UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
501 West Ocean Boulevard, Suite 4200
Long Beach, California 90802-4213

February 6, 2012

In response refer to:
2011/05589

Kathleen A. Dadey, Ph.D.
Chief, California Delta Branch
Sacramento District
U.S. Army Corps of Engineers
1325 J Street
Sacramento, California 95814-2922

Dear Dr. Dadey:

This document transmits NOAA's National Marine Fisheries Service's (NMFS) biological opinion (Enclosure 1) based on our review of the proposed deployment and implementation of the 2012 Temperature Study of the Sacramento Regional Wastewater Plant's Discharge on Aquatic Life in the Sacramento River (Temperature Study) in Sacramento County proposed by the Sacramento Regional County Sanitation District, and its effects on federally listed endangered Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*), threatened Central Valley spring-run Chinook salmon (*O. tshawytscha*), threatened California Central Valley steelhead (*O. mykiss*), and threatened Southern distinct population segment (DPS) of North American green sturgeon (*Acipenser medirostris*) and the designated critical habitat of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, California Central Valley steelhead, and the Southern DPS of green sturgeon in accordance with section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*). The U.S. Army Corps of Engineers (Corps) requested formal consultation regarding the effects of the 2012 Temperature Study in a letter dated November 2, 2011, upon listed salmonids, green sturgeon, and their designated critical habitats. NMFS received this request from the Corps on November 7, 2011.

This biological opinion is based on information presented in the Application for Department of the Army Permit, including the following documents attached in the Section 7 consultation package: Standard Operating Procedure for Study Element 6 (Standardized Angling) of the Sacramento Regional County Sanitation District (SRCSD) Temperature Study, descriptions of Study Element 4 and Study Element 5, and the response to Block 18 in the permit application. These documents were prepared by the project environmental consultant, Robertson-Bryan, Incorporated (RBI). Additional information and documents were provided by the Corps and RBI via email. An extensive literature review was completed by NMFS staff in support of the consultation. A complete administrative record of this consultation is on file at the NMFS Central Valley Office.

Based on the best available scientific and commercial information, the biological opinion concludes that 2012 SRCSD Temperature Study, including the deployment of hydroacoustic equipment and hydrophones in the Sacramento River channel and the implementation of the standardized angling component of Study Element 6, is not likely to jeopardize the continued existence of the above listed species or adversely modify or destroy designated critical habitats. NMFS also has included an incidental take statement with reasonable and prudent measures and non-discretionary terms and conditions that are necessary and appropriate to minimize incidental take of listed salmonids associated with the project.

Also enclosed are Essential Fish Habitat (EFH) Conservation Recommendations (Enclosure 2) for Pacific salmon as required by the Magnuson-Stevens Fishery Conservation and Management Act (MSA) as amended (16 U.S.C. 1801 *et seq.*). This document concludes that deployment of the anchor mounts for the 2012 Temperature Study will adversely affect EFH of Pacific salmon in the action area and adopts the ESA reasonable and prudent measures and associated terms and conditions from the biological opinion as well as the recommendations in Appendix A of Amendment 14 to the Pacific Coast Salmon Plan as the EFH Conservation Recommendations. NMFS did not find that EFH for groundfish (starry flounder, *Platicthys stellatus*) or coastal pelagics (northern anchovy, *Engraulis mordax*) would be affected by the proposed project and study.

Section 305(b)(4)(B) of the MSA requires the Corps to provide NMFS with a detailed written response within 30 days, and 10 days in advance of any action, to the EFH Conservation Recommendations, including a description of measures adopted by the Corps for avoiding, minimizing, or mitigating the impact of the project on EFH (50 CFR 600.920(k)). In the case of a response that is inconsistent with NMFS recommendations, the Corps must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the proposed action and the measures needed to avoid, minimize, or mitigate such effects.

We appreciate your continued cooperation in the conservation of listed species and their habitat, and look forward to working with you and your staff in the future. If you have any questions regarding this document, please contact Mr. Jeffrey Stuart in our Sacramento Area Office, 650 Capitol Mall, Suite 5-100, Sacramento, CA 95814. Mr. Stuart may be reached by telephone at (916) 930-3607 or by Fax at (916) 930-3629.

Sincerely,

For

Rodney R. McInnis
Regional Administrator

Enclosures (2)

cc: Chris Yates, NMFS, Long Beach
Steven Nebozuk, Sacramento Regional County Sanitation District, 10060 Goethe Road Sacramento, California, 95827
Keith Whitener, Robertson-Bryan, Inc., 9888 Kent Street, Elk Grove, California 95624
Commander (dpw), Attention: Paton, Eleventh Coast Guard District, Bldg. 50-2, Coast Guard Island, Alameda, California 94502
Jim Starr, California Department of Fish and Game, 830 "S" Street, Sacramento, California 95811
Kim S. Turner, Bay-Delta Fish and Wildlife Office, U.S. Fish and Wildlife Service, 650 Capitol Mall, Suite 8-300, Sacramento, California 95814
Copy to file: 151422SWR2011SA00557

Enclosure 1

BIOLOGICAL OPINION

ACTION AGENCY: U.S. Army Corps of Engineers, Sacramento District

ACTIVITY: Formal consultation for the 2012 Temperature Study of the Sacramento Regional County Sanitation District Waste Water Treatment Plant's Discharge on Aquatic Life in the Sacramento River

CONSULTATION CONDUCTED BY: Southwest Region, National Marine Fisheries Service

FILE NUMBER: **151422SWR2011SA000557**

DATE ISSUE: **February 6, 2012**

I. CONSULTATION HISTORY

On February 8, March 1, and April 15, 2011, staff from NOAA's National Marine Fisheries Service (NMFS) attended meetings intended to facilitate development of a Work Plan to meet a requirement of Sacramento Regional County Sanitation District's (SRCSD) newly adopted NPDES permit, which required completion of a study to determine if SRCSD's existing and proposed Thermal Plan exceptions are protective of aquatic life beneficial uses in the Sacramento River.

On June 7, 2011, the Final Work Plan (Robertson-Bryan Incorporated [RBI] 2011a) was submitted for approval to the Regional Water Quality Control Board (Regional Board).

On July 6, 2011, the Regional Board approved the Work Plan.

On July 7, 2011, at the direction of NMFS's Stephen Hillyer, SRCSD's lead consultant Robertson-Bryan, Inc. (RBI) contacted NMFS's Jeffrey Jahn to determine if a Section 10(a)(1)(A) would be needed for the project. At his request a copy of the Final Work Plan was submitted to NMFS.

On July 14, 2011, at the direction of NMFS' Jeffrey Jahn, RBI contacted NMFS' Shirley Witalis to determine if a Section 10(a)(1)(A) permit would be needed for the project. A copy of the Final Work Plan was submitted to Ms. Witalis at her request.

On August 22, 2011, Ms. Witalis informed RBI that a Section 10(a)(1)(A) would be needed for the project if listed fish were intentionally taken as part of the study objectives. If take was incidental to the study, a more efficient route would be through a Section 7 consultation if a federal nexus existed for the permitting of the study.

On August 23, 2011, Jeff Stuart and RBI staff discussed the best approach for completing a Section 7 consultation, including which federal nexus options were appropriate for this study.

On August 30, 2011, RBI staff discussed the project with United States Army Corps of Engineers (Corps) staff and it was determined that a Nationwide 5 permit under Section 10 of the Rivers and Harbors Act would be required, which could serve as the federal nexus for the NMFS Section 7 consultation.

On October 14, 2011, an application for a Nationwide 5 permit under Section 10 of the Rivers and Harbors Act was submitted to Corps.

On November 7, 2011, NMFS received a letter from Corps requesting initiation of formal Section 7 consultation for the proposed Temperature Study of the Sacramento Regional Wastewater Treatment Plant's Discharge on Aquatic Life in the Sacramento River (Temperature Study). The Corps assigned identification number SPK-2011-01052 to this project. The initiation package contained copies of two supplemental memos, dated October 26 and 31, 2011, prepared by the applicant's consultant, RBI.

During November 2011, staff from NMFS conferred with RBI to discuss additional information needs required for the consultation. NMFS requested standardized angling data from the November and December monitoring periods and from a similar scientific study that occurred in 2011 on the Sacramento River, downstream of the project site.

On November 14, 2011, NMFS received a technical memorandum regarding the results of angling efforts on the Sacramento River for the month of October, 2011.

On December 1, 2011, NMFS received a technical memorandum from RBI that included the requested standardized angling data for the months of October and November 2011.

On December 12, 2011, NMFS issued a 30-day sufficiency letter to the Corps regarding the initiation of section 7 consultation for the 2012 Temperature Study.

II. DESCRIPTION OF THE PROPOSED ACTION

A. General Overview

The Sacramento Regional Wastewater Treatment Plant (SRWTP), owned and operated by the Sacramento Regional County Sanitation District (SRCSD), provides wastewater treatment for over one million residents within Sacramento County. Treated effluent from the SRWTP is discharged to the Sacramento River near the town of Freeport within the legal boundary of the Sacramento-San Joaquin Delta (Delta) (see Figure 1 in text).

The SRWTP discharge to the Sacramento River is permitted by the Central Valley Regional Water Quality Control Board (Regional Water Board) for a design average dry weather flow (ADWF) of 181 million gallons per day (mgd) under NPDES Permit No. CA0077682 (Order No.

R5-2010-0114), adopted December 9, 2010. The NPDES permit includes waste discharge requirements that must be met to discharge to the Sacramento River, including effluent and receiving water limitations for temperature. Special Provision VI.C.2.d (Temperature Study) of the current NPDES permit required the SRCSD to prepare and submit a work plan for conducting a study to determine "…whether permitted conditions are protective of aquatic life beneficial uses in the Sacramento River."

Figure 1: Location of the SRWTP outfall and sampling stations for Study Element 6 (Standardized Angling) in support of the Temperature Study.

As an initial step in the process for developing the study, a working group (Working Group) with representatives from several State and federal agencies were convened in January 2011, to provide technical input on the study's goal, study questions, objectives, and study elements. The Working Group was facilitated by the SRCSD and its consultant, RBI, with assistance from Flow Science, Inc. (Flow Science) and Hydroacoustic Technology, Inc. (HTI). In accordance with Special Provision VI.C.2.d (Temperature Study) of the SRCSD's NPDES permit, the Working Group included staff from the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), and California Department of Fish and Game (CDFG). In addition, the Working Group included staff from the Regional Water Board. Input on the study design was obtained from the Working Group through a series of meetings and personal communications.

In June 2011, the SRCSD submitted a work plan titled "*Temperature Study to Assess the Thermal Impacts of the Sacramento Regional Wastewater Treatment Plant Discharge on Aquatic Life of the Sacramento River*" (Work Plan) (RBI 2011a) to the Regional Water Board. The Work Plan was approved by the Regional Water Board's Executive Officer on July 6, 2011. The Work Plan identifies eight (8) study elements, which are defined as the specific, individual components of the overall study effort that must be completed in order to achieve the project objectives and answer the study questions. The Temperature Study will consist of eight study elements, which include:

Study Element 1 – Scientific Fisheries Literature Review and Summary

Study Element 2 – Compilation of Historically Modeled Fully Mixed Incremental Temperature Increases and Measured River Temperature and DO Data

Study Element 3 – Summarize Data from Other Past and On-going Fish Tracking Studies

Study Element 4 – Hydroacoustic Monitoring of Fish Movements near the Diffuser

Study Element 5 – Acoustic Tagging of Juvenile Chinook salmon

Study Element 6 – Standardized Angling

Study Element 7 – Target Species Acoustic Tagging

Study Element 8 – Characterization of Stomach Contents of Piscivorous Fishes

Among the eight elements of the Temperature Study, three elements; Elements 4, 5, and 7, will require the in the river placement and operation of hydroacoustic and acoustic tag monitoring equipment, which will be connected by cables to a trailer located on the eastern levee of the Sacramento River. SRCSD's application for a Nationwide 5 permit from the Corps is the result of the placement of this scientific equipment within the navigable waters of the United States. As discussed below, the placement and operation of the of the scientific equipment (i.e., Elements 4, 5, and 7), implementation of the three study elements that consist of desk top assessments (i.e., Elements 1, 2 and 3), and analysis of stomach contents (i.e., Element 8) are not

expected to adversely affect listed species or adversely modify designated critical habitat for listed species in the delta action area. However, the standardized angling study element (Element 6) has the potential to affect listed species (RBI 2011c).

This Opinion is required as part of the Corps permitting of the proposed 2012 Temperature Study Project under Section 10 of the Rivers and Harbors Act. The nationwide permits (NWPs) associated with this project are NWP 5, installation of scientific measuring devices. The Corps determined that the project, as proposed, may adversely affect individual fish from the federally-listed Sacramento River winter-run Chinook salmon (*Oncorhynchus tschawytscha*) and Central Valley spring-run Chinook evolutionarily significant units (ESUs), the California Central Valley steelhead (*O. mykiss*) distinct population segment (DPS) hereafter referred to as Central Valley steelhead, and the Southern DPS of the North American green sturgeon (*Acipenser medirostris*). The Corps also determined that the project may affect elements of the designated critical habitat for Sacramento River winter-run and Central Valley spring-run Chinook salmon, Central Valley steelhead, and Southern DPS green sturgeon. The project will also adversely affect essential fish habitat for Pacific salmon.

B. Project Actions

1. Elements 1, 2 and 3

Implementation of Elements 1, 2, and 3 will consist of literature reviews, compilation of historical data, and summarization of data from other acoustic tagging studies, as such; none of these elements will require the placement of equipment or any type of direct or indirect contact with fishes and, therefore, have no potential to affect listed species or critical habitat designations.

2. Elements 4, 5, and 7

a. *Element 4: Hydroacoustic Monitoring of Fish Movements near the Diffuser*

Implementation of Elements 4, 5, and 7 will require placement and operation of scientific equipment in the Sacramento River. Element 4 will utilize fixed-position split-beam hydroacoustic techniques that will be used to characterize the behavior, location, and duration with which fish hold immediately downstream of the diffuser. An HTI Model 243 Split-Beam System will be utilized, which will consist of a scientific-quality echo sounder/transceiver, transducers, and a computer-based echo processor. The primary component of a hydroacoustic data collection system is the scientific echo sounder and transducer. When triggered, the echo sounder emits a short electrical pulse of known frequency, duration, and transmited power. The transducer then converts the electrical pulse into mechanical energy (i.e., a sound pulse with the same characteristics as the electrical pulse). When the sound waves encounter fish, echoes are reflected back to the transducer from the fish. The transducer then converts the received sound energy back into electrical energy and the electrical signal is sent back to the receiver portion of the echo sounder. The echo signals, now defined by an electrical signal from the conversion of sound waves received by the transducer into electrical current, are relayed to the computer-based

echo processor. The returning echoes from fish have characteristics that allow them to be tracked across successive echo returns.

A hydroacoustic transducer will be deployed near each bank of the river near the diffuser using a boat-mounted boom to lower the transducer unit into position, for a total of two transducers in the study area situated on the eastern and western banks of the Sacramento River just downstream of the discharge diffuser array. Each transducer will be mounted on a dual-axis rotator and secured to an anchoring mount. Deployment will occur by lowering the transducers and anchoring mount from a boat to a preselected location on the river bottom adjacent to the bank. The footprint of each transducer assembly will be less than five feet in diameter. Each transducer emits an acoustic signal that is 10° in width in the horizontal plan and has a 6° width in the vertical plane. The rotators will allow the transducer's 10° horizontal ensonified sample volume to be automatically rotated each hour to cover a 90° sample swath. The transducers will be anchored at a sufficient depth as to stay submerged throughout the monitoring period and therefore will not be affected by tidal or river stage changes in the water surface elevation (see Figure 2).

The Model 243 Split-Beam Echo Sounder, data collection computer, and associated electronic instruments will be housed in a trailer parked immediately adjacent to SRCSD operations building, located atop the levee on the east bank of the river immediately adjacent to the diffuser (RBI 2011b). Transducer cables will be routed in a conduit from this location down the levee to the river, at which point they will be routed along the bottom of the river to each transducer. The cables will be anchored to the river bottom by attaching them to a weighted cable line. The cable extending to the transducer on the far (i.e., west bank) will be anchored along the river bottom in the low-velocity area immediately downstream of the diffuser.

The hydroacoustic study will be conducted for a total monitoring period of 5 weeks, which will occur over a 3-month period extending from February through April 2012 (see Table 1 and 2). The hydroacoustic system will collect data intermittently throughout this period; however, the equipment will remain deployed throughout the 3-month period, even during periods of non-operation. Following the last data collection period in April, the transducers and cables will be permanently removed from the river using a boat-mounted boom and, if necessary, assisted by divers.

The use of hydroacoustic technology to monitor fish populations has become increasingly common. In the last 35 years, tens of thousands of mobile and fixed-location hydroacoustic evaluations have been conducted worldwide (RBI 2011c). The advantages of using hydroacoustic technology for monitoring fishes include the ability to collect large volumes of data, results are available real-time, the methodologies are established and defensible, and, importantly, the use of hydroacoustic technology does not harm or alter the behavior of fishes (RBI 2011c).

Element 4 will consist of the placement and operation of hydroacoustic equipment. Operation of hydroacoustic technologies have been shown to not harm or affect the behavior of fishes (RBI 2011c). In addition, the applicant (SRCSD) believes the deployment and placement of the transducers and associated cables will not affect listed species, and will only temporarily modify

critical habitat and then only in a very superficial manner. Placement of the equipment on the river bottom will temporarily affect the substrate but is not expected to affect the critical habitat designations associated with the project site due to the temporary nature of the placement and the fact that the project site is used primarily as a migration corridor, with secondary use as a rearing area for salmonids and green sturgeon.

b. *Element 5: Acoustic Tagging of Juvenile Chinook salmon*

Under Study Element 5, groups of hatchery-derived juvenile Chinook salmon will be implanted with acoustic tags, released several miles upstream of the SRWTP outfall during their seasonal emigration period, and monitored individually using an HTI Model 290 Acoustic Tag Tracking System as they move downstream and past the SRWTP diffuser location. This system will use a total of 15 hydrophones placed in the river to monitor the movement of tagged juvenile Chinook salmon in three dimensional space (3D) as they migrate through the hydrophone array located adjacent to the discharge diffuser (see Figures 3 and 4).

In order to track the movements of tagged fish in 3D, a portion of the hydrophones will be deployed on the river bottom and a portion will be deployed just below the water surface in an alternating sequence within the array. The proposed array will have three surface oriented hydrophones positioned in mid-channel and 12 bottom oriented hydrophones, situated in 4 rows of 3 hydrophones across the channel bottom (see Figure 4). Metal bottom mounts approximately 5-ft in diameter each will be deployed from a boat-mounted boom at each of the 15 hydrophone locations. Bottom-oriented hydrophones will be attached directly to the bottom mount. Surface oriented hydrophones will be deployed by connecting them to tensioned aircraft cable or rope lines extending from the bottom mounts to buoys at the water surface. This transducer mount arrangement has been used successfully in past studies, and provides the necessary near-surface and bottom mounting locations for optimal hydrophone placement.

Like the hydroacoustic system discussed above in Element 4, the Model 290 Acoustic Tag Receiver and computers will be housed in a trailer parked immediately adjacent to the SRCSD operations building, located atop the levee on the east bank of the river immediately adjacent to the diffuser. Hydrophone cables will be routed in a conduit from this location down the levee to the river, at which point they will be routed along the bottom of the river to each hydrophone (RBI 2011b). The cables will be anchored to the river bottom by attaching them to a weighted cable line.

The HTI Model 290 Acoustic Tag Tracking System will be deployed and tested prior to initiation of the tagged fish releases. The acoustic tag study will be conducted over a 6-7 week period beginning in April and ending in May, 2012. Therefore, the acoustic tag tracking system will be deployed for a period of approximately 8 weeks beginning in late March or early April and extending through May, 2012. Following the 6-7 week data collection period, the hydrophones and cables will be permanently removed from the river using a boat-mounted boom and, if necessary, assisted by divers.

Element 5 will consist of the placement and operation of an array of 15 hydrophones. Operation of hydroacoustic technologies have been shown to not harm or affect the behavior of fishes. In

addition, the project applicant anticipates that the deployment and placement of the hydrophones and associated cables will not adversely affect listed species. Placement of the equipment on the river bottom will temporarily affect the substrate but is not expected to permanently affect the critical habitats associated with the project site due to the temporary nature of the placement, and the small scope of disturbance associated with the placement of the mooring mounts.

c. *Element 6: Standardized Angling for Predators*

Study element 6 is fully described in the document entitled "Standard Operating Procedures for Study Element 6 (Standardized Angling) of the Sacramento Regional County Sanitation District Temperature Study" (RBI 2011d). This element of the study will utilize professional anglers and a standardized angling approach and effort to determine the relative abundance (as determined by catch-per-unit-effort (CPUE)) of eight piscivorous (predatory) fish species at two locations near the diffuser site and two reference sites (i.e., the Freeport Bridge and Miller Park) outside of the influence of the diffuser discharge. The eight target species are: striped bass *(Morone saxatilis*), largemouth bass (*Micropterus salmoides*), smallmouth bass *(M. dolomieui*), spotted bass (*M. punctulatus*), redeye bass (*M. coosae*), white catfish (*Ictalurus catus*), channel catfish (*I. punctatus*), and Sacramento pikeminnow (*Ptychocheilus grandis*).

Standardized angling was chosen as the preferred methodology for sampling predatory fish after considering other collection methodologies. These other methodologies were considered to be either inefficient or inappropriate for this particular study and the environmental conditions associated with it. Electrofishing would not be effective for the collection of predatory fishes at the diffuser or reference sites due to the depth and turbidity of the Sacramento River. Moreover, other traditional methods such as drifting gills nets or use of fyke or hoop nets are also unsuitable due to river depth, flow velocities, and concerns over harming ESA-listed fishes. As with all fish sampling methodologies, use of standardized angling as a means of characterizing relative abundance of predatory fishes at study sites has its own biases. However, these biases are recognized and will be addressed in the final study report as part of interpreting the data. Also, the bias of this sampling method will be similar at the diffuser site as it is at the reference sites, thereby facilitating meaningful comparisons of CPUE data, by species, among sites.

Although the standardized angling techniques to be utilized during implementation of this element will be specifically targeting predatory fish species, there is a risk to listed salmonids and Southern DPS green sturgeon. Angling will take place during the winter and spring, when adult Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead may be migrating upstream through the project area. It is possible that winter-run and spring-run Chinook salmon and steelhead could possibly be caught during sampling efforts. In addition, adult Southern DPS green sturgeon are expected to be moving upriver towards their spawning grounds in the upper Sacramento River from February through June, and therefore will be exposed to the angling efforts. Likewise juvenile and sub-adult green sturgeon rear in the Sacramento River and delta waterways and thus will be present in the action area during the angling efforts.

Angling will be conducted at four (4) sites in the Sacramento River (Figures 5; Table 3). The locations of these sites are:

(1) Study Site 1 – at the SRWTP diffuser,

(2) Study Site 2 - 400 ft downstream of the SRWTP diffuser within the plume,

(3) Reference Site 1 – at the Freeport Bridge, and

(4) Reference Site 2 – adjacent to Miller Park.

Study sites 1 and 2 are both located within the near-field portion of the SRWTP plume and, therefore, are both affected by elevated water temperatures in the dilution zone of the diffuser. These two thermally affected study sites are stratified based on differences in available in-channel habitat (i.e., physical structure). Study Site 1 (SRWTP outfall) will consist of a transect line that is positioned over the top of and parallel to the diffuser pipe alignment on the channel bottom. The diffuser pipe is located approximately 600 feet downstream of the Freeport Bridge location and extends from the east bank of the Sacramento River to approximately 100 ft from the west bank of the Sacramento River (Figure 5). This site encompasses the area from the diffuser to 100 ft downstream of the diffuser. It is both thermally affected by the SRWTP discharge and provides substantial structural in-channel habitat in the form of the SRWTP diffuser pipe. Because a primary objective of this study is to characterize the relative abundance of the eight fish species in the three Target Species Groups, the anglers will target fish holding along and immediately downstream of the diffuser pipe at the SRWTP outfall site, which extends along the channel bottom perpendicular to the main flow vector in the river channel.

Study Site 2 is located within the SRWTP plume, but at a location in which the river consists of a trapezoidal-shaped channel cross-section with a soft sediment bottom and largely lacking any in-channel structural habitat to provide holding habitat for predatory fish. This site will encompass the entire width of the Sacramento River from 400 to 500 ft downstream of the SRWTP outfall (Figure 5).

The reference sites were selected by examining maps and aerial images of the lower Sacramento River for locations that could provide holding habitat for the predatory fish species targeted for this angling study and for known or suspected locations of in-channel structure. A reconnaissance survey was then conducted by RBI and JD Richey staff on July 29, 2011, to ground-truth the presence and location of suitable study sites.

Reference Site 1 will consist of a parallel transect to the Freeport Bridge. The transect will be positioned underneath and downstream of the Freeport Bridge, approximately 0.1 mile upstream of the SRWTP diffuser location. The bridge supports create obstructions to the flow of water in the river, which in turn creates a series of hydraulic breaks immediately downstream from each of the supports. Predatory fish will congregate in these hydraulic breaks and use them as holding habitat and for mounting ambush attacks on passing prey fish in the river flow.

Reference Site 2 will consist of a transect at Miller Park, approximately 11.3 miles upstream of the SRWTP diffuser upstream on the Sacramento River from the diffuser site. This location is near the terminus of the Sacramento River Deep Water Ship Channel, where abandoned boat locks separate the ship channel from the Sacramento River. A backwater eddy has formed at the

mouth of the remnant channel leading from the Sacramento River to the abandoned locks on the western side of the river. On the eastern shore of the Sacramento River, the bank configuration provides hydraulic breaks in which striped bass and other piscivorous fish can hold. These conditions are particularly evident under high flow situations on the Sacramento River mainstem. Consequently, this area is a popular fishing location during the winter months when rivers flows are typically higher than at other times of the year.

The eight target fish species will be divided into three groups based on habitat preferences, foraging strategies, and the type of angling gear and methods best suited to capture them. These groups are:

- **Target Species Group 1 (Striped bass/pikeminnow**) – Striped bass and Sacramento pikeminnow;
- **Target Species Group 2 (Black Basses)** – largemouth bass, smallmouth bass, redeye bass, and spotted bass; and
- **Target Species Group 3** (catfishes) – channel catfish and white catfish.

Angling events for the purposes of this consultation will be conducted between March and June 2012. A sampling event will consist of three (3) days of fishing within a period of a week. To the greatest extent possible, one sampling event will occur in the first half and one in the second half of each month; the 3-day sampling period will be selected by the anglers, based on weather and flow conditions.

On each sampling day, anglers will target each of the target species groups for 45 minutes at the SRWTP outfall site (*i.e.*, Study Site 1), 400 feet downstream of the SRWTP (*i.e.*, Study Site 2), the Freeport Bridge (*i.e.*, Reference Site 1), and at Miller Park (*i.e.*, Reference Site 2), for a total of 9 hours of sampling effort (4 sites x 3 target species groups x 45 minutes/ target species group) per day. The period of the day to be fished at each site will be determined through a stratified randomization procedure, in which both the starting time and order of sites fished on a given day will be randomized. In order to minimize transit time resulting from travel both to and from the upstream site (*i.e.*, Reference Site 2), the field crew will randomly select whether Reference Site 2 or the three downstream sites (i.e., study sites 1 and 2 and Reference Site 1) are fished first each day. The order of the three downstream sites will then be determined randomly. Each sampling day will consist of an approximately 12-hour consecutive period within a calendar day. On each sampling day, a total of approximately 3 hours will be allocated to each sampling site (preparation, transit, and break time + 45 minutes x 3 Target Species Groups). The order in which the sites are fished will be determined through a random process, and the start time for sampling at the first site will be determined by randomly selecting the hours between 5:00 A.M. and 12:00 noon. Factors considered in determining this time range included: (1) park hours and the associated times at which access to the boat launch ramps is available, and (2) ensuring that each 12-hour sampling event begins and ends on the same calendar day. Likewise, the order in which target species groups are fished at each site will be randomized (*e.g.*, with a random selection table).

At all sites, the primary goal of the anglers will be to maximize the angling success rate for the species in each target species group, while maintaining a standardized level of effort between

sites and minimizing the potential for by-catch (*i.e*., non-target fish species or fish species belonging to the two target species groups that are not being targeted at that specific time point). In order to best maintain a standardized level of effort, angling will be conducted using two professional anglers fishing from a single boat. The same anglers will be used to fish all sampling sites. However, upon the initial sampling efforts, should it be determined that two anglers fishing from one boat is insufficient for meeting the relevant objectives of the Temperature Study, the number of boats and/or anglers will be reassessed in accordance with the adaptive management framework specified in the Work Plan and, in coordination with the Working Group, the number of anglers and boats will be revised accordingly. The gear used will consist of spin-casting or bait-casting gear, as determined appropriate by the professional anglers based on the Target Species Group, field conditions, and bait used. The angling methods and baits used will vary for each of the three target species groups, as discussed in the following subsections.

(1.) ***Target Species Group 1 (Striped Bass/Sacramento Pikeminnow*.** Striped bass and Sacramento pikeminnow will be targeted primarily with live bait (*i.e.*, minnows or earthworms); however, in some cases, cut bait (*i.e.*, strips of anchovy, mackerel, sardine), whole bait (*i.e.*, shrimp, dead minnows or threadfin shad) or artificial lures (jigs, spinner baits, plugs, etc.) that have been proven successful by the anglers will be used, as necessary, to maximize angling success. The depth fished will be determined by the depth at which fish are observed on a fish finder and the likelihood (based on the anglers' best professional judgment) that the observed fish include striped bass or Sacramento pikeminnow. In most cases, the live bait will be drifted at or near the river bottom. In order to limit by-catch of other Target Group Species, the live bait used for striped bass and Sacramento pikeminnow will be of a larger size than that used for the other species.

(2.) ***Target Species Group 2 (Black Basses).*** The black basses will be targeted using two different approaches. The primary approach will use artificial hard and plastic baits that are designed to imitate the preferred prey species of black basses. A secondary approach will consist of drifting live bait. In order to minimize the potential for by-catch, the size of the live bait will be smaller than that used for Target Species Group 1. In both cases, the depth fished will be determined by the depth at which fish are observed on a fish finder and the likelihood (based on the anglers' best professional judgment) that the observed fish include species of black basses.

(3.) ***Target Species Group 3 (catfishes).*** Catfishes will be targeted primarily by fishing cut baits from an anchored vessel. The cut baits selected will consist of those that are favored by catfishes, and accordingly will likely differ from the baits used to target species groups 1 and 2. Because white and channel catfish are demersal (i.e., bottom-dwelling), the cut bait will be fished along the river bottom.

(4.) *Record Keeping*. A third field person in the boat will record information regarding the angling event and fish captured while the two professional anglers fish. For each sampling event, four different data sheets (Appendix C) will be printed on waterproof paper and completed in the field. These four data sheets are:

1. Standardized Angling Event Field Data Sheet,

2. Fish Capture Log,

3. Target Species Group Fish Data Sheet, and

4. Photo Log.

The Standardized Angling Event Field Data Sheet summarizes the date and time of sampling for each target species group, the order in which target species groups were fished at each site, lure/bait and gear used for each target species group, weather and river conditions at each site, and water temperature and electrical conductivity (EC) at the location at which each fish is captured.

Every fish captured will be identified to species and the following information will be recorded on the Fish Capture Log:

- Fish ID,
- Fish species,
- Landed (yes or no),
- Time of capture, and
- Species group targeted.

Any fish captured that are not one of the eight target fish species will be revived and released after entry into the Fish Capture Log. Fish that are hooked, but not landed, will also be noted and, if possible, identified to species.

The non-angling crew member will record specific information regarding all target fish species that are captured on the Target Species Group Fish Data Sheet. The GPS coordinates (from a handheld or boat-mounted GPS unit) and depth of water (from the boat's depth finder) at which the fish was captured will be recorded. Each fish will be measured (fork length [FL]) to the nearest millimeter (mm) and weighed to the nearest gram (g). The fish will be observed for existing markings (e.g., fin clips tags) indicating that it is of hatchery origin and/or previously marked for research purposes by this study or another study. If possible, based on visual examination, the gender of the fish will be determined and recorded. All target fish species that are captured will be marked with a fin clip representative of the angling site, which will be recorded on the Target Species Group Fish Data Sheet. The Target Species Group Fish Data Sheet is used to record specific information regarding each target fish species captured. This information includes:

- Fish ID (corresponding with the Fish Capture Log),
- Fish species,
- Presence of existing markings (e.g., fin clips, tags),
- GPS coordinates of capture,

- Depth of water in which fish was captured,
- Fish length (FL in mm),
- Fish weight (g),
- Gender,
- Marking method (i.e., for the purposes of this study), and
- Fate of the fish (i.e., revived and released, implanted with an acoustic tag, used for stomach content analyses, perished, or retained for voucher).

All target fish species that are captured will be photographed from a lateral perspective and the photo ID and fish ID will be recorded on the Photo Log data sheet. The Photo Log data sheet will also be used to record information and descriptions of any other photos taken during each angling event.

A portion of the target fish species captured under Study Element 6 will be used to address two other study elements of the Temperature Study Work Plan: Study Elements 7 (Target Species Tagging) and Study Element 8 (Characterize the Stomach Contents of Piscivorous Fishes Captured). To the extent practicable, target fish species that are captured while angling for a different target species group (e.g., capturing a striped bass while fishing for the black bass Target Species Group) will be utilized for Study Elements 7 and 8. The field crew used for angling will not be responsible for these additional study elements. Rather, all Target Fish Species used for these study elements will be processed as described above, and then transferred to a separate field crew for tagging or stomach content removal and release of the fish.

d. *Element 7: Target Species Acoustic tagging*

Under Study Element 7, a portion of target fish species captured at the SRWTP outfall site during sampling events occurring between late March and mid-May will be retained and implanted with acoustic tags by a separate field crew. As a means to ensure that target fish species are tagged at rates comparable to their occurrence near the diffuser, the proportion of fish tagged per species will be determined by the angling capture rates of each species near the diffuser in the preceding angling events. If the primary predator found near the diffuser is striped bass, then the majority of tags will be implanted into striped bass, whereas if predator populations near the diffuser consist of equal amounts of the various predator species, then tags will be used relatively equally amongst the various species. During the tagging period, approximately 15 fish captured at the outfall site during each angling event will be retained for tagging. No fish from the two reference sites will be tagged.

e. *Element 8 Target Species Stomach Content Analysis*

Under Study Element 8, a portion of each Target Species Group will be retained for extraction and analyses of their stomach contents by a separate field crew to determine the portion of their diet consisting of special-status fishes. The stomach contents of up to 45 fishes per site and

Target Species Group (i.e., as a total for all sampling events) will be collected and analyzed. The actual number of each species for which stomach contents are analyzed will be proportional to the number of each fish species captured under Study Element 6. Because juvenile life stages of ESA-listed species are not anticipated to be present in the lower Sacramento River in October and November, the number fishes to be processed for stomach contents at each site in the initial October–November sampling efforts for Study Element 6 will be smaller relative to the March through June sampling efforts. In order to minimize the potential for injury, lethality, or excessive stress, the stomach contents of piscivorous fishes that will be implanted with acoustic tags under Study Element 7 will not have their stomach contents removed or examined. Fish used for that study element will be prioritized for tagging; therefore, the number of fish for which stomach contents will be examined will be determined by the number of each target fish species captured at each site that exceed the number to be implanted with acoustic tags.

C. Action Area

The action area is defined as all of the 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). For this project, the area affected by the actions described in the project description include the water and channel bottom surrounding the SRCSD diffuser discharge (approximately Latitude 38.4542^{o}, Longitude -121.5016^{o}, nearest town Freeport, Sacramento County, California) as well as the riparian banks and upland areas surrounding the operations building influenced by the staging and positioning of the equipment trailer and positioning of cables and anchor lines on the levee face (approximately Latitude 38.45434^{o}, Longitude -121.500297^{o}, nearest town Freeport, Sacramento County, California). The staging area is described in the environmental documents as the asphalt pad adjacent to the operations building for the SRCSD (Figure 1). Placement of hydrophones will occur in the river channel immediately adjacent to the location of the diffuser structure on the Sacramento River. Twelve hydrophones will be placed on the channel bottom, the first row located slightly upstream of the diffuser structure, and the next two rows positioned downstream of the structures. Three surface hydrophones will be anchored in the same area as the bottom mounted hydrophones. The angling efforts will take place in a reach of river roughly extending from study site 2, located 400 feet downstream of the diffuser structure to the Freeport Bridge, reference site 1, a distance of approximately 960 feet. In addition, the action area also includes reference site 2, which includes the section of the Sacramento River adjacent to the location of Miller Park, in the City of Sacramento, approximately 11 miles upstream of the diffuser location. Approximately 1.5 acres of water will be fished in reference site 1, the Freeport Bridge site, assuming that the study area is the width of the river, bank to bank underneath the bridge and extending downstream for 100 feet. For study sites 1 and 2, the combined area is 5 acres. At study site 1, the study area is defined by assuming a polygon that extends 100 upstream and downstream of the diffuser structure, and is full channel width. Study site 2 is similar in dimensions and is located 400 feet downstream of the diffuser structure. The area of reference site 2 at Miller Park is approximately 16 acres. It is assumed to be defined by a polygon that encompasses the mouth of the abandoned ship channel to the east of the locks, and

extends across the river to the northern point of the inlet leading to the Miller Park marina and upriver to a point directly across from the point on the north bank of the abandoned channel.

