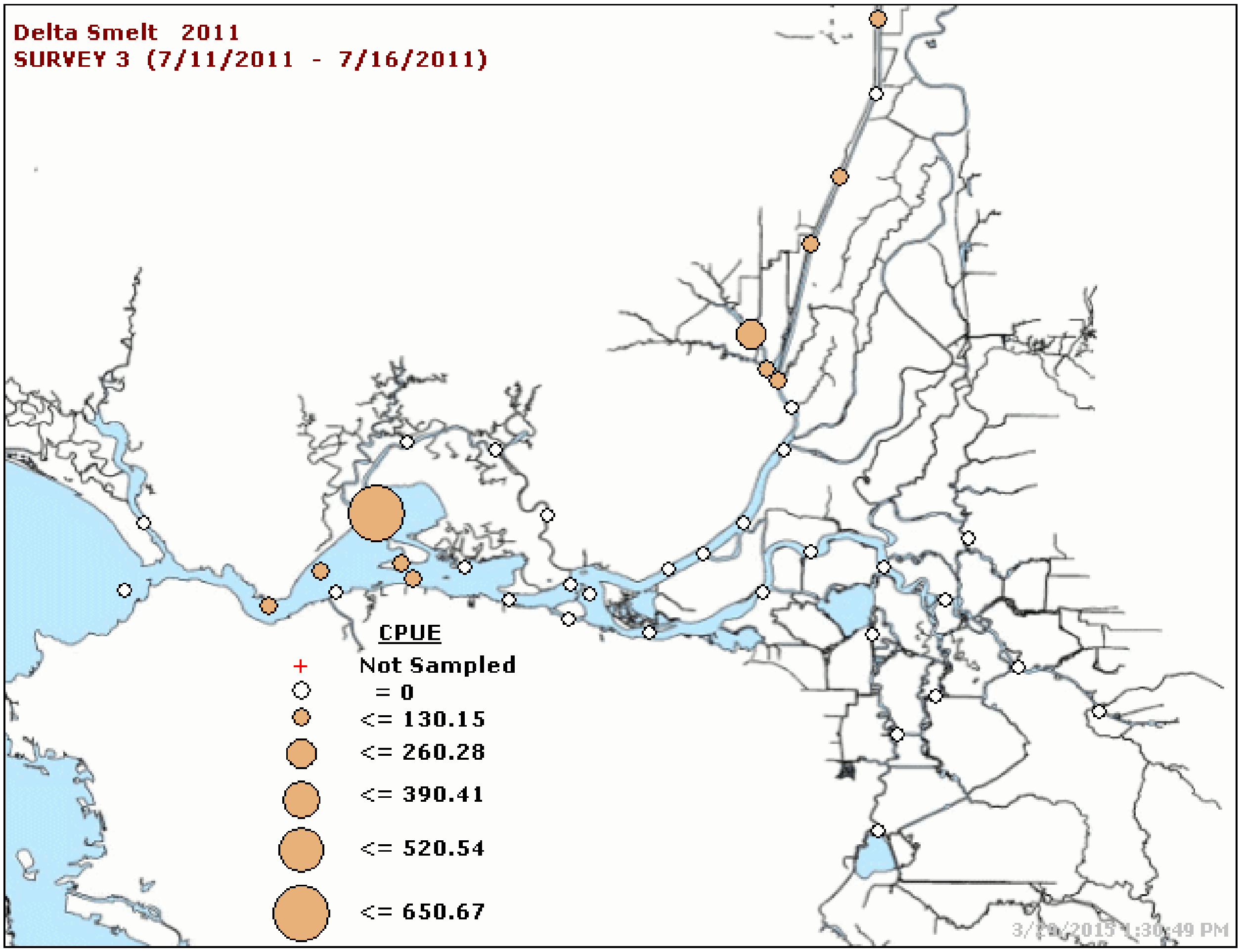
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D28. Density of Delta Smelt from Summer Townet Survey 1, 2011.



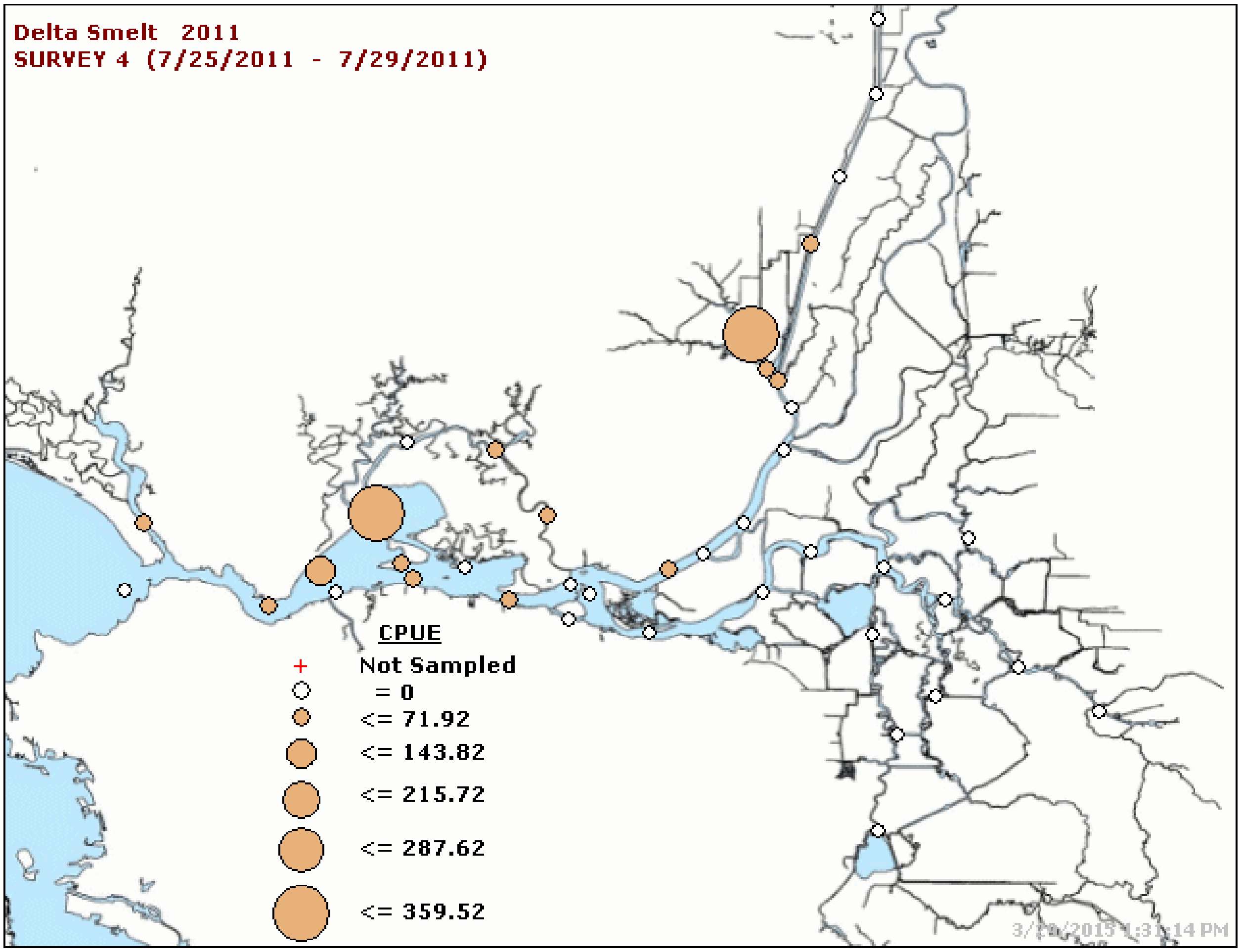
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D29. Density of Delta Smelt from Summer Townet Survey 2, 2011.



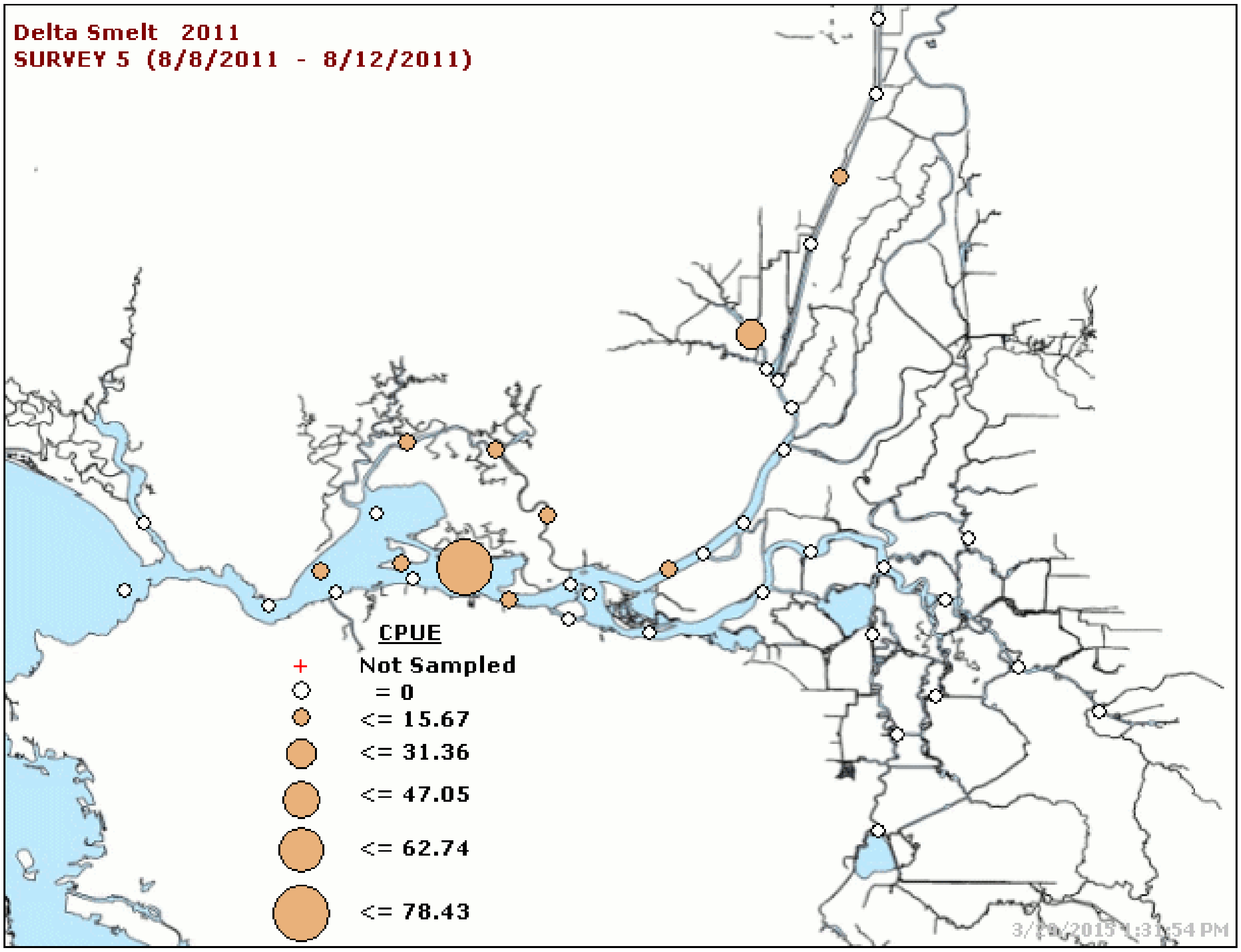
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D30. Density of Delta Smelt from Summer Townet Survey 3, 2011.



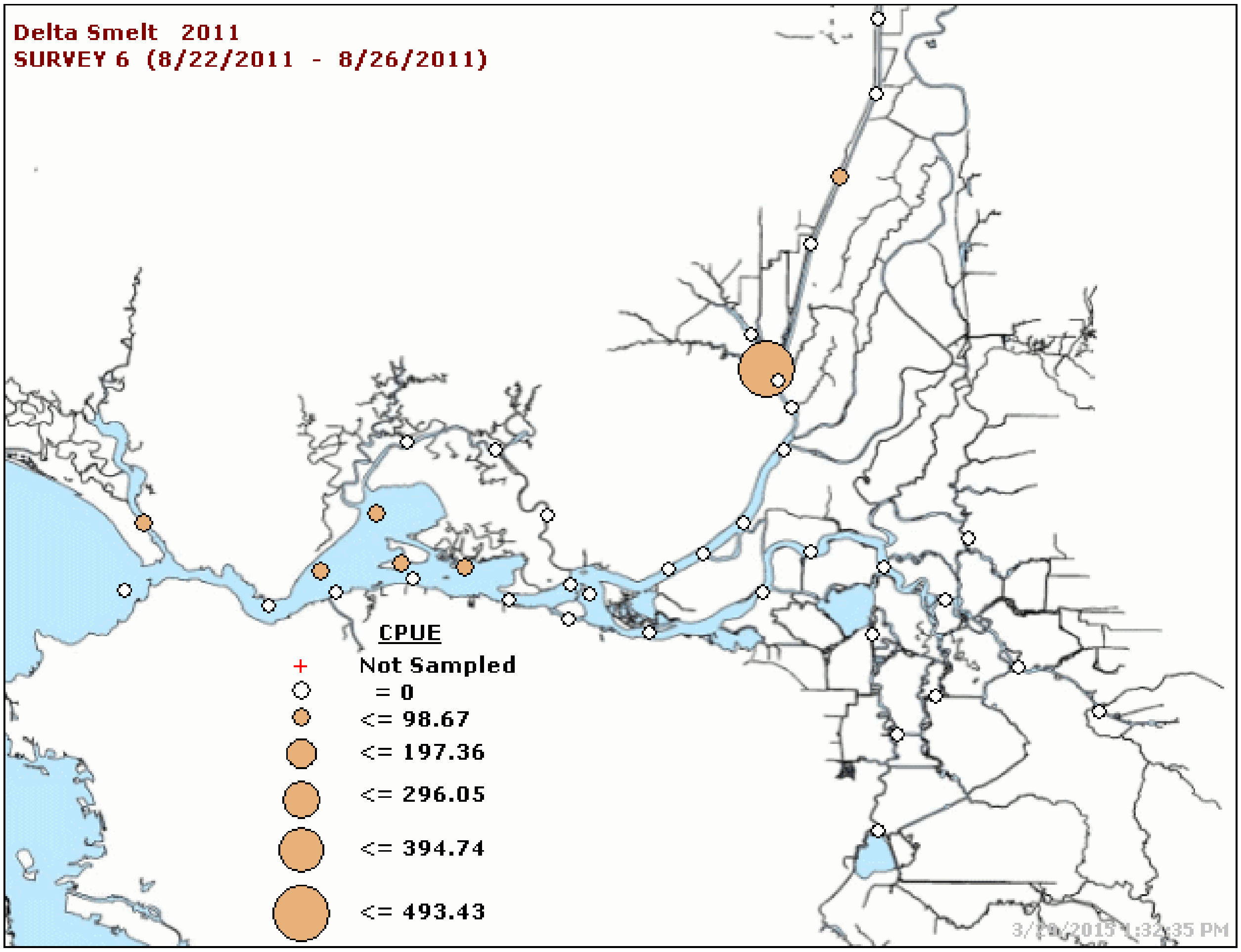
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D31. Density of Delta Smelt from Summer Townet Survey 4, 2011.



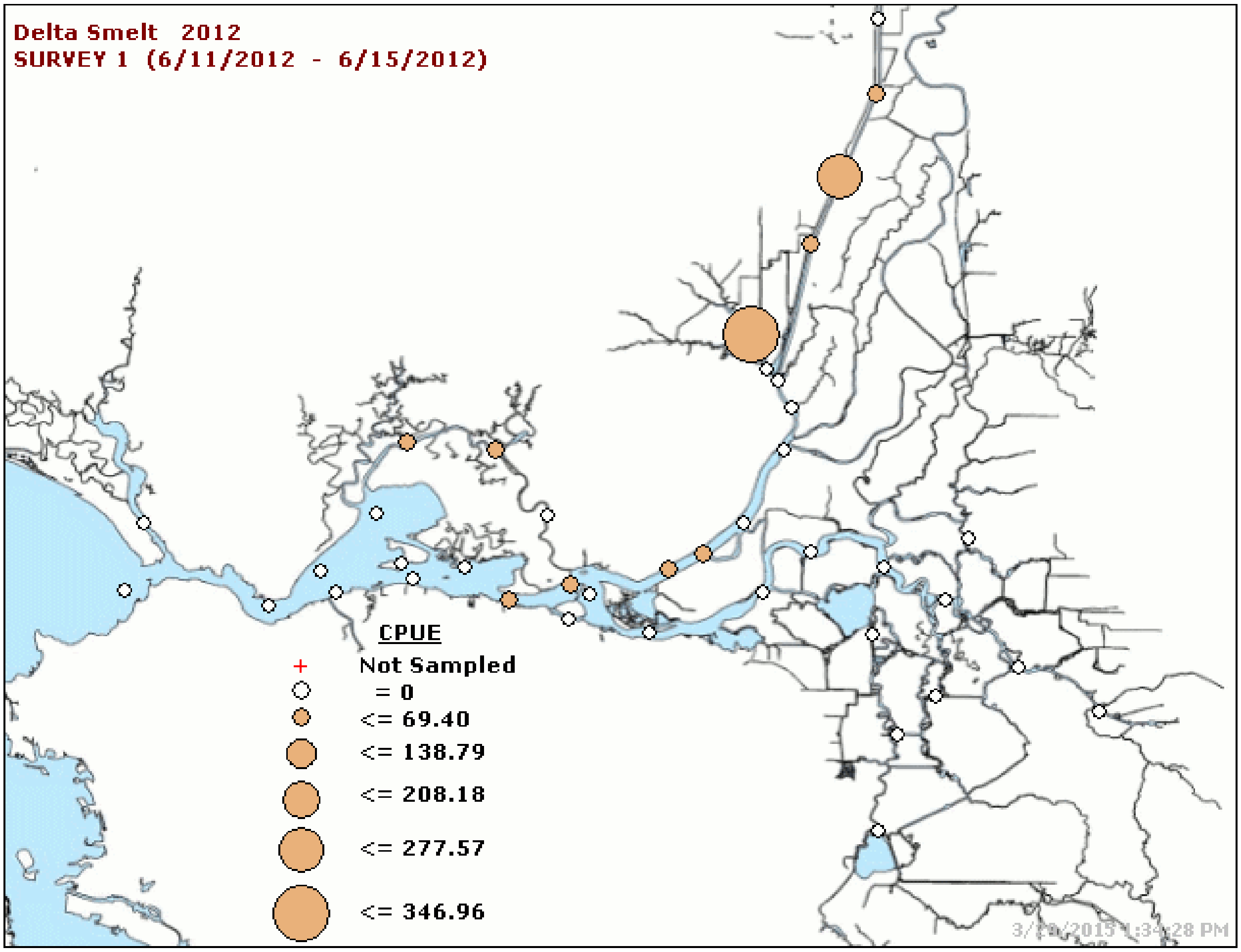
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D32. Density of Delta Smelt from Summer Townet Survey 5, 2011.



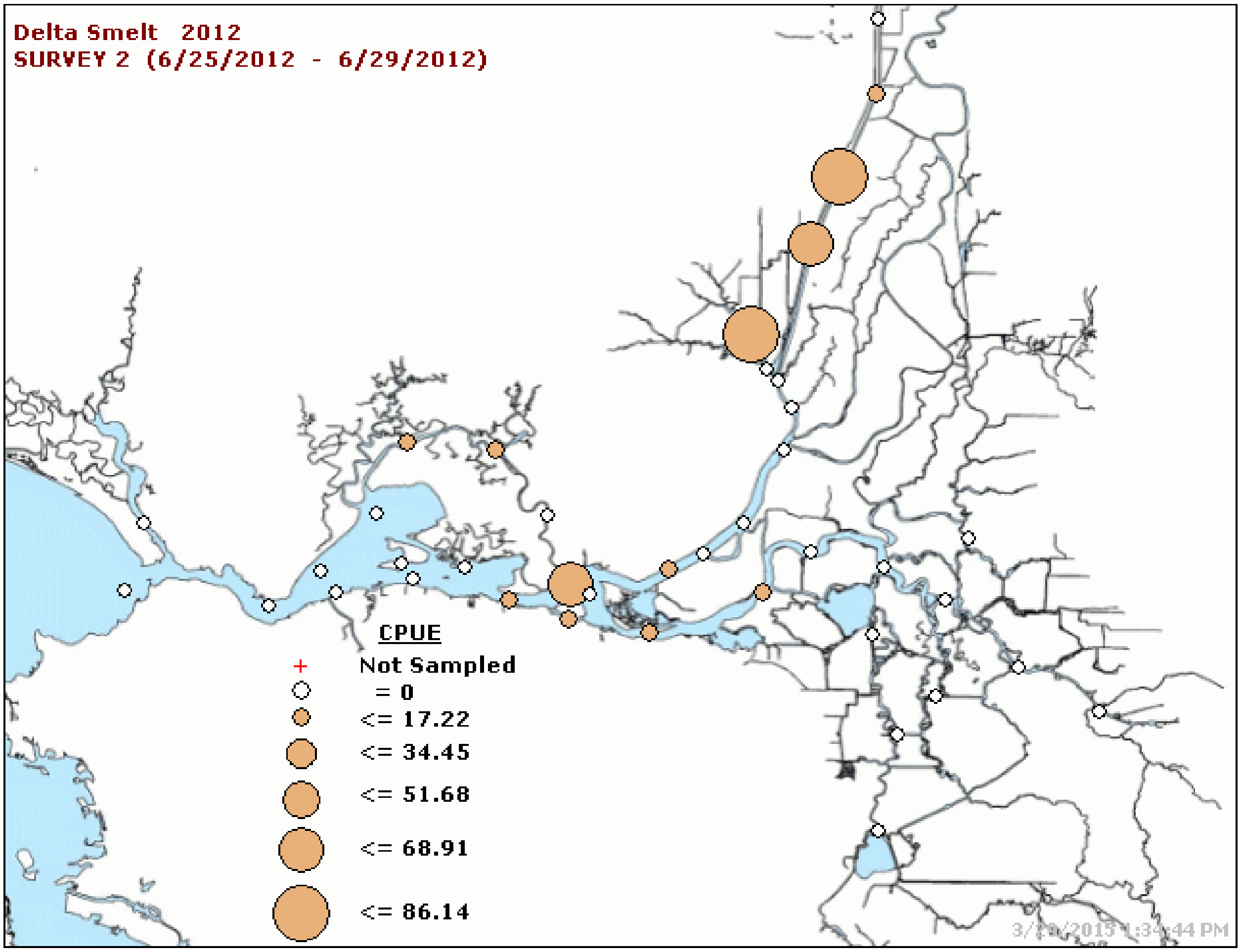
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D33. Density of Delta Smelt from Summer Townet Survey 6, 2011.