III. STATUS OF THE SPECIES AND CRITICAL HABITAT

The following Federally listed species ESUs or DPSs and designated critical habitat occur in the action area and may be affected by the proposed 2012 GSNPB:

Sacramento River winter-run Chinook salmon ESU
endangered (June 28, 2005, 70 FR 37160)

Sacramento River winter-run Chinook salmon designated critical habitat
(June 16, 1993, 58 FR 33212)

Central Valley spring-run Chinook salmon ESU
threatened (June 28, 2005, 70 FR 37160)

Central Valley spring-run Chinook salmon designated critical habitat
(September 2, 2005, 70 FR 52488)

California Central Valley steelhead DPS (referred to as Central Valley steelhead throughout this biological opinion)
threatened (January 5, 2006, 71 FR 834)

Central Valley steelhead designated critical habitat
(September 2, 2005, 70 FR 52488)

Southern DPS of North American green sturgeon
Listed as threatened (April 7, 2006, 71 FR 17757)

Southern DPS of North American green sturgeon designated critical habitat
(October 9, 2009, 74 FR 52300)

A. Species and Critical Habitat Listing Status

In 2005, NMFS conducted a 5-year status review of 16 salmon ESUs, including Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon, and concluded that the species' status should remain as previously listed (70 FR 37160, June 28, 2005). On January 5, 2006, NMFS published a final listing determination for 10 steelhead DPSs, including Central Valley steelhead. This listing concluded that Central Valley steelhead should remain listed as threatened (71 FR 834). The status of the species was updated again on August 15, 2011, (FR 50447) with publication in the Federal Register of the availability of the 5-year status reviews for 5 ESU's of Pacific salmon and 1 DPS of steelhead in California, including the Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon, and the California Central Valley steelhead. The status review determined that the status of

winter-run should remain as endangered, and that similarly, the status of Central Valley spring-run Chinook salmon and California Central Valley steelhead should remain as threatened. The 2011 review indicated that although the listings remained unchanged since the 2005 and 2006 reviews for Sacramento River winter-run and Central Valley spring-run Chinook salmon and California Central Valley steelhead, the status of these populations of salmonids has worsened over the past 5 years since the 2005/2006 reviews.

Sacramento River winter-run Chinook salmon were originally listed as threatened by an emergency interim rule, which was published on August 4, 1989 (54 FR 32085). A new emergency interim rule was published on April 2, 1990 (55 FR 12191). A final rule listing Sacramento River winter-run Chinook salmon as threatened was published on November 5, 1990 (55 FR 46515). The ESU consists of only one population that is confined to the upper Sacramento River in California's Central Valley. The ESU was reclassified as endangered on January 4, 1994 (59 FR 440), due to increased variability of run sizes, expected weak returns as a result of two small year classes in 1991 and 1993, and a 99 percent decline between 1966 and 1991. The Livingston Stone National Fish Hatchery (LSNFH) population has been included in the listed Sacramento River winter-run Chinook salmon population (70 FR 37160, June 28, 2005). NMFS designated critical habitat for winter-run Chinook salmon on June 16, 1993 (58 FR 33212). Critical habitat was delineated as the Sacramento River from Keswick Dam at river mile (RM) 302 to Chipps Island (RM 0) at the westward margin of the Sacramento-San Joaquin Delta (Delta), including Kimball Island, Winter Island, and Brown's Island; all waters from Chipps Island westward to the Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and the Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge, and all waters of San Francisco Bay north of the San Francisco-Oakland Bay Bridge. Critical habitat for Sacramento River winter-run Chinook salmon occurs within the action area for the proposed 2012 SRCSD Temperature Study as part of the Sacramento River main stem.

Central Valley spring-run Chinook salmon were listed as threatened on September 16, 1999 (64 FR 50394). This ESU consists of spring-run Chinook salmon occurring in the Sacramento River basin. The Feather River Hatchery (FRH) spring-run Chinook salmon population was included as part of the Central Valley spring-run Chinook salmon ESU in the 2005 modification of the Central Valley spring-run Chinook salmon listing status (70 FR 37160, June 28, 2005). Critical habitat was designated for Central Valley spring-run Chinook salmon on September 2, 2005 (70 FR 52488). It includes stream reaches such as those of the Feather and Yuba rivers, Big Chico, Butte, Deer, Mill, Battle, Antelope, and Clear creeks, the main stem of the Sacramento River from Keswick Dam through the Delta; and portions of the network of channels in the northern Delta. Critical habitat for Central Valley spring-run Chinook salmon occurs in the action area for the proposed 2012 SRCSD Temperature Study.

California Central Valley steelhead were listed as threatened under the ESA on March 19, 1998 (63 FR 13347). This DPS consists of steelhead populations in the Sacramento and San Joaquin rivers (inclusive of and downstream of the Merced River) basins in California's Central Valley. The Coleman National Fish Hatchery and FRH steelhead populations have been included as part of the Central Valley steelhead DPS in the 2006 modification of the Central Valley steelhead listing status (71 FR 834, January 5, 2006). These populations were previously included in the DPS but were not deemed essential for conservation and thus not part of the listed steelhead

population. Critical habitat was designated for steelhead in the Central Valley on September 2, 2005 (70 FR 52488). Critical habitat includes the stream channels to the ordinary high water line within designated stream reaches such as those of the American, Feather, and Yuba rivers, and Deer, Mill, Battle, Antelope, and Clear creeks in the Sacramento River basin; the Calaveras, Mokelumne, Stanislaus, and Tuolumne rivers in the San Joaquin River basin; and the Sacramento and San Joaquin rivers and the entire Delta. Critical habitat for Central Valley steelhead occurs within the action area for the 2012 SRCSD Temperature Study.

The Southern DPS of North American green sturgeon was listed as threatened on April 7, 2006 (71 FR 17757). The Southern DPS presently contains only a single spawning population within the Sacramento River basin, primarily in the main stem Sacramento River below Keswick Dam but spawning has been documented to occur in the Feather River below Oroville Dam and potentially in the Yuba River where adults exhibiting spawning behavior have been observed. Adults and juveniles occur within the Delta and both life history stages may occur within the action area at any time of the year. Critical habitat was designated for the Southern DPS of green sturgeon on October 9, 2009 (74 FR 52300). Critical habitat 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 Feather River Fish Hatchery. Coastal Marine areas include waters out to a depth of 60 meters from Monterey Bay, California, to the Juan De Fuca Straits in 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. Designated critical habitat for the Southern DPS of green sturgeon occurs within the action area of the 2012 SRCSD Temperature Study.

B. Species Life History and Population Dynamics

1. Chinook Salmon

a. *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 38ºF to 56ºF (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 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 1995a). 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, and 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 flow. 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^{o}F [Moyle 2002]). A significant reduction in egg viability occurs at water temperatures above 57.5^{o}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 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 1996a). 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 main stems 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 54ºF to 57ºF (Brett 1952). In Suisun and San Pablo Bays water temperatures can reach 54ºF by February in a typical year. Other portions of the Delta (*i.e*., south Delta and central Delta) can reach 70ºF 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

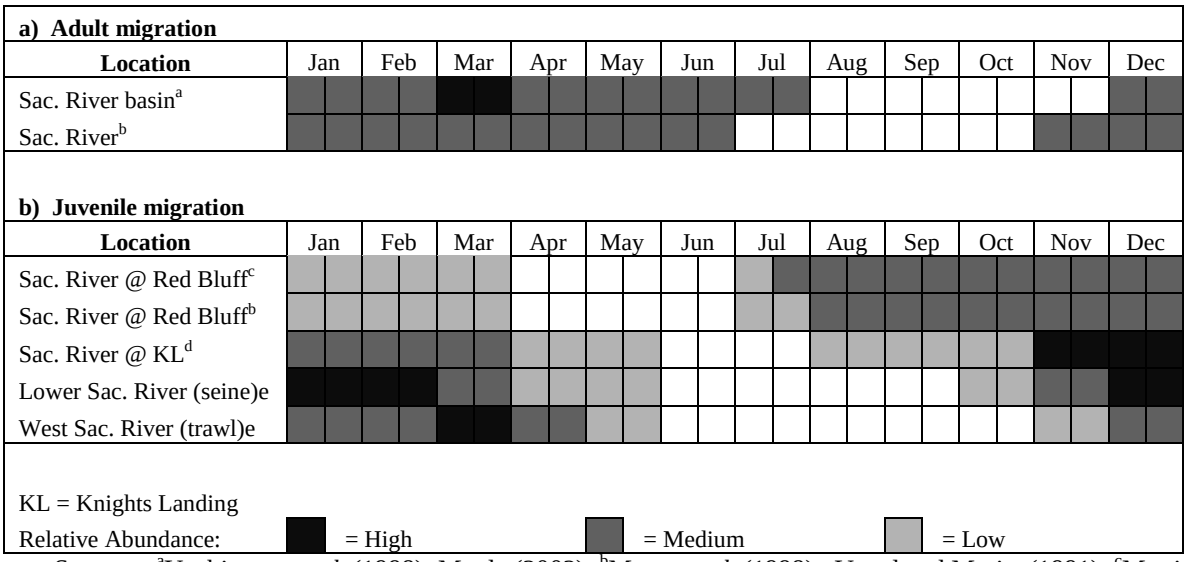
protective cover, and in dead-end tidal channels. Kjelson *et al.* (1982) reported that juvenile Chinook salmon demonstrated a diel migration pattern, orienting themselves to nearshore cover and structure during the day, but moving into more open, offshore waters at night. The fish also distributed themselves 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.

b. *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 in text; 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.

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.



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)

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 (RM 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 millimeters (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 (15,875) and 2006 (17,304) show a recent increase in the population size (CDFG GrandTab, March 2010, and February 2011) and a 4-year average of 12,316 (see Table 5 in text and Appendix B: Figure 6). 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, 2008, 2009, 2010, and 2011 show a precipitous decline in escapement numbers based on redd counts and carcass counts. Estimates place the adult escapement numbers for 2007 at 2,542 fish, 2,830 fish for 2008, and 4,658 fish for 2009 (CDFG Grand Tab 2010), 1,596 fish for 2010 (NMFS 2011[JPE letter], CDFG Grand Tab 2011), and 824 fish for 2011 (CDFG letter 2011).

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

Table 5. Winter-run Chinook salmon population estimates from RBDD counts (1986 to 2001) and carcass counts (2001 to 2011), and corresponding cohort replacement rates for the years since 1986 (CDFG Grand Tab March 2010, February 2011, CDFG 2011 winter-run adult escapement estimate).

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
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	2,542	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	824[d]	2,466	0.29	0.34	NA[e]
median	2,364	2,218	1.05	2.26	412,507
mean[f]	3,814	4,113	1.63	1.90	
Last 10[g]	7,020	7,059	1.63	1.98	
Last 6[h]	4,938	7,966	0.63	1.37	

[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, NMFS calculated the CRR using spawning population of a given year, divided by the spawning population 3 years prior.

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

[d]CDFG (2011 estimate to NMFS)

[e] JPE value has not been calculated for 2011 at the time of this opinion's writing.
[f] Average of 1986 through 2011
[g] Average of last 10 years (2001 to 2011)
[h] Average of last 6 years (2006 to 2011)

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 *et al*. (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 in the previous 5 years (2007 – 2011) have indicated that the status of the winter-run Chinook salmon population may be changing as reflected in the diminished abundance during this period. The current winter-run Chinook salmon JPE for 2011 (2010 brood year) is only 332,012 fish entering the Delta, a substantial decline from the previous JPE values seen in the last decade. The current data regarding the low estimates of redds and adult carcasses found in the upper Sacramento River spawning reaches for brood year 2011, will produce a fifth year of declining juvenile numbers and a JPE value even lower than for brood year 2010.

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 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 (see Figure 6). Furthermore, Lindley's assessment in 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 ESU (NMFS 2011a; August 2011) 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, 2008, 2009, 2010, and 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. Population growth is estimated to be positive in the short-term trend at 0.26; however, the long-term trend is negative, averaging -0.14. Recent winter-run Chinook salmon abundance represents only 3 percent of the maximum post-1967, 5-year geometric mean, and is not yet well established (Good *et al.* 2005). The current annual and five year averaged cohort replacement rates (CRR) are both below 1.0. The annual CRR has been below 1.0 for the past five years and indicates that the winter-run population is not replacing itself (see Figures 8 and 9).

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. 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 a reduction in productivity for the three separate cohorts, starting in 2007.

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 basin habitat, and they are more likely to be exposed to the impacts of drought in a lower basin environment. 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 2009 OCAP BiOp, 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 (see Figure 10).

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 (see Figure 7).

c. *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). 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).

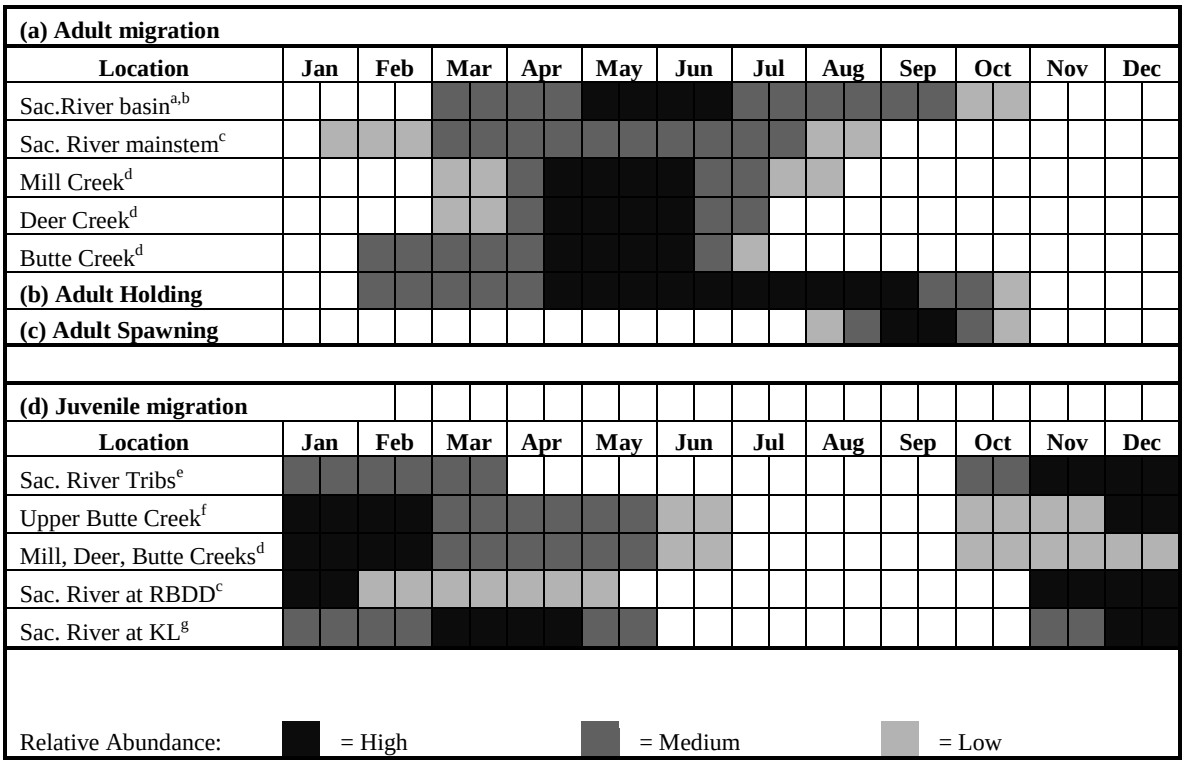
Adult Central Valley spring-run Chinook salmon leave the ocean to begin their upstream migration in late January and early February (CDFG 1998) and enter the Sacramento River between March and September, primarily in May and June (see Table 6 in text; Yoshiyama *et al*. 1998, Moyle 2002). Lindley *et al*. (2004) indicates adult Central Valley spring-run Chinook salmon enter native tributaries from the Sacramento River primarily between mid-April and mid-June. Typically, spring-run Chinook salmon utilize mid- to high-elevation streams that provide appropriate temperatures and sufficient flow, cover, and pool depth to allow over-summering while conserving energy and allowing their gonadal tissue to mature (Yoshiyama *et al*. 1998).

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

Spring-run Chinook salmon fry emerge from the gravel from November to March (Moyle 2002) and the emigration timing is highly variable, as they may migrate downstream as young-of-the-year or as juveniles or yearlings. The modal size of fry migrants at approximately 40 mm

between December and April in Mill, Butte, and Deer creeks reflects a prolonged emergence of fry from the gravel (Lindley *et al*. 2004). Studies in Butte Creek (Ward *et al*. 2002, 2003, McReynolds *et al*. 2005) found the majority of Central Valley spring-run Chinook salmon migrants to be fry occurring primarily during December, January, and February; and that these movements appeared to be influenced by flow. 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).

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.



Note: Yearling spring-run Chinook salmon rear in their natal streams through the first summer following their birth. Downstream emigration generally occurs the following fall and winter. Young of the year spring-run Chinook salmon emigrate during the first spring after they hatch.

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)

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. 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 FRH. In 2002, the FRH 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 Basin. The most recent status review for Central Valley spring-run Chinook salmon (NMFS 2011b) reported that there were subtle differences between the Feather River Hatchery 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 Feather River Hatchery 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 above, 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 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 Red Bluff Diversion Dam. 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.

The Central Valley spring-run Chinook salmon ESU has displayed broad fluctuations in adult abundance, ranging from 1,403 in 1993 to 24,903 in 1998 (see Table 7 in text and Appendix B: Figure 11). Sacramento River tributary populations in Mill, Deer, and Butte creeks are probably the best trend indicators for the Central Valley spring-run Chinook salmon ESU as a whole because these streams contain the primary independent populations within the ESU. Generally, these streams have shown a positive escapement trend since 1991 up through 2005. Escapement numbers are dominated by Butte Creek returns, which have averaged over 7,000 fish during the 10 year period between 1995 and 2005. During this same period, adult returns on Mill Creek have averaged 778 fish, and 1,463 fish on Deer Creek. Although trends through the first half of the past decade were generally positive, annual abundance estimates display a high level of fluctuation, and the overall number of Central Valley spring-run Chinook salmon remains well below estimates of historic abundance. The past several years (since 2005) have shown declining abundance numbers in most of the tributaries. Exceptions to this negative population trend are increases in the number of spring-run Chinook entering Clear Creek and Battle Creek. Additionally, in 2002 and 2003, mean water temperatures in Butte Creek exceeded 21°C for 10 or more days in July (reviewed by Williams 2006). These persistent high water temperatures, coupled with high fish densities, precipitated an outbreak of Columnaris Disease (*Flexibacter columnaris*) and Ichthyophthiriasis (*Ichthyophthirius multifiis*) in the adult spring-run Chinook salmon over-summering in Butte Creek. In 2002, this contributed to the pre-spawning mortality of approximately 20 to 30 percent of the adults. In 2003, approximately 65 percent of the adults succumbed, resulting in a loss of an estimated 11,231 adult spring-run Chinook salmon in Butte Creek.

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" 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

Table 7. Central Valley Spring-run Chinook salmon population estimates from CDFG Grand Tab (March 2010, February 2011) 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	1.70	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	0.60	2.14	8,355	0.84	1.84
1998	31,649	6,746	24,903	8,303	2.53	2.60	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	17,598	4,135	13,463	10,372	0.54	1.93	14,757	0.56	1.27
2002	17,419	4,189	13,230	12,710	2.08	2.23	17,202	1.72	1.45
2003	17,691	8,662	9,029	9,536	1.62	2.04	14,410	1.91	1.42
2004	13,982	4,212	9,770	10,216	0.73	1.72	15,187	0.79	1.35
2005	16,126	1,774	14,352	11,969	1.08	1.21	16,563	0.93	1.18
2006	10,948	2,181	8,767	11,030	0.97	1.29	15,233	0.62	1.20
2007	9,974	2,674	7,300	9,844	0.75	1.03	13,744	0.71	0.99
2008	6,420	1,624	4,796	8,997	0.33	0.77	11,490	0.40	0.69
2009	3,801	989	2,812	7,605	0.32	0.69	9,454	0.35	0.60
2010	3,792	1,661	2,131	5,161	0.29	0.53	6,987	0.38	0.49
2011	4967	1,900	3,067	4,021	0.64	0.47	5,790	0.77	0.52
Median	10,037	3,655	6,727	8,262	0.73	1.70	12,386	0.79	1.27
Average[c]	11,647	3,621	8,026	7,708	1.29	1.48	11,585	1.08	1.21
Last 10[d]	11,156	3,091	8,065	9,224	0.85	1.27	12,802	0.83	1.02
Last 6[e]	6,650	1,838	4,812	7,776	0.55	0.80	10,450	0.54	0.75

[a] NMFS included both the escapement numbers from the Feather River Fish Hatchery (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 2011
[d] Average over last 10 years (2001 to 2011)
[e] Average over last 6 years (2005 to 2011)
2011 numbers are preliminary

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 FRH 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. In contrast to the first half of the decade, the last 6 years of adult returns indicate that population abundance is declining from the peaks seen in the 5 years prior (2001 to 2005) for the entire Sacramento River basin. According to the latest species status review (NMFS 2011b), the recent declines in abundance 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. Butte Creek has sufficient abundance to retain its low extinction risk classification, but the rate of population decline in the past several years is nearly sufficient to classify it as a high extinction risk based on this criteria. Some tributaries, such as Clear Creek and Battle Creek have seen population gains, but the overall abundance numbers are still low. The recent increases in Battle Creek would qualify this population as being at a moderate risk of extinction. The Yuba River also has a spring-run population. The annual run size on the Yuba River generally ranges from a few hundred fish to several thousand fish, with the annual trends closely following the annual abundance trend of the Feather River Hatchery spring-run Chinook salmon population. 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. See Figure 12 for spring-run Chinook salmon population trends in the Central Valley

Productivity. The 5-year geometric mean for the extant Butte, Deer, and Mill Creek spring-run Chinook salmon populations ranges from 491 to 4,513 fish (Good *et al.* 2005), indicating increasing productivity over the short-term and was projected to likely continue into the future (Good *et al.* 2005). However, as mentioned in the previous paragraph, the last 5 years of adult escapement to these tributaries has seen a cumulative decline in fish numbers and the CRR has declined in concert with the population declines. In the past decade (2001 to 2011), the 10 year average annual spring-run escapement for Mill, Deer, and Butte creeks has been 875, 1,235, and 5,419 fish, respectively. The average for the last 6 years for Mill, Deer, and Butte creeks has decreased to 559, 660, and 3,134 fish, respectively. Over the past 3 years the average escapement has declined further to 356, 249, and 1,783 fish for Mill, Deer, and Butte creeks, respectively (GrandTab February 2011, CDFG survey data 2011). The productivity of the Feather River and Yuba River 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 and Northwestern California Coastal Range diversity group areas.

Diversity. The Central Valley spring-run Chinook salmon ESU is comprised of 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 FRH 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 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.

2. Central Valley Steelhead

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).

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 though March in small streams and tributaries where cool, well oxygenated water is available year-round (Hallock *et al.* 1961, McEwan and Jackson 1996; see Table 8 in text). 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) Central Valley steelhead in the Central Valley. Darker shades indicate months of greatest relative abundance.

(a) Adult migration/holding

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
[1,3]Sac. River												
[2,3]Sac R at Red Bluff												
[4]Mill, Deer Creeks												
[6]Sac R. at Fremont Weir												
[6]Sac R. at Fremont Weir												
[7]San Joaquin River												

(b) Juvenile migration

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
[1,2]Sacramento River												
[2,8]Sac. R at KL												
[9]Sac. River @ KL												
[10]Chipps Island (wild)												
[8]Mossdale												
[11]Woodbridge Dam												
[12]Stan R. at Caswell												
[13]Sac R. at Hood												

Relative Abundance: = High = Medium = Low

Sources: [1]Hallock 1961; [2]McEwan 2001; [3]USFWS unpublished data; [4]CDFG 1995; [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 2003; [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 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 Central Valley steelhead feed mostly on drifting aquatic organisms and terrestrial insects and will also take active bottom invertebrates (Moyle 2002).

Some 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 (2003) also have verified these temporal findings based on analysis of captures at Chipps Island.

Historic 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 (see Appendix B: Figure 13). 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 (2003) 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). Recent 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, 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 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). California Department of Fish and Game (CDFG) staff have prepared catch summaries for juvenile migrant 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" (Letter from Dean Marston, CDFG, to Michael Aceituno, NMFS, 2004). The documented returns on the order of single fish in these tributaries suggest that existing populations of Central Valley steelhead on the Tuolumne, Merced, and lower San Joaquin rivers are severely depressed (see Appendix B: Figure 14 steelhead at Mossdale).

Recent assessments of the status of the California Central Valley steelhead DPS 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 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). Central Valley steelhead populations generally show a continuing decline, an overall low abundance, and fluctuating return rates. The future of 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 (see Figure 15). 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% and in 2010 was 95% 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 (see Figure 16).

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, see Figure 17). 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 CV 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, one million in-DPS hatchery steelhead smolts and another half million out-of-DPS hatchery steelhead smolts are released annually in the Central Valley. The estimated ratio of nonclipped to clipped steelhead has decreased from 0.3 percent to less than 0.1 percent, 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.

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.* 2008, NMFS 2011c). The efforts to provide passage of salmonids over impassable dams may increase the spatial diversity of 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 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 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 *O. mykiss* populations.

3. <u>Southern Distinct Population Segment of North American Green Sturgeon</u>

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). During the late summer and early fall, subadults and nonspawning adult green sturgeon frequently can be found aggregating in estuaries along the Pacific coast (Emmett *et al.* 1991, Moser and Lindley 2007). 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, and Beamesderfer *et al.* 2007). Lindley *et al.* (2008) reported that green sturgeon make seasonal migratory movements along the west coast of North America, overwintering north of Vancouver Island and south of Cape Spencer, Alaska. Individual fish from the Southern DPS of green sturgeon have been detected in these seasonal aggregations. Information regarding the migration and habitat use of the Southern DPS of green sturgeon has recently emerged. 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). To date, the data indicates 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 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 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 (Beamesderfer *et al.* 2007). 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 than those of white sturgeon (Kynard *et al.* 2005, Van Eenennaam *et al.* 2009). Adults begin their upstream spawning migrations into freshwater in late February with spawning occuring between March and July (CDFG 2002. Heublin 2006, Heublin *et al.* 2009, Vogel 2008). Peak spawning is believed to occur between April and June in deep, turbulent, mainstem channels over large cobble and rocky substrates with crevices and interstices. 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, Heublin *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. Although no historical accounts exist for identified green sturgeon spawning occuring 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.

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 the California Department of Water Resources (CDWR) on the Feather River and several adult green sturgeon were recorded on video congregating below Daguerre Dam on the Yuba River.

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 in the western side of the San Joaquin Valley. Green sturgeon have recently been identified by UC 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 mainstem San Joaquin River (2007 sturgeon report card - CDFG 2008).

Kelly *et al.* (2007) indicated that green sturgeon enter the San Francisco Estuary during the spring and remain until autumn (see Table 9 in text). 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. Recent acoustical 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 (> 5m), 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 Heublin (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 (Heublin 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.

Eggs and Larvae. Currently spawning appears 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). 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^{o}F and 62.6^{o}F. Temperatures over 23 ^{o}C (73.4^{o}F) resulted in 100 percent mortality of fertilized eggs before hatching. Eggs incubated at water temperatures between 63.5^{o}F and 71.6^{o}F resulted in elevated mortalities and an increased

occurrence of morphological abnormalities in those eggs that did hatch. At incubation temperatures below 57.2^{o}F, hatching mortality also increased significantly, and morphological abnormalities increased slightly, but not statistically so.

Newly hatched green sturgeon are approximately 12.5mm to 14.5 mm in length and have a large ovoid yolk sac that supplies nutritional energy until exogenous feeding occurs. These yolksac 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. The 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^{o}F, downstream migrational behavior diminished and holding behavior increased. This data suggests 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 bioenergetic performance (*i.e.* growth, food conversion, swimming ability) between 59°F and 66.2^{o}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^{o}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 mainstem (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.

Table 9. The temporal occurrence of (a) adult, (b) larval (c) juvenile and (d) subadult coastal migrant Southern DPS of green sturgeon. Locations emphasize the Central Valley of California. Darker shades indicate months of greatest relative abundance.

(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]												
SF Bay Estuary[d,h,i]												

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

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

(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]												
Sac-SJ Delta[f]												
Sac-SJ Delta[e]												
Suisun Bay[e]												

(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]												

Relative Abundance: = High = Medium = Low

* Fish Facility salvage operations

Sources: [a]USFWS (2002); [b]Moyle *et al*. (1992); [c]Adams *et al*. (2002) and NMFS (2005a); [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 (2008)

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 rotary screw trap, approximately 30 miles downstream of RBDD, ranged from 33 mm to 44 mm between 1997 and 2005 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 rotary-screw trap 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 Harvey O. Banks Pumping Plant and the John E. Skinner Fish Collection Facility (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 green sturgeon likely hold in the mainstem Sacramento River, as suggested by Kynard *et al.* (2005).

Population abundance information concerning the Southern DPS green sturgeon is described in the NMFS status reviews (Adams *et al*. 2002, NMFS 2005a). Limited population abundance information comes from incidental captures of North American green sturgeon from the white sturgeon monitoring program by the CDFG sturgeon tagging program (CDFG 2002). By comparing ratios of white sturgeon to green sturgeon captures, CDFG 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. Unfortunately, there are many biases and errors associated with these data, and CDFG does not consider these estimates reliable. Fish monitoring efforts at RBDD and GCID on the upper Sacramento River have captured between 0 and 2,068 juvenile North American green sturgeon per year (Adams *et al*. 2002). The only existing information regarding changes in the abundance of the Southern DPS of green sturgeon includes changes in abundance at the John E. Skinner Fish Facility between 1968 and 2001 (see Appendix A: Table 10 and Appendix B Figures 18a and 18b). The average number of North American green sturgeon taken per year at the State Facility prior to 1986 was 732; from 1986 on, the average per year was 47 (70 FR 17386, April 6, 2005). For the Harvey O. Banks Pumping Plant, 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 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. 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 portion of 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 North American green sturgeon. Recent spawning population estimates using

sibling based genetics by Israel (2006b) 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).

As described previously, the majority of spawning by green sturgeon in the Sacramento River system appears to take place above the location of RBDD. This is based on the length and estimated age of larvae captured at RBDD (approximately 2–3 weeks of age) and GCID (downstream, approximately 3–4 weeks of age) indicating that hatching occurred above the sampling location. Note that there are many assumptions with this interpretation (*i.e*., equal sampling efficiency and distribution of larvae across channels) and this information should be considered cautiously.

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 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 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 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 2007, NMFS 2011a,b,c). NMFS assumes that the general categories for assessing salmonid population viability will also be useful in assessing the viability of the Southern DPS of 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 is also lacking. Fishery data collected at Federal and State pumping facilities in the Delta indicate a decreasing trend in abundance between 1968 and 2006 (70 FR 17386). Captures of larval green sturgeon in the RBDD rotary screw traps 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 basin, captures in the rotary screw trap have been substantially higher than in previous years. 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 will be a strong year class.

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 indicates 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 Dam on the Yuba River suggests 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.

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.

C. Definition of Critical Habitat Condition and Function for Species' Conservation

1. Critical Habitat for 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 the Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and the Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge; and all waters of the San Francisco Estuary to the Golden Gate Bridge located 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.

2. Critical Habitat for Central Valley Spring-run Chinook Salmon and Central Valley Steelhead

Critical habitat was designated for Central Valley spring-run Chinook salmon and 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 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. Following are the inland habitat types used as PCEs for Central Valley spring-run Chinook salmon and Central Valley steelhead, and as physical habitat elements for Sacramento River winter-run Chinook salmon.

PCE for Central Valley Spring-run Chinook salmon and Central Valley steelhead include:

a. Spawning Habitat

Freshwater spawning sites are those with 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 egg 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 mainstem 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 Central Valley steelhead is similar in nature to the requirements of Chinook salmon, primarily occurring in reaches directly below the first impassable dams on perennial watersheds throughout the Central Valley (*i.e.*, between Keswick Dam and RBDD on the Sacramento River, below Whiskeytown Dam on Clear Creek, below Oroville Dam on the Feather River, below Nimbus Dam on the American River, below Goodwin Dam on the Stanislaus, etc.). 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.

b. Freshwater Rearing Habitat

Freshwater rearing sites are those with 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 outmigration to the marine environment. 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.

c. Freshwater Migration Corridors

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 outmigrant 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.

d. Estuarine Areas

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.

3. <u>Critical Habitat for the Southern DPS of North American Green Sturgeon</u>

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 Sacramento – San Joaquin River 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 Feather River Fish Hatchery. Coastal Marine areas include waters out to a depth of 60 meters from Monterey Bay, California, to the Juan De Fuca Straits in 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 elements:

a. Food Resources

Abundant food items within estuarine habitats and substrates for juvenile, subadult, and adult life stages are required for the proper functioning of this PCE for green sturgeon. Prey species for juvenile, subadult, 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, subadult, and adult green sturgeon within the bays and estuaries.

b. Water Flow

Within bays and estuaries adjacent to the Sacramento River (*i.e*., the Sacramento-San Joaquin Delta and the Suisun, San Pablo, and San Francisco bays), sufficient 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.

c. Water Quality

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 parts per thousand - 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 subadults and adults tolerate a wide range of salinities (Kelly *et al.* 2007). Subadult 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 mg O_2 hr^{-1} kg^{-1}, 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 subadult or adult stages.

d. *Migratory Corridor*

Safe and unobstructed migratory pathways 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 subadults 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 subadult green sturgeon to access feeding areas, holding areas, and thermal refugia, and to ensure passage back out into the ocean.

e. *Water Depth*

A diversity of depths is necessary for shelter, foraging, and migration of juvenile, subadult, and adult life stages. Tagged adults and subadults 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.

f. *Sediment Quality*

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.

D. Factors Impacting Listed Species

1. Habitat Blockage

Hydropower, flood control, and water supply dams of the CVP, SWP, and other municipal and private entities have permanently blocked or hindered salmonid access to historical spawning and rearing grounds. Clark (1929) estimated that originally there were 6,000 linear miles of salmon habitat in the Central Valley system and that 80 percent of this habitat had been lost by 1928. Yoshiyama *et al.* (1996) calculated that roughly 2,000 linear miles of salmon habitat was actually available before dam construction and mining, and concluded that 82 percent is not accessible today.

As a result of migrational barriers, winter-run Chinook salmon, spring-run Chinook salmon, and steelhead populations have been confined to lower elevation main stems that historically only were used for migration. Population abundances have declined in these streams due to decreased quantity and quality of spawning and rearing habitat. Higher temperatures at these lower elevations during late-summer and fall are also a major stressor to adult and juvenile salmonids. According to Lindley *et al.* (2004), of the four independent populations of Sacramento River winter-run Chinook salmon that occurred historically, only one mixed stock of winter-run Chinook salmon remains below Keswick Dam. Similarly, of the 18 independent populations of Central Valley spring-run Chinook salmon that occurred historically, only three independent populations remain in Deer, Mill, and Butte creeks. Dependent populations of Central Valley spring-run Chinook salmon continue to occur in Big Chico, Antelope, Clear, Thomes, Beegum, and Stony creeks, but rely on the three extant independent populations for their continued survival. Central Valley steelhead historically had at least 81 independent populations based on Lindley *et al.*'s (2006) analysis of potential habitat in the Central Valley. However, due to dam construction, access to 38 percent of all spawning habitat has been lost as well as access to 80 percent of the historically available habitat. Green sturgeon populations have been similarly affected by these barriers and alterations to the natural hydrology. In particular, RBDD blocked access to a significant portion of the adult green sturgeon spawning run under the pre OCAP BiOp operational procedures. Modifications to the operations of the RBDD as required under the 2009 OCAP BiOp will substantially reduce the impediment to upstream migrations of adult green sturgeon. Post BiOp interim operational procedures require the RBDD gates to remain in the open position from September 1 until June 15. Starting on June 15, 2012, the gates are required to remain open year round.

The Suisun Marsh Salinity Control Gates (SMSCG), located on Montezuma Slough, were installed in 1988, and are operated with gates and flashboards to decrease the salinity levels of managed wetlands in Suisun Marsh. The SMSCG have delayed or blocked passage of adult Chinook salmon migrating upstream (Edwards *et al.* 1996, Tillman *et al.* 1996, DWR 2002). The effects of the SMSCG on sturgeon are unknown at this time.