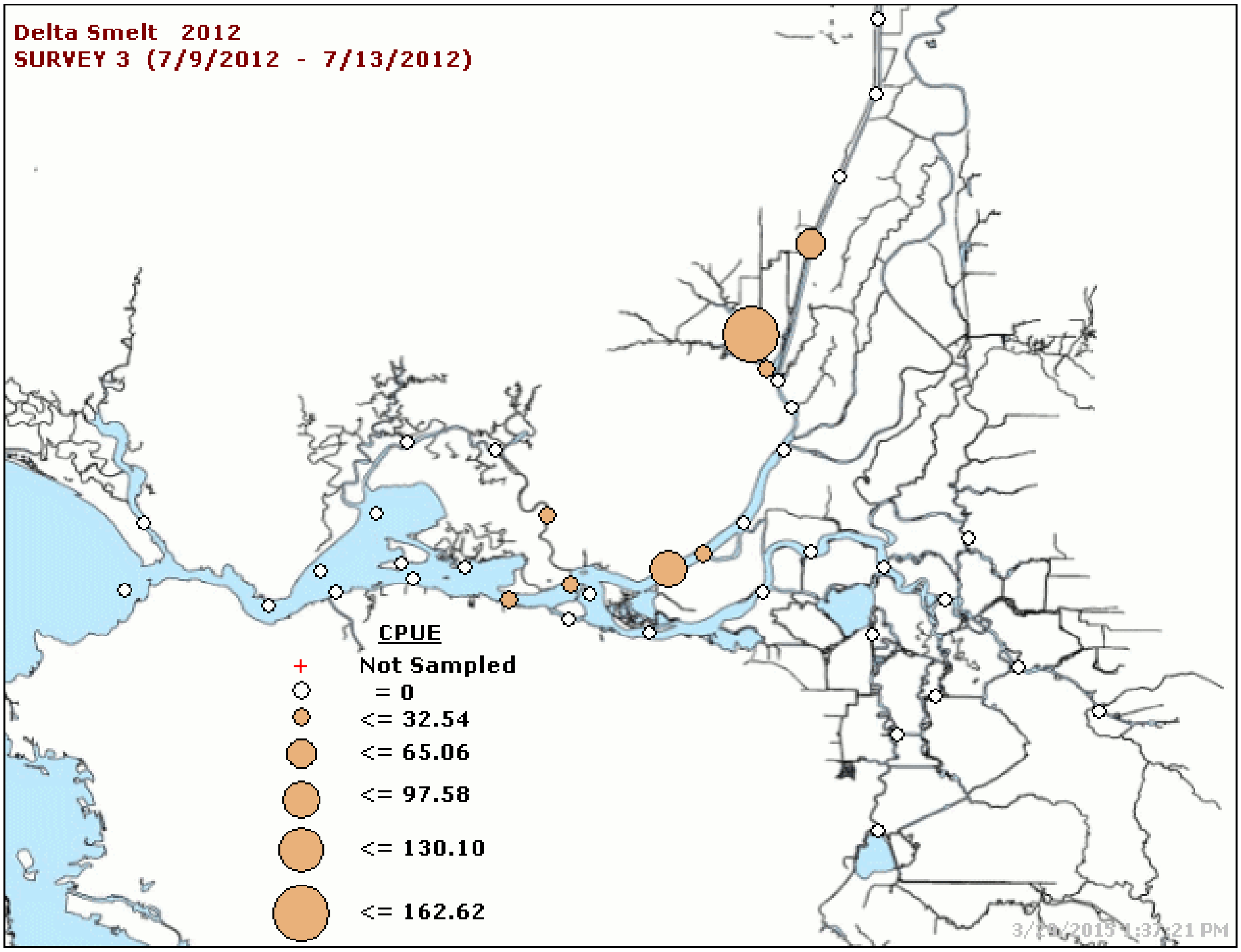
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D34. Density of Delta Smelt from Summer Townet Survey 1, 2012.



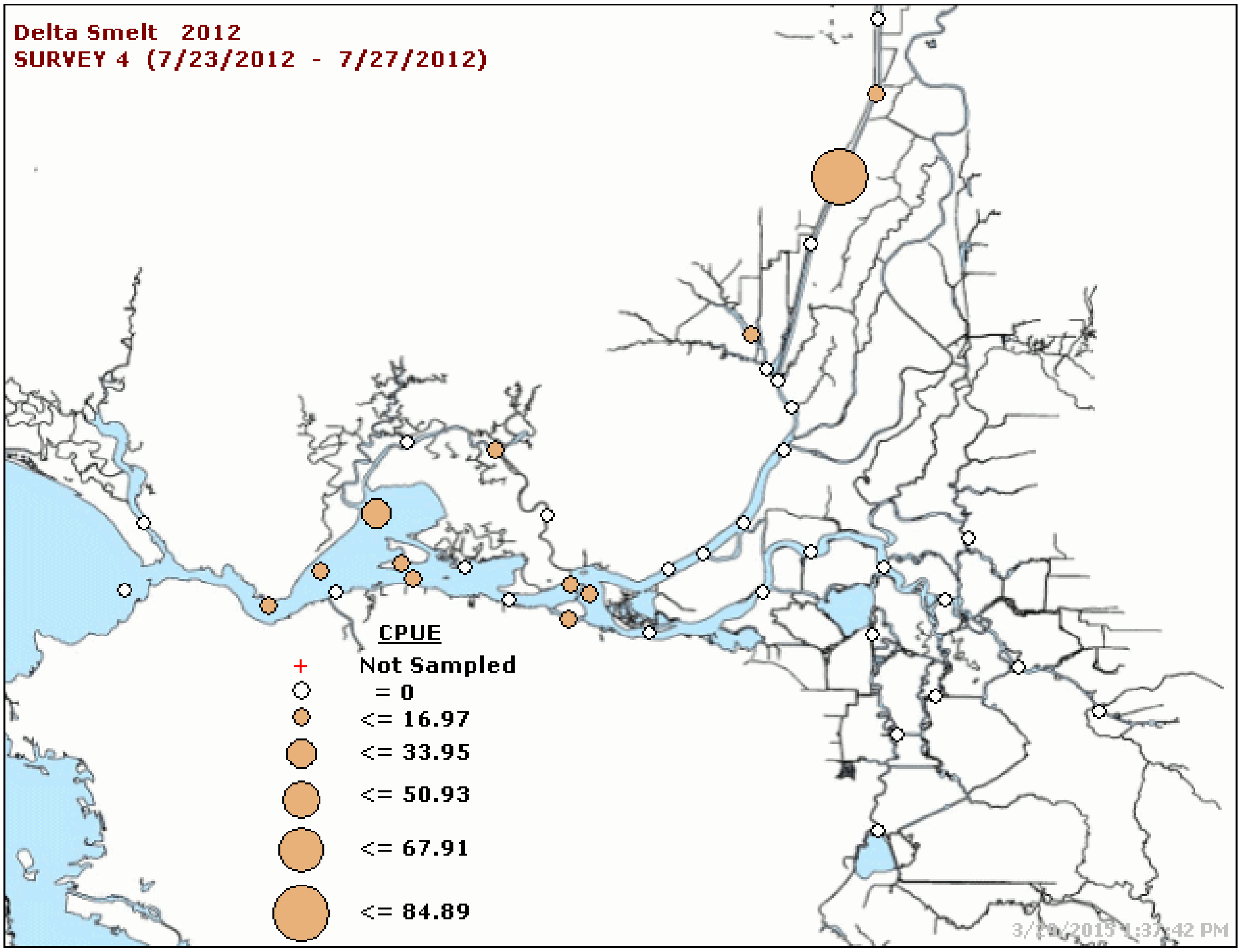
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D35. Density of Delta Smelt from Summer Townet Survey 2, 2012.



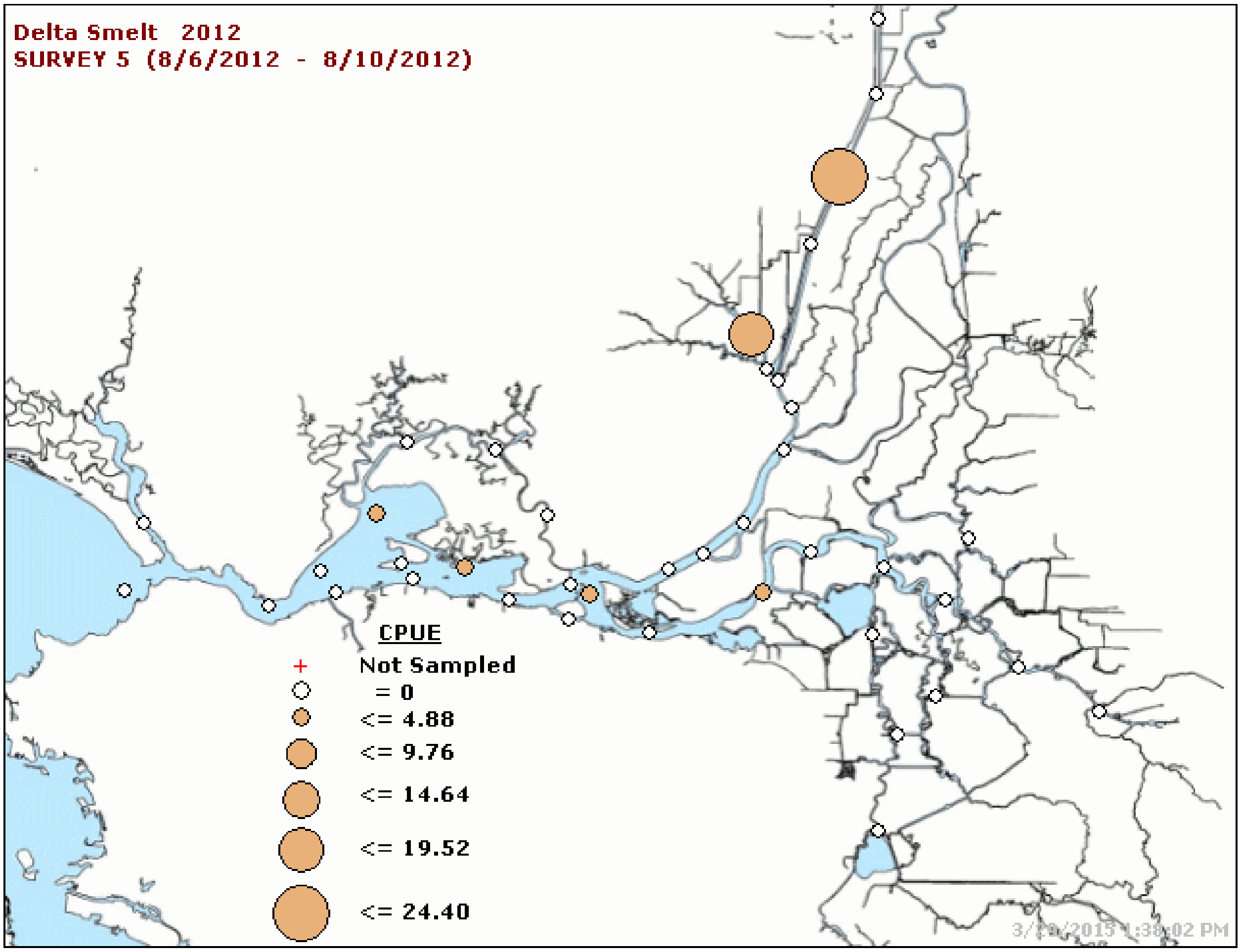
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D36. Density of Delta Smelt from Summer Townet Survey 3, 2012.



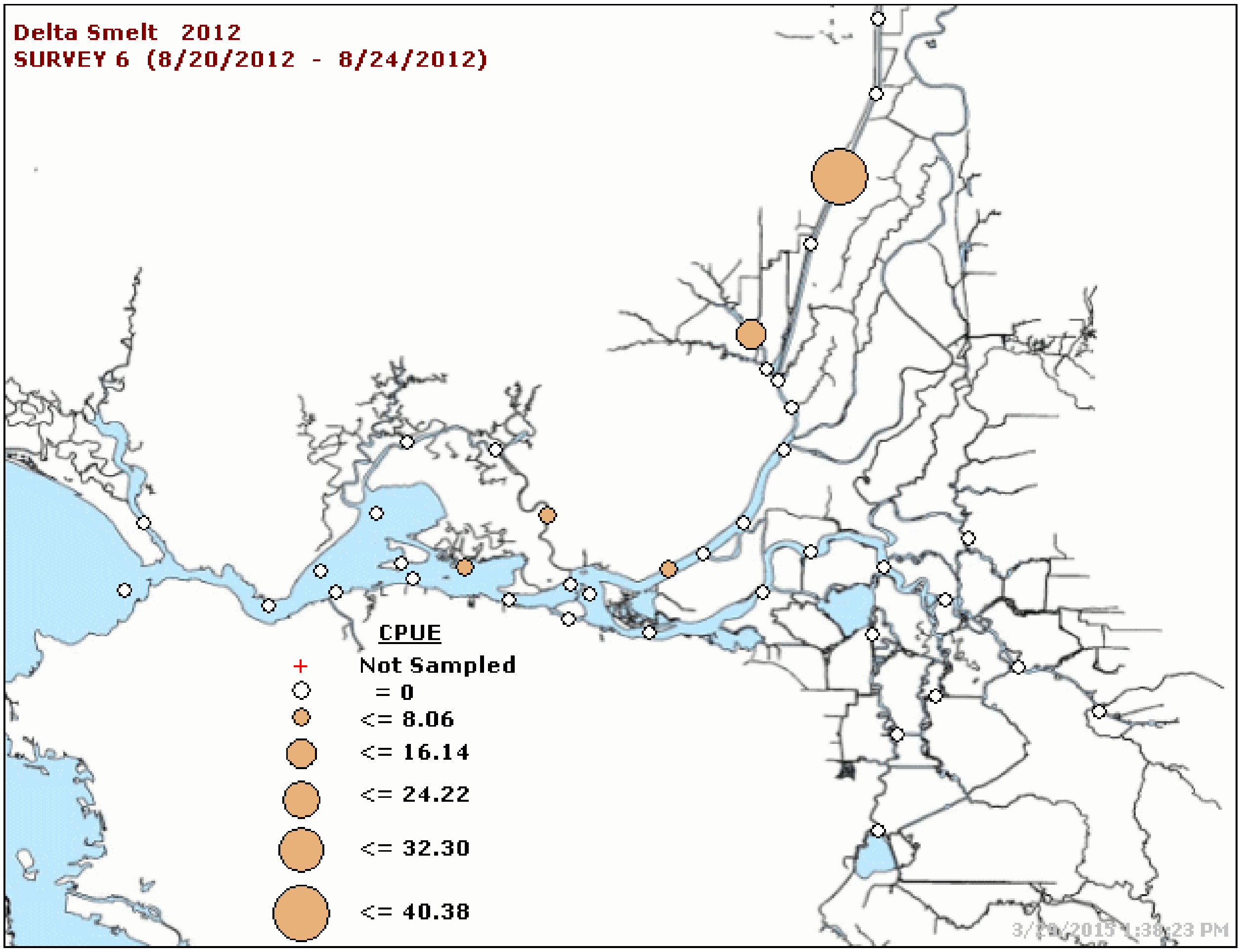
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D37. Density of Delta Smelt from Summer Townet Survey 4, 2012.



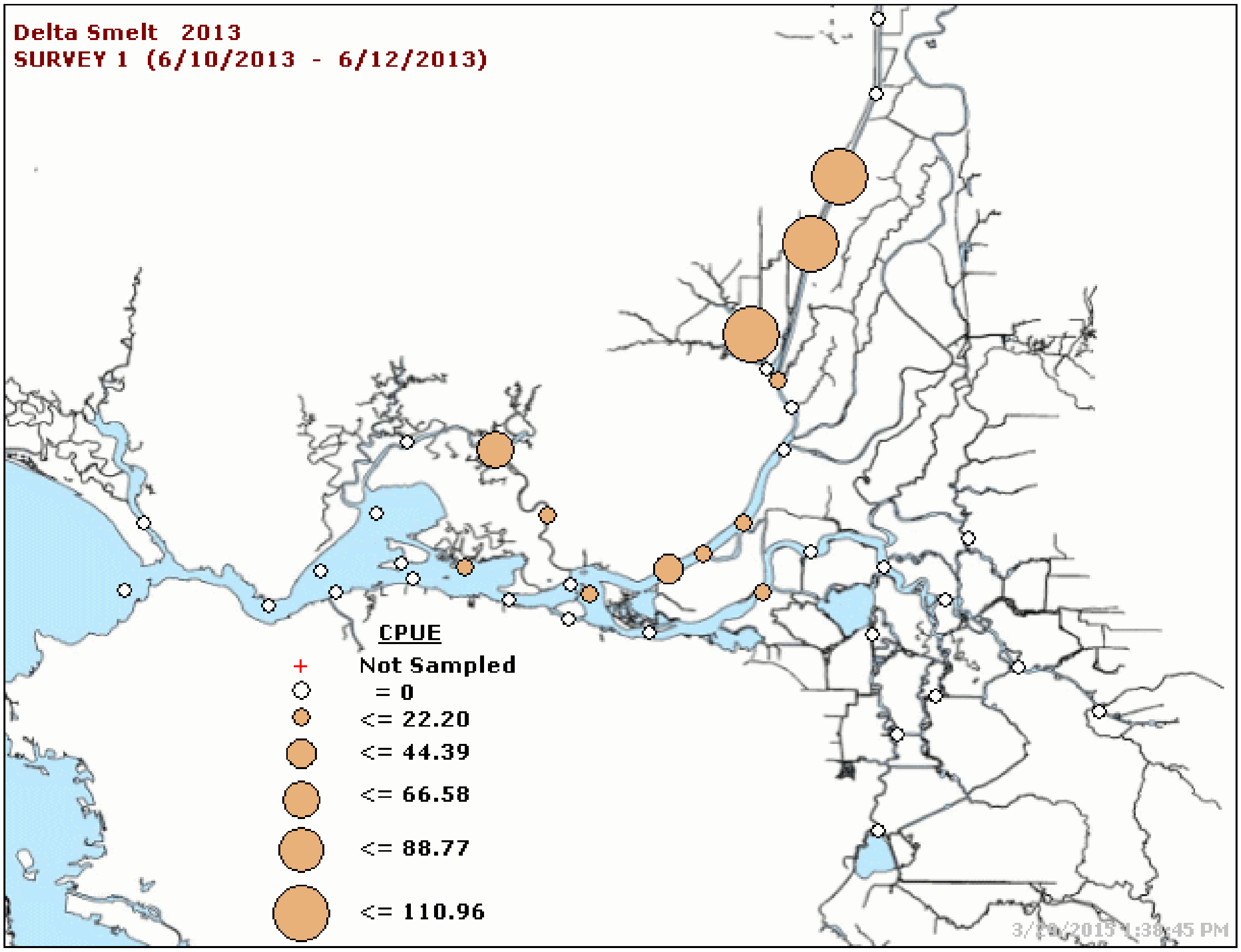
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D38. Density of Delta Smelt from Summer Townet Survey 5, 2012.