2. <u>Water Development</u>

The diversion and storage of natural flows by dams and diversion structures on Central Valley waterways have depleted stream flows and altered the natural cycles by which juvenile and adult salmonids base their migrations. As much as 60 percent of the natural historical inflow to Central Valley watersheds and the Delta have been diverted for human uses. Depleted flows have contributed to higher temperatures, lower DO levels, and decreased recruitment of gravel and large woody debris (LWD). More uniform flows year round have resulted in diminished natural channel formation, altered food web processes, and slower regeneration of riparian vegetation. These stable flow patterns have reduced bed load movement (Mount 1995, Ayers 2001), caused spawning gravels to become embedded, and decreased channel widths due to channel incision, all of which has decreased the available spawning and rearing habitat below dams. The storage of unimpeded runoff in these large reservoirs also has altered the normal hydrograph for the Sacramento and San Joaquin River watersheds. Rather than seeing peak flows in these river systems following winter rain events (Sacramento River) or spring snow melt

(San Joaquin River), the current hydrology has truncated peaks with a prolonged period of elevated flows (compared to historical levels) continuing into the summer dry season.

Water withdrawals, for agricultural and municipal purposes have reduced river flows and increased temperatures during the critical summer months, and in some cases, have been of a sufficient magnitude to result in reverse flows in the lower San Joaquin River (Reynolds *et al*. 1993). Direct relationships exist between water temperature, water flow, and juvenile salmonid survival (Brandes and McLain 2001). Elevated water temperatures in the Sacramento River have limited the survival of young salmon in those waters. Juvenile fall-run Chinook salmon survival in the Sacramento River is also directly related with June streamflow and June and July Delta outflow (Dettman *et al*. 1987).

Water diversions for irrigated agriculture, municipal and industrial use, and managed wetlands are found throughout the Central Valley. Thousands of small and medium-size water diversions exist along the Sacramento River, San Joaquin River, and their tributaries. Although efforts have been made in recent years to screen some of these diversions, many remain unscreened. Depending on the size, location, and season of operation, these unscreened diversions entrain and kill many life stages of aquatic species, including juvenile salmonids. For example, as of 1997, 98.5 percent of the 3,356 diversions included in a Central Valley database were either unscreened or screened insufficiently to prevent fish entrainment (Herren and Kawasaki 2001). Most of the 370 water diversions operating in Suisun Marsh are unscreened (Herren and Kawasaki 2001).

Outmigrant juvenile salmonids in the Delta have been subjected to adverse environmental conditions created by water export operations at the CVP and SWP facilities. Specifically, juvenile salmonid survival has been reduced by the following: (1) water diversion from the main stem Sacramento River into the Central Delta via the Delta Cross Channel; (2) upstream or reverse flows of water in the lower San Joaquin River and southern Delta waterways; (3) entrainment at the CVP/SWP export facilities and associated problems at Clifton Court Forebay; and (4) increased exposure to introduced, non-native predators such as striped bass, largemouth bass (*Micropterus salmoides*), and sunfishes (Centrarchidae). On June 4, 2009, NMFS issued a biological and conference opinion on the long-term operations of the CVP and SWP (NMFS 2009). As a result of the jeopardy and adverse modification determinations, NMFS provided a reasonable and prudent alternative (RPA) that reduces many of the adverse effects of the CVP and SWP resulting from the stressors described above. Several of the actions required by the RPA have been challenged in Federal court and their implementation is uncertain, thus rendering the improvements to the ecosystem tenuous and forestalling benefits to the affected salmonids and green sturgeon populations.

3. <u>Water Conveyance and Flood Control</u>

The development of the water conveyance system in the Delta has resulted in the construction of more than 1,100 miles of channels and diversions to increase channel elevations and flow capacity of the channels (Mount 1995). Levee development in the Central Valley affects spawning habitat, freshwater rearing habitat, freshwater migration corridors, and estuarine habitat PCEs. As Mount (1995) indicates, there is an “underlying, fundamental conflict inherent

in this channelization." Natural rivers strive to achieve dynamic equilibrium to handle a watersheds supply of discharge and sediment (Mount 1995). The construction of levees disrupts the natural processes of the river, resulting in a multitude of habitat-related effects.

Many of these levees use angular rock (riprap) to armor the bank from erosive forces. The effects of channelization, and riprapping, include the alteration of river hydraulics and cover along the bank as a result of changes in bank configuration and structural features (Stillwater Sciences 2006). These changes affect the quantity and quality of near shore habitat for juvenile salmonids and have been thoroughly studied (USFWS 2000, Schmetterling *et al.* 2001, Garland *et al*. 2002). Simple slopes protected with rock revetment generally create near shore hydraulic conditions characterized by greater depths and faster, more homogeneous water velocities than occur along natural banks. Higher water velocities typically inhibit deposition and retention of sediment and woody debris. These changes generally reduce the range of habitat conditions typically found along natural shorelines, especially by eliminating the shallow, slow-velocity river margins used by juvenile fish as refuge and escape from fast currents, deep water, and predators (Stillwater Sciences 2006).

Prior to the 1970s, there was so much debris resulting from poor logging practices that many streams were completely clogged and were thought to have been total barriers to fish migration. As a result, in the 1960s and early 1970s it was common practice among fishery management agencies to remove woody debris thought to be a barrier to fish migration (NMFS 1996b). However, it is now recognized that too much LWD was removed from the streams resulting in a loss of salmonid habitat and it is thought that the large scale removal of woody debris prior to 1980 had major, long-term negative effects on rearing habitats for salmonids in northern California (NMFS 1996b). Areas that were subjected to this removal of LWD are still limited in the recovery of salmonid stocks; this limitation could be expected to persist for 50 to 100 years following removal of debris.

Large quantities of downed trees are a functionally important component of many streams (NMFS 1996b). LWD influences stream morphology by affecting channel pattern, position, and geometry, as well as pool formation (Keller and Swanson 1979, Bilby 1984, Robison and Beschta 1990). Reduction of wood in the stream channel, either from past or present activities, generally reduces pool quantity and quality, alters stream shading which can affect water temperature regimes and nutrient input, and can eliminate critical stream habitat needed for both vertebrate and invertebrate populations. Removal of vegetation also can destabilize marginally stable slopes by increasing the subsurface water load, lowering root strength, and altering water flow patterns in the slope.

In addition, the armoring and revetment of stream banks tends to narrow rivers, reducing the amount of habitat per unit channel length (Sweeney *et al*. 2004). As a result of river narrowing, benthic habitat decreases and the number of macroinvertebrates, such as stoneflies and mayflies, per unit channel length decreases affecting salmonid food supply.

4. <u>Land Use Activities</u>

Land use activities continue to have large impacts on salmonid habitat in the Central Valley watershed. Until about 150 years ago, the Sacramento River was bordered by up to 500,000 acres of riparian forest, with bands of vegetation extending outward for 4 or 5 miles (California Resources Agency 1989). Starting with the gold rush, these vast riparian forests were cleared for building materials, fuel, and to clear land for farms on the raised natural levee banks. The degradation and fragmentation of riparian habitat continued with extensive flood control and bank protection projects, together with the conversion of the fertile riparian lands to agriculture outside of the natural levee belt. By 1979, riparian habitat along the Sacramento River diminished to 11,000 to 12,000 acres, or about 2 percent of historic levels (McGill 1987). The clearing of the riparian forests removed a vital source of snags and driftwood in the Sacramento and San Joaquin River basins. This has reduced the volume of LWD input needed to form and maintain stream habitat that salmon depend on in their various life stages. In addition to this loss of LWD sources, removal of snags and obstructions from the active river channel for navigational safety has further reduced the presence of LWD in the Sacramento and San Joaquin Rivers, as well as the Delta.

Increased sedimentation resulting from agricultural and urban practices within the Central Valley is one of the primary causes of salmonid habitat degradation (NMFS 1996a). Sedimentation can adversely affect salmonids during all freshwater life stages by: clogging or abrading gill surfaces, adhering to eggs, hampering fry emergence (Phillips and Campbell 1961), burying eggs or alevins, scouring and filling in pools and riffles, reducing primary productivity and photosynthesis activity (Cordone and Kelley 1961), and affecting intergravel permeability and DO levels. Excessive sedimentation over time can cause substrates to become embedded, which reduces successful salmonid spawning and egg and fry survival (Waters 1995).

Land use activities associated with road construction, urban development, logging, mining, agriculture, and recreation have significantly altered fish habitat quantity and quality through the alteration of stream bank and channel morphology; alteration of ambient water temperatures; degradation of water quality; elimination of spawning and rearing habitat; fragmentation of available habitats; elimination of downstream recruitment of LWD; and removal of riparian vegetation, resulting in increased stream bank erosion (Meehan 1991). Urban stormwater and agricultural runoff may be contaminated with herbicides and pesticides, petroleum products, sediment, *etc.* Agricultural practices in the Central Valley have eliminated large trees and logs and other woody debris that would otherwise be recruited into the stream channel (NMFS 1998a).

Since the 1850s, wetlands reclamation for urban and agricultural development has caused the cumulative loss of 79 and 94 percent of the tidal marsh habitat in the Delta downstream and upstream of Chipps Island, respectively (Conomos *et al.* 1985, Nichols *et al.* 1986, Wright and Phillips 1988, Monroe *et al.* 1992, Goals Project 1999). Prior to 1850, approximately 1400 km^2 of freshwater marsh surrounded the confluence of the Sacramento and San Joaquin Rivers, and another 800 km^2 of saltwater marsh fringed San Francisco Bay's margins. Of the original 2,200 km^2 of tidally influenced marsh, only about 125 km^2 of undiked marsh remains today. In Suisun Marsh, saltwater intrusion and land subsidence gradually has led to the decline of agricultural production. Presently, Suisun Marsh consists largely of tidal sloughs and managed wetlands for duck clubs, which first were established in the 1870s in western Suisun Marsh (Goals Project

1999). Even more extensive losses of wetland marshes occurred in the Sacramento and San Joaquin River Basins. Little of the extensive tracts of wetland marshes that existed prior to 1850 along the valley's river systems and within the natural flood basins exist today. Most has been "reclaimed" for agricultural purposes, leaving only small remnant patches.

Dredging of river channels to enhance inland maritime trade and to provide raw material for levee construction has significantly and detrimentally altered the natural hydrology and function of the river systems in the Central Valley. Starting in the mid-1800s, the Corps and other private consortiums began straightening river channels and artificially deepening them to enhance shipping commerce. This has led to declines in the natural meandering of river channels and the formation of pool and riffle segments. The deepening of channels beyond their natural depth also has led to a significant alteration in the transport of bed load in the riverine system as well as the local flow velocity in the channel (Mount 1995). The Sacramento Flood Control Project at the turn of the nineteenth century ushered in the start of large scale Corps actions in the Delta and along the rivers of California for reclamation and flood control. The creation of levees and the deep shipping channels reduced the natural tendency of the San Joaquin and Sacramento Rivers to create floodplains along their banks with seasonal inundations during the wet winter season and the spring snow melt periods. These annual inundations provided necessary habitat for rearing and foraging of juvenile native fish that evolved with this flooding process. The armored riprapped levee banks and active maintenance actions of Reclamation Districts precluded the establishment of ecologically important riparian vegetation, introduction of valuable LWD from these riparian corridors, and the productive intertidal mudflats characteristic of the undisturbed Delta habitat.

Urban storm water and agricultural runoff may be contaminated with pesticides, oil, grease, heavy metals, polycyclic aromatic hydrocarbons (PAHs), and other organics and nutrients (California Regional Water Quality Control Board-Central Valley Region [Regional Board] 1998) that can potentially destroy aquatic life necessary for salmonid survival (NMFS 1996a, b). Point source (PS) and non-point source (NPS) pollution occurs at almost every point that urbanization activity influences the watershed. Impervious surfaces (*i.e.*, concrete, asphalt, and buildings) reduce water infiltration and increase runoff, thus creating greater flood hazard (NMFS 1996a, b). Flood control and land drainage schemes may increase the flood risk downstream by concentrating runoff. A flashy discharge pattern results in increased bank erosion with subsequent loss of riparian vegetation, undercut banks and stream channel widening. In addition to the PS and NPS inputs from urban runoff, juvenile salmonids are exposed to increased water temperatures as a result of thermal inputs from municipal, industrial, and agricultural discharges.

Past mining activities routinely resulted in the removal of spawning gravels from streams, the straightening and channelization of the stream corridor from dredging activities, and the leaching of toxic effluents into streams from mining operations. Many of the effects of past mining operations continue to impact salmonid habitat today. Current mining practices include suction dredging (sand and gravel mining), placer mining, lode mining and gravel mining. Present day mining practices are typically less intrusive than historic operations (hydraulic mining); however, adverse impacts to salmonid habitat still occur as a result of present-day mining activities. Sand and gravel are used for a large variety of construction activities including base material and

asphalt, road bedding, drain rock for leach fields, and aggregate mix for concrete to construct buildings and highways.

Most aggregate is derived principally from pits in active floodplains, pits in inactive river terrace deposits, or directly from the active channel. Other sources include hard rock quarries and mining from deposits within reservoirs. Extraction sites located along or in active floodplains present particular problems for anadromous salmonids. Physical alteration of the stream channel may result in the destruction of existing riparian vegetation and the reduction of available area for seedling establishment (Stillwater Sciences 2002). Loss of vegetation impacts riparian and aquatic habitat by causing a loss of the temperature moderating effects of shade and cover, and habitat diversity. Extensive degradation may induce a decline in the alluvial water table, as the banks are effectively drained to a lowered level, affecting riparian vegetation and water supply (NMFS 1996b). Altering the natural channel configuration will reduce salmonid habitat diversity by creating a wide, shallow channel lacking in the pools and cover necessary for all life stages of anadromous salmonids. In addition, waste products resulting from past and present mining activities, include cyanide (an agent used to extract gold from ore), copper, zinc, cadmium, mercury, asbestos, nickel, chromium, and lead.

Juvenile salmonids are exposed to increased water temperatures in the Delta during the late spring and summer due to the loss of riparian shading, and by thermal inputs from municipal, industrial, and agricultural discharges. Studies by DWR on water quality in the Delta over the last 30 years show a steady decline in the food sources available for juvenile salmonids and sturgeon and an increase in the clarity of the water due to a reduction in phytoplankton and zooplankton. These conditions have contributed to increased mortality of juvenile Chinook salmon, steelhead, and sturgeon as they move through the Delta.

5. Water Quality

The water quality of the Delta has been negatively impacted over the last 150 years. Increased water temperatures, decreased DO concentrations, altered turbidity levels and increased contaminant loads have degraded the quality of the aquatic habitat for the rearing and migration of salmonids. The Regional Board, in its 1998 Clean Water Act §303(d) list characterized the Delta as an impaired waterbody having elevated levels of chlorpyrifos, dichlorodiphenyltrichlor (*i.e.* DDT), diazinon, electrical conductivity, Group A pesticides (aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexanes [including lindane], endosulfan and toxaphene), mercury, low DO, organic enrichment, and unknown toxicities (Regional Board 1998, 2001).

In general, water degradation or contamination can lead to either acute toxicity, resulting in death when concentrations are sufficiently elevated, or more typically, when concentrations are lower, to chronic or sublethal effects that reduce the physical health of the organism, and lessens its survival over an extended period of time. Mortality may become a secondary effect due to compromised physiology or behavioral changes that lessen the organism's ability to carry out its normal activities. For example, increased levels of heavy metals are detrimental to the health of an organism because they interfere with metabolic functions by inhibiting key enzyme activity in metabolic pathways, decrease neurological function, degrade cardiovascular output, and act as

mutagens, teratogens or carcinogens in exposed organisms (Rand *et al*. 1995, Goyer 1996). For listed species, these effects may occur directly to the listed fish or to its prey base, which reduces the forage base available to the listed species.

In the aquatic environment, most anthropogenic chemicals and waste materials including toxic organic and inorganic chemicals eventually accumulate in sediment (Ingersoll 1995). Direct exposure to contaminated sediments may cause deleterious effects to listed salmonids or the threatened green sturgeon. This may occur if a fish swims through a plume of the resuspended sediments or rests on contaminated substrate and absorbs the toxic compounds through one of several routes: dermal contact, ingestion, or uptake across the gills. Elevated contaminant levels may be found in localized "hot spots" where discharge occurs or where river currents deposit sediment loads. Sediment contaminant levels can thus be significantly higher than the overlying water column concentrations (Environmental Protection Agency 1994). However, the more likely route of exposure to salmonids or sturgeon is through the food chain, when the fish feed on organisms that are contaminated with toxic compounds. Prey species become contaminated either by feeding on the detritus associated with the sediments or dwelling in the sediment itself. Therefore, the degree of exposure to the salmonids and green sturgeon depends on their trophic level and the amount of contaminated forage base they consume. Response of salmonids and green sturgeon to contaminated sediments is similar to water borne exposures.

Low DO levels frequently are observed in the portion of the Stockton deep water ship channel (DWSC) extending from Channel Point, downstream to Turner and Columbia Cuts. For example, starting in 2000, a DO meter recorded channel DO levels at Rough and Ready Island (Dock 20 of the West Complex). Over the course of the 5-year time period between 2000 and 2005, there have been 297 days in which violations of the 5 mg/L DO criteria for the protection of aquatic life in the San Joaquin River between Channel Point and Turner and Columbia Cuts have occurred during the September through May migratory period for salmonids in the San Joaquin River. The data derived from the California Data Exchange Center (CDEC) files indicate that DO depressions occur during all migratory months, with significant events occurring from November through March when listed Central Valley steelhead adults and smolts would be utilizing this portion of the San Joaquin River as a migratory corridor (see Appendix A: Table 11).

Potential factors that contribute to these DO depressions are reduced river flows through the ship channel, released ammonia from the City of Stockton Wastewater Treatment Plant, upstream contributions of organic materials (*e.g.*, algal loads, nutrients, agricultural discharges) and the increased volume of the dredged ship channel. During the winter and early spring emigration period between 2000 and 2005, increased ammonia concentrations in the discharges from the City of Stockton Waste Water Treatment Facility lowered the DO in the adjacent DWSC near the West Complex. In addition to the adverse effects of the lowered DO on salmonid physiology, ammonia is in itself toxic to salmonids at low concentrations. Actions have been taken to remedy this source of ammonia by modifying the treatment train at the wastewater facility. Likewise, adult fish migrating upstream will encounter lowered DO in the DWSC as they move upstream in the fall and early winter due to low flows and excessive algal and nutrient loads coming downstream from the upper San Joaquin River watershed. There is insufficient flow to adequately mix the water mass and maintain the necessary level of dissolved oxygen.

Currently, an aerator located at the West Complex is being utilized to help reduce the incidence of low DO concentrations in this reach of the DWSC when conditions warrant it. Levels of DO below 5 mg/L have been reported as delaying or blocking fall-run Chinook salmon in studies conducted by Hallock *et al.* (1970).

6. Hatchery Operations and Practices

Five hatcheries currently produce Chinook salmon in the Central Valley and four of these also produce steelhead. Releasing large numbers of hatchery fish can pose a threat to wild Chinook salmon and steelhead stocks through genetic impacts, competition for food and other resources between hatchery and wild fish, predation of hatchery fish on wild fish, and increased fishing pressure on wild stocks as a result of hatchery production (Waples 1991). The genetic impacts of artificial propagation programs in the Central Valley primarily are caused by straying of hatchery fish and the subsequent interbreeding of hatchery fish with wild fish. In the Central Valley, practices such as transferring eggs between hatcheries and trucking smolts to distant sites for release contribute to elevated straying levels [Department of the Interior (DOI) 1999]. For example, the original source of steelhead broodstock at Nimbus Hatchery on the American River came from the Eel River basin and was not from the Central Valley. Thus, the progeny from that initial broodstock served as the basis for the hatchery steelhead reared and released from the Nimbus Fish Hatchery. One of the recommendations in the Joint Hatchery Review Report (NMFS and CDFG 2001) was to identify and designate new sources of steelhead brood stock to replace the current Eel River origin brood stock.

Hatchery practices as well as spatial and temporal overlaps of habitat use and spawning activity between spring- and fall-run fish have led to the hybridization and homogenization of some subpopulations (CDFG 1998). As early as the 1960s, Slater (1963) observed that early fall- and spring-run Chinook salmon were competing for spawning sites in the Sacramento River below Keswick Dam, and speculated that the two runs may have hybridized. The FRH spring-run Chinook salmon have been documented as straying throughout the Central Valley for many years (CDFG 1998), and in many cases have been recovered from the spawning grounds of fall-run Chinook salmon, an indication that FRH spring-run Chinook salmon may exhibit fall-run life history characteristics. Although the degree of hybridization has not been comprehensively determined, it is clear that the populations of spring-run Chinook salmon spawning in the Feather River and counted at RBDD contain hybridized fish.

The management of hatcheries, such as Nimbus Hatchery and FRH, can directly impact spring-run Chinook salmon and steelhead populations by oversaturating the natural carrying capacity of the limited habitat available below dams. In the case of the Feather River, significant redd superimposition occurs in-river due to hatchery overproduction and the inability to physically separate spring- and fall-run Chinook salmon adults. This concurrent spawning has led to hybridization between the spring- and fall-run Chinook salmon in the Feather River. At Nimbus Hatchery, operating Folsom Dam to meet temperature requirements for returning hatchery fall-run Chinook salmon often limits the amount of water available for steelhead spawning and rearing the rest of the year within the American River downstream of Nimbus Dam.

The increase in Central Valley hatchery production has reversed the composition of the steelhead population, from 88 percent naturally-produced fish in the 1950s (McEwan 2001) to an estimated 23 percent to 37 percent naturally-produced fish by 2000 (Nobriga and Cadrett 2001), and less than 10 percent currently (NMFS 2011c). The increase in hatchery steelhead production proportionate to the wild population has reduced the viability of the wild steelhead populations, increased the use of out-of-basin stocks for hatchery production, and increased straying (NMFS and CDFG 2001). Thus, the ability of natural populations to successfully reproduce and continue their genetic integrity likely has been diminished.

The relatively low number of spawners needed to sustain a hatchery population can result in high harvest-to-escapements ratios in waters where fishing regulations are set according to hatchery population. This can lead to over-exploitation and reduction in the size of wild populations existing in the same system as hatchery populations due to incidental bycatch (McEwan 2001). Currently, hatchery produced fall-run Chinook salmon comprise the majority of fall-run adults returning to Central Valley streams. Based on a 25 percent constant fractional marking of hatchery produced fall-run Chinook salmon juveniles, adult escapement of fin clipped fish greater than 25 percent in Central Valley tributaries would indicate that hatchery produced fish are the predominate source of fish in the spawning population. Recent surveys (2010) have seen percentages approaching this or exceeding it in area tributaries (Sacramento Bee, January 4, 2011, editorial by John Williams). This trend has also been observed with the 2011 returns of fall-run Chinook salmon, in which ad-clipped fish make up more than 25% of the observed fish spawning in area rivers.

Hatcheries also can have some positive effects on salmonid populations. Artificial propagation has been shown to be effective in bolstering the numbers of naturally spawning fish in the short term under specific scenarios. Artificial propagation programs can also aid in conserving genetic resources and guarding against catastrophic loss of naturally spawned populations at critically low abundance levels, as was the case with the Sacramento River winter-run Chinook salmon population during the 1990s. However, relative abundance is only one component of a viable salmonid population.

7. Over Utilization

a. *Ocean Commercial and Sport Harvest – Chinook Salmon and Steelhead*

Extensive ocean recreational and commercial troll fisheries for Chinook salmon exist along the northern and central California coast, and an inland recreational fishery exists in the Central Valley for Chinook salmon and steelhead. Ocean harvest of Central Valley Chinook salmon is estimated using an abundance index, called the Central Valley Index (CVI) harvest index. The CVI is the sum of the ocean fishery Chinook salmon harvested south of Point Arena (where 85 percent of Central Valley Chinook salmon are caught), plus the Central Valley adult Chinook salmon escapement. The CVI harvest index is the ocean harvest landed south of Point Arena divided by the CVI. CWT returns indicate that Sacramento River salmon congregate off the California coast between Point Arena and Morro Bay.

Since 1970, the CVI harvest index for Sacramento River winter-run Chinook salmon generally has ranged between 0.50 and 0.80. In 1990, when ocean harvest of winter-run Chinook salmon was first evaluated by NMFS and the Pacific Fisheries Management Council (PFMC), the CVI harvest index was near the highest recorded level at 0.79. NMFS determined in a 1991 biological opinion that continuance of the 1990 ocean harvest rate would not prevent the recovery of Sacramento River winter-run Chinook salmon. In addition, the final rule designating winter-run Chinook salmon critical habitat (58 FR 33212, June 16, 1993) stated that commercial and recreational fishing do not appear to be significant factors for the decline of the species. Through the early 1990s, the ocean harvest index was below the 1990 level (*i.e.*, 0.71 in 1991 and 1992, 0.72 in 1993, 0.74 in 1994, 0.78 in 1995, and 0.64 in 1996). In 1996 and 1997, NMFS issued a biological opinion which concluded that incidental ocean harvest of Sacramento River winter-run Chinook salmon represented a significant source of mortality to the endangered population, even though ocean harvest was not a key factor leading to the decline of the population. As a result of these opinions, measures were developed and implemented by the PFMC, NMFS, and CDFG to reduce ocean harvest by approximately 50 percent. In 2001 the CVI dropped to 0.27, most likely due to the reduction in harvest and the higher abundance of other salmonids originating from the Central Valley (Good *et al*. 2005). In April 2010, NMFS reached a jeopardy conclusion regarding the ongoing Fisheries Management Plan (FMP) for west coast ocean salmon fishery in regards to its impacts on the continued survival of the winter-run Chinook salmon population (NMFS 2010). Reasonable and Prudent Alternative (RPA) actions which include new size limits and ocean harvest area closures were instituted to help reduce the impacts of the ocean salmon fishery on winter-run Chinook salmon. For the period between 2000-2007, the age-3 (fully vulnerable) ocean fishery exploitation rate estimate has remained stable and averaged about 17% (see figure19). The rates for 2008 and 2009 will be much lower due to the ocean fisheries closure that affected ocean waters south of Point Arena. The RPA actions in the 2010 Ocean Harvest biological opinion regarding winter-run harvest are designed to further reduce commercial and sport fishery impacts on winter-run in the ocean.

Ocean fisheries have affected the age structure of Central Valley spring-run Chinook salmon through targeting large fish for many years and reducing the numbers of 4- and 5-year-old fish (CDFG 1998). Winter-run spawners have also been affected by ocean fisheries, as most spawners now return as 3-year olds. Few, if any 4 and 5-year old fish survive the additional years in the ocean to return as spawners. These fish would be greater than the minimum size limits that would protect younger fish from harvest in the ocean during the regulated fishing season.

As a result of very low returns of fall-run Chinook salmon to the Central Valley in 2007 and 2008, there was a complete closure of commercial and recreational ocean Chinook salmon fishery in 2008 and 2009, respectively. Salmon fisheries were again restricted in 2010 with a limited fishing season due to poor returns of fall-run Chinook salmon in 2009. The Sacramento River winter-run Chinook salmon population increased by approximately 60 percent in 2009, but declined again in 2010 to 1,596 fish. In 2011, the estimated adult escapement of winter-run Chinook salmon fell to 824 fish. A similar trend has been seen in the spring-run population in the Central Valley following the ocean salmon fishery closures. Contrary to expectations, even with the 2 years of ocean fishery closures, the Central Valley spring-run Chinook salmon population continued to decline in 2010. Adult escapement was up slightly in 2011 by

approximately 1000 fish basin wide, but the tributary and basin CRRs were still less than 1, indicating that the cohorts were not replacing themselves. Populations held steady or declined in Deer and Mill creeks, but increased by about 1,000 fish in Butte Creek (GrandTab February 2011, CDFG survey data 2011). Ocean harvest rates of Central Valley spring-run Chinook salmon are thought to be a function of the CVI (Good *et al*. 2005). Harvest rates of Central Valley spring-run Chinook salmon ranged from 0.55 to nearly 0.80 between 1970 and 1995 when harvest rates were adjusted for the protection of Sacramento River winter-run Chinook salmon. The drop in the CVI in 2001 as a result of high fall-run escapement to 0.27 also reduced harvest of Central Valley spring-run Chinook salmon. The 2011 status review for spring-run (NMFS 2011b) reported that the fall-run Chinook salmon ocean harvest rate peaked in the late 1980's at 84% and then steadily declined over the 1990's to an average level of 51% from 2000-2007. The fall-run harvest index is used as a proxy for the harvest of spring-run Chinook salmon. As mentioned previously, the closure of ocean commercial and sport fisheries in 2008 and 2009, and a reduced season in 2010 sharply reduced the harvest index (6% in 2008, 0% in 2009, and an estimated 22% for 2010, see Figure 19). NMFS concluded in its 2011 status review that the ocean fishery did not result in overutilization of this ESU since the last status review in 2005 due to substantially reduced fishing pressure in 2008, 2009, and 2010. There is essentially no ocean harvest of steelhead.

b. *Inland Sport Harvest –Chinook Salmon and Steelhead*

Historically in California, almost half of the river sport fishing effort was in the Sacramento-San Joaquin River system, particularly upstream from the city of Sacramento (Emmett *et al.* 1991). Since 1987, the Fish and Game Commission has adopted increasingly stringent regulations to reduce and virtually eliminate the in-river sport fishery for Sacramento River winter-run Chinook salmon. Present regulations include a year-round closure to Chinook salmon fishing between Keswick Dam and the Deschutes Road Bridge and a rolling closure to Chinook salmon fishing on the Sacramento River between the Deschutes River Bridge and the Carquinez Bridge. The rolling closure spans the months that migrating adult Sacramento River winter-run Chinook salmon are ascending the Sacramento River to their spawning grounds. These closures have virtually eliminated impacts on Sacramento River winter-run Chinook salmon caused by recreational angling in freshwater. In 1992, the California Fish and Game Commission adopted gear restrictions (all hooks must be barbless and a maximum of 5.7 cm in length) to minimize hooking injury and mortality of winter-run Chinook salmon caused by trout anglers. That same year, the Commission also adopted regulations which prohibited any salmon from being removed from the water to further reduce the potential for injury and mortality.

In-river recreational fisheries historically have taken Central Valley spring-run Chinook salmon throughout the species' range. During the summer, holding adult Central Valley spring-run Chinook salmon are easily targeted by anglers when they congregate in large pools. Poaching also occurs at fish ladders, and other areas where adults congregate; however, the significance of poaching on the adult population is unknown. Specific regulations for the protection of Central Valley spring-run Chinook salmon in Mill, Deer, Butte, and Big Chico creeks and the Yuba River have been added to the existing CDFG regulations. The current regulations, including those developed for Sacramento River winter-run Chinook salmon provide some level of protection for spring-run fish (CDFG 1998).

There is little information on steelhead harvest rates in California. Hallock *et al.* (1961) estimated that harvest rates for Sacramento River steelhead from the 1953-1954 through 1958-1959 seasons ranged from 25.1 percent to 45.6 percent assuming a 20 percent non-return rate of tags. The average annual harvest rate of adult steelhead above RBDD for the 3-year period from 1991-1992 through 1993-1994 was 16 percent (McEwan and Jackson 1996). Since 1998, all hatchery steelhead have been marked with an adipose fin clip allowing anglers to distinguish hatchery and wild steelhead. Current regulations restrict anglers from keeping unmarked steelhead in Central Valley streams. Overall, this regulation has greatly increased protection of naturally produced adult steelhead; however, the total number of Central Valley steelhead contacted might be a significant fraction of basin-wide escapement, and even low catch-and-release mortality may pose a problem for wild populations (Good *et al*. 2005).

c. *Green Sturgeon Harvest*

Commercial harvest of white sturgeon results in the incidental bycatch of green sturgeon primarily along the Oregon and Washington coasts and within their coastal estuaries. Oregon and Washington have recently prohibited the retention of green sturgeon in their waters for commercial and recreational fisheries. Adams *et al*. (2002) reported harvest of green sturgeon from California, Oregon, and Washington between 1985 and 2001. Total captures of green sturgeon in the Columbia River Estuary by commercial means ranged from 240 fish per year to 6,000. Catches in Willapa Bay and Grays Harbor by commercial means combined ranged from 9 fish to 2,494 fish per year. Emmett *et al*. (1991) indicated that averages of 4.7 tons to 15.9 tons of green sturgeon were landed annually in Grays Harbor and Willapa Bay respectively. Overall, captures appeared to be dropping through the years; however, this could be related to changing fishing regulations. Adams *et al*. (2002) also reported sport fishing captures in California, Oregon, and Washington. Within the San Francisco Estuary, green sturgeon are captured by sport fisherman targeting the more desirable white sturgeon, particularly in San Pablo and Suisun bays (Emmett *et al*. 1991). Sport fishing in the Columbia River, Willapa Bay, and Grays Harbor captured from 22 to 553 fish per year between 1985 and 2001. Again, it appears sport fishing captures are dropping through time; however, it is not known if this is a result of abundance, changed fishing regulations, or other factors. Based on new research by Israel (2006a) and past tagged fish returns reported by CDFG (2002), a high proportion of green sturgeon present in the Columbia River, Willapa Bay, and Grays Harbor (as much as 80 percent in the Columbia River) may be Southern DPS North American green sturgeon. This indicates a potential threat to the Southern DPS North American green sturgeon population. Beamesderfer *et al.* (2007) estimated that green sturgeon will be vulnerable to slot limits (outside of California) for approximately 14 years of their life span. Fishing gear mortality presents an additional risk to the long-lived sturgeon species such as the green sturgeon (Boreman 1997). Although sturgeon are relatively hardy and generally survive being hooked, their long life makes them vulnerable to repeated hooking encounters, which leads to an overall significant hooking mortality rate over their lifetime. An adult green sturgeon may not become sexually mature until they are 13 to 18 years of age for males (152-185cm), and 16 to 27 years of age for females (165-202 cm, Van Eenennaam 2006). Even though slot limits "protect" a significant proportion of the life history of green sturgeon from harvest, they do not protect them from fishing pressure.

Green sturgeon are caught incidentally by sport fisherman targeting the more highly desired white sturgeon within the Delta waterways and the Sacramento River. New regulations which went into effect in March 2007, reduced the slot limit of sturgeon from 72 inches to 66 inches, and limit the retention of white sturgeon to one fish per day with a total of 3 fish retained per year. In addition, a non-transferable sturgeon punch card with tags must be obtained by each angler fishing for sturgeon. All sturgeon caught must be recorded on the card, including those released. All green sturgeon must be released unharmed and recorded on the sturgeon punch card by the angler. In 2010, further restrictions to fishing for sturgeon in the upper Sacramento River were enacted between Keswick Dam and the Highway 162 Bridge over the Sacramento River near the towns of Cordora and Butte City. These regulations are designed to protect green sturgeon in the upper Sacramento River from unnecessary harm due to fishing pressure (CDFG freshwater fishing regulations 2010-2011).

Poaching rates of green sturgeon in the Central Valley are unknown; however, catches of sturgeon occur during all years, especially during wet years. Unfortunately, there is no catch, effort, and stock size data for this fishery which precludes making exploitation estimates (USFWS 1995a). Areas just downstream of Thermalito Afterbay outlet and Cox's Spillway, and several barriers impeding migration on the Feather River may be areas of high adult mortality from increased fishing effort and poaching. The small population of sturgeon inhabiting the San Joaquin River (believed to be currently comprised of only white sturgeon) experiences heavy fishing pressure, particularly regarding illegal snagging and it may be more than the population can support (USFWS 1995a).

8. Disease and Predation

Infectious disease is one of many factors that influence adult and juvenile salmonid survival. Salmonids are exposed to numerous bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, hatcheries, migratory routes, and the marine environment (NMFS 1996a, 1996b, 1998a). Specific diseases such as bacterial kidney disease, C*eratomyxosis shasta* (C-shasta), columnaris, furunculosis, infectious hematopoietic necrosis, redmouth and black spot disease, whirling disease, and erythrocytic inclusion body syndrome are known, among others, to affect steelhead and Chinook salmon (NMFS 1996a, 1996b, 1998a). Very little current or historical information exists to quantify changes in infection levels and mortality rates attributable to these diseases; however, studies have shown that wild fish tend to be less susceptible to pathogens than are hatchery-reared fish. Nevertheless, wild salmonids may contract diseases that are spread through the water column (*i.e.*, waterborne pathogens) as well as through interbreeding with infected hatchery fish. The stress of being released into the wild from a controlled hatchery environment frequently causes latent infections to convert into a more pathological state, and increases the potential of transmission from hatchery reared fish to wild stocks within the same waters.

Accelerated predation also may be a factor in the decline of Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon, and to a lesser degree Central Valley steelhead. Human-induced habitat changes such as alteration of natural flow regimes and installation of bank revetment and structures such as dams, bridges, water diversions, piers, and

wharves often provide conditions that both disorient juvenile salmonids and attract predators (Stevens 1961, Decato 1978, Vogel *et al.* 1988, Garcia 1989).