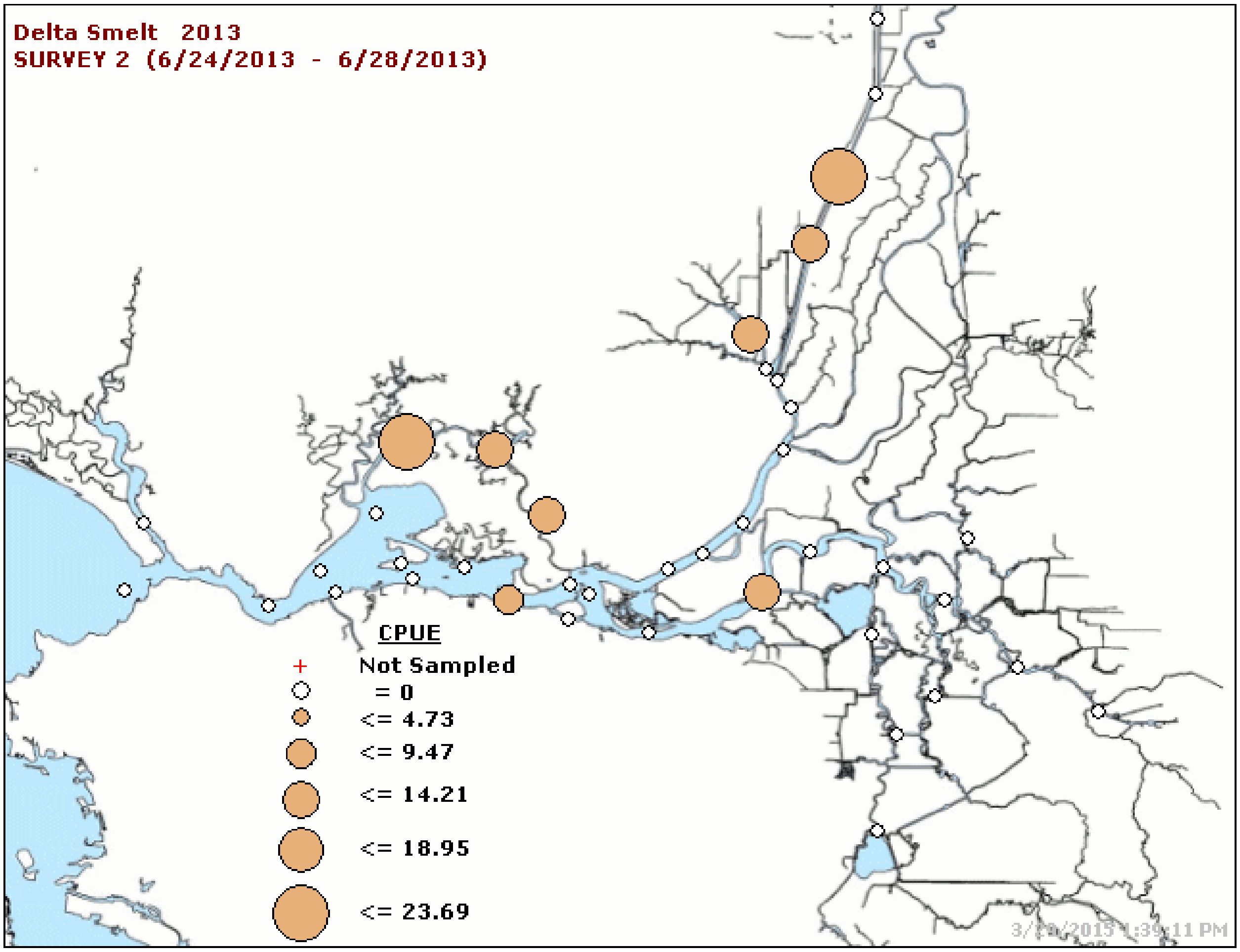
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D39. Density of Delta Smelt from Summer Townet Survey 6, 2012.



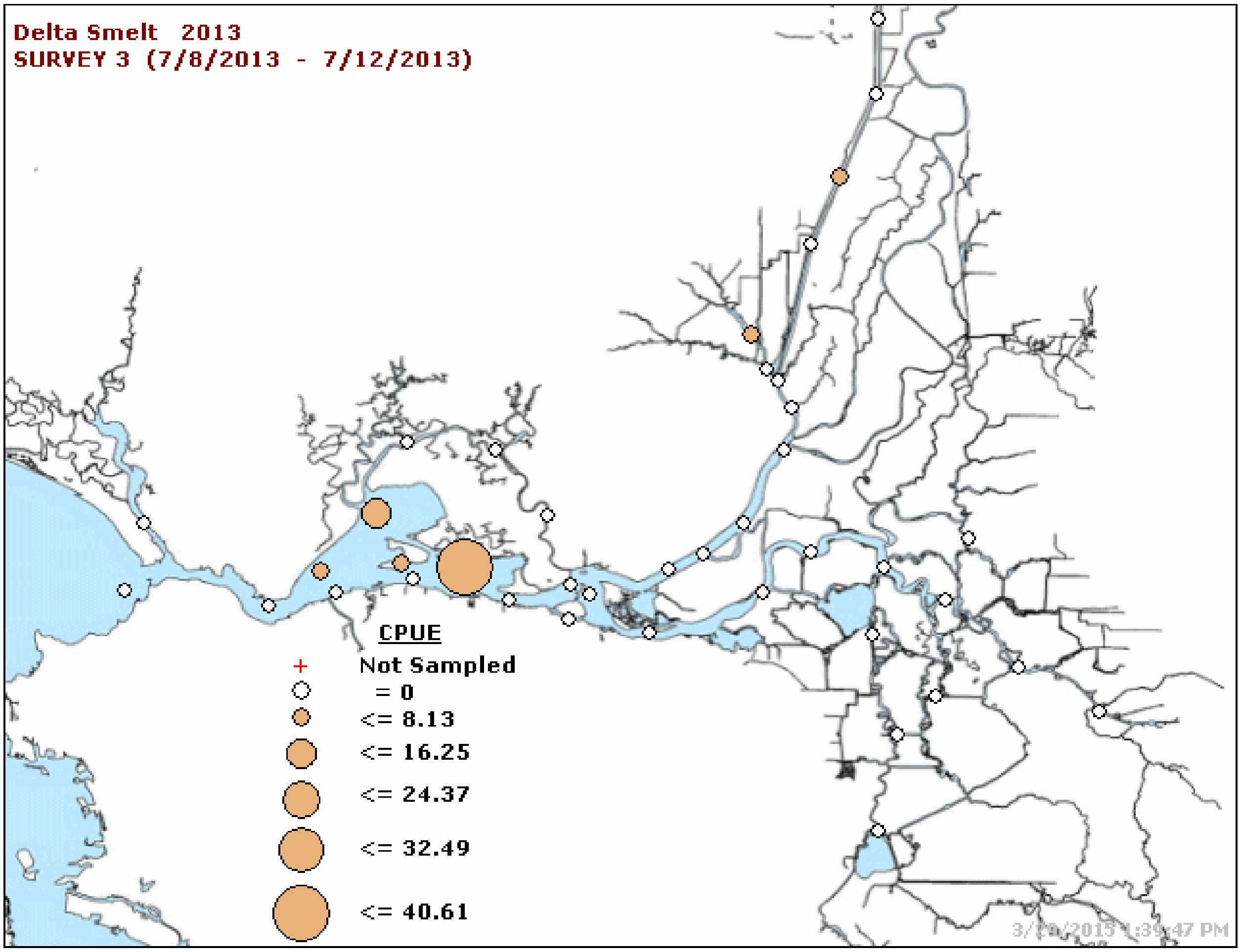
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D40. Density of Delta Smelt from Summer Townet Survey 1, 2013.



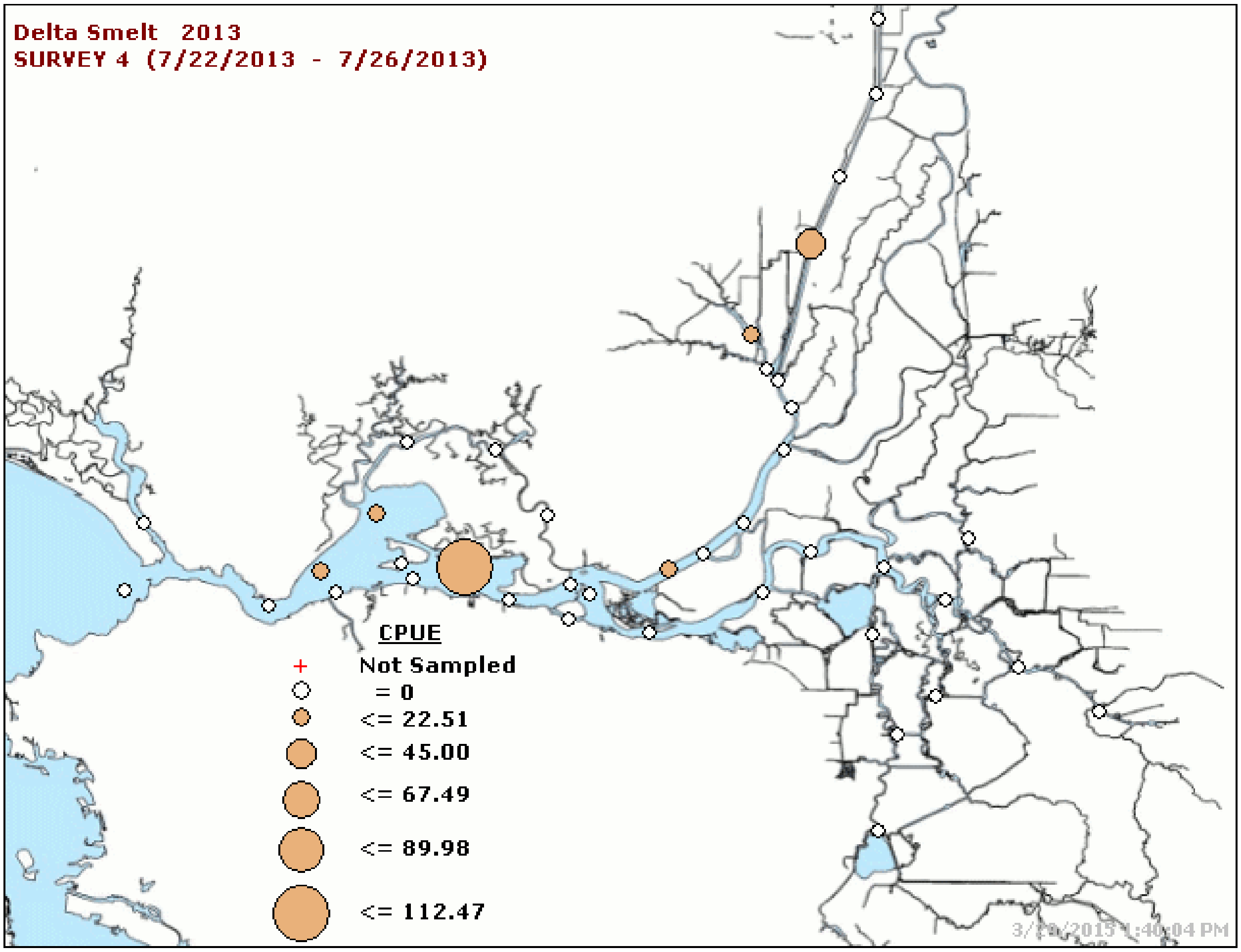
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D41. Density of Delta Smelt from Summer Townet Survey 2, 2013.



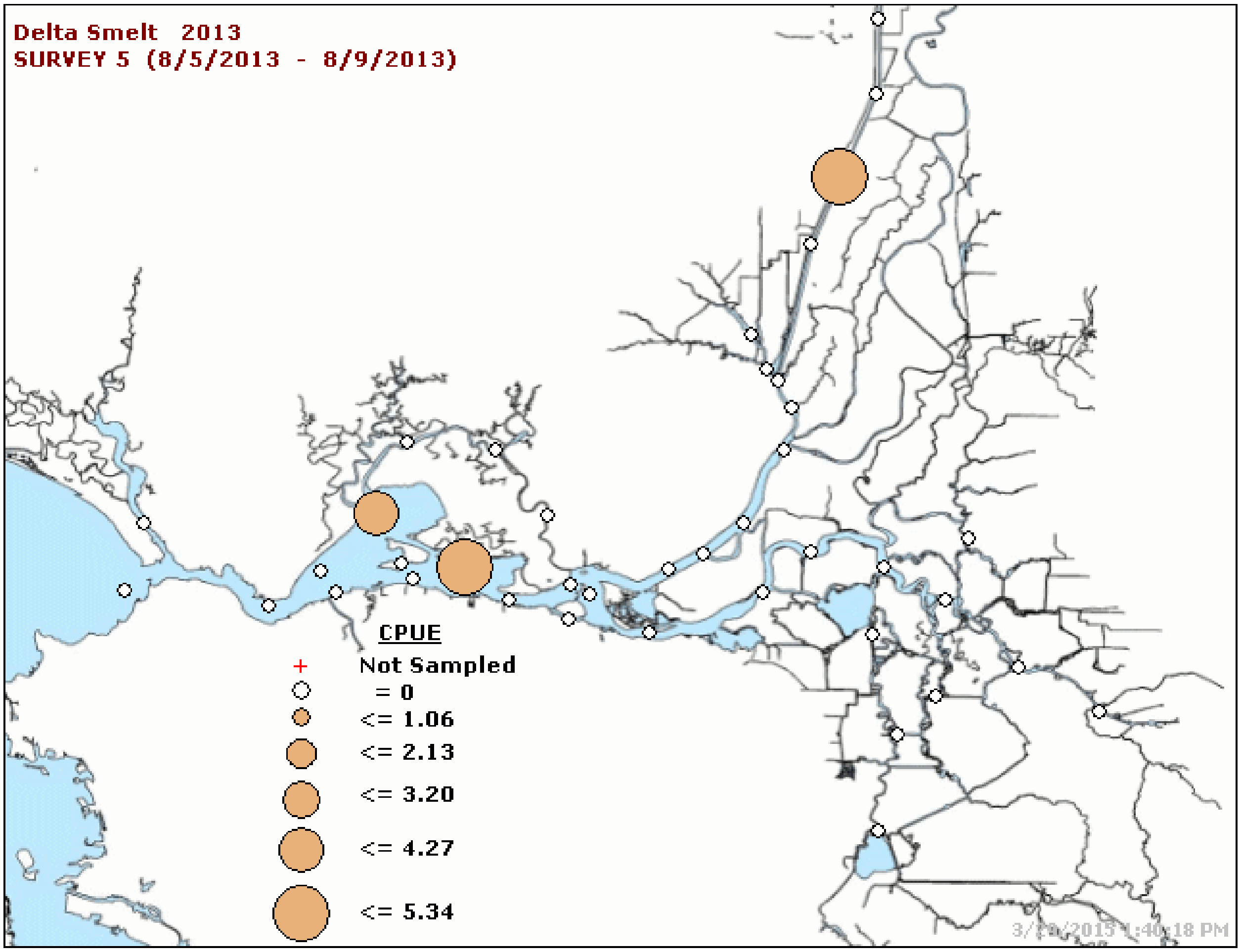
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D42. Density of Delta Smelt from Summer Townet Survey 3, 2013.



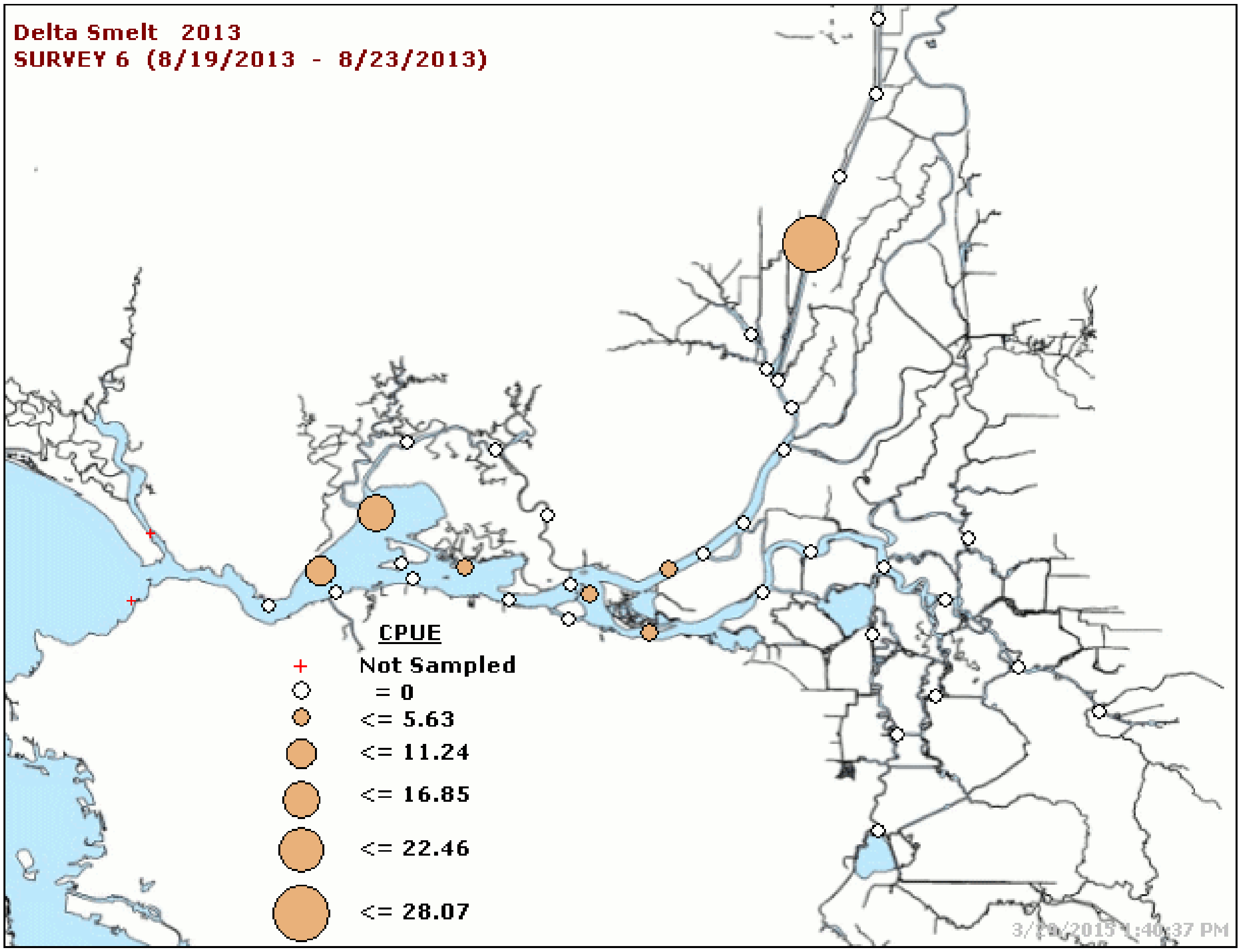
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D43. Density of Delta Smelt from Summer Townet Survey 4, 2013.



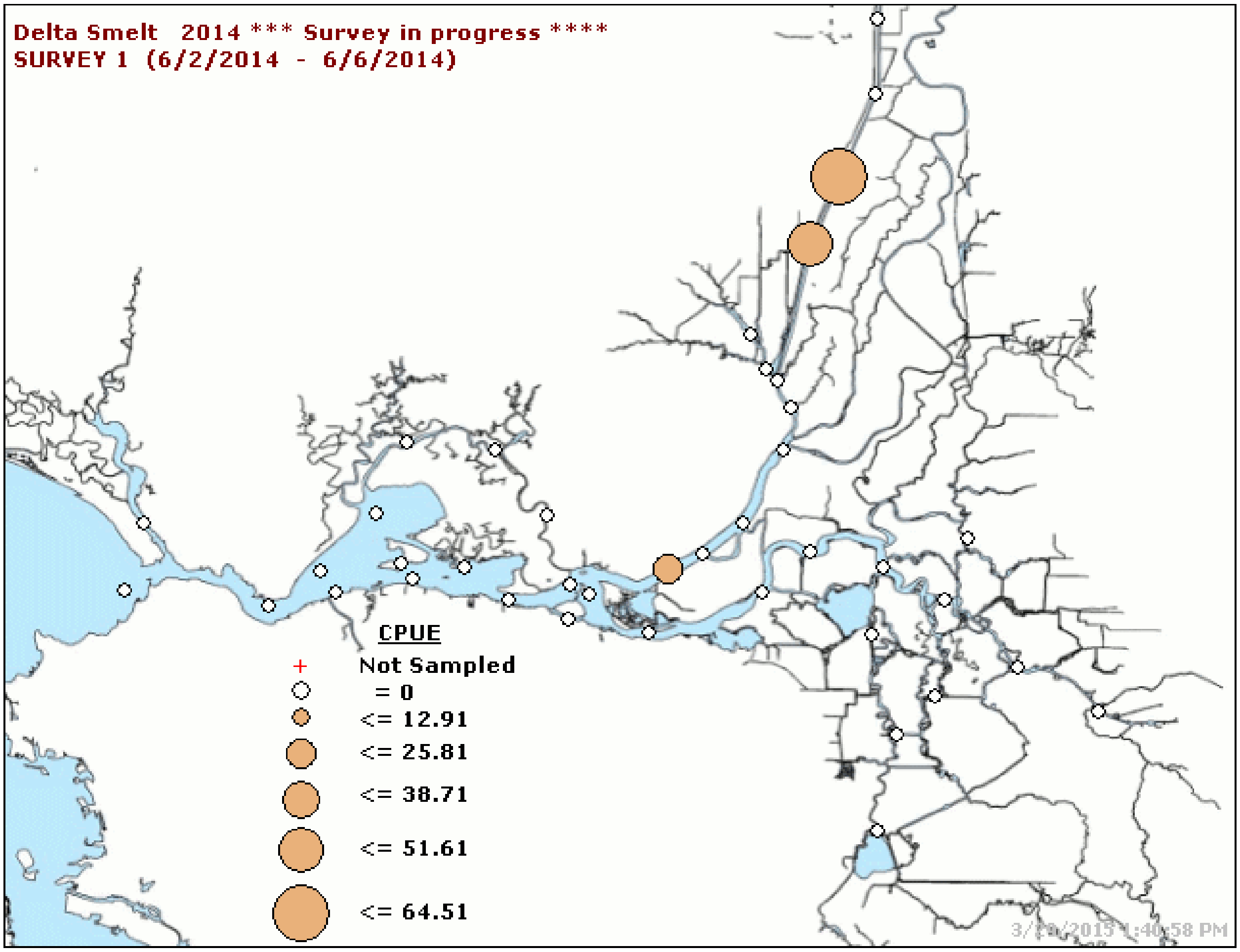
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D44. Density of Delta Smelt from Summer Townet Survey 5, 2013.