On the main stem Sacramento River, high rates of predation are known to occur at the RBDD, Anderson-Cottonwood Irrigation District's (ACID) diversion dam, GCID's diversion facility, areas where rock revetment has replaced natural river bank vegetation, and at South Delta water diversion structures (*e.g*., Clifton Court Forebay; CDFG 1998). Predation at RBDD on juvenile winter-run Chinook salmon is believed to be higher than normal due to flow dynamics associated with the operation of this structure. Due to their small size, early emigrating winter-run Chinook salmon may be very susceptible to predation in Lake Red Bluff when the RBDD gates remain closed in summer and early fall. In passing the dam, juveniles are subject to conditions which greatly disorient them, making them highly susceptible to predation by fish or birds. Sacramento pikeminnow (*Ptychocheilus grandis*) and striped bass congregate below the dam and prey on juvenile salmon in the tail waters. The Sacramento pikeminnow is a species native to the Sacramento River basin and has co-evolved with the anadromous salmonids in this system. However, rearing conditions in the Sacramento River today (*e.g.*, warm water, low-irregular flow, standing water, and water diversions) compared to its natural state and function decades ago in the pre-dam era, are more conducive to warm water species such as Sacramento pikeminnow and striped bass than to native salmonids. Tucker *et al.* (1998) reported that predation during the summer months by Sacramento pikeminnow on juvenile salmonids increased to 66 percent of the total weight of stomach contents in the predatory pikeminnow. Striped bass showed a strong preference for juvenile salmonids as prey during this study. This research also indicated that the percent frequency of occurrence for juvenile salmonids nearly equaled other fish species in the stomach contents of the predatory fish. Tucker *et al.* (2003) showed the temporal distribution for these two predators in the RBDD area were directly related to RBDD operations (predators congregated when the dam gates were in, and dispersed when the gates were removed). With the interim RBDD operations proposed under the 2009 OCAP BiOp the gates of the RBDD remain open for a longer period of time. This should reduce the level of predation upon emigrating salmonids. Eventually the gates will remain open year round and predation should be even further reduced. Some predation is still likely to occur due to the physical structure of the dam remaining in the water way, even with the gates in the open position.

USFWS found that more predatory fish were found at rock revetment bank protection sites between Chico Landing and Red Bluff than at sites with naturally eroding banks (Michny and Hampton 1984). From October 1976 to November 1993, CDFG conducted 10 mark/recapture studies at the SWP's Clifton Court Forebay to estimate pre-screen losses using hatchery-reared juvenile Chinook salmon. Pre-screen losses ranged from 69 percent to 99 percent. Predation by striped bass is thought to be the primary cause of the loss (Gingras 1997, DWR 2009).

Predation on juvenile salmonids has increased as a result of water development activities which have created ideal habitats for predators and non-native invasive species (NIS). Turbulent conditions near dam bypasses, turbine outfalls, water conveyances, and spillways disorient juvenile salmonid migrants and increase their predator avoidance response time, thus improving predator success. Increased exposure to predators has also resulted from reduced water flow through reservoirs; a condition which has increased juvenile travel time. Other locations in the

Central Valley where predation is of concern include flood bypasses, post-release sites for salmonids salvaged at the CVP and SWP Fish Facilities, and the SMSCG. Predation on salmon by striped bass and pikeminnow at salvage release sites in the Delta and lower Sacramento River has been documented (Orsi 1967, Pickard *et al.* 1982); however, accurate predation rates at these sites are difficult to determine. CDFG conducted predation studies from 1987 to 1993 at the SMSCG to determine if the structure attracts and concentrates predators. The dominant predator species at the SMSCG was striped bass, and the remains of juvenile Chinook salmon were identified in their stomach contents (Edwards *et al.* 1996, Tillman *et al.* 1996, NMFS 1997).

Avian predation on fish contributes to the loss of migrating juvenile salmonids by constraining natural and artificial production. Fish-eating birds that occur in the California Central Valley include great blue herons (*Ardea herodias*), gulls (*Larus* spp.), osprey (*Pandion haliaetus*), common mergansers (*Mergus merganser*), American white pelicans (*Pelecanus erythrorhynchos*), double-crested cormorants (*Phalacrocorax* spp.), Caspian terns (*Sterna caspia*), belted kingfishers (*Ceryle alcyon*), black-crowned night herons (*Nycticorax nycticorax*), Forster's terns (*Sterna forsteri*), hooded mergansers (*Lophodytes cucullatus*), and bald eagles (*Haliaeetus leucocephalus*) (Stephenson and Fast 2005). These birds have high metabolic rates and require large quantities of food relative to their body size.

Mammals can also be an important source of predation on salmonids within the California Central Valley. Predators such as river otters (*Lutra canadensis*), raccoons (*Procyon lotor*), striped skunk (*Mephitis mephitis*), and western spotted skunk (*Spilogale gracilis*) are common. Other mammals that take salmonids include: badger (*Taxidea taxus*), bobcat (*Lynx rufus*), coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), long-tailed weasel (*Mustela frenata*), mink (*Mustela vison*), mountain lion (*Felis concolor*), red fox (*Vulpes vulpes*), and ringtail (*Bassariscus astutus*). These animals, especially river otters, are capable of removing large numbers of salmon and trout from the aquatic habitat (Dolloff 1993). Mammals have the potential to consume large numbers of salmonids, but generally scavenge post-spawned salmon. In the marine environment, pinnipeds, including harbor seals (*Phoca vitulina*), California sea lions (*Zalophus californianus*), and Steller's sea lions (*Eumetopia jubatus*) are the primary marine mammals preying on salmonids (Spence *et al*. 1996). Pacific striped dolphin (*Lagenorhynchus obliquidens*) and killer whale (*Orcinus orca*) can also prey on adult salmonids in the nearshore marine environment, and at times become locally important. Although harbor seal and sea lion predation primarily is confined to the marine and estuarine environments, they are known to travel well into freshwater after migrating fish and have frequently been encountered in the Delta and the lower portions of the Sacramento and San Joaquin Rivers. All of these predators are opportunists, searching out locations where juveniles and adults are most vulnerable, such as the large water diversions in the South Delta.

9. <u>Environmental Variation</u>

Natural changes in the freshwater and marine environments play a major role in salmonid abundance. Recent evidence suggests that marine survival among salmonids fluctuates in response to 20- to 30-year cycles of climatic conditions and ocean productivity (Hare *et al*. 1999, Mantua and Hare 2002). This phenomenon has been referred to as the Pacific Decadal Oscillation. In addition, large-scale climatic regime shifts, such as the El Niño condition, appear

to change productivity levels over large expanses of the Pacific Ocean. A further confounding effect is the fluctuation between drought and wet conditions in the basins of the American west. During the first part of the 1990s, much of the Pacific Coast was subject to a series of very dry years, which reduced inflows to watersheds up and down the west coast. A three year period of reduced precipitation from 2007 to 2009 is thought to have been a contributing factor to reduced salmonid populations in the Central Valley.

"El Niño" is an environmental condition often cited as a cause for the decline of West Coast salmonids (NMFS 1996b). El Niño is an unusual warming of the Pacific Ocean off South America and is caused by atmospheric changes in the tropical Pacific Ocean (Southern Oscillation-ENSO) resulting in reductions or reversals of the normal trade wind circulation patterns. The El Niño ocean conditions are characterized by anomalous warm sea surface temperatures and changes to coastal currents and upwelling patterns. Principal ecosystem alterations include decreased primary and secondary productivity in affected regions and changes in prey and predator species distributions. Cold-water species are displaced towards higher latitudes or move into deeper, cooler water, and their habitat niches occupied by species tolerant of warmer water that move upwards from the lower latitudes with the warm water tongue.

A key factor affecting many West Coast stocks has been a general 30-year decline in ocean productivity. The mechanism whereby stocks are affected is not well understood, partially because the pattern of response to these changing ocean conditions has differed among stocks, presumably due to differences in their ocean timing and distribution. It is presumed that survival in the ocean is driven largely by events occurring between ocean entry and recruitment to a sub-adult life stage.

10. Ecosystem Restoration

a. *California Bay-Delta Authority (CBDA)*

Two programs included under CBDA; the Ecosystem Restoration Program (ERP) and the EWA, were created to improve conditions for fish, including listed salmonids, in the Central Valley (CALFED 2000a). Restoration actions implemented by the ERP include the installation of fish screens, modification of barriers to improve fish passage, habitat acquisition, and instream habitat restoration. The majority of these actions address key factors affecting listed salmonids and emphasis has been placed in tributary drainages with high potential for steelhead and spring-run Chinook salmon production. Additional ongoing actions include new efforts to enhance fisheries monitoring and directly support salmonid production through hatchery releases. Recent habitat restoration initiatives sponsored and funded primarily by the CBDA-ERP Program have resulted in plans to restore ecological function to 9,543 acres of shallow-water tidal and marsh habitats within the Delta. Restoration of these areas primarily involves flooding lands previously used for agriculture, thereby creating additional rearing habitat for juvenile salmonids. Similar habitat restoration is imminent adjacent to Suisun Marsh (*i.e.*, at the confluence of Montezuma Slough and the Sacramento River) as part of the Montezuma Wetlands project, which is intended to provide for commercial disposal of material dredged from San Francisco Bay in conjunction with tidal wetland restoration.

A sub-program of the ERP called the Environmental Water Program (EWP) has been established to support ERP projects through enhancement of instream flows that are biologically and ecologically significant in anadromous reaches of priority streams controlled by dams. This program is in the development stage and the benefits to listed salmonids are not yet clear. Clear Creek is one of five priority watersheds in the Central Valley that has been targeted for action during Phase I of the EWP.

The EWA is designed to provide water at critical times to meet ESA requirements and incidental take limits without water supply impacts to other users, particularly South of Delta water users. In early 2001, the EWA released 290 thousand acre feet of water from San Luis Reservoir at key times to offset reductions in South Delta pumping implemented to protect winter-run Chinook salmon, delta smelt, and Sacramento splittail (*Pogonichthys macrolepidotus*). However, the benefit derived by this action to winter-run Chinook salmon in terms of number of fish saved was very small. The anticipated benefits to other Delta fisheries from the use of the EWA water are much higher than those benefits ascribed to listed salmonids by the EWA release. Under the long term operations of the CVP and SWP, EWA assets have declined to 48 thousand acre feet after carriage water costs. The RPA actions developed within the 2009 OCAP BiOp are designed to minimize or remove the adverse impacts associated with many of the OCAP project related stressors. Within the Delta, stressors such as the Delta Cross Channel (DCC) gates and export operations have been modified to reduce the hydraulic changes created by the project operations. Earlier closures of the DCC gates prevent early emigrating listed salmonids from entering the Delta interior through the open DCC gates. Management of the Old and Middle River flows prevents an excessive amount of negative flow towards the export facilities from occurring in the channels of Old and Middle River. When flows are negative, water moves in the opposite direction than would occur naturally, drawing fish into the south Delta and towards the export facilities or delaying their migration through the system.

b. *Central Valley Project Improvement Act*

The CVPIA, implemented in 1992, requires that fish and wildlife get equal consideration with other demands for water allocations derived from the CVP. From this act arose several programs that have benefited listed salmonids: the Anadromous Fish Restoration Program (AFRP), the Anadromous Fish Screen Program (AFSP), and the Water Acquisition Program (WAP). The AFRP is engaged in monitoring, education, and restoration projects geared toward recovery of all anadromous fish species residing in the Central Valley. Restoration projects funded through the AFRP include fish passage, fish screening, riparian easement and land acquisition, development of watershed planning groups, instream and riparian habitat improvement, and gravel replenishment. The AFSP combines Federal funding with State and private funds to prioritize and construct fish screens on major water diversions mainly in the upper Sacramento River. The goal of the WAP is to acquire water supplies to meet the habitat restoration and enhancement goals of the CVPIA and to improve the DOI's ability to meet regulatory water quality requirements. Water has been used successfully to improve fish habitat for spring-run Chinook salmon and steelhead by maintaining or increasing instream flows in Butte and Mill Creeks and the San Joaquin River at critical times.

c. *Iron Mountain Mine Remediation*

Environmental Protection Agency's Iron Mountain Mine remediation involves the removal of toxic metals in acidic mine drainage from the Spring Creek Watershed with a state-of-the-art lime neutralization plant. In addition, dredging of the contaminated sediment within the pool behind Keswick Dam has removed significant amounts of toxic metals that may become mobilized during high flows. Contaminant loading into the Sacramento River from Iron Mountain Mine has shown measurable reductions since the early 1990s (see Reclamation 2004 Appendix J). Decreasing the heavy metal contaminants that enter the Sacramento River should increase the survival of salmonid eggs and juveniles. However, during periods of heavy rainfall upstream of the Iron Mountain Mine, Reclamation substantially increases Sacramento River flows in order to dilute heavy metal contaminants being spilled from the Spring Creek debris dam. This rapid change in flows can cause juvenile salmonids to become stranded or isolated in side channels below Keswick Dam.

d. *State Water Project Delta Pumping Plant Fish Protection Agreement (Four-Pumps Agreement)*

The Four Pumps Agreement Program has approved about $49 million for projects that benefit salmon and steelhead production in the Sacramento-San Joaquin basins and Delta since the agreement inception in 1986. Four Pumps projects that benefit spring-run Chinook salmon and steelhead include water exchange programs on Mill and Deer creeks; enhanced law enforcement efforts from San Francisco Bay upstream to the Sacramento and San Joaquin rivers and their tributaries; design and construction of fish screens and ladders on Butte Creek; and screening of diversions in Suisun Marsh and San Joaquin tributaries. Predator habitat isolation and removal, and spawning habitat enhancement projects on the San Joaquin tributaries benefit steelhead (see Reclamation 2004 Chapter 15).

11. Non-Native Invasive Species

As currently seen in the San Francisco estuary, NIS can alter the natural food webs that existed prior to their introduction. Perhaps the most significant example is illustrated by the Asiatic freshwater clams *Corbicula fluminea* and *Potamocorbula amurensis*. The arrival of these clams in the estuary disrupted the normal benthic community structure and depressed phytoplankton levels in the estuary due to the highly efficient filter feeding of the introduced clams (Cohen and Moyle 2004). The decline in the levels of phytoplankton reduces the population levels of zooplankton that feed upon them, and hence reduces the forage base available to salmonids transiting the Delta and San Francisco estuary which feed either upon the zooplankton directly or their mature forms. This lack of forage base can adversely impact the health and physiological condition of these salmonids as they emigrate through the Delta region to the Pacific Ocean.

Attempts to control the NIS also can adversely impact the health and well-being of salmonids within the affected water systems. For example, the control programs for the invasive water hyacinth (*Eichhornia crassipes*) and Brazilian waterweed (*Egeria densa*) plants in the Delta must balance the toxicity of the herbicides applied to control the plants to the probability of exposure to listed salmonids during herbicide application. In addition, the control of the nuisance plants have certain physical parameters that must be accounted for in the treatment protocols,

particularly the decrease in DO resulting from the decomposing vegetable matter left by plants that have died.

12. Summary

For Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead, the construction of high dams for hydropower, flood control, and water supply resulted in the loss of vast amounts of upstream habitat (*i.e.*, approximately 80 percent, or a minimum linear estimate of over 1,000 stream miles), and often resulted in precipitous declines in affected salmonid populations. For example, the completion of Friant Dam in 1947 has been linked with the extirpation of spring-run Chinook salmon in the San Joaquin River upstream of the Merced River within just a few years. The reduced populations that remain below Central Valley dams are forced to spawn in lower elevation tailwater habitats of the mainstem rivers and tributaries that were previously not used for this purpose. This habitat is entirely dependent on managing reservoir releases to maintain cool water temperatures suitable for spawning, and/or rearing of salmonids. This requirement has been difficult to achieve in all water year types and for all life stages of affected salmonid species. Steelhead, in particular, seem to require the qualities of small tributary habitat similar to what they historically used for spawning; habitat that is largely unavailable to them under the current water management scenario. All salmonid species considered in this consultation have been adversely affected by the production of hatchery fish associated with the mitigation for the habitat lost to dam construction (*e.g.*, from genetic impacts, increased competition, exposure to novel diseases, *etc*.).

Land-use activities such as road construction, urban development, logging, mining, agriculture, and recreation are pervasive and have significantly altered fish habitat quantity and quality for Chinook salmon and steelhead through alteration of streambank and channel morphology; alteration of ambient water temperatures; degradation of water quality; elimination of spawning and rearing habitat; fragmentation of available habitats; elimination of downstream recruitment of LWD; and removal of riparian vegetation resulting in increased streambank erosion. Human-induced habitat changes, such as: alteration of natural flow regimes; installation of bank revetment; and building structures such as dams, bridges, water diversions, piers, and wharves, often provide conditions that both disorient juvenile salmonids and attract predators. Harvest activities, ocean productivity, and drought conditions provide added stressors to listed salmonid populations. In contrast, various ecosystem restoration activities have contributed to improved conditions for listed salmonids (*e.g.*, various fish screens). However, some important restoration activities (*e.g.*, Battle Creek Restoration Project) have not yet been completed and benefits to listed salmonids from the EWA have been less than anticipated.

Similar to the listed salmonids, the Southern DPS of North American green sturgeon have been negatively impacted by hydroelectric and water storage operations in the Central Valley which ultimately affect the hydrology and accesibility of Central Valley rivers and streams to anadromous fish. Anthropogenic manipulations of the aquatic habitat, such as dredging, bank stabilization, and waste water discharges have also degraded the quality of the Central Valley's waterways for green sturgeon.

F. Existing Monitoring Programs

Salmonid-focused monitoring efforts are taking place throughout the Sacramento and San Joaquin River basins, and the Suisun Marsh. Many of these programs incidentally gather information on steelhead but a focused, comprehensive steelhead monitoring program has not been funded or implemented in the Central Valley. The existing salmonid monitoring efforts are summarized in Appendix A: Table 12 by geographic area and target species. Information for this summary was derived from a variety of sources:

- IEP's (1999) Steelhead Project Work Team report on monitoring, assessment, and research on steelhead: status of knowledge, review of existing programs, and assessment of needs;
- CDFG Plan;
- U.S. Forest Service Sierra Nevada Framework monitoring plan;
- ESA section 10 and section 4(d) scientific research permit applications;
- Trinity River Restoration Program biological monitoring; and
- Suisun Marsh Monitoring Program.

Studies focused on the life history of green sturgeon are currently being implemented by researchers at academic institutions such as University of California, Davis. Future plans include radio-telemetry studies to track the movements of green sturgeon within the Delta and Sacramento River systems. Additional studies concerning the basic biology and physiology of green sturgeon are also being conducted to better understand the fish's niche in the aquatic system.

IV. 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).

A. Status of the Species and Critical Habitat in the Action Area

1. Status of the Species within the Action Area

The action area functions primarily as a migratory corridor for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, 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.

a. *Sacramento River Winter-Run Chinook Salmon*

The temporal occurrence of Sacramento River winter-run Chinook salmon smolts and juveniles within the action area (northern Delta) are best described by a combination of the salvage records of the CVP and SWP fish collection facilities and the fish monitoring programs conducted in the northern and central Delta (see Appendix A: Tables 13 and 14). Based on salvage records covering the period between 1999 and 2009 at the CVP and SWP fish collection facilities, juvenile Sacramento River winter-run Chinook salmon are typically present in the action area 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, 24 percent of the annual winter run juvenile population emigrates into the Delta in December, 17 percent in January, 19 percent in February, 37 percent in March and only 1 percent in April. The majority of winter-run juveniles (57 percent) enter the action area during the proposed study window (February 1, through June 30, 2012). During the hydroacoustic study (Study Element 4) which runs from February 1 through April 30, 2012, all 57 percent of the emigrating winter-run Chinook salmon juveniles will be exposed. During Study Element 5 (acoustically tagged salmon smolts study), a considerably smaller fraction of the annual winter-run emigration will occur during the study period of April and May 2012 (approximately 1 percent) since most winter-run smolts have already moved through the action area by April. During Study Element 6 (Standardized Angling) which targets predatory fish during the period between March 1, and June 30, 2012, approximately 38 percent of the annual winter-run juvenile population will move through the action area. Most of these fish will move through in March (37 percent). Few, if any, juvenile winter-run will be exposed after the first half of April, continuing through the end of the proposed study element. Presence of adult Chinook salmon is interpolated from historical data. Adult winter-run Chinook salmon are expected to enter the action area starting in January (≈ 4 percent), with the majority of adults passing through the action area between February and April (≈ 76 percent). During the proposed 5-month study period occurring between February 1, and June 30, 2012, approximately 93 percent of the adult winter-run spawning population is expected to pass through the action area. During Study Element 6, which is scheduled to occur between March 1, and June 30, 2012, approximately 80 percent of the annual adult winter-run escapement will pass through the action area (see Appendix A: Table 15).

b. *Central Valley Spring-Run Chinook salmon*

A similar application of the CVP and SWP salvage records and the northern and Central Delta fish monitoring data to the presence of Central Valley spring-run Chinook salmon indicates that juvenile spring-run Chinook salmon first begin to appear in the action area 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). 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 comprised of older yearling spring-run juveniles based on their size at date. Based on the Delta size criteria by date, the majority of spring-run Chinook salmon juveniles (young of year size) emigrate in March (53

percent) and April (43 percent) and tails off sharply by May (1 percent) and thus will be present in the action area during these periods. This pattern is further supported and consistent with salmonid passage estimates derived from rotary screw trap data collected by USFWS dating back to 2003, which indicate two significant peaks in the annual passage of juvenile spring-run Chinook salmon at RBDD occurring in the months of December and April. During the proposed study period (February 1, through June 30, 2012) it is estimated that approximately 97 percent of the annual spring-run Chinook salmon juvenile population will move through the Delta waterways within the action area. Adult spring-run Chinook salmon are expected to start entering the action area in approximately January. Low levels of adult migration are expected through early March. The peak of adult spring-run Chinook salmon movement through the action area in the Delta is expected to occur between April and June with adults continuing to enter the system through the summer (see Appendix A: Tables 13, 14, and 15). During the proposed Study Element 4 experimental window approximately 2.5 percent of the estimated annual adult escapement population will have moved upriver through the action area. During the proposed 60 day study for Element 5, it is estimated that approximately 7 percent of the adult escapement will move upriver through the Delta waterways associated with the action area. During Study Element 6, which spans the months of March through June, 2012, an estimated 17.5 percent of the annual adult escapement population is expected to move through the Delta waterways surrounding the action area. Currently, all known populations of Central Valley spring-run Chinook salmon inhabit the Sacramento River watershed. The San Joaquin River watershed populations have been extirpated, with the last known runs on the San Joaquin River being extirpated in the late 1940s and early 1950s by the construction of Friant Dam and the opening of the Kern-Friant irrigation canal.

c. *Central Valley Steelhead*

The Central Valley steelhead DPS occurs 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 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, otilith microchemistry indicating maternal anadromy in some specimens collected within the tributary (Zimmerman, 2008), and historical presence prior to dam construction. Central Valley steelhead smolts first start to appear in the action area in November based on the records from the CVP and SWP fish salvage facilities, as well as the fish monitoring program in the northern and central Delta (Appendix A: Tables 13 and 14). Their 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 CDFG on the main stem 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. Approximately 92 percent of the juvenile steelhead emigrants will move into and through the action area during the study

window (February through June 2012). The proposed 60 day study period for Study Element 5 will occur sometime between April and May, 2012, and will avoid exposure to the vast majority of emigrating Central Valley steelhead smolts. Study Element 6 of the Temperature Study will occur between March 1 and June 30, 2012, and has the potential to expose approximately 60 percent of the Central Valley steelhead smolt population emigrating from the Sacramento River basin. Adult steelhead are expected to move through the action area during Temperature Study implementation periods (February through June, 2012), but the peak of upriver immigration is expected to occur earlier (August through November on the Sacramento River) than the study implementation period (February through June)(see Figure 21). There is potential exposure to adult steelhead moving back downstream in a post-spawn condition (kelts) through the action area during the February to May period. It is expected that more kelts will be observed earlier in the period (February) due to the timing of spawning in the Sacramento River basin.

d. *Southern DPS of North American Green Sturgeon*

Juvenile green sturgeon from the Southern DPS are routinely collected at the SWP and CVP salvage facilities throughout the year. However, numbers are considerably lower than for other species of fish monitored at the facilities. Based on the salvage records from 1981 through 2007, 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 meter 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 CVP and SWP facilities, which are approximately 35 river miles south of the action area, would indicate that green sturgeon are more likely to be present in the action area during the proposed project, and in higher densities, than are observed at the fish collection facilities. Likewise, since the action area is on the main migratory route utilized by adult green sturgeon to access the spawning grounds in the upper Sacramento River, it is likely that adult green sturgeon will be present in the action area. Adult green sturgeon begin to enter the Sacramento – San Joaquin 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. It is also possible that some adult green sturgeon will be moving back downstream in April and May through the action area, either as early post spawners or as unsuccessful spawners. Some adult green sturgeon have been observed to rapidly move back downstream following spawning, while others linger in the upper river until the following fall.

2. <u>Status of Critical Habitat Within the Action Area</u>

The action area occurs within the CALWATER Hydrologic Unit (HU) for the Sacramento Delta Subbasin, designated HU 5510. Designated critical habitat for Sacramento River winter-run Chinook salmon (June 16, 1993, 58 FR 33212), Central Valley spring-run Chinook salmon (September 2, 2005, 70 FR 52488), Central Valley steelhead (September 2, 2005, 70 FR 52488)

and the southern DPS of green sturgeon (October 9, 2009, 74 FR 52300) occur in this hydrologic unit. The HU includes portions of the Sacramento River and the Sacramento Deep Water Ship Channel as well as smaller waterways such as Sutter and Steamboat Sloughs. The HU encompasses an area of approximately 446 mi^2 and occurs in portions of Solano, Yolo, and Sacramento Counties. This HU contains a single hydrologic subarea (HSA) which is occupied by the listed species described above, and contains approximately 355 miles of waterways (at 1:100,000 hydrography). NMFS biologists identified approximately180 to 200 miles of occupied riverine habitat in this HSA for spring-run Chinook and steelhead. Occupation of the riverine habitat by winter-run Chinook salmon and green sturgeon is expected to be similar. The critical habitat analytical review team (CHART) concluded that it contained one or more PCEs for both the Central Valley steelhead DPS and Central Valley spring-run Chinook salmon ESU (NMFS 2005b). 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 the Central Valley steelhead DPS 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 nutrients 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 Central Valley steelhead and Central Valley spring-run Chinook salmon juveniles and smolts and for adult freshwater migration. No spawning of Central Valley steelhead or Central 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.

In regards to the designated critical habitat for the Southern DPS of 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, subadults, 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 has already been described in the *Status of the Species and Critical Habitat* section of this biological opinion. The substantial degradation over time of several of the essential critical elements has diminished the function and condition of the freshwater rearing and migration habitats in the action area. It has only rudimentary functions 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 "reclaimed" and subsequently 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*).

In the central, eastern, and southern Delta numerous artificial channels also have been created to bring water to irrigated lands that historically did not have access to the river channels (*i.e.*, Victoria Canal, Grant Line Canal, Fabian and Bell Canal, Woodward Cut, *etc*.). These artificial channels have disturbed the natural flow of water through the southern, eastern, and central Delta. As a byproduct of this intensive engineering of the Delta's hydrology, numerous irrigation diversions have been placed along the banks of the flood control levees to divert water from the area's waterways to the agricultural lands of the Delta's numerous "reclaimed" islands. Most of these diversions are not screened adequately to protect migrating fish from entrainment. Sections of the South Delta have been routinely dredged by DWR to provide adequate intake depth to these agricultural water diversions. Shallow water conditions created by the actions of the SWP enhance the probability of pump cavitation or loss of head on siphons. NMFS has issued a biological opinion that assesses the impacts DWR's South Delta Diversions Dredging and Modification Program (October 27, 2003; SWR-02-SA-6433). That biological opinion included NMFS' terms and conditions to avoid and minimize incidental take of listed species in the South Delta. That biological opinion expired at the end of 2008.

Water flow through the South Delta is highly manipulated to serve human purposes. Rainfall and snowmelt is captured by reservoirs in the upper watersheds, from which its release is dictated primarily by downstream human needs. The SWP and CVP pumps draw water towards the southwest corner of the Delta which creates a net upstream flow of water towards their intake points through the channels located to the north of the projects. Operations of the SWP and CVP were the focus of a biological opinion issued on June 4, 2009 (151422SWR2007SA00142). In addition, water diversions by water districts servicing cities and counties through screened intakes also impact migrating fish. Such effects have been assessed in biological opinions for the Patterson Irrigation District Fish Screen Project (151422SWR2006SA00684), the Contra Costa Water District Alternative Intake Project (151422SWR2005SA20268), the Freeport Regional Water Project (151422SWR2001SA5822), and the City of Stockton Delta Water Supply Project (151422SWR2005SA9037). Fish, and the forage base they depend upon for food, represented by free floating phytoplankton and zooplankton, as well as larval, juvenile, and adult forms, are drawn along with the current towards these diversion points. In addition to the altered flow patterns in the central and southern Delta, numerous discharges of treated wastewater from sanitation wastewater treatment plants (*e.g.*, Cities of Sacramento, Walnut Grove, Tracy, Stockton, Manteca, Lathrop, Modesto, Turlock, Riverbank, Oakdale, Ripon, Mountain House, Oakley, Antioch, and the Town of Discovery Bay) and the untreated discharge of numerous agricultural wasteways are emptied into the waters of the Delta and rivers and tributaries feeding into the delta. This leads to cumulative additions to the system of thermal effluent loads as well

as cumulative loads of potential contaminants (*i.e.*, ammonia and other nitrogenous compounds, selenium, boron, endocrine disruptors, pesticides, biostimulatory compounds, pharmaceuticals, *etc*.). These chemical and physical constituents create conditions that can adversely impact aquatic life exposed to excessive levels, either through direct mortality or reduced physiological status. NMFS has assessed several wastewater diffuser projects in the Delta, including the Mountain House Wastewater Treatment Plant Diffuser Project (151422SWR2002SA8308) and the Ironhouse Sanitation District Wastewater Treatment Plant Diffuser Project (151422SWR2008SA00041).

Within the Delta, maintenance dredging of the main shipping channels and the shipping berths associated with the Ports of Stockton and Sacramento to benefit maritime commerce occurs on a continuing basis. NMFS assessed these impacts in two separate biological opinions, the Stockton Deep Water Ship Channel Dredging Project (151422SWR2004SA9121) and the Sacramento Deep Water Shipping Channel Dredging Project (151422SWR2006SA00041). In addition, the redevelopment of the West Complex in the Port of Stockton, which included deepening of the channel adjacent to the shipping berths in the West Complex, was the subject of a biological opinion by NMFS (151422SWR2003SA9009).

The San Joaquin River and the three major tributaries discharging into it have also been substantially modified. All of the major tributaries have been dammed to create water storage reservoirs in upriver locations for human use and flood control. This has substantially altered both the volume of water being discharged into the lower river and the timing of those discharges. This has had negative impacts on the native fishes occupying those tributaries, particularly anadromous salmonids. As stated above, numerous discharges of urban and agricultural wastewater are made to the tributaries and main stem San Joaquin River. This negatively affects the quality of the water flowing in these channels with subsequent reduction in the health of the aquatic environment.

In addition to the above mentioned projects, other types of projects addressed by NMFS through biological opinions have included the development of a large marina for the City of Stockton (151422SWR2008SA00231), the proposed construction of a housing development project with associated small community marina (Rock Island Marina, 151422SWR2003SA8893) near Bethel Island, and the construction of bridges over the San Joaquin River (Navy Drive Bridge Project, 151422SWR2007SA000453). DWR has constructed physical rock barriers in the channels of the South delta for the past several years to enhance water surface elevations for agricultural water diversions. In addition, a fish diversion barrier has been constructed at the Head of Old River during April and May for 31 days to protect outmigrating San Joaquin River basin Chinook salmon from the effects of the SWP and CVP export facilities. NMFS has written a series of biological opinions for this South Delta Temporary Barriers Program over the years (151422SWR2007SA00142). Furthermore, the effects of the construction and operation of experimental non-physical barriers on listed fish species have been assessed through biological opinions (Georgiana Slough Non-Physical Barrier Project, 151422SWR2011SA00052 and subsequent opinions for the South Delta Temporary Barriers Program in 2009, 2010, and 2011).

Even though the habitat 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, Central Valley steelhead, and southern DPS green sturgeon. All juvenile winter-run and spring-run Chinook salmon, southern DPS green sturgeon, as well as those Central Valley steelhead smolts originating in the Sacramento River basin must pass into and through the Sacramento Delta HU to reach the lower Delta and the ocean. A large fraction of these fish will likely pass downstream through the action area within the Sacramento River channel or other channels within the Delta. Likewise, adults 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. A large proportion of the population is expected to move through the action area within the main channel of the Sacramento River, or gain access to the river through Georgiana Slough from the south. Therefore, it is of critical importance to the long-term viability of the Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon ESUs, the southern DPS of green sturgeon, and the Sacramento River basin portion of the Central Valley steelhead DPS to maintain a functional migratory corridor and freshwater rearing habitat through the action area and the Sacramento Delta subbasin HU in general. Similarly, those Central Valley steelhead originating in the San Joaquin River basin must pass through the San Joaquin Delta HU to access their spawning grounds in the basin's tributaries, located in the San Joaquin Valley Floor HU. Conserving passage and suitable rearing habitat in the waterways of the San Joaquin Delta HU are necessary for maintaining the viability of the Central Valley steelhead diversity group inhabiting those San Joaquin River Basin watersheds.

B. Factors Affecting the Species and Habitat in the Action Area

The action area encompasses a small portion of the area utilized by the Sacramento River winter-run and Central Valley spring-run Chinook salmon ESUs, and the Central Valley steelhead DPS as well as the Southern DPS of North American green sturgeon. Many of the factors affecting these species throughout their range are discussed in the *Status of the Species and Critical Habitat* section of this biological opinion, and are considered the same in the action area. This section will focus on the specific factors in the action area that are most relevant to the proposed project.

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 extended the reservoir releases over a protracted period. These actions reduce or eliminate the scouring flows necessary to mobilize gravel and clean sediment from the spawning reaches of the river channel.

High water temperatures also limit habitat availability for listed salmonids in the lower Sacramento River. High summer water temperatures in the lower Sacramento River can exceed 72°F (22.2^{o}C), and create a thermal barrier to the migration of adult and juvenile salmonids

(Kjelson *et al*. 1982). In addition, water diversions at the dams (*i.e.* Friant, Goodwin, La Grange, Folsom, Nimbus, and other dams) for agricultural and municipal purposes have reduced in-river flows below the dams. These reduced flows frequently result in increased temperatures during the critical summer months which potentially limit the survival of juvenile salmonids in these tailwater sections (Reynolds *et al*. 1993). The elevated water temperatures compel many salmon juveniles to migrate out of the valley floor systems before summer heat makes the tailwaters unsuitable for salmonids. Those fish that remain either succumb to the elevated water temperatures or are crowded into river reaches with suitable environmental conditions.

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 LWD.

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 near shore 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. The effects of these impacts are discussed in detail in the *Status of the Species and Critical Habitat* section. 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). Principle sources of organic contamination in the Sacramento River are rice field discharges from Butte Slough, USBR District 108, Colusa Basin Drain, Sacramento Slough, and Jack Slough (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, such as migration barriers, water conveyance factors, water quality, NIS, *etc.*, are discussed in the *Status of Species and Critical Habitat* section.

As previously stated in the *Status of the Species and Critical Habitat* section, the transformation of the Sacramento River from a meandering waterway lined with a dense riparian corridor, to a highly leveed system under varying degrees of control over riverine erosional processes resulted in homogenization of the river, including effects to the rivers sinuosity (USFWS 2000). These impacts likely included the removal of valuable pools and holding habitat for North American green sturgeon. In addition, the change in the ecosystem as a result of the removal of riparian vegetation and LWD likely impacted potential prey items and species interaction that green sturgeon would experience while holding. The effects of channelization on upstream migration of green sturgeon are unknown.

V. EFFECTS OF THE ACTION

A. Approach to the Assessment

Pursuant to section 7(a)(2) of the ESA (16 U.S.C. §1536), Federal agencies are directed to ensure that their activities are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat. Regulations that implement section 7(b)(2) of the ESA require biological opinions to evaluate the direct and indirect effects of Federal actions and actions that are interrelated with or interdependent to the Federal action to determine if it would be reasonable to expect them to appreciably reduce listed species' likelihood of surviving and recovering in the wild by reducing their reproduction, numbers, or distribution (16 U.S.C. §1536; 50 CFR 402.02). Section 7 of the ESA and its implementing regulations also require biological opinions to determine if Federal actions would destroy or adversely modify the conservation value of critical habitat (16 U.S.C. §1536). This biological opinion does not rely on the regulatory definition of "destruction or adverse modification" of critical habitat at 50 CFR 402.02. Instead, we have relied upon the statutory provisions of the ESA to complete the following analysis with respect to critical habitat. NMFS will evaluate destruction or adverse modification of critical habitat by determining if the action reduces the value of critical habitat for the conservation of the species. This biological opinion assesses the effects of the proposed action on endangered Sacramento River winter-run Chinook salmon, threatened Central Valley spring-run Chinook salmon, threatened Central Valley steelhead, and the threatened Southern DPS of North American green sturgeon and the designated critical habitat for each of these listed anadromous fish species, respectively.