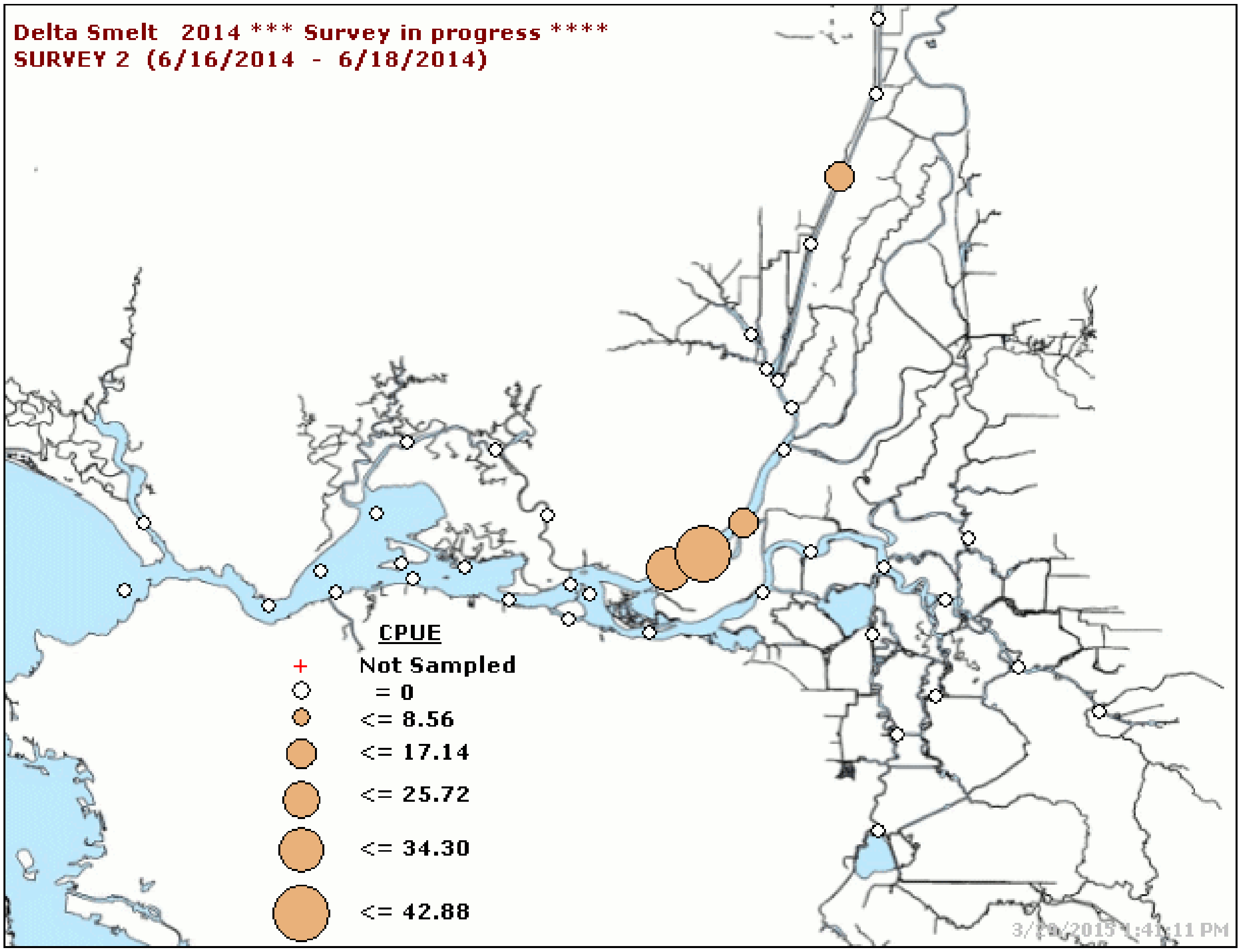
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D45. Density of Delta Smelt from Summer Townet Survey 6, 2013.



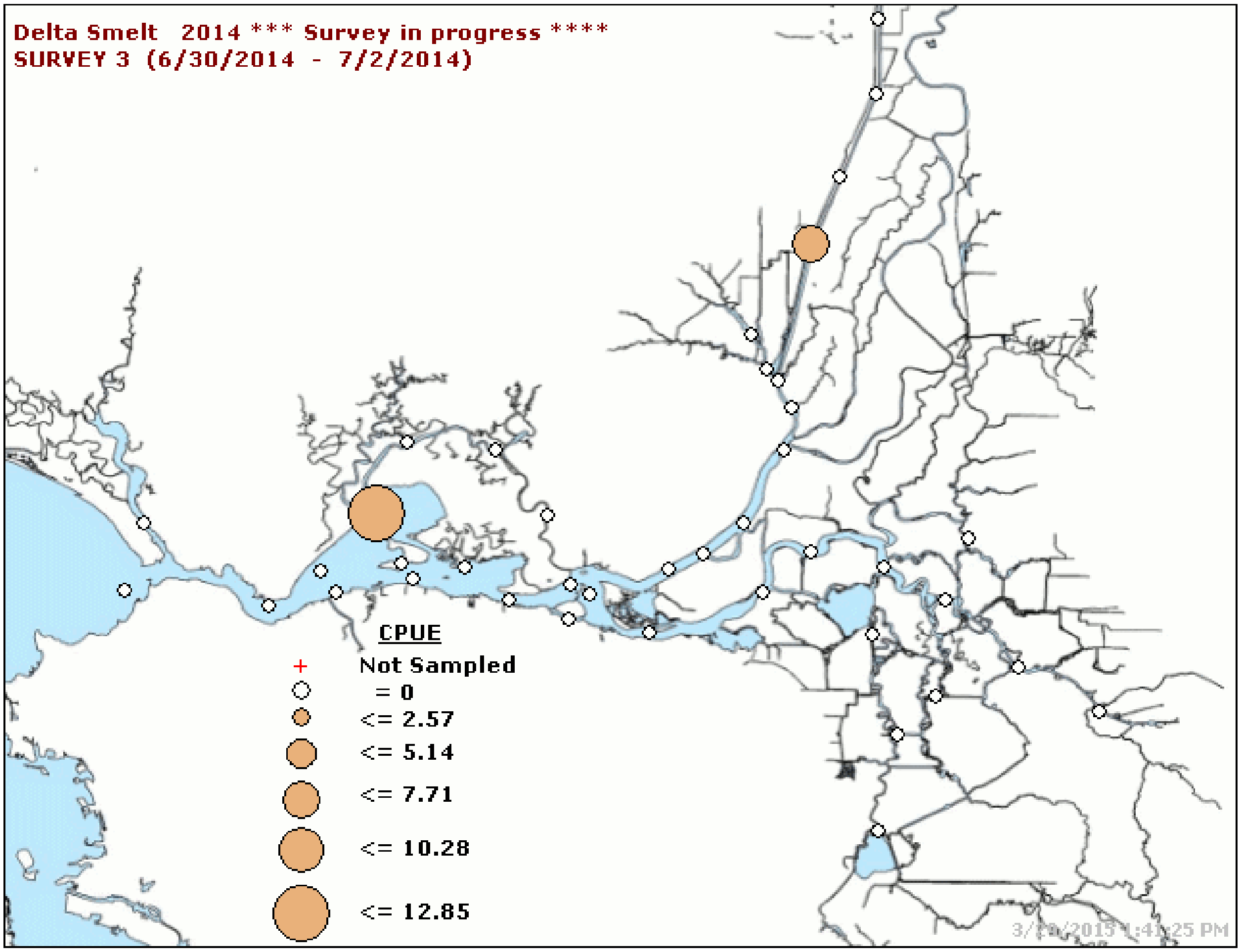
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D46. Density of Delta Smelt from Summer Townet Survey 1, 2014.