In the *Description of the Proposed Action* section of this biological opinion, NMFS provided an overview of the action. In the *Status of the Species and Critical Habitat* and *Environmental Baseline* sections of this biological opinion, NMFS provided an overview of the threatened and endangered species and critical habitats that are likely to be adversely affected by the activity under consultation.

NMFS generally approaches the "jeopardy" and critical habitat modification analyses in a series of steps. First, NMFS evaluates the available evidence to identify direct and indirect physical,

chemical, and biotic effects of the proposed action on individual members of listed species or aspects of the species' environment (these effects include direct, physical harm or injury to individual members of a species; modifications to something in the species' environment - such as reducing a species' prey base, enhancing populations of predators, altering its spawning substrate, altering its ambient temperature regimes; or adding something novel to a species' environment - such as introducing exotic competitors or a sound). Once NMFS has identified the effects of the action, the available evidence is evaluated to identify a species' probable response (including behavioral responses) to those effects to determine if those effects could reasonably be expected to reduce a species' reproduction, numbers, or distribution (for example, by changing birth, death, immigration, or emigration rates; increasing the age at which individuals reach sexual maturity; or decreasing the age at which individuals stop reproducing). The available evidence is then used to determine if these reductions, if there are any, could reasonably be expected to appreciably reduce a species' likelihood of surviving and recovering in the wild.

To conduct this assessment, NMFS examined information from a variety of sources. Detailed background information on the status of these species and critical habitat has been published in a number of documents including peer reviewed scientific journals, primary reference materials, government and non-government reports, the BA for this project, and supplemental material provided by the applicant in response to questions asked by NMFS.

The proposed Temperature Study generally will affect more adult fish than juvenile fish. The larger effects to the adult population, in terms of numbers of adults subjected to project activities (in particular angling impacts) compared to juveniles, will result in a higher impact to the population because individual adult fish have a higher contribution to the cohort replacement rate than individual juvenile fish. In particular, adult fish that return to freshwater have survived the risks during their freshwater and ocean residence (*e.g.*, predation, competition, water diversions, *etc.*) that outmigrating juvenile fish have yet to face and adult abundance is considerably lower. For example, Emmett *et al*. (1997) estimated a general juvenile Chinook salmon survival in freshwater to be between 5 and 25 percent and ocean survival to be between 1 and 10 percent. Thus, overall survival of juveniles to adult would range from 0.05 percent to 2.5 percent (5 percent * 1 percent = 0.05 percent, 25 percent * 10 percent = 2.5 percent) and the abundance of juveniles in freshwater needed to maintain a cohort replacement of 1.0 with a population level of 10,000 spawners would range between 400,000 and 20 million (10,000/.025 = 400,000, 10,000/0.0005 = 20 million) juveniles. The impacts of the proposed Temperature Study on adult abundance could affect the cohort replacement rate by decreasing the contributing number of adult winter-run and spring-run Chinook salmon or adult steelhead that eventually reach the spawning grounds. Mortality related to angling efforts (*i.e.*, direct and indirect hooking mortality) would reduce the number of spawners. Similarly, because of the high fecundity of adult North American green sturgeon and their relatively long life span, the impacts of the project on the green sturgeon population would be more severe if adult fish were taken during their upstream spawning migration and their capture by angling resulted in their loss.

B. Assessment

1. Study Element 4: Hydroacoustic Monitoring of Fish Movement near the Diffuser Outfall Structure

Adult and juvenile Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and North American green sturgeon use the action area primarily as a migration corridor (see the *Status of the Listed Species and Critical Habitat* and *Environmental Baseline* sections). In-channel placement of the HTI Model 243 Split-beam system will occur over a one to two week period from approximately mid-January through the end of January, 2012. The hydroacoustic system will then be completely removed following the completion of Element 4 at the end of April, 2012 (see tables 1 and 2). The hydroacoustic system will be lowered into position from a utility boat equipped with a winch and boom. There will be no pile driving or other mechanical installation associated with positioning the two devices on the channel bottom other than the operation of the winch and boom as described in the project description (RBI 2011a). Therefore, noise associated with the installation of the hydroacoustic device is expected to be minimal and be comprised of transient noises that may momentarily spike and then fall back to background levels. The transient spikes are not expected to reach levels that would be sufficient to cause acute or delayed injury to fish in the vicinity of the device placement. Sharp transients are most likely to occur where the metal of the anchoring mount strikes a hard object, such as a rocky outcropping or the rock rip rap of the levee face. Since the substrate along the toe of the levee and outwards from the bank is typically soft sediment, there is little expectation that the anchoring mount will encounter a hard surface from which sharp transients will be produced.

The hydroacoustic array will be mounted on an anchor mount (see figure 22) which will secure the array in a fixed position on the river channel bottom. Power and signal feed cables will be routed from the anchor mounts to the shore facilities. Each anchor mount will have a dual axis rotator to which the transducer and receiver unit is attached. This configuration will allow the transducer to sweep through a 90 degree arc each hour as the rotator turns back and forth in the horizontal plane of the rotator. The transducer will emit acoustic signals at 200 kilo hertz (kHz). This frequency is above the threshold of hearing for both salmonids and green sturgeon, and therefore should not be detectable to these fish species. The footprint of the anchoring mount will be approximately 5 feet in diameter and therefore cover approximately 20 square feet in area. Since the deployment of the unit is temporary, lasting only 3.5 months (mid-January through the end of April, 2012), there is no permanent impact to the designated critical habitat in the Sacramento River channel for winter-run and spring- run Chinook salmon, Central Valley steelhead, and Southern DPS green sturgeon. Temporary impacts are anticipated to include disruption of the channel substrate from the anchor mount's points of contact with the bottom, a small physical obstructions to the river's flow creating hydraulic breaks along the bottom, and potential "crushing" of benthic infauna in the channel substrate by the weight of the unit's anchoring mount. These impacts are considered temporary as the anchoring mount will be completely removed after April 30, 2012, and the impacted channel bottom allowed to recover. Since the impacted footprint is very small compared the area of the surrounding undisturbed channel bottom (20 square feet x 2 mounts = 40 square feet), the integrity of the designated critical habitat in the action area is not diminished, and the impacted area is expected to be recolonized by benthic invertebrates from the immediate surrounding area. The cumulative footprint of both the hydroacoustic array for Study Element 4 and the acoustic hydrophone array

for Study Element 5 is 340 square feet (17 anchor mounts * 20 square feet/ anchor mount = 340 square feet) plus the area covered by cables supplying power to the units and carrying data back to the shoreside electronics.

2. Study Element 5: Acoustic Tagging of Juvenile Chinook salmon

The goal of Study Element 5 is to determine the rate at which tagged juvenile Chinook salmon (hatchery origin) emigrate through the study area (*i.e.*, distance covered per unit time), the rate at which they pass specifically through the diffuser location, and the rate of predation associated with the diffuser site in comparison to other reference sites. Like Study Element 4, Study Element 5 requires the placement of 15 hydrophones in the river channel surrounding the location of the diffuser array. The three surface oriented hydrophones, coupled with the 12 hydrophones positioned on the bottom will allow tracking of tagged fish through the reach with 3D spatial orientation. Each of the hydrophones will be attached to anchoring mounts, and the mounts lowered to the channel bottom with the boat mounted winch and boom. The surface oriented hydrophones will be attached to aircraft cables suspended from the anchoring mount by a float and positioned in the upper portion of the water column, but below the water surface. As described above for Element 4, no additional mechanical equipment is proposed to situate the anchor mounts. Thus any noise associated with the installation should be related to transients and therefore should not produce acoustic noise that would result in acute or long term cumulative injuries to exposed fish during the installation process. Installation of the hydrophones for Study Element 5 will take place prior to April 1, 2012, and the study conducted over a 6 to 7 week period beginning no earlier than April 1, 2012, and ending prior to May 31, 2012. The hydrophones are passive receivers of the acoustic signals present in the water column, which includes the signals emitted by the HTI acoustic tags. The frequency of the tags used in this element of the study (307 kHz) is above the upper threshold for hearing in the fish species of interest and therefore is not expected to affect the fish exposed to the emitted signals from the HTI tags, either physically or behaviorally.

The placement of the anchoring mounts (15 anchor mounts for this study element) will temporarily impact the bottom substrate of the Sacramento River channel. As described in the previous sections describing designated critical habitat for winter-run and spring-run Chinook salmon, California Central Valley steelhead, and Southern DPS green sturgeon, the channel bottom substrate is considered essential to the proper functioning of the critical habitat. The placement of the 15 anchor mounts is not likely to substantially alter or degrade the functioning of the impacted substrate. The anchor mounts will rest superficially on the bottom and may crush organisms immediately beneath them. In addition, the anchor mounts, aircraft cables, and surface buoys may serve to attract fish to hold in their vicinity due to hydraulic breaks created by these structures, although relatively small compared to the area within the action area. As previously described, the anchor mounts are approximately 5 feet in diameter, and will impact an area of approximately 20 square feet of bottom substrate per anchor mount. The total area impacted by the anchor mounts in this element of the Temperature Study is approximately 300 square feet (15 anchor mounts * 20 square feet/ mount = 300 square feet). Since the impacted footprint is very small compared to the area of the surrounding undisturbed channel bottom, the overall impact of the anchor mounts is considered to be inconsequential to the functioning of the critical habitat within the larger study area. Furthermore, the placement of the

hydrophones for this element of the study is temporary, lasting approximately 2.5 to 3 months (mid-March to the end of May) and will encompass the 6 to 7 weeks of the experiment. Following the removal of the anchor mounts, it is expected that the disturbed areas of the channel bottom related to the anchor mounts will be recolonized by invertebrates from surrounding undisturbed areas. It is impossible to absolutely predict the final species composition that will recolonize these disturbed areas. Non-native invasive species may potentially out-compete native species in recolonizing these areas. Likewise, rapid colonizers may preferentially colonize these disturbed areas compared to a more stable climax community species. That being said, the disturbed area is very small compared to the total area available in the action area, and species that have the potential to colonize these disturbed area are assumed to originate within the immediate vicinity of the disturbed area.

3. Study Element 6: Standardized Angling

The standardized angling portion of the Temperature Study (Study Element 6) has the greatest potential to incur take of listed species. Angling has the potential to contact listed species during the proposed period of implementation for this portion of the study. The proposed period for conducting the standardized angling is from March 1 through June 30, 2012. To reiterate, during the 4 month period between March and June, approximately 80 percent of the adult winter-run escapement and 17.5 percent of the adult spring-run escapement moves through the action area (see Table 15). Approximately 60 percent of the steelhead juvenile emigration moves downstream through the action area in March and then drops off to essentially zero from April through the end of summer (see Table 14). Steelhead juveniles are typically 200 to 250 mm in length (8 to 10 inches) and are capable of being caught by fishing techniques proposed for Study Element 6. During the same period, low numbers of adult steelhead are expected to move through the action area both as upstream migrants and as kelts moving back downstream (see Figure 21). During the March through June period multiple life history stages of the Southern DPS of green sturgeon are also expected to be present in the action area. In March and April, adult green sturgeon are expected to be migrating upstream through the action area towards spawning grounds in the upper Sacramento River basin, including potentially the Feather and Yuba river systems. By late May and June, some adults may be moving back downstream, either as post spawners, or as unsuccessful spawners. In addition, juveniles and sub-adults may be present in the waters of the Delta, including the action area, as they are present year round during their rearing life history stage.

Study Element 6 proposes to use various fishing techniques to catch predatory fish within the action area. Techniques will use both spin fishing and bait casting rods and reels as determined by the professional anglers for a given situation on the river. A variety of lures and baits will be employed to target the three groups of predatory fish; these include hard and soft baits, plugs, live bait, and cut or preserved bait. Any of these methods can potentially catch listed fish species as bycatch to the three target groups (striped bass/ pikeminnow; black basses; and catfishes).

Being captured by hook and line fishing exposes fish to both direct and indirect mortality. There have been relatively few studies to determine the sport fishing hooking mortality rate of Pacific salmon caught and released in freshwater (Cowen et al. 2007; Lindsay et al. 2004; Bendock and Alexandersdottir 1993). Studies of hooking mortality in hook-and-line salmon fisheries in

marine waters are more common (Gjernes *et al.*, 1993; Chinook Technical Committee [CTC] 1997; Diewert *et al.*, 2002).

In marine waters, estimates of hooking mortality in commercial troll fisheries ranges from approximately 18.5 percent (15.4 – 21.6 percent) for legal Chinook salmon and 21.7 percent (18.6 - 24.8 percent) for sub-legal Chinook salmon taken off Alaska, with the location of the hook wound being the most significant variable associated with mortality (CTC 1997). The CTC (1997) made the following recommendations for total hook and release mortality rates for commercial troll fisheries which include immediate mortality and delayed mortality:

Barbed, legal:	21.1%
Barbed, sublegal:	25.5%
Barbless, legal:	18.5%
Barbless, sublegal:	22.0%

In addition the CTC (1997) also recommends that an additional mortality increment be added to the total mortality rate to account for drop-off mortality. Drop-off mortality is for fish that are hooked, but are not landed for one reason or another (including predation mortality by predators). These rates are:

Average barbed hooks:	1.7%
Average barbless hooks	1.6%

The CTC report also presented data for recreational fisheries for Chinook salmon in both marine and freshwater environments. The overall mortality of sport caught Chinook salmon on the Kenai River in Alaska (Bendock and Alexandersdottir 1993), a freshwater environment, had an overall mortality of 7.6 percent and ranged from 4.1 percent to 10.6 percent. In this particular study, mortality was greatest for small males compared with large males and females. Wound locations and heavy bleeding were factors principally associated with mortality. Low survival was associated with fish hooked in critical areas such as the esophagus, gills, or eyes. Over the three years of their study, 24 fish were hooked in critical areas, of which 11 died (46 percent). The vast majority of Chinook salmon were hooked in the jaw or were snagged (95 percent) of which only 4.7 percent died after the 5 day observation period. Heavy bleeding at time of release was also found to be a factor in hooking mortality. Of those fish bleeding heavily (70 fish), 15 eventually died (21.4 percent), whereas 16 of 376 fish released that were not bleeding (4.3 percent) died. Bleeding occurred in approximately 16 percent of fish hooked. There was no difference between artificial lures and bait and the frequency of hooking mortality in this study. In addition most mortality occurred within 72 hours of hooking, suggesting mortality related to hooking injuries occurred quickly.

Information from several marine recreational fisheries studies indicate that hooking mortalities for legal size fish are likely to be similar to the 7.6 percent seen in the Bendock and Alexandersdottir (1993) study. The CTC reported that trolling with single point barbed hooks had an average mortality of 9.9 percent for legal size fish (Gjernes [1990] as reported in CTC 1997), but that sublegal (first year in marine environment) Chinook salmon and coho salmon (*O. kisutch*) caught by recreational trolling methods (Gjernes *et al.* 1993) had a higher hooking

mortality rate, approximately 30 percent for Chinook salmon and 14 percent for coho salmon. As in other studies, hook injury location was a significant factor in determining overall hooking mortality. This study also indicated that hook type and barb type influenced the location of the injury, and therefore affected the rate of mortality. Larger hooks could penetrate deeper into the tissue and cause more damage than smaller hooks or hooks with smaller gapes. High mortality rates for legal size Chinook salmon were seen in studies conducted in California using the "mooching" technique versus trolling (CTC [1997] referring to two studies conducted by Grover in California). In the first study, total mortality rates were calculated to be 4 to 6 times higher for both sub-legal and legal sized Chinook salmon caught on mooching gear than with trolling gear. Mortality rates ranged from 46 - 63 percent for sub-legals and 61 - 75 percent for legal sized Chinook salmon caught by mooching. In comparison, typical trolling methods had mortality rates of 13-14 percent for sublegals and 10 - 13 percent for legal sized fish. The higher rates of mortality for mooching were based on the higher frequency of Chinook salmon hooked in critically sensitive areas utilizing the mooching techniques. More fish were hooked in the esophagus/stomach and gills than in the mouth compared to trolling techniques. Over 67 percent of fish caught mooching were hooked in the gut or gill areas. Of these, 51 percent of the gut hooked and 46 percent of the gill hooked fish died within the holding period (1.5 days). Necropsy of the surviving gut-hooked fish suggested that the wounds would ultimately be fatal over a longer holding period (estimated 98 percent mortality). In contrast, fish hooked in the mouth had a mortality rate of only 7 percent. In the second study, Grover estimated overall mortality rates for mooching techniques to be 37 percent for all wound locations (CTC 1997).

A more recent study in freshwater (Lindsay *et al*. 2004) found that spring-run Chinook salmon caught on the lower Willamette River, Oregon, incurred differing mortality rates based on the location of their hooking injuries. Hooking mortality in the lower Willamette River fishery was estimated from individual hooking mortality rates for each of five anatomical locations for hook injuries: jaw, 2.3 percent; tongue, 17.8 percent; eye, 0.0 percent; gills, 81.6 percent; and esophagus – stomach, 67.3 percent. The frequency of hooking a fish in these anatomical locations in the sport fishery on the Willamette River over the course of the study was: jaw 81.5 percent; tongue 5.1 percent; eye 0.4 percent; gills, 5.1 percent; and esophagus – stomach, 7.8 percent. The overall estimate of hooking mortality for the four years of the study (1998 – 2001) was 12.2 percent (95 percent confidence interval [CI] = 1.8 - 22.6 percent). The study also found that anglers who used bait (shrimp or prawns) had a higher proportion of Chinook salmon that were caught in the gills and esophagus-stomach locations than in the jaw, compared to anglers who used lures, spinners, or cut bait such as Pacific herring (*Clupea pallasi*). Lindsay *et al.* (2004) compared their total mortality rate (12.2 percent) to the findings of Bendock and Alexandersdotti (1993; 7.6 percent) and concluded that their higher rate was due to the higher frequency of fish hooked in the esophagus – stomach (7.8 percent), a higher mortality location, than on the Kenai River (0 percent). In addition water temperatures on the Kenai River (10.7^{o}C) were cooler than on the Willamette River (12.8^{o}C) during the studies. Hooking mortality increases with higher water temperatures.

A study by Cowen *et al.* (2007) focused on bait fishing for Chinook salmon in the Nicola River, British Columbia from 1996 to 2002. Cured salmon roe was typically used as bait during this study and anglers recorded the relative amount of bleeding from the hooked fish, the hook penetration location, and the status of the fish as it was released after being tagged. Cowen *et al.*

(2007) had a very low immediate hooking mortality of 0.9 percent for the duration of their study. Fish were hooked in non-critical areas 81 percent of the time (critical areas are defined as the roof of the mouth, esophagus, gills, tongue, or eye; non-critical areas are all other locations). Hooking in critical locations produced more incidences of heavy and moderate bleeding than non-critical locations. In most years, hooking in critical locations was also correlated with significantly more deaths than non-critical locations ($p < 0.01$) and heavy bleeding was also associated with a higher rate of mortality ($p < 0.01$).

Additional studies examined the effects of hook and line fishing mortalities on salmonids in freshwater. Dotson (1982) examined hooking mortality in cutthroat trout (*O. clarki*) that were part of a study on catch and release fishing using single-barbless, single-barbed, and barbed hooks on artificial lures and flies. In this study most fish were hooked in the upper and lower jaw and total mortalities were low (overall average of 6.7 percent). However, the rate of mortality was highest in fish sampled under higher water temperatures (16.1^{o}C, mortality rate of 8.6 percent) compared to a mortality rate ranging from 0 percent to 2.9 percent when water temperatures were cooler (8.9^{o}C). Schill (1996) examined hooking mortality in rainbow trout (*O. mykiss*) using number 8 worm baited hooks in both hatchery and natural stream settings. This study found that the incidence of deeply hooked fish (esophagus-stomach or gills) increased when the line was presented in a "slack" drift compared to a tight line presentation. In addition, post release mortality was markedly reduced (36 percent in hatchery fish, 58 percent wild stream trout) by cutting the line in deeply hooked fish and leaving the hook in place compared to removing the hook from the fish. Hooks in surviving fish were eventually shed. Overall mortality in deeply hooked fish in the hatchery setting was 74.3 percent when the hook was removed, 47.4 percent when the hook was left in place and the line cut. Survival of lightly hooked hatchery fish (*i.e.*, jaw) was 1.9 percent. Schill (1996) estimated total mortality for wild rainbow trout to be 16 percent using worm baited hooks and 46 percent for hatchery fish. Dubois and Kuklinski (2004) had similar results with single worm baited hooks fished in a tight-line method with brook trout (*Salvelinus fontanalis*) and brown trout (*Salmo trutta*). Overall mortality was low for the tight-line fishing technique for both trout species (2 to 7 percent over 72 hours). Anatomical hooking location was an important factor in determining mortality; 10 of 11 fish that died were hooked in the gills or esophagus-stomach locations. Mortality was 16 percent for deeply hooked brook trout and 8 percent in brown trout.

Preliminary results for targeted fishing were obtained from four angling events in the fall of 2011. Angling events occurred on the following 3-day periods (RBI 2011e,f):

Angling event 1 – October 18-20
Angling event 2 – October 25-27
Angling event 3 – November 16-18
Angling event 4 – November 28-30

Each of the 12 angling days resulted in 9 hours of fishing per day, 45 minutes at each site, 2 anglers fishing, for a total of 216 hours of fishing overall, and 36 hours per target species group. A total of 140 fish were caught during the 12 days of angling effort (see Table 16). Of the 140 fish captured, 138 were from one of the three target groups. The remaining 2 fish were both white sturgeon which do not belong to any of the three target groups. The sturgeon were both

captured at study site 2, the diffuser plume, on November 29 and 30, 2011. No fish listed under the ESA were captured during the 216 hours of fishing. Striped bass comprised 88 percent of the total catch, followed by Sacramento pikeminnow (4.3 percent), spotted bass (2.9 percent), white catfish (2.1 percent), small mouth bass (1.4 percent) and white sturgeon (1.4 percent).

The number of fish captured at each site ranged from 19 (Reference Site 2) to 43 (Study Site 2); however, catches were similar at the three locations in the Freeport area: Study Site 1 (41), Study Site 2 (43), and Reference Site 1 (37) (see Table 17). The majority (87.1%) of fish at all sites were captured using cut bait (i.e., anchovy or mackerel) fished along the river bottom, followed by earthworms fished along the river bottom (7.1%), artificial lures including plugs, spinner baits, and jigs fished in the water column with spin-casting gear (4.3%), live minnows fished along the river bottom (0.7%), and shrimp fished along the river bottom (0.7%) (see Table 18).

In 2011, a fishing survey in support of the 2011 Georgiana Slough non-physical barrier study was conducted. The primary purpose of the angling survey was to collect predatory fishes (i.e., striped bass, Sacramento pikeminnow, black basses, and catfishes) to implant with hydroacoustic tags and monitor their movement within the study area. The goal of the angling was to maximize the catch of predator-sized fishes. The exact effort (i.e., man-hours of fishing) is not known. However, the anglers fished two full days per week from March through May, 2011. The crew consisted of two anglers on a boat and up to 3 anglers fishing from a dock (i.e., a minimum of 2 and maximum of 5 anglers fishing on a given day). A total of two (2) spring-run Chinook salmon were captured during this period, both of which were hooked in the mouth and, therefore, apparently took the cut bait intentionally (i.e., not accidentally snagged). No winter-run Chinook salmon, steelhead, or green sturgeon were captured during this angling study. Assuming an average of 3.5 anglers (two in the boat plus and average of 1.5 on the dock), the total number of hours fished by this crew would be 819 (13 weeks * 2 days/week) * 9 hours/day * 3.5 anglers). Based on this level of effort, the catch-per-unit-effort (CPUE) for spring-run Chinook salmon would be 0.00244 (2 fish captured / 819 hours of effort = 0.244 fish per hour effort). Applying that CPUE to the SRCSD angling study for the March-June angling events would yield an estimated capture of 1.05 spring-run Chinook salmon (0.0024 * 4 months * 6 angling days/month * 9 hours/day * 2 anglers).

4.) Summary of Project Effect

Study Element 4 is anticipated to have little direct or indirect effects upon listed fish species. Some fish may be exposed to transient noises during the installation of the hydroacoustic instruments (split-beam sonars and cables) but exposure is expected to be negligible. NMFS anticipates a low probability of the anchor mounts contacting hard objects on the bottom or sides of the river channel that would create the conditions necessary for transient noise emissions to occur. Furthermore, any transients that could potentially occur would be of insufficient duration and magnitude to cause acute or chronic injuries to exposed fish.

Study Element 4 will temporarily impact critical habitat. Installation of the anchor mounts may crush benthic invertebrates dwelling upon or beneath the channel substrate directly underneath the anchor mount structure. As portrayed in the project description, the anchor mount covers approximately 20 square feet, but most of this space is not directly in contact with the bottom

(see Figure 22. Given both anchor mounts used for this portion of the study, only 40 square feet of channel bottom plus the area beneath the power and data cables, is affected. This is trivial compared to the total area within the project area surrounding the diffuser. In addition, the duration of the installation of the hydroacoustic equipment is short (3 months) and any damage to the substrate is expected to be restored by natural processes within the river channel. The surrounding channel habitat also is expected to serve as a recruitment source to replace any loss of the benthic invertebrate community damaged or killed by the anchor mount structures.

The impacts of Study element 5 are expected to be similar to Study Element 4. NMFS anticipates that the placement of the 15 acoustic hydrophone receivers and their anchor mounts will have negligible effects on listed fish and the designated critical habitat elements within the action area. The placement of the anchor mounts may cause noise transients. However, as discussed already, these transients are unlikely to be of sufficient duration and magnitude to cause acute or chronic injury to exposed fish. Likewise, the total area of benthic substrate impacted by the 15 anchor mounts is 300 square feet (0.007 acres), which is a trivial amount compared to the amount of bottom substrate available in the immediate vicinity of the hydrophone array. Impacts will be of short duration, lasting only 2 to 2.5 months during the deployment of the hydrophone array. Any disturbance to the benthic substrate is expected to be short lived in the dynamic environment present in the Sacramento River channel. Likewise, any loss of benthic invertebrates due to the placement of the anchor mounts will be replaced by movements of invertebrate fauna from the immediate surroundings into the impacted area following removal of the mounts.

Of the 8 study elements proposed for the Temperature Study, Study Element 6 will have the most significant effects on listed fish species due to the potential for direct exposure of the listed fish to fishing efforts. The directed standardized angling efforts in Study Element 6 occur during periods of active fish migration for adult Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, California Central Valley steelhead, and Southern DPS green sturgeon through the action area of the proposed Temperature Study. The methods proposed for the directed angling survey are methods that are known to have the capacity to catch Chinook salmon, steelhead, and sturgeon. Any time a fish is hooked using one of the techniques proposed for the standardized angling effort, there is a risk of the fish being captured suffering injury or mortality. The risk of injury or mortality is predominantly associated with the location of the hooking wound. Wound location is generally a function of fishing techniques (tight line versus slack line, hard lure versus bait, hook size and type) and the method in which the fish is released (played to exhaustion, cutting line on deeply hooked fish, etc.). There is general agreement in the literature that fish hooked in more critical areas such as the gills or stomach – esophagus region suffer higher rates of mortality than those fish that are hooked in the jaw or mouth region. Fish played quickly, and released without removing from the water or excessive handling fair better than fish handled for greater periods of time, which increases the level of stress hormones and physiological changes in captured fish (Wydoski *et al.* 1976). Cutting the line and leaving the hook in place increases the survival rate for fish that have ingested the hook deeply and have it lodged in vital areas. For this consultation, NMFS will use a total hooking mortality value that represents the upper range reported in the literature for freshwater angling (15 percent total mortality). This represents a “worst case scenario for hooking related mortality).

VI. CUMULATIVE EFFECTS

For purposes of the ESA, cumulative effects are defined as the effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR §402.02). Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultations pursuant to section 7 of the ESA.

A. Agricultural Practices

Agricultural practices in the Delta may adversely affect riparian and wetland habitats through upland modifications of the watershed that lead to increased siltation or reductions in water flow in stream channels flowing into the Delta. Unscreened agricultural diversions throughout the Delta entrain fish including juvenile salmonids. Grazing activities from dairy and cattle operations can degrade or reduce suitable critical habitat for listed salmonids by increasing erosion and sedimentation as well as introducing nitrites, nitrates, ammonia, and other nutrients into the watershed, which then flow into the receiving waters of the Delta. Stormwater and irrigation discharges related to both agricultural and urban activities contain numerous pesticides and herbicides that may adversely affect salmonid reproductive success and survival rates (Dubrovsky *et al.* 1998, 2000; Daughton 2003).

B. Increased Urbanization

The Delta, East Bay, and Sacramento regions, which include portions of Contra Costa, Alameda, Sacramento, San Joaquin, Solano, Stanislaus, and Yolo counties, are expected to increase in population by nearly 3 million people by the year 2020. Increases in urbanization and housing developments can impact habitat by altering watershed characteristics, and changing both water use and stormwater runoff patterns. For example, the General Plans for the cities of Stockton, Brentwood, Lathrop, Tracy and Manteca and their surrounding communities anticipate rapid growth for several decades to come. City of Manteca (2007) anticipated 21 percent annual growth through 2010 reaching a population of approximately 70,000 people. City of Lathrop (2007) expects to double its population by 2012, from 14,600 to approximately 30,000 residents. 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 which are situated away from waterbodies, will not require Federal permits, and thus will not undergo review through the ESA section 7 consultation process with NMFS.

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. This in turn would reduce habitat quality for the invertebrate forage base required for the survival of juvenile salmonids and green sturgeon moving through the system. 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, particularly those that can be trailered from one water body to another, greatly increases the risk of spreading non-native invasive species into the Delta.

C. Global Climate Change

The world is about 1.3°F warmer today than a century ago and the latest computer models predict that, without drastic cutbacks in emissions of carbon dioxide and other gases released by the burning of fossil fuels, the average global surface temperature may rise by two or more degrees in the 21st century (Intergovernmental Panel on Climate Change [IPCC] 2001). Much of that increase likely will occur in the oceans, and evidence suggests that the most dramatic changes in ocean temperature are now occurring in the Pacific (Noakes 1998). Using objectively analyzed data Huang and Liu (2000) estimated a warming of about 0.9 °F per century in the Northern Pacific Ocean.

Sea levels are expected to rise by 0.5 to 1.0 meters in the northeastern Pacific coasts in the next century, mainly due to warmer ocean temperatures, which lead to thermal expansion much the same way that hot air expands. This will cause increased sedimentation, erosion, coastal flooding, and permanent inundation of low-lying natural ecosystems (*e.g.*, salt marsh, riverine, mud flats) affecting salmonid PCEs. Increased winter precipitation, decreased snow pack, permafrost degradation, and glacier retreat due to warmer temperatures will cause landslides in unstable mountainous regions, and destroy fish and wildlife habitat, including salmon-spawning streams. Glacier reduction could affect the flow and temperature of rivers and streams that depend on glacier water, with negative impacts on fish populations and the habitat that supports them.

Summer droughts along the South Coast and in the interior of the northwest Pacific coastlines will mean decreased stream flow in those areas, decreasing salmonid survival and reducing water supplies in the dry summer season when irrigation and domestic water use are greatest. Global warming may also change the chemical composition of the water that fish inhabit: the amount of oxygen in the water may decline, while pollution, acidity, and salinity levels may increase. This will allow for more invasive species to outcompete native fish species and impact predator-prey relationships (Peterson and Kitchell 2001, Stachowicz *et al.* 2002).

In light of the predicted impacts of global warming, the Central Valley has been modeled to have an increase of between 2°C and 7°C by 2100 (Dettinger *et al.* 2004, Hayhoe *et al.* 2004, Van Rheenen *et al.* 2004, Dettinger 2005), with a drier hydrology predominated by precipitation rather than snowfall. This will alter river runoff patterns and transform the tributaries that feed the Central Valley from a spring/summer snowmelt dominated system to a winter rain dominated system. It can be hypothesized that summer temperatures and flow levels will become

unsuitable for salmonid survival. The cold snowmelt that furnishes the late spring and early summer runoff will be replaced by warmer precipitation runoff. This should truncate the period of time that suitable cold-water conditions exist 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 snow pack 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 Central Valley steelhead) that must hold below the dam over the summer and fall periods.

Within the context of the brief period over which the proposed project is scheduled to be constructed and operated, however, the near term effects of global climate change are unlikely to result in any perceptible declines to the overall health or distribution of the listed populations of anadromous fish within the action area that are the subject of this consultation.

VII. INTEGRATION AND SYNTHESIS

This section integrates the current conditions described in the environmental baseline with the effects of the proposed action and the cumulative effects of future actions. The purpose of this synthesis is to develop an understanding of the likely short term and long term response of listed species and critical habitat to the proposed project.

A. Summary of Current Conditions and Environmental Baseline

The *Status of Species and Critical Habitat* and *Environmental Baseline* sections show that past and present impacts to the Sacramento and San Joaquin river basins and the Delta have caused significant salmonid and green sturgeon habitat loss, fragmentation and degradation. This has significantly reduced the quality and quantity of freshwater rearing sites and the migratory corridors within the lower valley floor reaches of the Sacramento and San Joaquin Rivers and the Delta region for these listed species. Additional loss of freshwater spawning sites, rearing sites, and migratory corridors have also occurred upstream of the Delta in the upper main stem and tributaries of the Sacramento and San Joaquin river basins.

Anthropogenic activities in Central Valley watersheds have contributed substantially to declines in Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead and Southern DPS green sturgeon populations. In the Sacramento River basin, the winter-run Chinook salmon ESU has been reduced to one population spawning below Keswick Dam. Access to upper elevation watersheds in the Sacramento River basin have been severely curtailed for spring-run Chinook salmon and Central Valley steelhead by the construction of large dams on the foothill sections of the valley's major tributaries. These rim dams effectively block access of anadromous fish, including salmonids and sturgeon to the entire watershed above the dams since effective fish ways and ladders are non-existent at this time. Construction of large dams on the major tributaries found in the San Joaquin River basin led to the extirpation of the endemic Central Valley spring-run Chinook salmon populations found in the basin's watersheds. The last self-sustaining population of spring-run Chinook salmon in the

San Joaquin River basin was extirpated by the completion of Friant Dam and the Kern and Friant canals in the late 1940s. The populations of steelhead that historically inhabited these various watersheds have also been severely reduced in number, with only a few small populations remaining in the tailwaters below the dams. The operations of dam have reduced the extent of suitable water temperatures for over summering steelhead juveniles to the tailwaters immediately below these dams. In some cases the water temperatures reach incipient lethal temperatures only a few miles downstream of the dams. Alterations in the geometry of the Delta channels, removal of riparian vegetation and shallow water habitat, construction of armored levees for flood protection, changes in river flow created by demands of water diverters (including pre-1914 riparian water right holders, CVP and SWP contractors, and municipal entities), and the influx of contaminants from agricultural and urban dischargers have substantially reduced the functionality of the action area's aquatic habitat. The proposed action, the installation and implementation of the Temperature Study by SRCSD will occur over a 5 ½ month period, mid-January through June, 2012. The effects will be temporary since the hydroacoustic instruments and hydrophones will be completely removed by the end of May, 2012, following the completion of the experimental study. Furthermore, the standardized angling component of the project, Study Element 6, will terminate by the end of June, 2012.

B. Summary of Effects of the Proposed Action

The proposed project, the SRCSD Temperature Study and the associated study elements, which includes placement of hydroacoustic instruments and hydrophones in the river channel, and a 4-month angling survey effort will have adverse effects on Sacramento River Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and Southern DPS green sturgeon. However these effects are expected to minor in scope, affecting a limited number of fish and lasting only a very short time. The Temperature Study is designed to fulfill the provisions of the current NPDES permit for the SRCSD WWTP outfall, which requires the SRCSD to develop and implement a study to evaluate the potential thermal effects of the outfall diffuser on aquatic life in the Sacramento River.

1. Sacramento River Winter-Run Chinook Salmon

The majority of winter-run juveniles (57 percent) enter the action area during the proposed study window (February 1, through June 30, 2012). During the hydroacoustic study (Study Element 4) which runs from February 1 through April 30, 2012, all 57 percent of the emigrating winter-run Chinook salmon juveniles will be exposed. During Study Element 5 (acoustically tagged salmon smolts study), a considerably smaller fraction of the annual winter-run emigration will occur during the study period of April and May, 2012 (approximately 1 percent) since most winter-run smolts have already moved through the action area by April. During Study Element 6 (Standardized Angling) which targets predatory fish during the period between March 1, and June 30, 2012, approximately 38 percent of the annual winter-run juvenile population will move through the action area. Most of these fish will move through in March (37 percent). Few, if any, juvenile winter-run will be exposed after the first half of April, continuing through the end of the proposed study element. The angling component of the Study is not expected to affect juvenile winter-run Chinook salmon as the lures and bait are appropriate for larger fish sizes than the typical lengths of winter-run Chinook salmon smolts during this period of time. Presence of

adult Chinook salmon is interpolated from historical data. Adult winter-run Chinook salmon are expected to enter the action area starting in January (≈ 4 percent), with the majority of adults passing through the action area between February and April (≈ 76 percent). During the proposed 5-month study period occurring between February 1, and June 30, 2012, approximately 93 percent of the adult winter-run spawning population is expected to pass through the action area. During Study Element 6, which is scheduled to occur between March 1, and June 30, 2012, approximately 80 percent of the annual adult winter-run escapement will pass through the action area (see Appendix A: Table 15).

Based on the data from the 2011 Georgiana Slough Non-physical Barrier Project, approximately 2.5 adult Chinook salmon were caught per a thousand hours of angling effort, using similar techniques as proposed for the Temperature Study. Applying that CPUE to the SRCSD angling study for the March-June angling events would yield an estimated capture of 1.05 adult Chinook salmon (0.0024 * 4 months * 6 angling days/month * 9 hours/day * 2 anglers) during the study period. Proceeding forward with estimates of overall mortality due to hooking mortality rates ranging from 5 percent to 15 percent, there is at most a 15 percent chance that the one Chinook salmon caught by angling methods would die from hooking related injuries. In trying to determine which run this fish would belong to, the relative frequency of the annual adult escapement moving through the Delta is useful. Assuming that the numbers of adult fish in the winter-run and spring-run populations are somewhat equal (see last 10 year average in Tables 5 and 7), it is more likely, based on the distribution of run timing, that any adult Chinook salmon caught prior to June is most likely a winter-run Chinook salmon in the delta (see Table 15).

2. Central Valley spring-run Chinook salmon

A similar application of the CVP and SWP salvage records and the northern and Central Delta fish monitoring data to the presence of Central Valley spring-run Chinook salmon indicates that juvenile spring-run Chinook salmon first begin to appear in the action area 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). 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 comprised of older yearling spring-run juveniles based on their size at date. Based on the Delta size criteria by date, the majority of spring-run Chinook salmon juveniles (young of year size) emigrate in March (53 percent) and April (43 percent) and tails off sharply by May (1 percent) and thus will be present in the action area during these periods. This pattern is further supported and consistent with salmonid passage estimates derived from rotary screw trap data collected by USFWS dating back to 2003, which indicate two significant peaks in the annual passage of juvenile spring-run Chinook salmon at RBDD occurring in the months of December and April. During the proposed study period (February 1, through June 30, 2012) it is estimated that approximately 97 percent of the annual spring-run Chinook salmon juvenile population will move through the Delta waterways within the action area. Adult spring-run Chinook salmon are expected to start entering the action area in approximately January. Low levels of adult migration are expected through early March. The peak of adult spring-run Chinook salmon movement through the

action area in the Delta is expected to occur between April and June with adults continuing to enter the system through the summer (see Appendix A: Tables 13, 14, and 15). During the proposed Study Element 4 experimental window approximately 2.5 percent of the estimated annual adult escapement population will have moved upriver through the action area. During the proposed 60 day study for Element 5, it is estimated that approximately 7 percent of the adult escapement will move upriver through the Delta waterways associated with the action area. During Study Element 6, which spans the months of March through June, 2012, an estimated 17.5 percent of the annual adult escapement population is expected to move through the Delta waterways surrounding the action area. Currently, all known populations of Central Valley spring-run Chinook salmon inhabit the Sacramento River watershed. The San Joaquin River watershed populations have been extirpated, with the last known runs on the San Joaquin River being extirpated in the late 1940s and early 1950s by the construction of Friant Dam and the opening of the Kern-Friant irrigation canal.

As described above, it is likely that only 1 adult Chinook salmon will be captured by angling during Study Element 6. Due to the overlap of Chinook salmon runs moving through the Delta, it is impossible to determine with any certainty which run this one fish might belong to solely on a visual examination. However the general trend would be to say that the capture of an adult spring-run Chinook salmon is more likely in May and June, but that the relative fraction of winter-run Chinook salmon present in the action area is still high, and either run is still susceptible to angling efforts.

3. Central Valley Steelhead

The Central Valley steelhead DPS occurs 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 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, otilith microchemistry indicating maternal anadromy in some specimens collected within the tributary (Zimmerman, 2008), and historical presence prior to dam construction. Central Valley steelhead smolts first start to appear in the action area in November based on the records from the CVP and SWP fish salvage facilities, as well as the fish monitoring program in the northern and central Delta (Appendix A: Tables 13 and 14). Their 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 CDFG on the main stem 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. Approximately 92 percent of the juvenile steelhead emigrants will move into and through the action area during the study window (February through June, 2012). The proposed 6 to 7 week study period for Study Element 5 will occur sometime between April and May, 2012, and will avoid exposure to the

vast majority of emigrating Central Valley steelhead smolts. Study Element 6 of the Temperature Study will occur between March 1, and June 30, 2012, and has the potential to expose approximately 60 percent of the Central Valley steelhead smolt population emigrating from the Sacramento River basin. Adult steelhead are expected to move through the action area during the Temperature Study implementation period (February through June, 2012), but the peak of upriver immigration is expected to occur earlier (August through November on the Sacramento River) than the study implementation period (February through June) (see Figure 21). There is potential exposure to adult steelhead moving back downstream in a post-spawn condition (kelts) through the action area during the February to May period. It is expected that more kelts will be observed earlier in the period (February) due to the timing of spawning in the Sacramento River basin.

Although no steelhead have been captured during the reported angling efforts to date, including the 2011 Georgiana Slough Non-physical Barrier study angling efforts (RBI 2011e,f), both adults and smolts are sufficiently large enough to take the hard and soft lures, as well as baited hooks used in the hook and line fishing used in Study Element 6. Both adult and smolts may strike spinners, spoons, stick baits, soft plastics or jigs used as part of the artificial lure portion of the study element. Likewise, steelhead may also strike at live or dead bait such as worms, shrimp, or roe (if used) presented on the bottom or drifted. NMFS will use the same total hooking mortalities as described above (15 percent of hooked fish), but the likelihood of capturing a steelhead by the hook and line method would appear to be less than the 2.5 fish per thousand hours of angling effort seen for Chinook salmon, and for this study would essentially be zero since the total hours fished will be 432 hours and would have to be less than the 1 fish estimated for the Chinook salmon catch under Study Element 6.

4. Southern DPS Green Sturgeon

Juvenile green sturgeon from the Southern DPS are routinely collected at the SWP and CVP salvage facilities throughout the year. However, numbers are considerably lower than for other species of fish monitored at the facilities. Based on the salvage records from 1981 through 2007, 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 meter 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 CVP and SWP facilities, which are approximately 35 river miles south of the action area, would indicate that green sturgeon are more likely to be present in the action area during the proposed project, and in higher densities, than are observed at the fish collection facilities. Likewise, since the action area is on the main migratory route utilized by adult green sturgeon to access the spawning grounds in the upper Sacramento River, it is likely that adult green sturgeon will be present in the action area. Adult green sturgeon begin to enter the Sacramento – San Joaquin 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. It is also possible that some adult green sturgeon will be moving back downstream in April and May through the action area, either as early post spawners or as unsuccessful spawners. Some adult green sturgeon have been observed to rapidly move back downstream following spawning, while others linger in the upper river until the following fall.

The extent and duration of rearing in the Delta is unclear (i.e., months to years), but NMFS believes that juvenile green sturgeon, including sub-adults, could be found during any month of the year within the waters of the Delta. Therefore, both adult and juvenile green sturgeon have the potential to be within the action area during the deployment of hydroacoustic and hydrophone equipment, as well as during the acoustic tag study and standardized angling elements of the Temperature Study.

In the 2011 fall standardized angling survey, 2 adult white sturgeon were caught during 216 hours of fishing (12 days * 9 hours/day * 2 anglers). This is a catch per unit effort (fish per angler hour) of 0.0093 fish per hour angling. Based on the ratio of green sturgeon caught to white sturgeon caught in the sturgeon sport fishery in the Delta between Rio Vista and Chipps Island (2007-2010), NMFS expects 1 green sturgeon to be caught for every 20 white sturgeon caught in the sport fishery. This ratio slips to 1 green sturgeon per 50 white sturgeon for the river stretch between Rio Vista and Knights Landing. Based on the catch rate, 4 white sturgeon should be caught during the 432 hours of fishing in Study Element 6. The ratio of green sturgeon to white sturgeon indicates that less than 1 green sturgeon will be caught (0.2 fish) during the implementation of Study Element 6 if the Rio Vista to Chipps Island ratio is used (worst case). NMFS determined that a capture rate of 0.000465 green sturgeon per hour fished should be applied to the study based on the capture rate of white sturgeon.

5. Effects of the Project on Designated Critical Habitat

The proposed project should have minimal effects on the designated critical habitat for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and the Southern DPS of green sturgeon. Within the action area, the relevant PCEs of the designated critical habitat for listed salmonids are migratory corridors and rearing habitat, and for green sturgeon the six PCEs include food resources, water flow, water quality, migratory corridors, water depth, and sediment quality. The project is unlikely to demonstrably affect rearing habitat or food resources or their availability. The foot print of the project is relatively small. The 17 anchor mounts placed on the channel bottom will only impact 340 ft^2 of substrate. The total in-channel footprint for the barrier is less than 0.01 acres. This will result in only a temporary disturbance of the channel substrate as the anchor mounts will be completely removed from the channel, including all power and data cables following the completion of the study. Any disturbance to the channel bottom is considered to temporary and it is expected that the dynamic processes present in the river channel will return the configuration of the bottom to a natural state within a short period of time following the removal of the anchor mounts. Furthermore, any disturbance or loss of benthic invertebrates caused by the deployment of the anchor mounts is expected to be ephemeral, due to the colonization of the disturbed substrate by the surrounding benthic invertebrate communities.

The operation of the hydroacoustic split beam sonar devices will introduce sound into the aquatic environment. The frequency at which the hydroacoustic instrumentation emits sound into the water column is above the threshold for sound reception by listed fish species, therefore no behavioral effect to the listed species of fish is anticipated. The intensity of the emitted sound does not reach the level to which physical effects on the bodies of listed fish can be determined. Likewise the frequency of the acoustic "pings" emitted by the acoustic tags inserted into the test fish, including both predatory fish and hatchery Chinook salmon smolts, is above the threshold for sound reception by listed fish. The intensity of the acoustic "ping" signal is below that which causes physical injury to the test fish or those in the surrounding aquatic medium.

VIII. CONCLUSION

After reviewing the best available scientific and commercial information, the current status of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and the Southern DPS of North American green sturgeon, the environmental baseline, the effects of the proposed SRCSD Temperature Study, and the cumulative effects, it is NMFS' biological opinion that the SRCSD Temperature Study, as proposed, is not likely to jeopardize the continued existence of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, or the Southern DPS of North American green sturgeon, nor will it result in the destruction or adverse modification of designated critical habitat for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, or Southern DPS green sturgeon in the Sacramento River and Georgiana Slough.

IX. INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and Federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by NMFS as an act which kills or injures fish or wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the ESA provided that such taking is in compliance with the terms and conditions of this incidental take statement (ITS).

The measures described below are non-discretionary and must be undertaken by the Corps so that they become binding conditions of any grant or permit issued to the applicant, as appropriate, for the exemption in section 7(o)(2) to apply. The Corps has a continuing duty to regulate the activity covered in this ITS. If the Corps: (1) fails to assume and implement the terms and conditions of the ITS; and/or (2) fails to require the agents of the Corps to adhere to

the terms and conditions of the ITS through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, the Corps and the Corp's agents must report the progress of the action and its impact on the species to NMFS as specified in this ITS (50 CFR §402.14[i][3]).

A. Amount or Extent of Take

NMFS anticipates that the proposed action may result in the incidental take of individuals from the Sacramento River winter-run Chinook salmon ESU, the Central Valley spring-run Chinook salmon ESU, the Central Valley steelhead DPS, and the Southern DPS of North American green sturgeon. Incidental take associated with this action is expected to be in the form of mortality, harm, or harassment of adult Sacramento River winter-run Chinook salmon, adult Central Valley spring-run Chinook salmon, adult and juvenile Central Valley steelhead, and juveniles, sub-adults, and adults from the Southern DPS of North American green sturgeon, resulting from the hooking, playing, landing, and releasing of these fish during the standardized angling component (Study Element 6) of the Temperature Study. Incidental take of adult Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, juvenile and adult Central Valley steelhead, and juvenile, sub-adult, and adult Southern DPS green sturgeon is expected to occur during the 4-month period occurring between March 1, 2012, and June 30, 2012, when individuals from these four populations could potentially be present in the action area during the implementation of Study Element 6.

NMFS, using the best available information, can estimate the anticipated incidental take of listed fish. However, because of the variability and uncertainty associated with the population size of each species, annual variations in the timing of migration, occurrence within the action area during angling activities, and the willingness of listed fish species to take the offered baits and/or lures when presented to them, these rates are only estimates, and actual participation by the fish in the angling study may vary from predicted levels. In addition to the predicted fishing encounter rates and the estimates of hooking mortalities based on these encounter rates, NMFS will also designate ecological surrogates to complement the estimates of incidental take related to the angling efforts. These surrogates will be monitored to determine if the parameters used in estimating the level of incidental take and the impacts to critical habitat remain valid throughout the study.

Anticipated take of Listed Species:

<u>Chinook salmon</u>:
Based on the data from the previous angling surveys, NMFS anticipates that no more than 3 Chinook salmon will be taken by the angling methods described in the Standard Operating Procedure for Study Element 6 for the Temperature Study. The rate of capture, as determined by the previous angling surveys conducted in the river reaches within the action area, including other studies such as the 2011 Georgiana Non-physical Barrier study, show that the capture rate for Chinook salmon is 0.0024 fish per 1,000 hours of sampling, or 1.05 fish for the 432 hours of angling predicted for the completion of Study Element 6. Using a Poisson distribution with a capture rate of 0.00244 fish per hour, a sample size of 432 hours (total hours of angling in Study Element 6), the Poisson mean is 1.0368: (432 hours fished * 0.00244 fish/hr fished = 1.0368).

The cumulative distribution for a Poisson distribution indicates that 98 percent of the time, 3 or fewer fish are captured. In comparison, zero fish are caught 35.5 percent of the time, zero or 1 fish are caught 72 percent of the time and two or fewer fish are caught 91 percent of the time based on the available data. Therefore, a maximum of 3 Chinook salmon are allowed to be captured by the angling component of the Temperature Study. Based on the average total hooking mortality rates which encompasses all anatomical hooking locations and their probabilities of occurrence, NMFS will apply a maximum mortality rate of 15 percent to the captured fish. If three fish are caught, no more than 1 mortality is expected 94 percent of the time, and no more than 2 mortalities greater than 99.9 percent of the time (probability in a binomial distribution). No mortalities are expected approximately 61.4 percent of the time. Adult Chinook salmon released are expected to survive and continue their migration upriver.

Steelhead:
NMFS anticipates that no more than 1 California Central Valley steelhead will be captured during the 432 hours of angling effort, based on the available data. Therefore, the incidental take for Central Valley steelhead will be 1 fish captured by hook and line angling. Using the 15 percent mortality rate for hooked salmonids, no mortalities are expected.

Green Sturgeon:
NMFS anticipates that no more than 1 green sturgeon will be captured during angling efforts in Study Element 6. Using a Poisson distribution, a green sturgeon catch rate of 0.000465 green sturgeon /hour fished and 432 hours fished; there is a 98 percent probability that 1 or fewer green sturgeon will be captured during the angling efforts for Study Element 6. Although NMFS could not find studies determining the hooking mortality rate for sturgeon captured by hook and line angling, NMFS expects that there will be a very low probability of mortality associated with the capture of 1 fish (see above discussion for salmon mortality).

Ecological Surrogates

- The analysis of the effects of the proposed Temperature Study anticipates that the installation of the anchor mounts will directly impact approximately 340 square feet (< 0.01 acres) of channel bottom.
- Temperature Study activities will take place between mid-January and the end of June, 2012. Deployment of the anchor mounts in Study Element 4 will occur in mid-January to early February, 2012. Removal will occur following completion of this study element (end of April, 2012). No more than 2 anchor mounts are anticipated for this element of the study. For study element 5, no more than 15 anchor mounts are anticipated to be deployed. Deployment of these anchor mounts will occur prior to April 1, 2012, and will be completely removed after May 31, 2012, but no later than the end of June, 2012.
- All in-water work will take place during daylight hours, up to 12 hours per day, 7 days per week. Absence of in-water work during the night time will allow for unimpeded movement through the action area by listed salmonids and green sturgeon.
- Standardized angling will follow the standard operating procedures provided for Study Element 6 this project. Fishing will occur within the 4-month period bounded by March, 2012 and June, 2012. No more than 432 hours of total fishing effort will occur during this period based on the procedures described in the project description.

If these ecological surrogates are exceeded, the proposed 2012 SRCSD Temperature Study project will be considered to have exceeded anticipated take levels, triggering the need to reinitiate consultation on the project.

B. Effect of the Take

In the accompanying biological opinion, NMFS determined that this level of anticipated take is not likely to result in jeopardy to the listed anadromous fish species.

C. Reasonable and Prudent Measures

NMFS believes that the following reasonable and prudent measure is necessary and appropriate to minimize take of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and the Southern DPS of North American green sturgeon resulting from implementation of the action.

1. The Corps shall ensure that the SRCSD avoids or minimizes impacts associated with the implementation of the SRCSD Temperature Study upon juvenile Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and southern DPS of North American green sturgeon within the action area of the SRCSD Temperature Study.

D. Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the ESA, the Corps and DWR must comply with the following terms and conditions, which implement the reasonable and prudent measure described above and outline prescribed reporting/monitoring requirements. These terms and conditions are non-discretionary:

1. The Corps shall ensure that the SRCSD avoids or minimizes impacts associated with the implementation of the SRCSD Temperature Study upon juvenile Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and Southern DPS of North American green sturgeon within the action area of the SRCSD Temperature Study.

    a.) The SRCSD Temperature Study shall deploy the hydroacoustic split beam sonar equipment and the hydrophone arrays at the locations described in the project description. The hydroacoustic equipment will be deployed at the following (approximate) coordinates: Latitude 38.454^{o}, Longitude -121.55026^{o}, and Latitude 38.454, Longitude -121.50007 near the town of Freeport, CA. The hydrophone array will deploy 15 units in the same general area as the hydroacoustic instruments, bracketing the diffuser structure.

    b.) Deployment of the anchoring mounts shall be done from a boat using a winch and boom to lower the units to the channel bottom. No additional attachments other

than the anchoring mounts shall be used to secure the units in place. This includes piles, anchors secured to chains and ropes, or other devices. Placement of the units shall be done with a minimum of repositioning prior to setting in their final location to reduce disturbance to the channel substrate.

c.) Removal of hydroacoustic instruments and hydrophones will be done from a boat using a winch and boom to recover the anchor mounts and cables from the bottom. Divers may be deployed to assist the recovery of the anchor mounts and cables. Disturbance of the channel substrate will be kept to a minimum during the recovery of the devices.

d.) During standardized angling efforts, fish shall be played quickly and brought to the boat as soon as possible to minimize stress. Listed fish species shall not be removed from the water to remove the hooks.

e.) Listed fish shall be observed for bleeding or other obvious injuries due to the placement of the hook or angling actions prior to release. This information shall be recorded as well as location of hooking wound.

f.) Any listed fish hooked in the gills or esophagus – stomach locations shall have the line cut at the jaw where the line exits the mouth, leaving the hook and remainder of the leader in place. Listed fish hooked in the jaw or mouth will have the hook removed with as minimal damage as possible, preferably using a de-hooking device or forceps.

g.) All listed fish shall be released in good condition. Fish should be held into the current and allowed to regain their equilibrium before release. Multiple attempts shall be made to resuscitate all listed fish captured so that the fish successfully swims away under their own power.

h.) Lures and bait shall be fished on a tight line rather than a slack line approach and efforts shall be made to minimize deep hooking of fish. Barbless hooks and circle hooks shall be used as appropriate to reduce injury and likelihood of deep hooking locations.

i.) The trailer housing the power supply and equipment to operate the instrumentation required for the Temperature Study shall be placed on the asphalt pad adjacent to SRCSD operations building (eastern bank of the Sacramento River). A spill prevention and control plan that includes actions to contain any fuel or chemical leaks shall be implemented at all times during the operation of the SRCSD Temperature Study. The containment area shall be sized to accommodate the entire volume of fuel or hazardous materials stored on site so that no leakage to the river can occur should the storage containers rupture and spill their contents.

j.) Any Chinook salmon, steelhead or green sturgeon that is killed or mortally injured due to the angling portion of the study or found dead or injured within 0.25 mile upstream or downstream of the study sites during the Temperature Study shall be reported immediately to NMFS via fax within 24 hours of discovery to:

Attention Supervisor, NMFS Sacramento Area Office
Fax at (916) 930-3623)
or by phone at: (916) 930-3600.

A follow-up written notification shall also be submitted to NMFS which includes the date, time, and location that the fishing related mortality occurred or when the carcass or injured specimen was found, a color photograph of the fish, the cause of injury or death, if known, and the name and affiliation of the person who found the specimen. Written notification shall be submitted within 72 hours of discovery to:

Supervisor, Sacramento Area Office
National Marine Fisheries Service
650 Capitol Mall, Suite 5-100
Sacramento, California 95814

Any dead specimen(s) should be placed in a cooler with ice and held for pick up by NMFS personnel or an individual designated by NMFS to do so.

k.) Copies of all reports, documents, and data sheets, generated by the Temperature Study shall be sent to NMFS at the address in sub-paragraph (j.) above following the completion of the study. NMFS will consider 6 months to be an adequate period of time to deliver these materials following completion of the field portion of this study. The SRCSD may request an extension of this timeline from NMFS in writing, which NMFS may approve if sufficient reasons exist to grant such an extension.

X. CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the ESA directs Federal agencies to utilize their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations include discretionary measures that the Corps and DWR can take to minimize or avoid adverse effects of a proposed action on a listed species or critical habitat.

1.) The Corps and SRCSD should implement biotechnical measures in place of traditional revetment techniques should any of their projects' riprap begin to cause scour and require additional bank stabilization.

2.) The Corps and SRCSD should conduct or fund studies to help quantify fish losses at water diversions, and prioritize fish screen projects for future funding.

3.) The Corps and SRCSD should conduct or fund studies to help determine movement and survival of listed fish through the Delta in response to water conveyance operations of the SWP and CVP.

4.) The Corps and SRCSD should continue to work cooperatively with other State and Federal agencies, private landowners, governments, and local watershed groups to identify opportunities for cooperative analysis and funding to support salmonid habitat restoration projects within the Delta region.

XI. REINITIATION OF CONSULTATION

This concludes the formal consultation on the construction and operation of the Sacramento Regional County Sanitation District's 2012 Temperature Study. As provided in 50 CFR §402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded, (2) new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered, (3) the identified action is subsequently modified in a manner that causes an effect to listed species or critical habitat that was not considered in the biological opinion, or (4) a new species is listed or critical habitat designated that may be affected by the identified action. In instances where the amount or extent of incidental take is exceeded, formal consultation shall be reinitiated immediately.

XII. LITERATURE CITED

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Appendix A: Tables

Table 1: Tentative schedule for hydroacoustic deployment and data collection for study element 4 during the period between February and April 2012.

Sub-Task	Dates	Data Collection Duration	Deployment and Idle Time
System Deployment	≈Jan. 15-30		≈1-2 weeks
Data Collection	Feb. 1-7	7 days	
Idle Period	Feb. 8-29		22 days
Data Collection	March 1-14	14 days	
Idle Period	March 15-April 14		31 days
Data Collection	April 15-30	16 days	
TOTAL DATA COLLECTION		37 days	

Table 2: Timing of hydroacoustic monitoring (green shading) and presence of listed and native fish species in the Delta study area.

Table 3: Location and description of angling sites for Study Element 6 (Standardized Angling).

Site ID	GPS Coordinates		Distance Upstream of the SRWTP Outfall (miles)
	Left Bank	Right Bank	
Study Site 1 (SRWTP Outfall)	N38.45431 W121.50067	N38.45409 W121.50267	n/a
Study Site 2 (400 ft downstream of SRWTP Outfall)	N38.45319 W121.50044	N38.45299 W121.50255	-0.1
Reference Site 1 (Freeport Bridge)	N38.45572 W121.50098	N38.45536 W121.50296	0.1
Reference Site 2 (Miller Park)	N38.56284 W121.51903	N38.56210 W121.52132	11.3

Table 10: The annual occurrence of juvenile Southern DPS of North American green sturgeon at the CVP and SWP fish collection facilities in the South Delta. (Adams et al, (2007), CDFG 2002)

Year	State Facilities		Federal Facilities	
	Salvage Numbers	Numbers per 1000 acre feet	Salvage Numbers	Numbers per 1000 acre feet
1968	12	0.0162		
1969	0	0		
1970	13	0.0254		
1971	168	0.2281		
1972	122	0.0798		
1973	140	0.1112		
1974	7313	3.9805		
1975	2885	1.2033		
1976	240	0.1787		
1977	14	0.0168		
1978	768	0.3482		
1979	423	0.1665		
1980	47	0.0217		
1981	411	0.1825	274	0.1278
1982	523	0.2005	570	0.2553
1983	1	0.0008	1475	0.653
1984	94	0.043	750	0.2881
1985	3	0.0011	1374	0.4917
1985	0	0	49	0.0189
1987	37	0.0168	91	0.0328
1988	50	0.0188	0	0
1989	0	0	0	0
1990	124	0.0514	0	0
1991	45	0.0265	0	0
1992	50	0.0332	114	0.0963
1993	27	0.0084	12	0.0045
1994	5	0.003	12	0.0068
1995	101	0.0478	60	0.0211
1996	40	0.0123	36	0.0139
1997	19	0.0075	60	0.0239
1998	136	0.0806	24	0.0115
1999	36	0.0133	24	0.0095
2000	30	0.008	0	0
2001	54	0.0233	24	0.0106
2002	12	0.0042	0	0
2003	18	0.0052	0	0
2004	0	0	0	0
2005	16	0.0044	12	0.0045
2006	39	0.0078	324	0.1235

Table 11: Monthly Occurrences of Dissolved Oxygen Depressions below the 5mg/L Criteria in the Stockton Deepwater Ship Channel (Rough and Ready Island DO monitoring site) Water Years 2000 to 2004

			Water Year			
Month	**2000-01**	**2001-02**	**2002-03**	**2003-04**	**2004-05**	**Monthly Sum**
September	0	26**	30**	16**	30**	102
October	0	0	7	0	4	11
November	0	0	12	0	3	15
December	6	4*	13	2	13	38
January	3	4	19	7	0	33
February	0	25	28	13	0	66
March	0	7	9	0	0	16
April	0	4	4	0	0	8
May	2*	0	2	4	0	8
Yearly Sum	11	70	124	42	50	**Total=297**

* = Suspect Data – potentially faulty DO meter readings

** = Wind driven and photosynthetic daily variations in DO level; very low night-time DO levels, high late afternoon levels

Table 12. Salmon and Steelhead monitoring programs in the Sacramento - San Joaquin River basins, and Suisun Marsh.

Geographic Region	Species	Watershed	Methods	Geographic Area Covered	Monitoring Parameters	Monitoring Period	Implementing Agency
Central Valley	***Chinook Salmon, Steelhead***	Sacramento River	Scale and otolith collection	Coleman National Hatchery, Sacramento River and tributaries	Scale and otolith microstructure analysis	Year-round	CDFG
		Sacramento River and San Joaquin River	Central Valley angler survey	Sacramento and San Joaquin rivers and tributaries downstream to Carquinez	In-river harvest	8 or 9 times per month, year round	CDFG
		Sacramento River	Rotary screw trap	Upper Sacramento River at Balls Ferry and Deschutes Road Bridge	Juvenile emigration timing and abundance	Year round	CDFG
		Sacramento River	Rotary screw trap	Upper Sacramento River at RBDD	Juvenile emigration timing and abundance	Year round	FWS
		Sacramento River	Ladder counts	Upper Sacramento River at RBDD	Escapement estimates, population size	Variable, May - Jul	FWS
		Sacramento River	Beach seining	Sacramento River, Caldwell Park to Delta	Spatial and temporal distribution	Bi-weekly or monthly, year-round	FWS
		Sacramento River	Beach seining, snorkel survey, habitat mapping	Upper Sacramento River from Battle Creek to Caldwell Park	Evaluate rearing habitat	Random, year-round	CDFG
		Sacramento River	Rotary screw trap	Lower Sacramento River at Knight's Landing	Juvenile emigration and post-spawner adult steelhead migration	Year-round	CDFG
		Sacramento-San Joaquin basin	Kodiak/Midwater trawling	Sacramento river at Sacramento, Chipps Island, San Joaquin River at Mossdale	Juvenile outmigration	Variable, year-round	FWS
		Sacramento-San Joaquin Delta	Kodiak trawling	Various locations in the Delta	Presence and movement of juvenile salmonids	Daily, Apr - Jun	IEP
		Sacramento-San Joaquin Delta	Kodiak trawling	Jersey Point	Mark and recapture studies on juvenile salmonids	Daily, Apr - Jun	Hanson Environmental Consultants

Geographic Region	Species	Watershed	Methods	Geographic Area Covered	Monitoring Parameters	Monitoring Period	Implementing Agency
Central Valley	*Chinook Salmon, Steelhead, Continued*	Sacramento-San Joaquin Delta	Salvage sampling	CVP and SWP south delta pumps	Estimate salvage and loss of juvenile salmonids	Daily	USBR/CDFG
		Battle Creek	Rotary screw trap	Above and below Coleman Hatchery barrier	Juvenile emigration	Daily, year-round	FWS
		Battle Creek	Weir trap, carcass counts, snorkel/ kayak survey	Battle Creek	Escapement, migration patterns, demographics	Variable, year-round	FWS
		Clear Creek	Rotary screw trap	Lower Clear Creek	Juvenile emigration	Daily, mid Dec- Jun	FWS
		Feather River	Rotary screw trap, Beach seining, Snorkel survey	Feather River	Juvenile emigration and rearing, population estimates	Daily, Dec - Jun	DWR
		Yuba River	Rotary screw trap	lower Yuba River	Life history evaluation, juvenile abundance, timing of emergence and migration, health index	Daily, Oct - Jun	CDFG
		Feather River	Ladder at hatchery	Feather River Hatchery	Survival and spawning success of hatchery fish (spring-run Chinook salmon), determine wild vs. hatchery adults (steelhead)	Variable, Apr - Jun	DWR, CDFG
		Mokelumne River	Habitat typing	Lower Mokelumne River between Comanche Dam and Cosumnes River confluence	Habitat use evaluation as part of limiting factors analysis	Various, when river conditions allow	EBMUD
		Mokelumne River	Redd surveys	Lower Mokelumne River between Comanche Dam and Hwy 26 bridge	Escapement estimate	Twice monthly, Oct 1- Jan 1	EBMUD
		Mokelumne River	Rotary screw trap, mark/recapture	Mokelumne River, below Woodbridge Dam	Juvenile emigration and survival	Daily, Dec- Jul	EBMUD

Geographic Region	Species	Watershed	Methods	Geographic Area Covered	Monitoring Parameters	Monitoring Period	Implementing Agency
Central Valley	*Chinook Salmon, Steelhead, Continued*	Mokelumne River	Angler survey	Lower Mokelumne River below Comanche Dam to Lake Lodi	In-river harvest rates	Various, year-round	EBMUD
	CV Steelhead	Mokelumne River	Beach seining, electrofishing	Lower Mokelumne	Distribution and habitat use	Various locations at various times throughout the year	EBMUD
		Mokelumne River	Video monitoring	Woodbridge Dam	Adult migration timing, population estimates	Daily, Aug - Mar	EBMUD
		Calaveras River	Adult weir, snorkel survey, electrofishing	Lower Calaveras River	Population estimate, migration timing, emigration timing	Variable, year-round	Fishery Foundation
		Stanislaus River	Rotary screw trap	lower Stanislaus River at Oakdale and Caswell State Park	Juvenile outmigration	Daily, Jan - Jun, dependent on flow	S.P. Cramer
		San Joaquin River basin	Fyke nets, snorkel surveys, hook and line survey, beach seining, electrofishing	Stanislaus, Tuolumne, Merced, and mainstem San Joaquin rivers	Presence and distribution, habitat use, and abundance	Variable, Mar- Jul	CDFG
		Sacramento River	Angler Survey	RBDD to Redding	In-river harvest	Random Days, Jul 15 - Mar 15	CDFG
		Battle Creek	Hatchery counts	Coleman National Fish Hatchery	Returns to hatchery	Daily, Jul 1 - Mar 31	FWS
		Clear Creek	Snorkel survey, redd counts	Clear Creek	Juvenile and spawning adult habitat use	Variable, dependent on river conditions	FWS
		Mill Creek, Antelope Creek, Beegum Creek	Spawning survey - snorkel and foot	Upper Mill, Antelope, and Beegum creeks	Spawning habitat availability and use	Random days when conditions allow, Feb - Apr	CDFG
		Mill Creek, Deer Creek, Antelope Creek	Physical habitat survey	Upper Mill, Deer, and Antelope creeks	Physical habitat conditions	Variable	USFS

Geographic Region	Species	Watershed	Methods	Geographic Area Covered	Monitoring Parameters	Monitoring Period	Implementing Agency
Central Valley	***CV Steelhead*** continued	Dry Creek	Rotary screw trap	Miner and Secret Ravine's confluence	Downstream movement of emigrating juveniles and post-spawner adults	Daily, Nov- Apr	CDFG
		Dry Creek	Habitat survey, snorkel survey, PIT tagging study	Dry Creek, Miner and Secret Ravine's	Habitat availability and use	Variable	CDFG
		Battle Creek	Otolith analysis	Coleman Hatchery	Determine anadromy or freshwater residency of fish returning to hatchery	Variable, dependent on return timing	FWS
		Feather River	Hatchery coded wire tagging	Feather River Hatchery	Return rate, straying rate, and survival	Daily, Jul - Apr	DWR
		Feather River	Snorkel survey	Feather River	Escapement estimates	Monthly, Mar to Aug (upper river), once annually (entire river)	DWR
		Yuba River	Adult trap	lower Yuba River	Life history, run composition, origin, age determination	Year-round	Jones and Stokes
		American River	Rotary screw trap	Lower American River, Watt Ave. Bridge	Juvenile emigration	Daily, Oct- Jun	CDFG
		American River	Beach seine, snorkel survey, electrofishing	American River, Nimbus Dam to Paradise Beach	Emergence timing, juvenile habitat use, population estimates	Variable	CDFG
		American River	Redd surveys	American River, Nimbus Dam to Paradise Beach	Escapement estimates	Once, Feb - Mar	CDFG, BOR
		Mokelumne River	Electrofishing, gastric lavage	Lower Mokelumne River	Diet analysis as part of limiting factor analysis	Variable	EBMUD
		Mokelumne River	Electrofishing, hatchery returns	Lower Mokelumne River, Mokelumne River hatchery	O. Mykiss genetic analysis to compare hatchery returning steelhead to residents	Variable	EBMUD

Geographic Region	Species	Watershed	Methods	Geographic Area Covered	Monitoring Parameters	Monitoring Period	Implementing Agency
Central Valley	***CV Steelhead*** continued	Calaveras River	Rotary screw trap, pit tagging, beach seining, electrofishing	lower Calaveras River	Population estimate, migration patterns, life history	Variable, year-round	S.P. Cramer
		San Joaquin River basin	Fyke nets, snorkel survey, hook and line survey, beach seining, electrofishing, fish traps/weirs	Stanislaus, Tuolumne, Merced, and mainstem San Joaquin rivers	Presence, origin, distribution, habitat use, migration timing, and abundance	Variable, Jun - Apr	CDFG
		Merced River	Rotary screw trap	Lower Merced River	Juvenile outmigration	Variable, Jan-Jun	Natural Resource Scientists, Inc.
		Central Valley-wide	Carcass survey, hook and line survey, electrofishing, traps, nets	Upper Sacramento, Yuba, Mokelumne, Calaveras, Tuolumne, Feather, Cosumnes and Stanislaus rivers, and Mill, Deer, Battle, and Clear creeks	Occurrence and distribution of *O. Mykiss*	Variable, year-round	CDFG
		Central Valley - wide	Scale and otolith sampling	Coleman NFH, Feather, Nimbus, Mokelumne River hatcheries	Stock identification, juvenile residence time, adult age structure, hatchery contribution	Variable upon availability	CDFG
		Central Valley - wide	Hatchery marking	All Central Valley Hatcheries	Hatchery contribution	Variable	FWS, CDFG
	SR Winter-run Chinook salmon	Sacramento River	Aerial redd counts	Keswick Dam to Princeton	Number and proportion of reds above and below RBDD	Weekly, May 1-July 15	CDFG
		Sacramento River	Carcass survey	Keswick Dam to RBDD	In-river spawning escapement	Weekly, Apr 15-Aug 15	FWS, CDFG
		Battle Creek	Hatchery marking	Coleman National Fish Hatchery	Hatchery contribution	Variable	FWS, CDFG
		Sacramento River	Ladder counts	RBDD	Run-size above RBDD	Daily, Mar 30- Jun 30	FWS