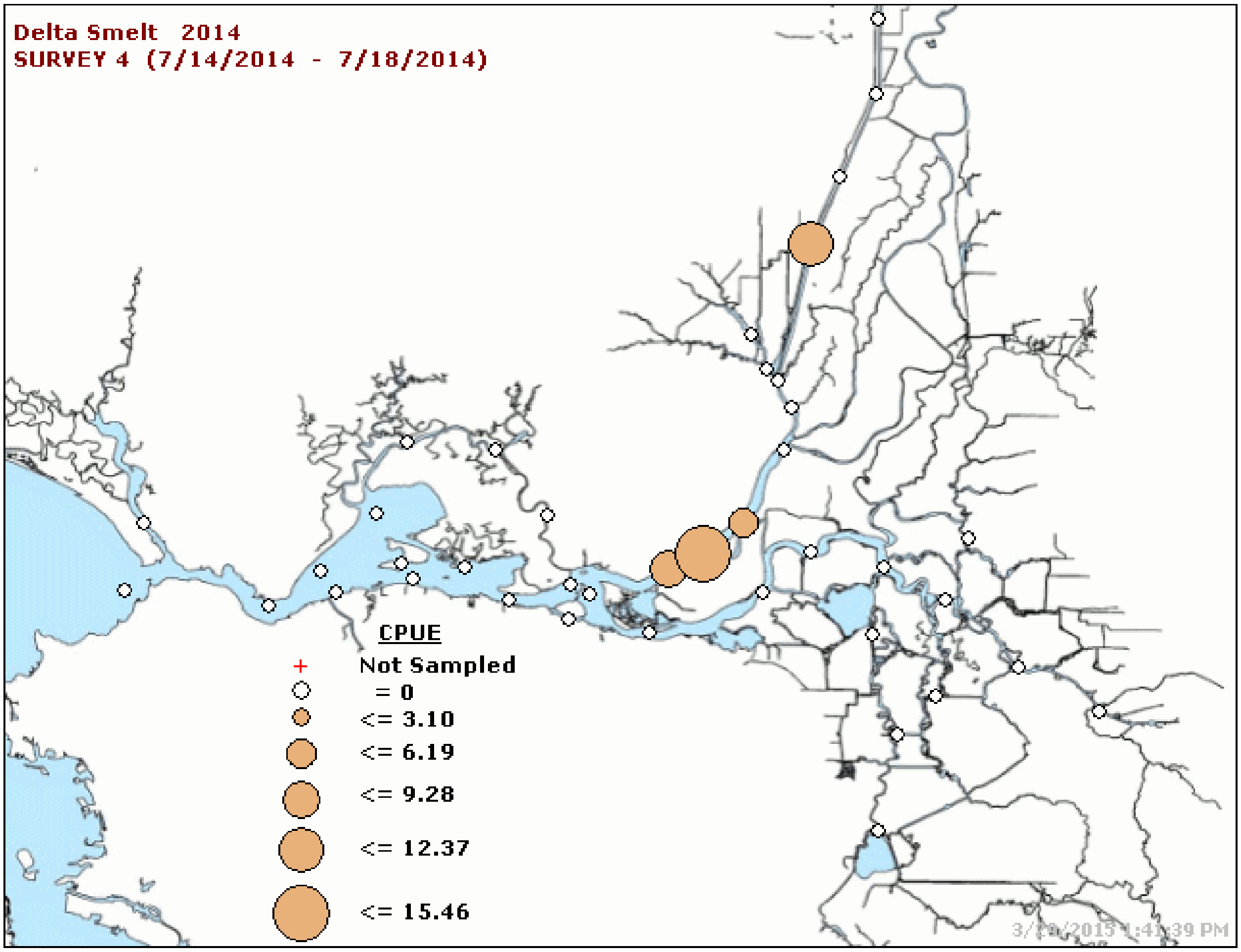
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D47. Density of Delta Smelt from Summer Townet Survey 2, 2014.



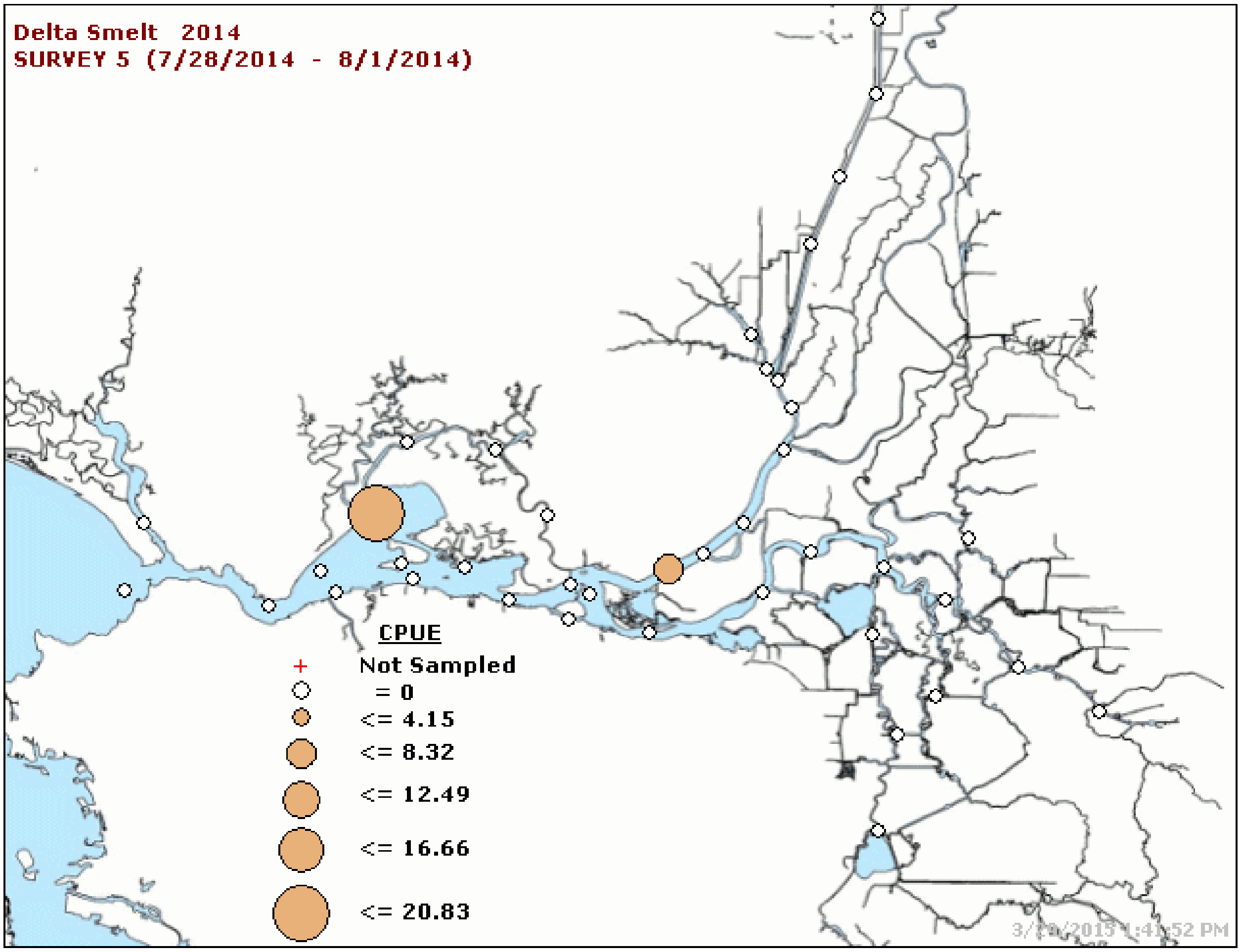
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D48. Density of Delta Smelt from Summer Townet Survey 3, 2014.



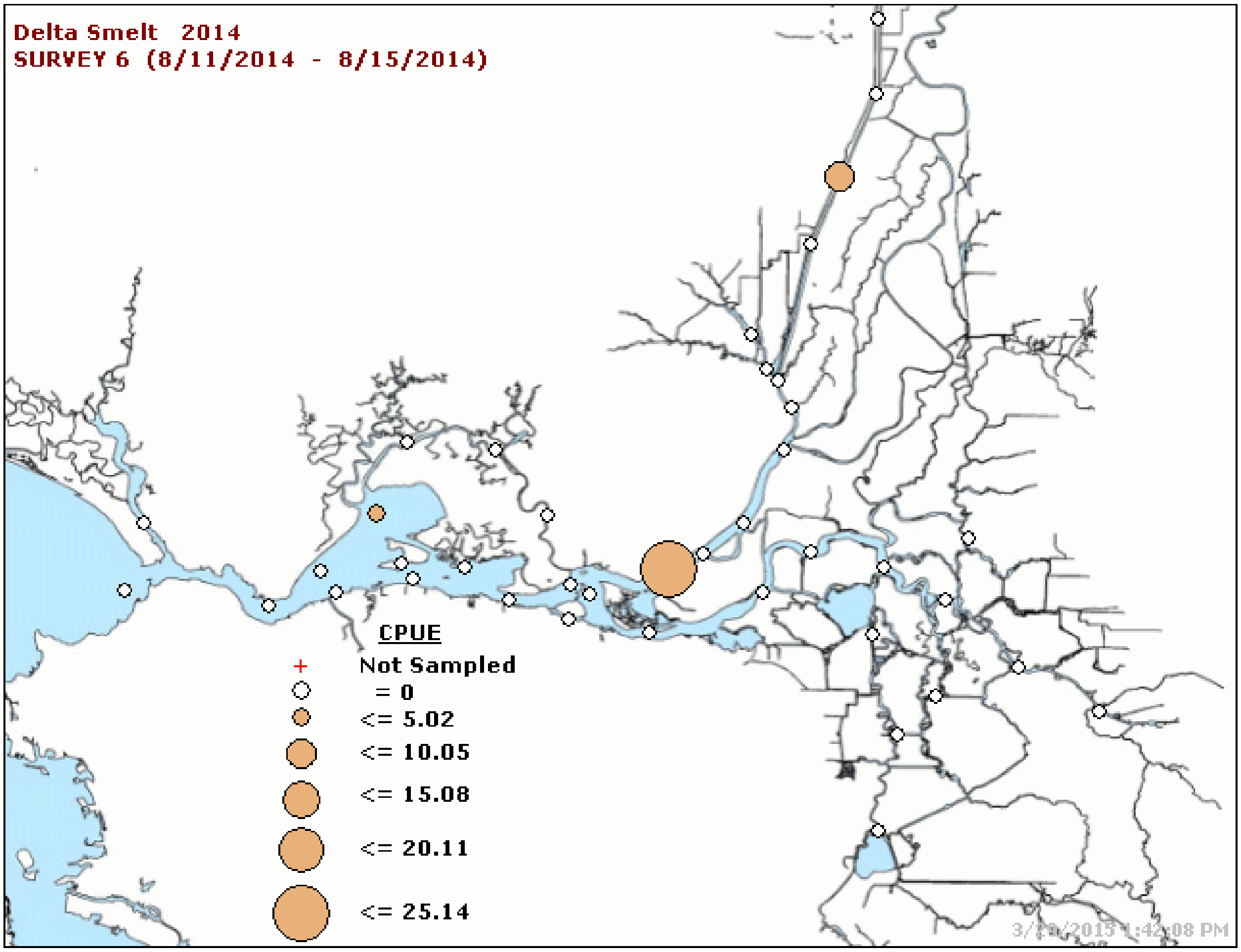
Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D49. Density of Delta Smelt from Summer Townet Survey 4, 2014.



Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D50. Density of Delta Smelt from Summer Townet Survey 5, 2014.



Source: http://www.dfg.ca.gov/delta/data/townet/CPUE_Map.asp. Accessed: March 29, 2015.

Figure D51. Density of Delta Smelt from Summer Townet Survey 6, 2014.

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