Geographic Region	Species	Watershed	Methods	Geographic Area Covered	Monitoring Parameters	Monitoring Period	Implementing Agency
Central Valley	***CV Spring-run Chinook salmon***	Pacific Ocean	Ocean Harvest	California ports south of Point Arena	Ocean landings	May 1- Sept 30 (commercial), Feb 15 - Nov 15 (sport)	CDFG
		Mill, Deer, Antelope, Cottonwood, Butte, Big Chico creeks	Rotary screw trap, snorkel survey, electrofishing, beach seining	upper Mill, Deer, Antelope, Cottonwood, Butte, and Big Chico creeks	Life history assessment, presence, adult escapement estimates	Variable, year-round	CDFG
		Feather River	Fyke trapping, angling, radio tagging	Feather River	Adult migration and holding behavior	Variable, Apr-June	DWR
		Yuba River	Fish trap	lower Yuba River, Daguerre Point Dam	Timing and duration of migration, population estimate	Daily, Jan - Dec	CDFG
Suisun Marsh	***Chinook salmon***	Suisun Marsh	Otter trawling, beach seining	Suisun Marsh	Relative population estimates and habitat use	Monthly, year-round	UC Davis
		Suisun Marsh	Gill netting	Suisun Marsh Salinity Control Gates	Fish passage	Variable, Jun - Dec	CDFG

Table 13: Summary table of monthly Winter-run and Spring-run Chinook salmon loss and Combined total salvage and loss of Central Valley steelhead at the CVP and SWP fish collection facilities from water year 1999-2000 to water year 2008-2009. Data from CVO web site: (http://www.usbr.gov/mp/cvo/)

Fish Facility Salvage Records (Loss)

Winter Run (loss)

Year	October	November	Dec	Jan	Feb	March	April	May	June	July	August	September	Sum
2008-2009	0	0	8	55	210	1654	21	0	0	NA	NA	NA	1948
2007-2008	0	0	0	164	484	628	40	0	0	NA	NA	NA	1316
2006-2007	0	0	87	514	1678	2730	330	0	0	NA	NA	NA	5339
2005-2006	0	0	649	362	1016	1558	249	27	208	NA	NA	NA	4069
2004-2005	0	0	228	3097	1188	644	123	0	0	NA	NA	NA	5280
2003-2004	0	0	84	640	2812	4865	39	30	0	NA	NA	NA	8470
2002-2003	0	0	1261	1614	1464	2789	241	24	8	NA	NA	NA	7401
2001-2002	0	0	1326	478	222	1167	301	0	0	NA	NA	NA	3494
2000-2001	0	0	384	1302	6014	15379	259	0	0	NA	NA	NA	23338
1999-2000	0	0				1592	250	0	0	NA	NA	NA	1842
Sum	0	0	4027	8226	15088	33006	1853	81	216	0	0	0	62497
Avg	0	0	447	914	1676	3301	185	8	22	0	0	0	6553
%Wr/yr	0.000	0.000	6.828	13.947	25.581	50.364	2.828	0.124	0.330	0.000	0.000	0.000	

Spring-Run (loss)

Year	October	November	Dec	Jan	Feb	March	April	May	June	July	August	September	Sum
2008-2009	0	0	0	0	0	333	5912	2604	4	NA	NA	NA	8853
2007-2008	0	0	0	0	15	315	6918	4673	87	NA	NA	NA	12008
2006-2007	0	0	0	0	7	190	4700	365	0	NA	NA	NA	5262
2005-2006	0	0	0	0	104	1034	8315	3521	668	NA	NA	NA	13642
2004-2005	0	0	0	0	0	1856	10007	1761	639	NA	NA	NA	14263
2003-2004	0	0	0	25	50	4646	5901	960	0	NA	NA	NA	11582
2002-2003	0	0	0	46	57	11400	27977	2577	0	NA	NA	NA	42057
2001-2002	0	0	0	21	8	1245	10832	2465	19	NA	NA	NA	14590
2000-2001	0	0								NA	NA	NA	0
1999-2000										NA	NA	NA	0
Sum	0	0	0	92	241	21019	80562	18926	1417	0	0	0	122257
Avg	0	0	0	12	30	2627	10070	2366	177	0	0	0	15282
% SR/yr	0.000	0.000	0.000	0.075	0.197	17.192	65.896	15.481	1.159	0.000	0.000	0.000	

Steelhead (combined salvage and loss, clipped and non-clipped)

Year	October	November	Dec	Jan	Feb	March	April	May	June	July	August	September	Sum
2008-2009	0	0	0	40	571	1358	210	68	13	7	NA	NA	2267
2007-2008	0	0	0	624	4639	717	300	106	24	15	NA	NA	6425
2006-2007	0	0	10	81	1643	4784	2689	113	20	NA	NA	NA	9340
2005-2006	0	0	0	129	867	3942	337	324	619	NA	NA	NA	6218
2004-2005	0	20	70	120	1212	777	687	159	116	NA	NA	NA	3161
2003-2004	0	12	40	613	10598	4671	207	110	0	NA	NA	NA	16251
2002-2003	0	0	413	13627	3818	2357	823	203	61	NA	NA	NA	21302
2001-2002	0	0	3	1169	1559	2400	583	37	42	NA	NA	NA	5793
2000-2001	0	0	89	543	5332	5925	720	69	12	NA	NA	NA	12690
1999-2000	3	60				1243	426	87	48	NA	NA	NA	1867
Sum	3	92	625	16946	30239	28174	6982	1276	955	22	0	0	85314
Avg	0	9	69	1883	3360	2817	698	128	96	11	0	0	9071
SH %/yr	0.0	0.1	0.8	20.8	37.0	31.1	7.7	1.4	1.1	0.1	0.0	0.0	

Table 14: The proportion of juvenile Chinook salmon and steelhead production entering the Delta from the Sacramento River by month.

Month	Sacramento River Total[1,2]	Fall-Run[3]	Spring-Run[3]	Winter-run[3]	Sacramento Steelhead[4]
January	12	14	3	17	5
February	9	13	0	19	32
March	26	23	53	37	60
April	9	6	43	1	0
May	12	26	1	0	0
June	0	0	0	0	0
July	0	0	0	0	0
August	4	1	0	0	0
September	4	0	0	0	1
October	6	9	0	0	0
November	9	8	0	03	1
December	11	0	0	24	1
Total	100	100	100	100	100

Notes:
[1] Mid Water trawl data
[2] All runs combined
[3] Runs from Sacramento River basin only
[4] Rotary screw trap data from Knights Landing
Source: SDIP Draft EIR/EIS 2005 Tables J-23 and J-24, Appendix J.

Table 15: 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).				

Source: DWR 2010a. Biological Assessment for the 2011 Georgiana Slough non-physical barrier study for NMFS managed species. ICF International. November 2010.

Table 16: Total number of fish captured at each sampling site by date and species.

Date	Species						Count
	Striped Bass [1]	Sacramento Pikeminnow [1]	Spotted Bass [2]	Smallmouth Bass [2]	White Catfish [3]	White Sturgeon [4]	
10/18	30	1					**31**
10/19	40		4	1	3		**48**
10/20	19	1					**20**
10/25	20	1		1			**22**
10/26	5						**5**
10/27	7						**7**
11/16		1					**1**
11/17	1	1					**2**
11/18		1					**1**
11/28	1						**1**
11/29						1	**1**
11/30						1	**1**
Total Count:	**123**	**6**	**4**	**2**	**3**	**2**	**140**

1 Target Species Group 1 – Striped Bass/Sacramento Pikeminnow.
2 Target Species Group 2 – Black Basses.
3 Target Species Group 3 – Catfishes.
4 Not a target piscivorous fish species for this study.

Table 17: Total number of species captured at each study site.

Site	Species						Count
	Striped Bass [1]	Sacramento Pikeminnow [1]	Spotted Bass [2]	Smallmouth Bass [2]	White Catfish [3]	White Sturgeon [4]	
Study Site 1 SRWTP Diffuser	38	2			1		**41**
Study Site 2 SRWTP Plume	39	2				2	**43**
Reference Site 1 Freeport Bridge	33	1	1		2		**37**
Reference Site 2 Miller Park	13	1	3	2			**19**
Total Count:	**123**	**6**	**4**	**2**	**3**	**2**	**140**

1 Target Species Group 1 – Striped Bass/Sacramento Pikeminnow.
2 Target Species Group 2 – Black Basses.
3 Target Species Group 3 – Catfishes.
4 Not a target piscivorous fish species for this study.

Table 18: Total number of fish species captured with each bait type.

Site	Species						Count
	Striped Bass [1]	Sacramento Pikeminnow [1]	Spotted Bass [2]	Smallmouth Bass [2]	White Catfish [3]	White Sturgeon [4]	
Cut Bait (anchovy, mackerel, sardine)	113	5			3	1	**122**
Live Minnow	1						**1**
Earthworm	9	1					**10**
Artificial Lure			4	2			**6**
Shrimp						1	**1**
Total Count:	**123**	**6**	**4**	**2**	**3**	**2**	**140**

1 Target Species Group 1 – Striped Bass/Sacramento Pikeminnow.
2 Target Species Group 2 – Black Basses.
3 Target Species Group 3 – Catfishes.
4 Not a target piscivorous fish species for this study.

Appendix B: Figures

Figure 2: HTI rotating Model 243 split-beam transducer system locations on the Sacramento River. Location of discharge diffuser is indicated relative to position of the two transducer locations proposed for study.

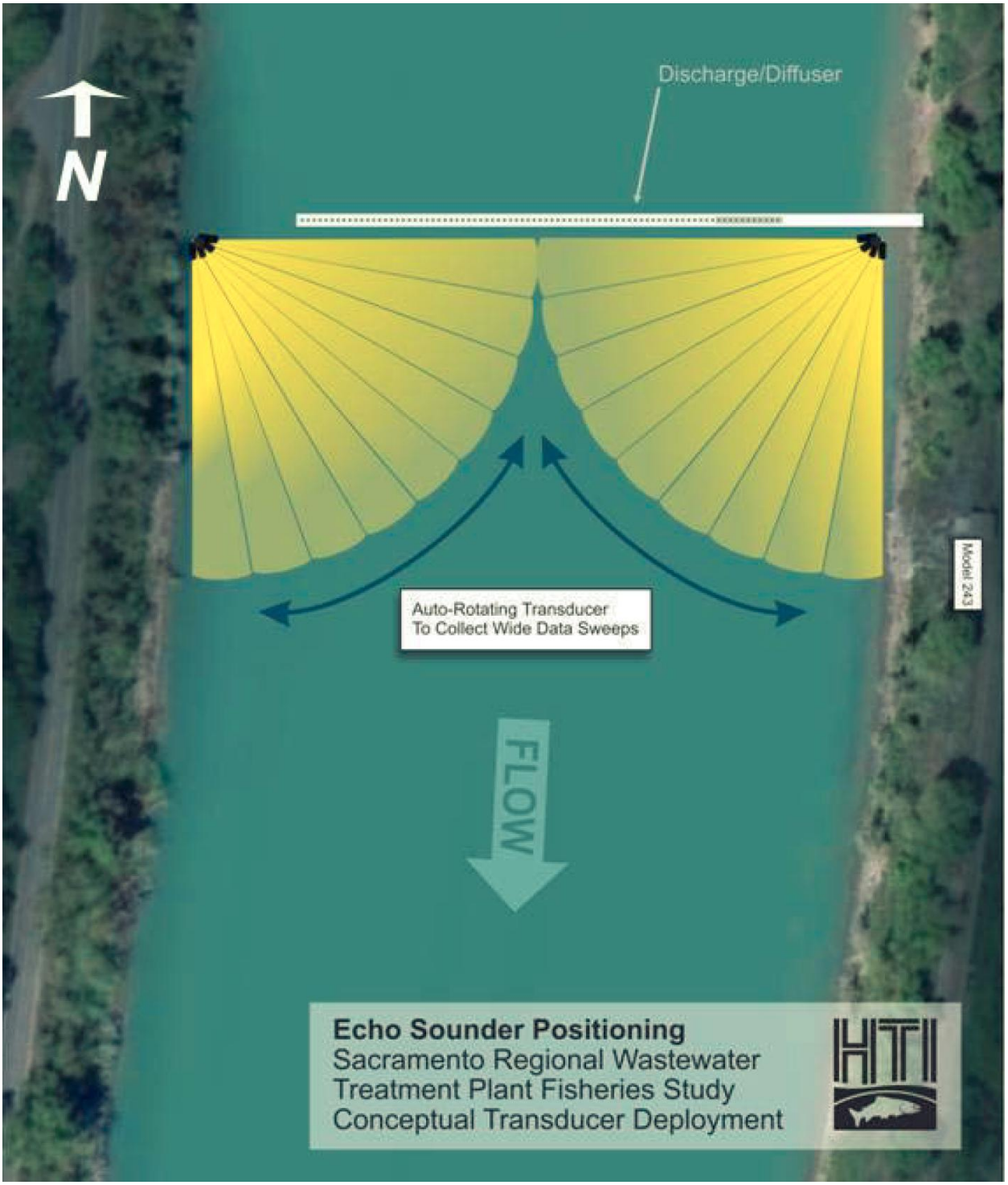


Figure 3: Location of the three proposed surface hydrophones in the Sacramento River channel, looking upstream towards the Freeport Bridge (upper margin of photo).

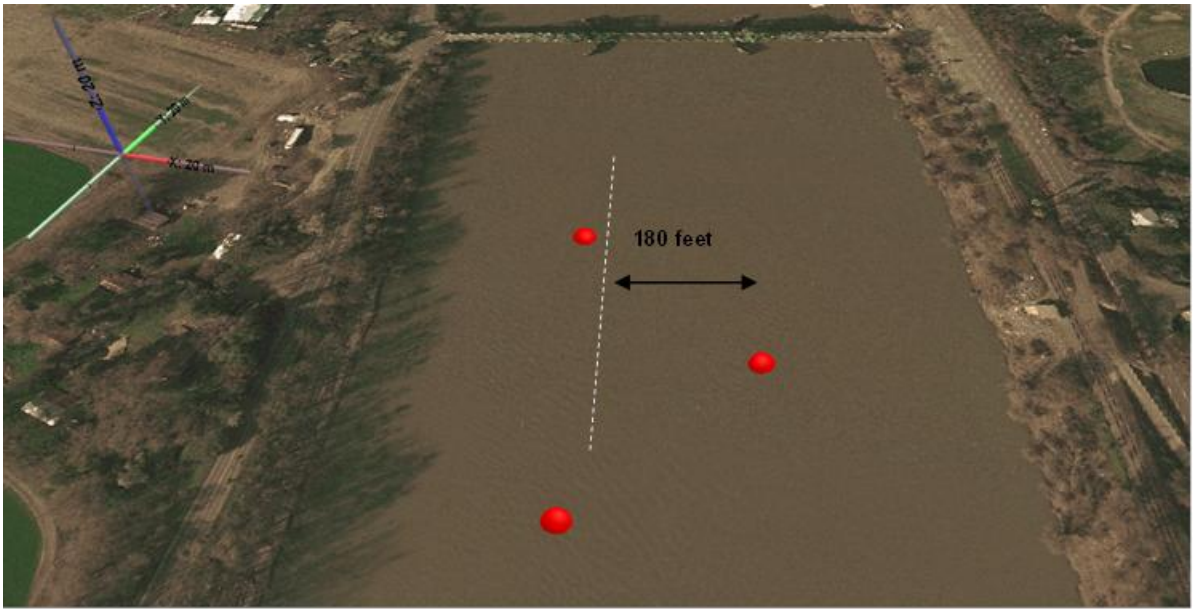


Figure 4: Cross-sectional view of the proposed placement of the 15 monitoring hydrophones proposed for the 2012 SRCSD Temperature Study, looking upstream towards the Freeport Bridge from mid-channel. Note the water depth (z-dimension) is scaled at a 5:1 ratio. Estimated water depth through the mid-channel invert is 23-25 feet deep, and approximately 19 feet in depth from water surface to the top of the discharge diffuser array. Red dots indicate surface oriented hydrophones, green dots are bottom oriented hydrophones.

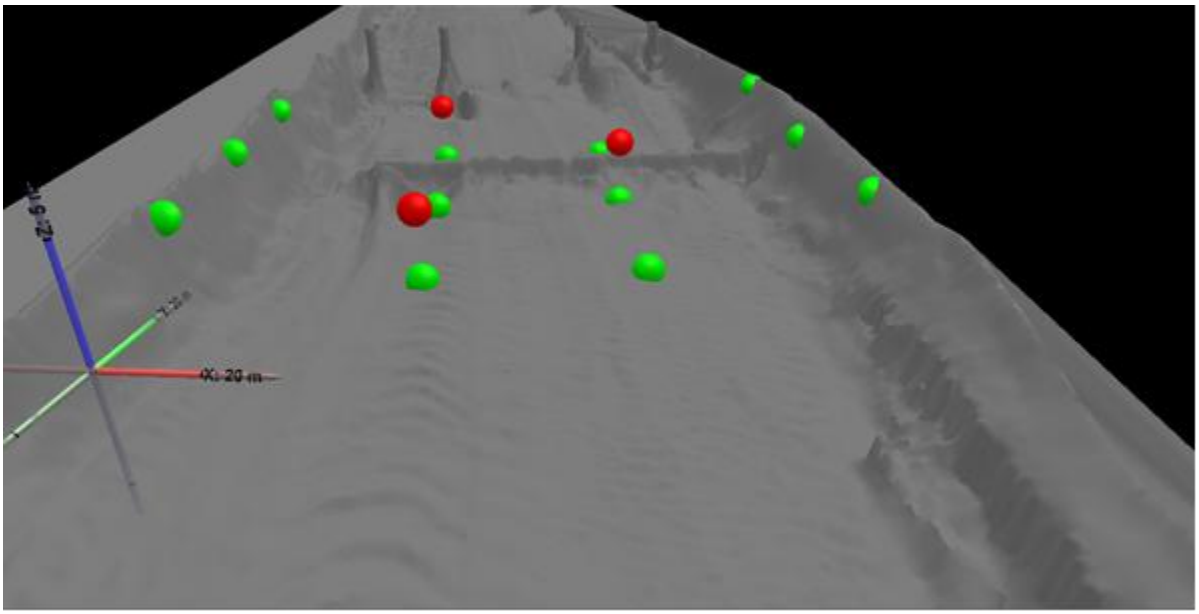


Figure 5: Aerial view of study site 1 (SRWTP Outfall), study site 2 (400 feet downstream of SRWTP outfall), reference site 1 (Freeport Bridge), and reference site 2 (Miller Park).

Figure 6: Annual estimated Sacramento River winter-run Chinook salmon escapement population 1970 through 2011. Sources: CDFG 2011 (Grand Tab February 1, 2011, CDFG 2011 survey data)

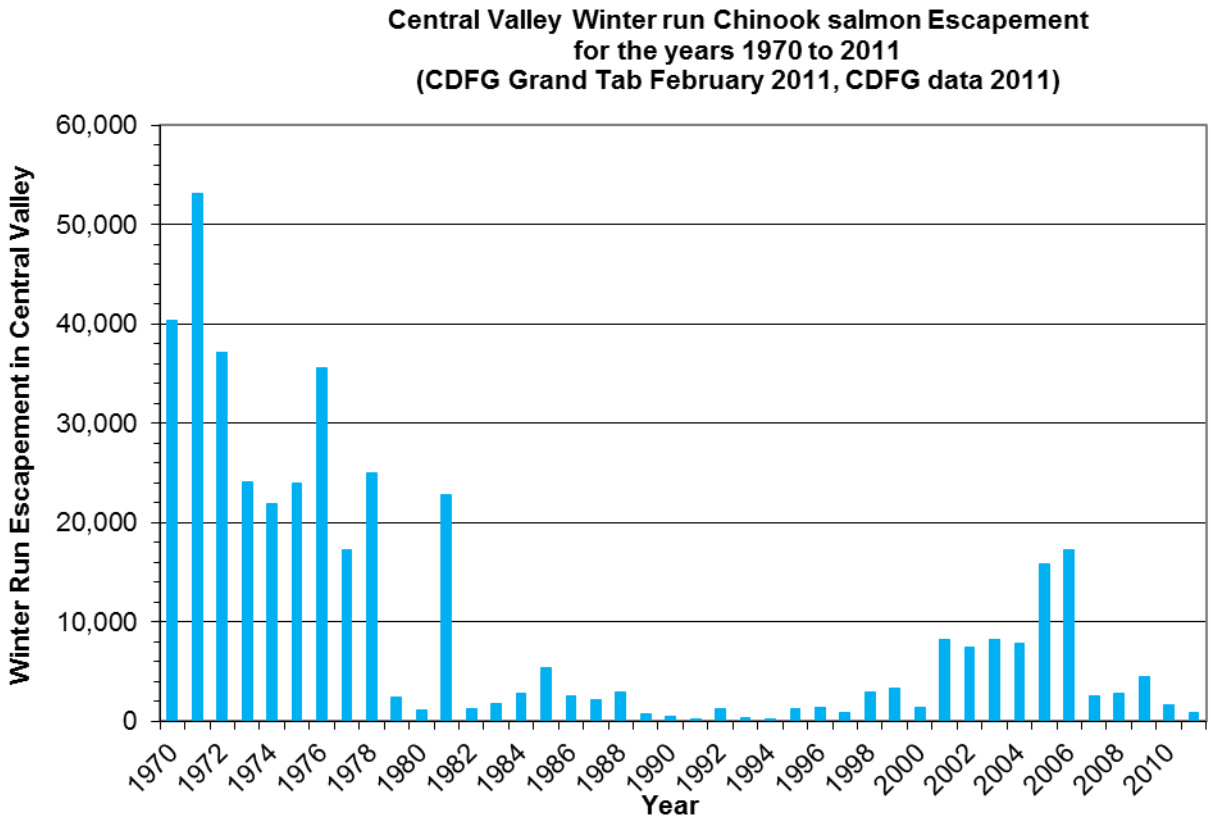


Figure 7: Annual Percentages of Sacramento River winter-run Chinook salmon adults spawning in the Sacramento River that are of hatchery origin (NMFS 2011a).

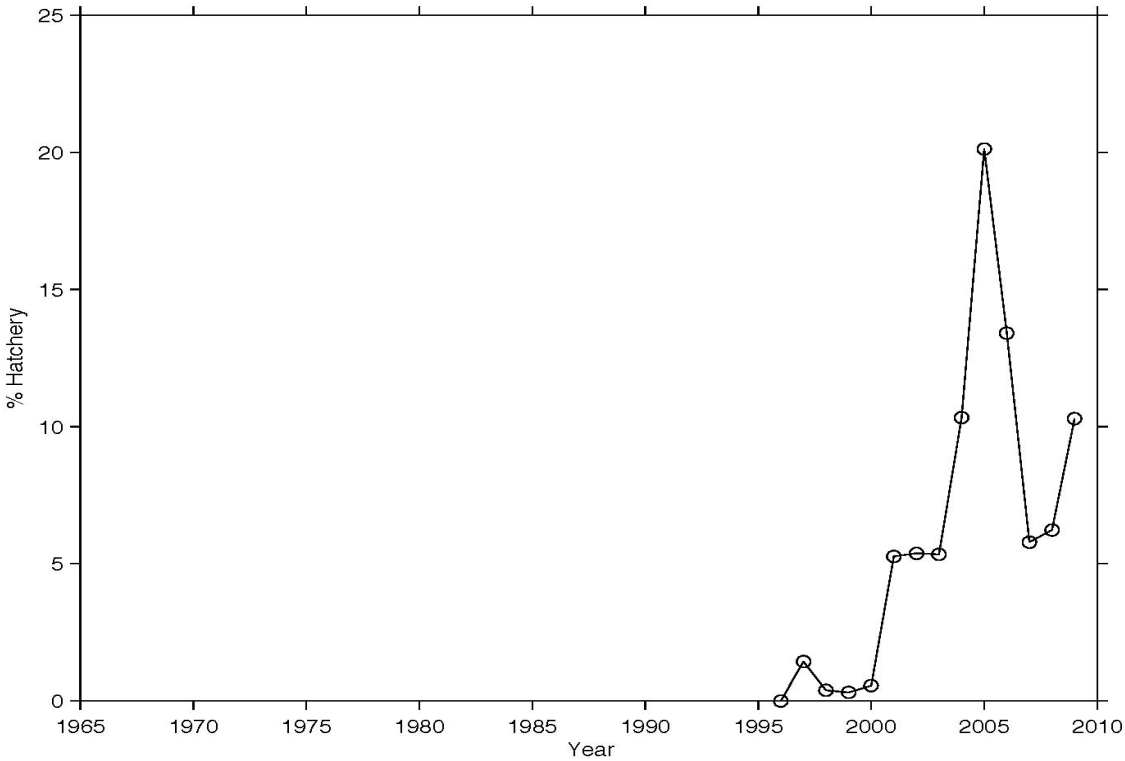


Figure 8: Adult winter-run escapement based on carcass surveys for the years 2005 through 2011 (NMFS 2011a, CDFG 2011 survey data).

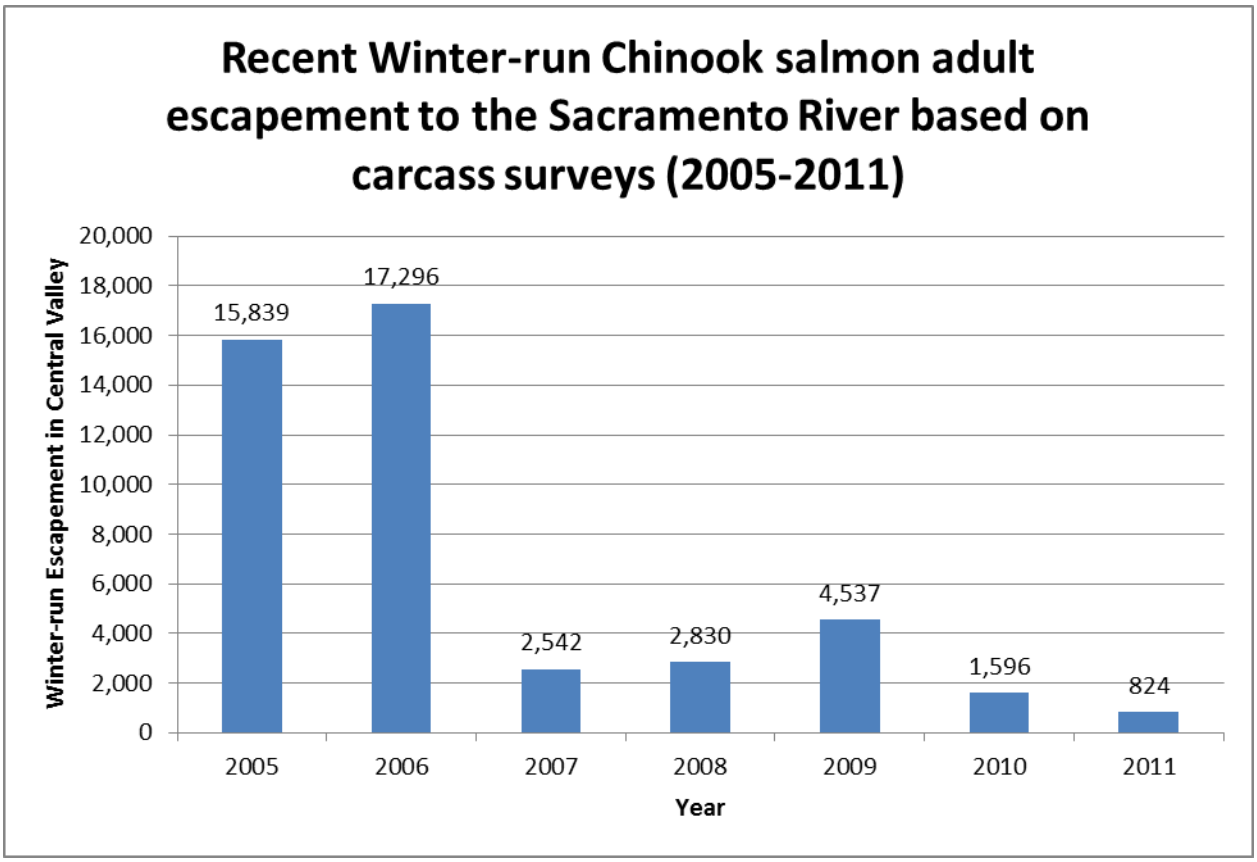


Figure 9: Annual cohort replacement rate for Sacramento River winter-run for the period 1999 to 2011 (NMFS 2011a, GrandTab February 1, 2011, CDFG survey data 2011).

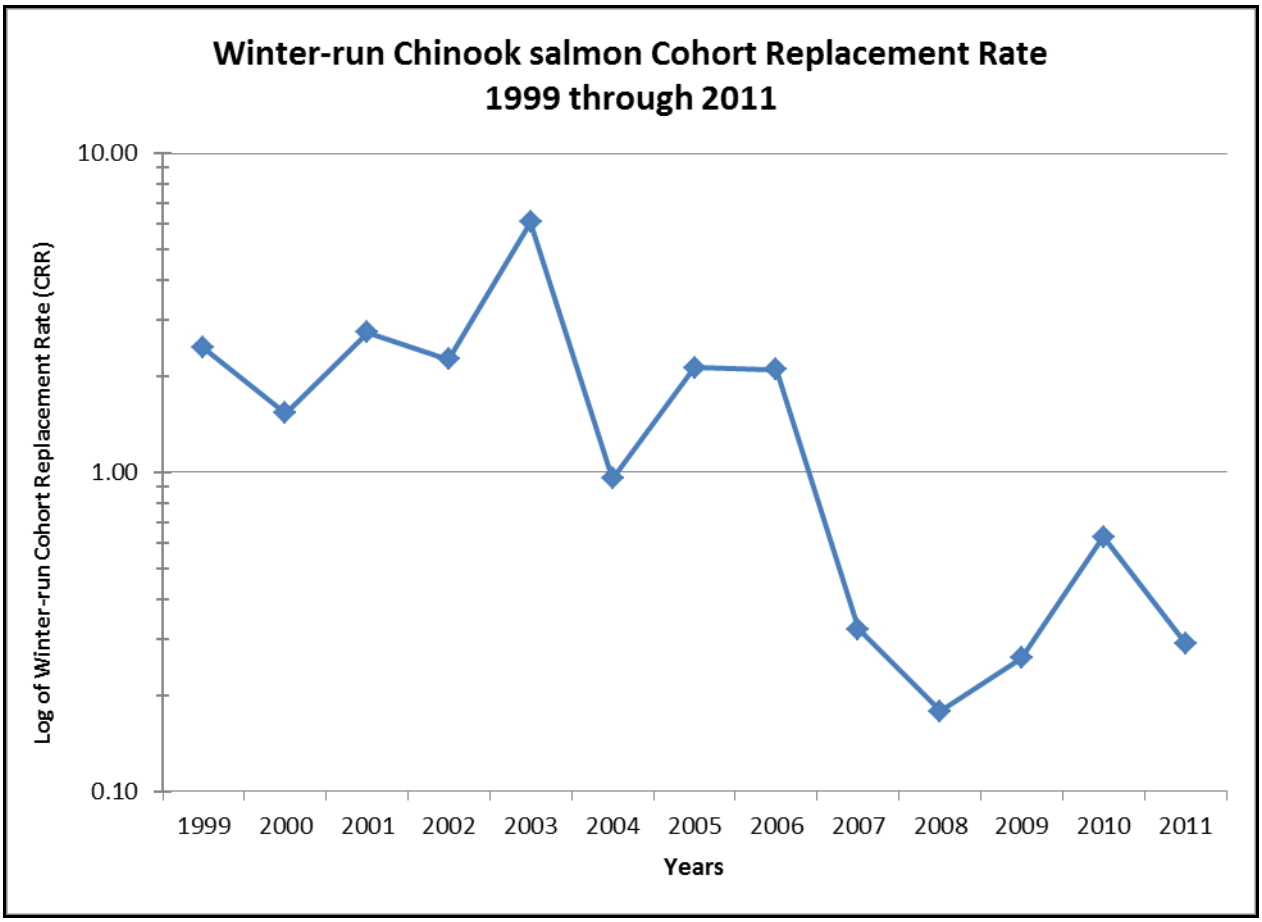


Figure 10: Current and historical distribution of Sacramento River winter-run Chinook salmon.

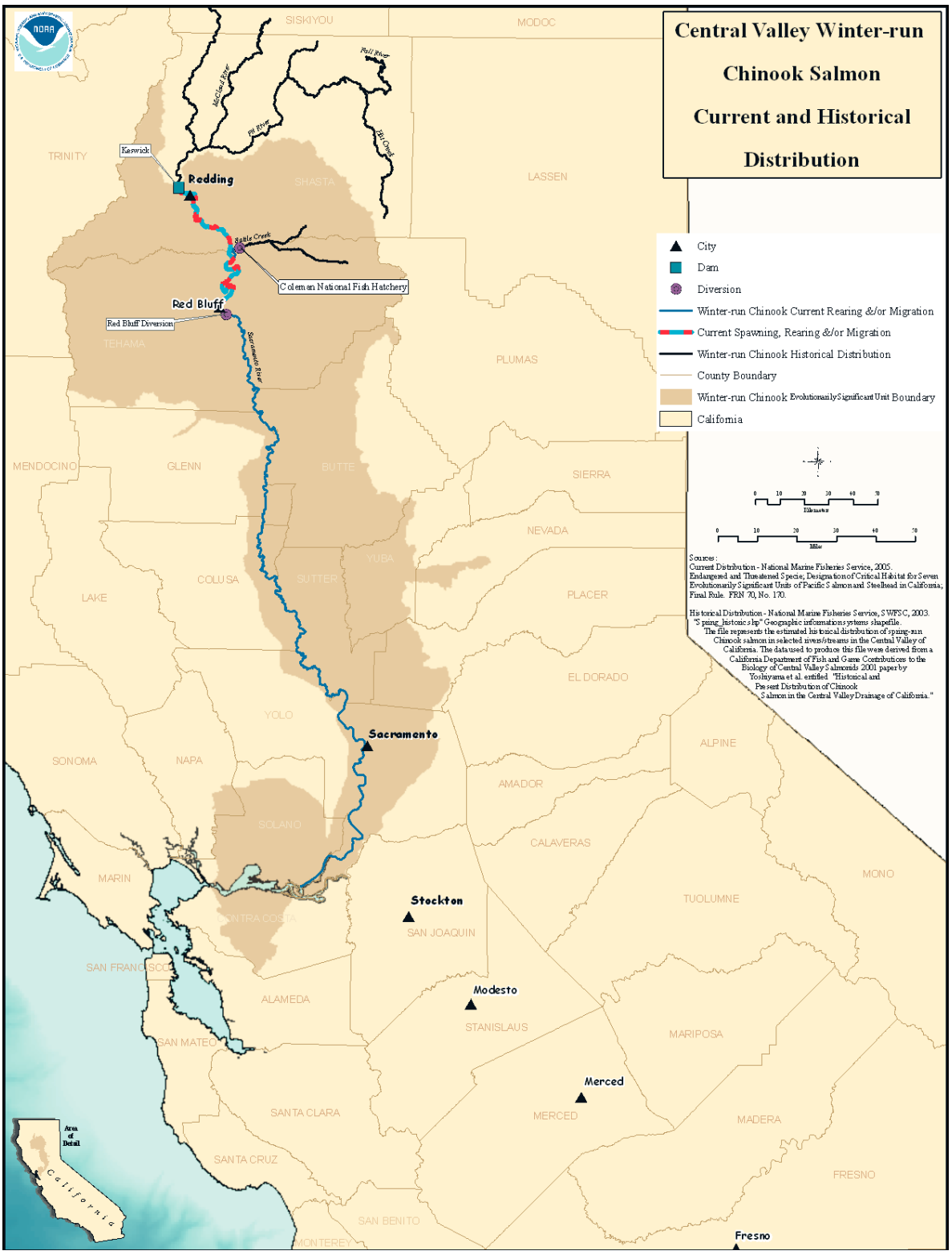


Figure 11: Annual estimated Central Valley in-river spring-run Chinook salmon escapement population for the Sacramento River watershed for years 1960 through 2011 (CDFG Grand Tab 2011).

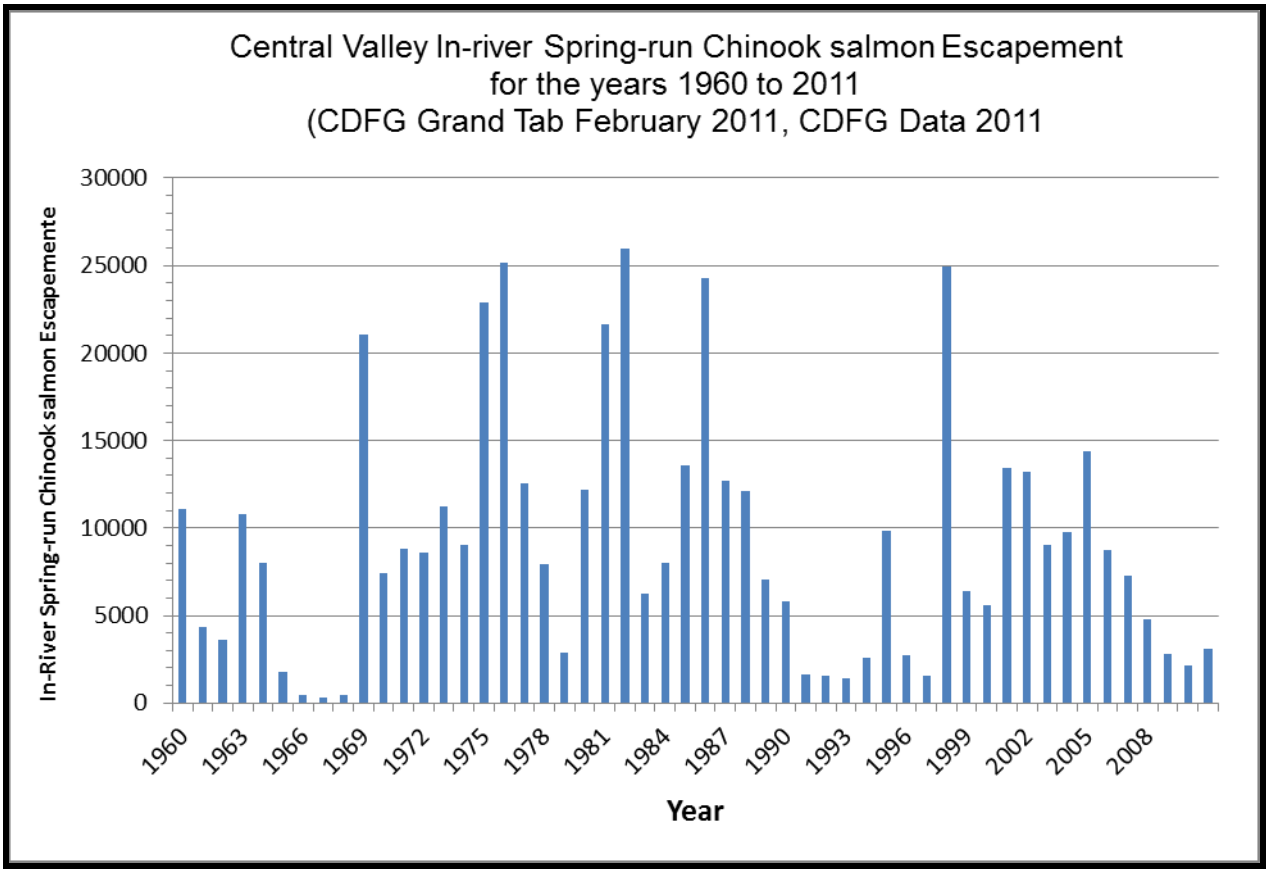


Figure 12: Adult escapement of Central Valley spring-run Chinook salmon for several tributary populations (1970 – 2010). Y-axis is in thousands of adult fish. Data from NMFS 2011b.

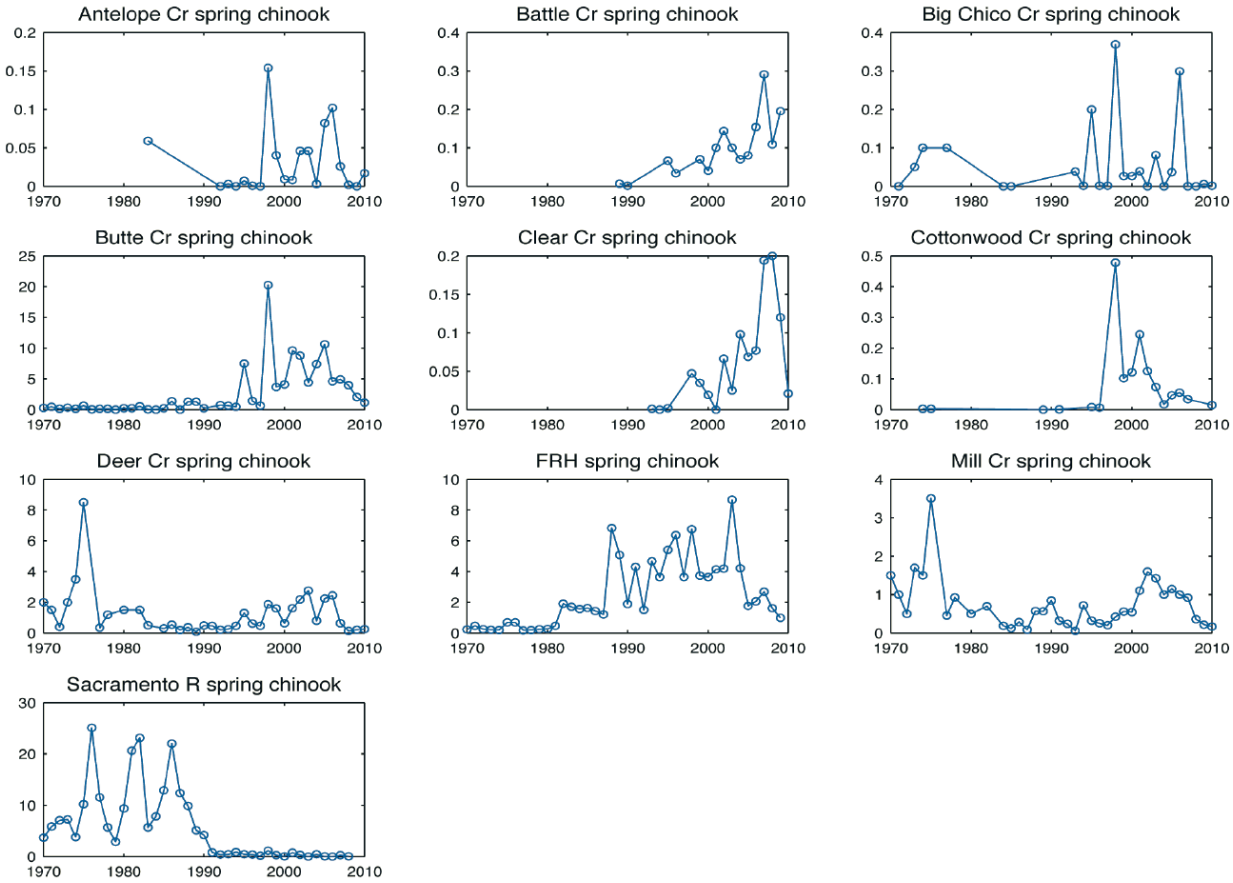
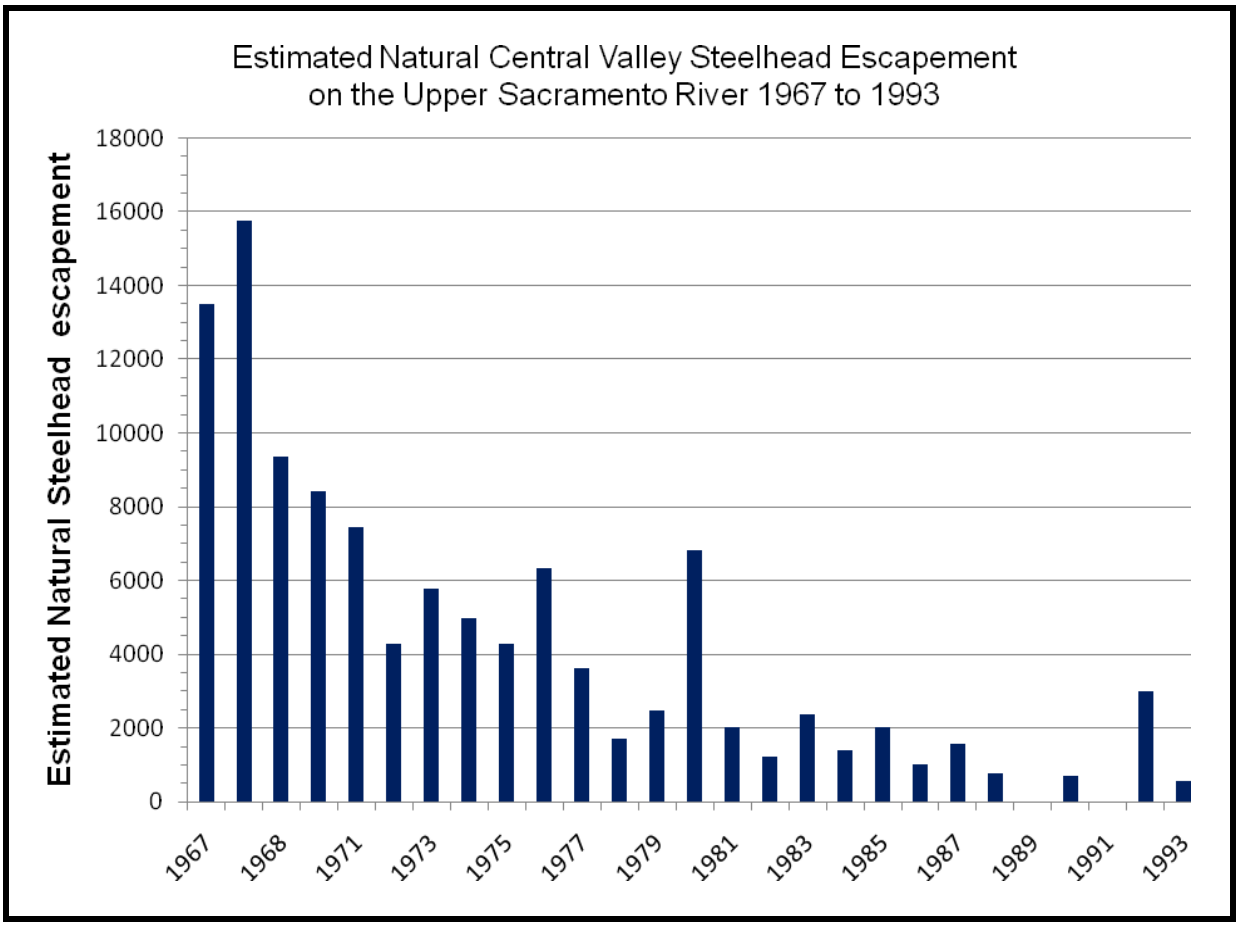


Figure 13: Estimated Central Valley natural steelhead escapement population in the upper Sacramento River based on RBDD counts.
Source: McEwan and Jackson 1996.



Note: Steelhead escapement surveys at RBDD ended in 1993

Figure 14: Annual number of Central Valley steelhead smolts caught while Kodiak trawling at the Mossdale monitoring location on the San Joaquin River (Marston 2004, SJRG 2007, Jonathan Speegle, USFWS 2008, personal communication).

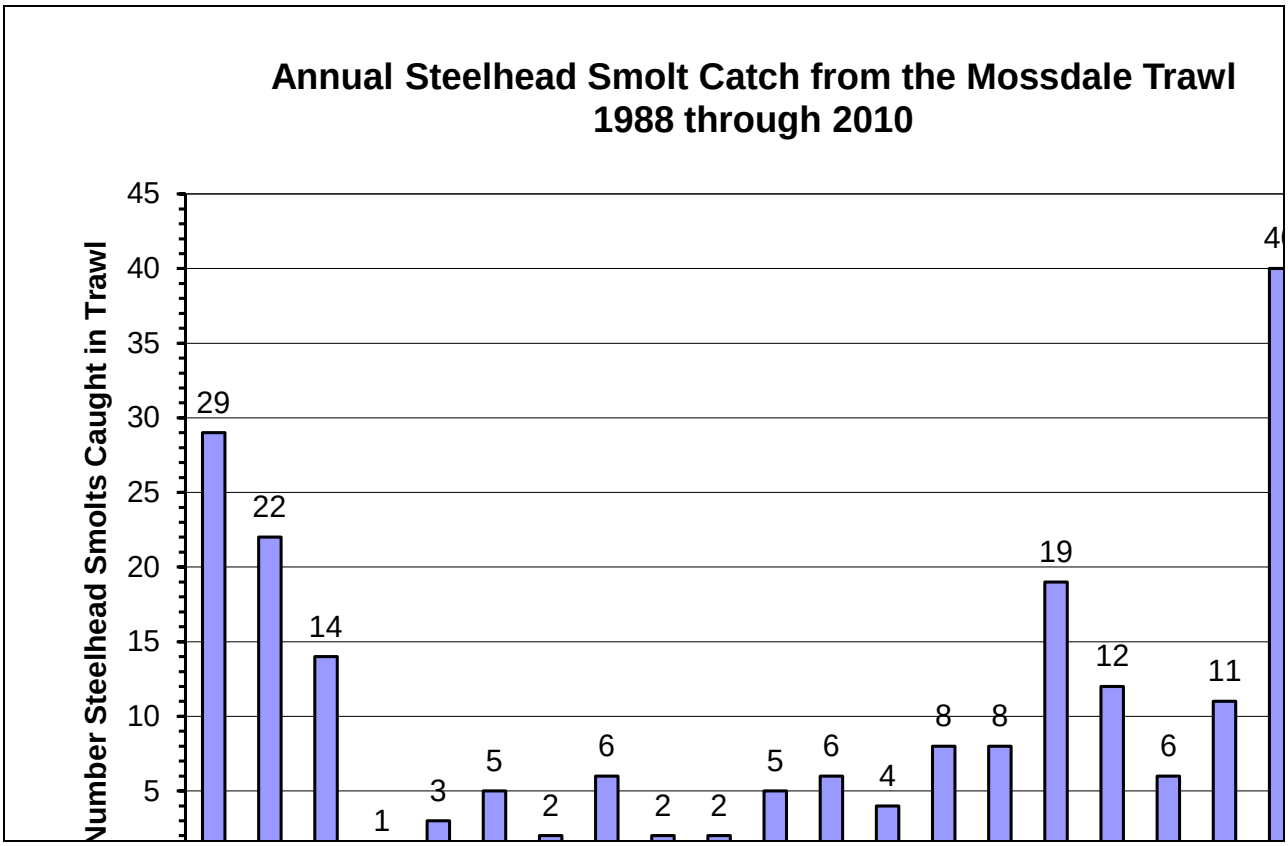


Figure 15: Top illustration - Catch of steelhead juveniles at Chipps Island by the USFWS midwater trawl survey from 1976 to 2010. Middle illustration – Fraction of the catch bearing an adipose fin clip. Vertical line denotes the start of 100% fin clipping of hatchery produced steelhead in 1998. Bottom illustration – Catch per unit effort in fish per million cubic meters of water swept through the survey nets.

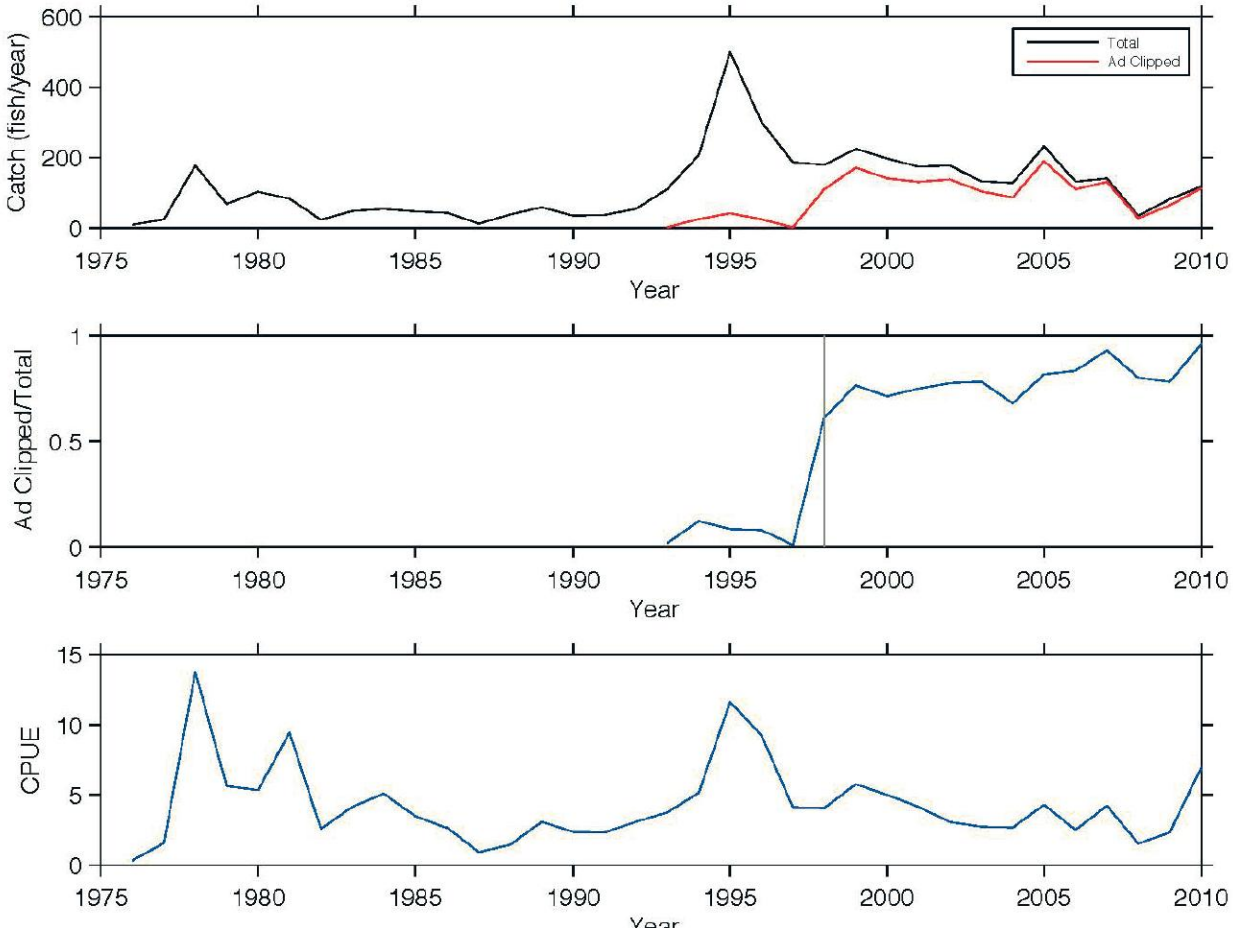


Figure 16: Steelhead salvaged in the delta fish collection facilities (CVP and SWP) from 1993 through 2010. All hatchery steelhead juveniles have been ad-clipped since 1998. Data from CDFG website: ftp.delta.dfg.ca.gov/salvage.

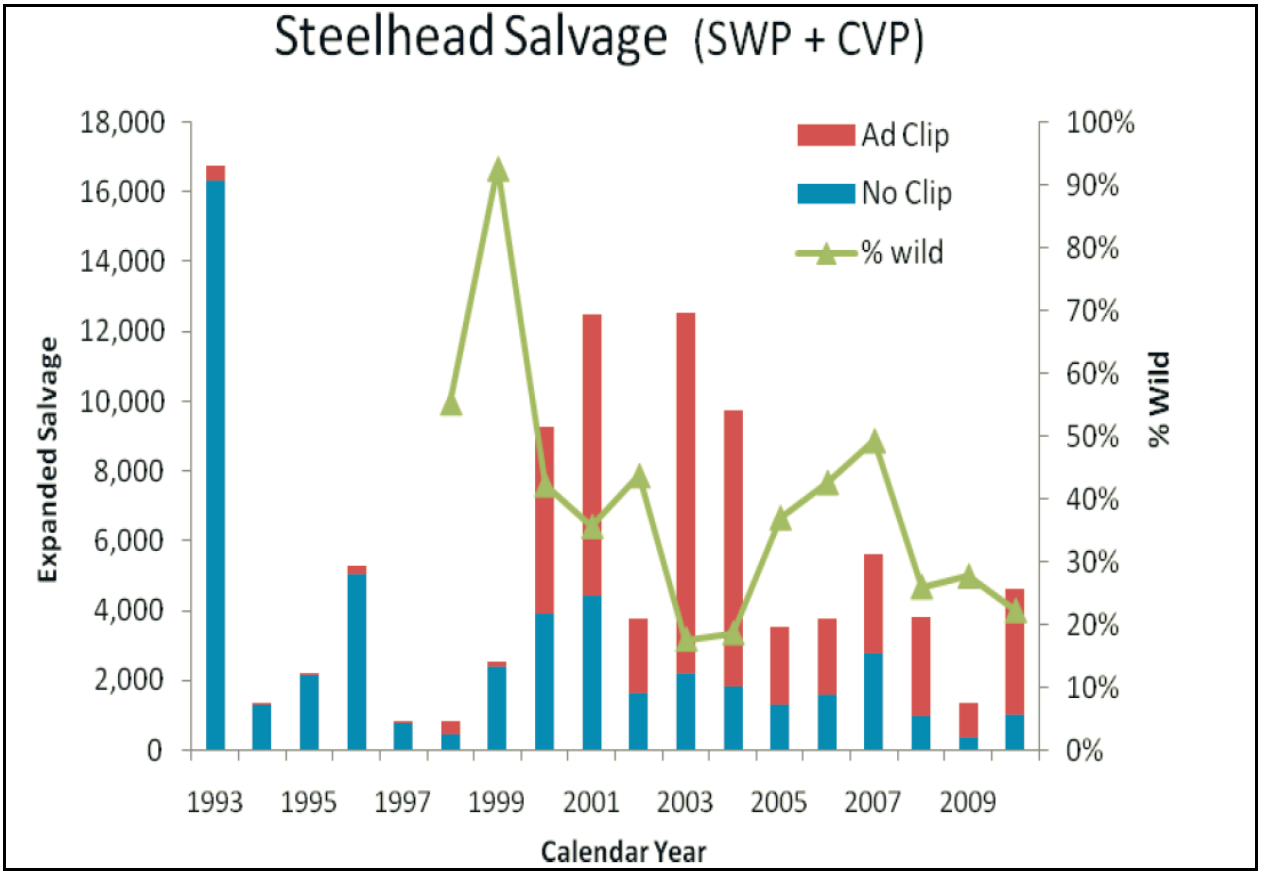


Figure 17: Annual return of adult steelhead to the Coleman National Fish Hatchery. Starting in 2003, fish were identified as either hatchery origin (ad-clipped) or naturally spawned (wild) fish. Data courtesy of USFWS as reported in NMFS 2011c.

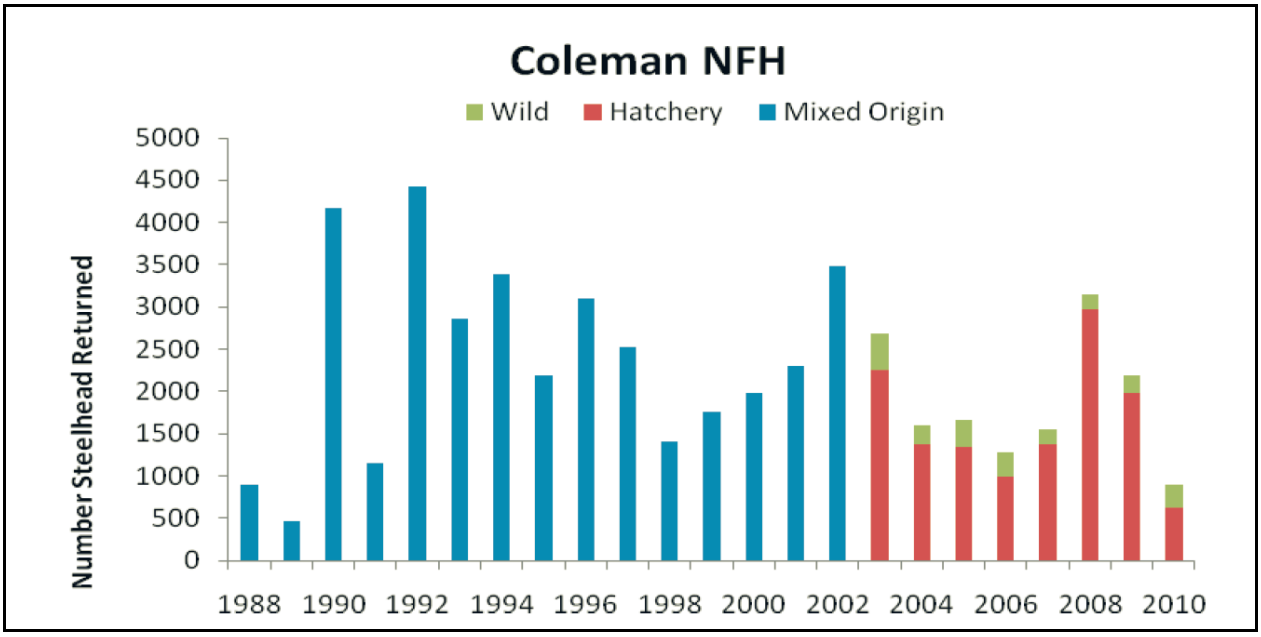


Figure 18a: Estimated number of North American green sturgeon (Southern DPS) salvaged from the State Water Project and the Central Valley Project fish collection facilities. Sources: Beamesderfer *et al.*, 2007, CDFG 2002, Adams *et al.* 2007.

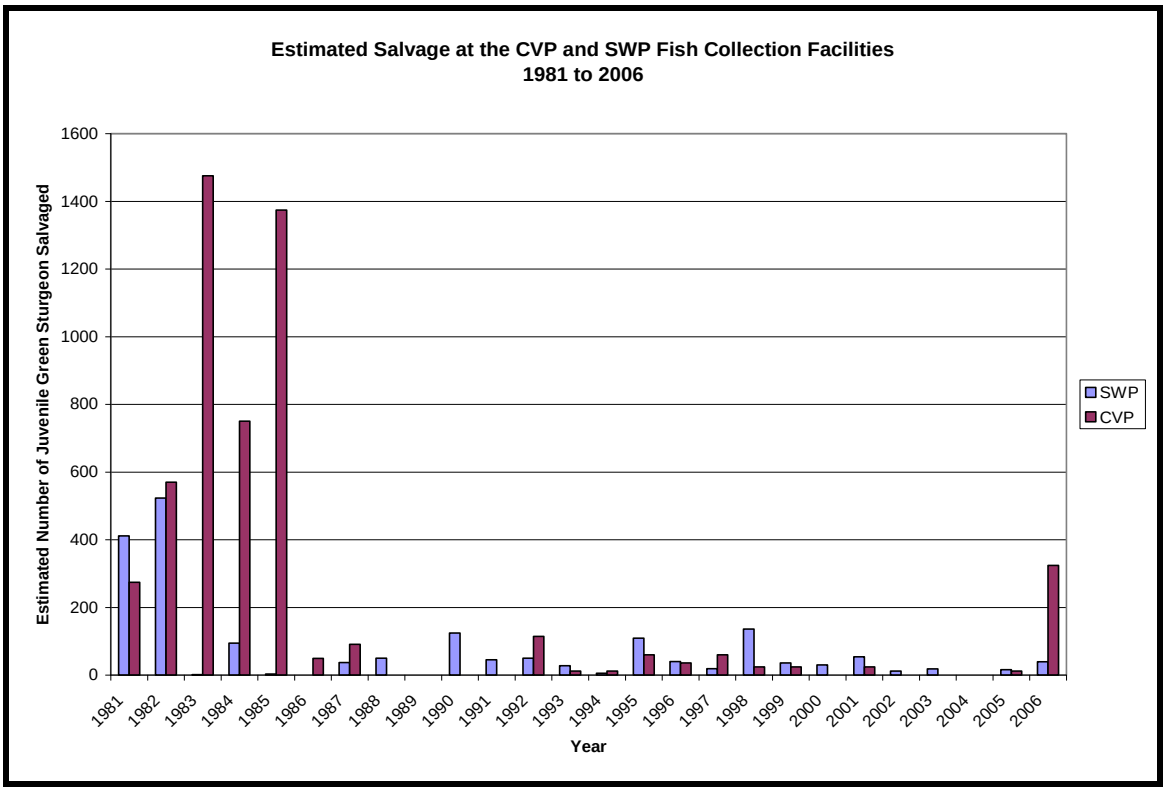


Figure 18b: Estimated number of North American green sturgeon (southern DPS) salvaged monthly from the State Water Project and the Central Valley Project fish collection facilities.

Source: CDFG 2002, unpublished CDFG records.

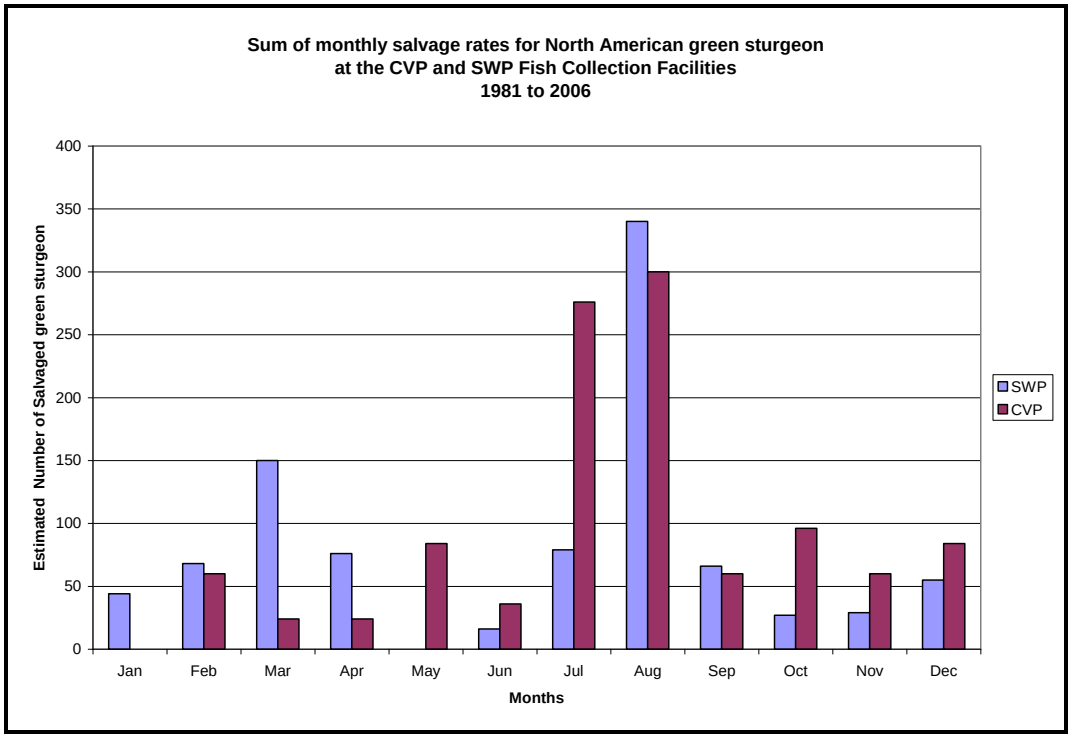


Figure 19: Sacramento winter-run Chinook salmon afe-3 ocean exploitation rate for the years 2000-2007. (NMFS 2011a citing O'Farrell *et al.* 2010).

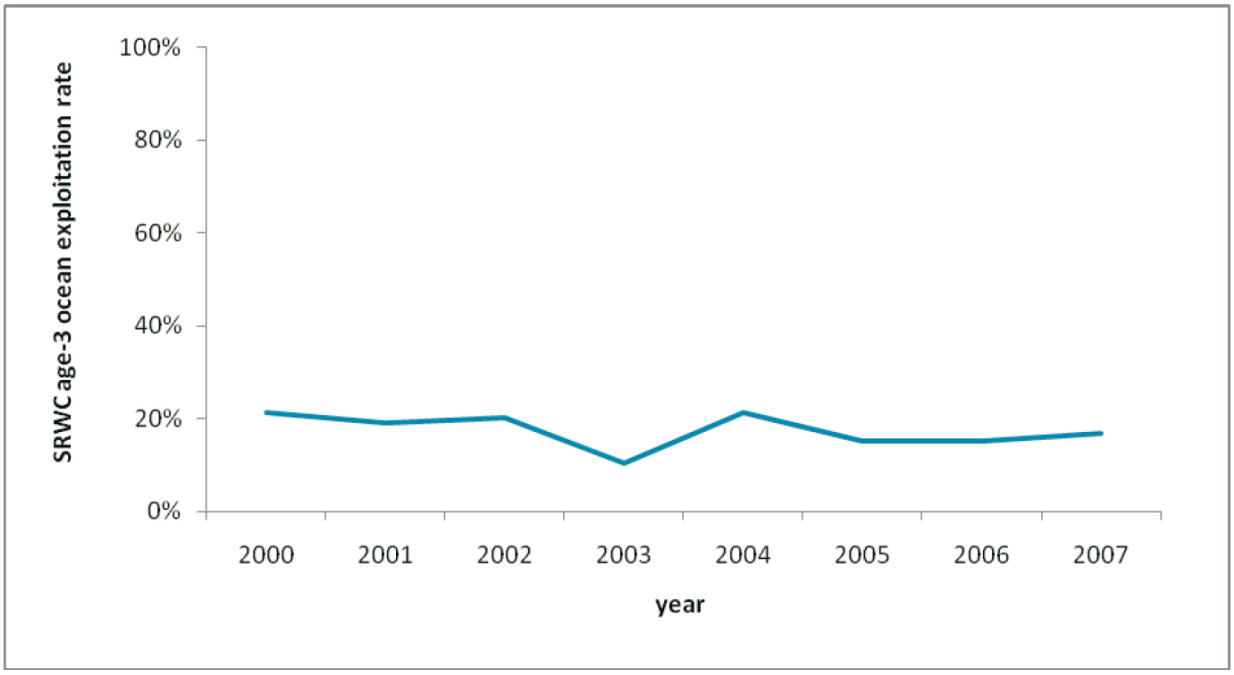


Figure 20: Sacramento River fall-run Chinook salmon ocean harvest rate index for the years 1983-2010. Data from PFMC 2010a,b, as reported in NMFS (2011b); 5-Year Review for Central Valley spring-run Chinook salmon ESU.

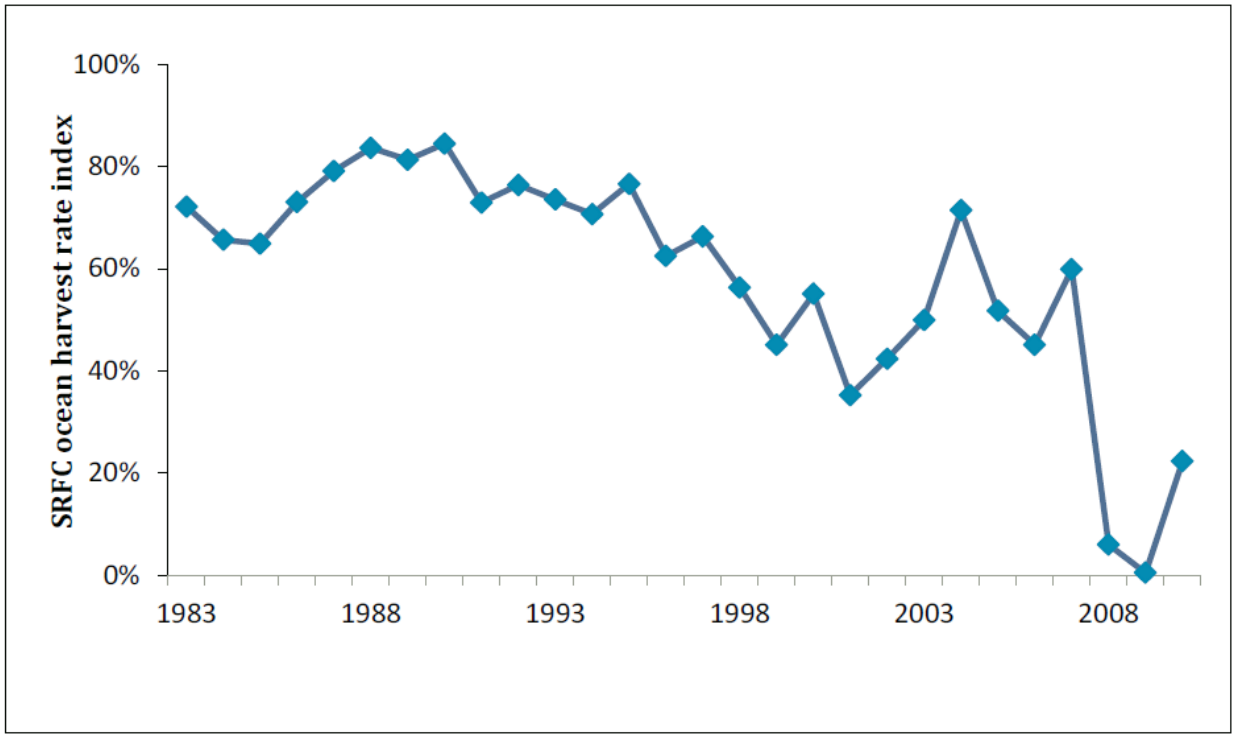


Figure 21: Time pattern of Sacramento River adult steelhead migration. Figure 2A shows migration timing from July through June of 1953 through 1959, determined by trapping upstream migrants in the Sacramento River just upstream of the confluence with the Feather River (from Hallock and others 1961). Figure 2B shows the weekly average number of adult steelhead counted at Red Bluff Diversion Dam from July through June of 1983 through 1986. (Figure 2 from McEwan 2001)

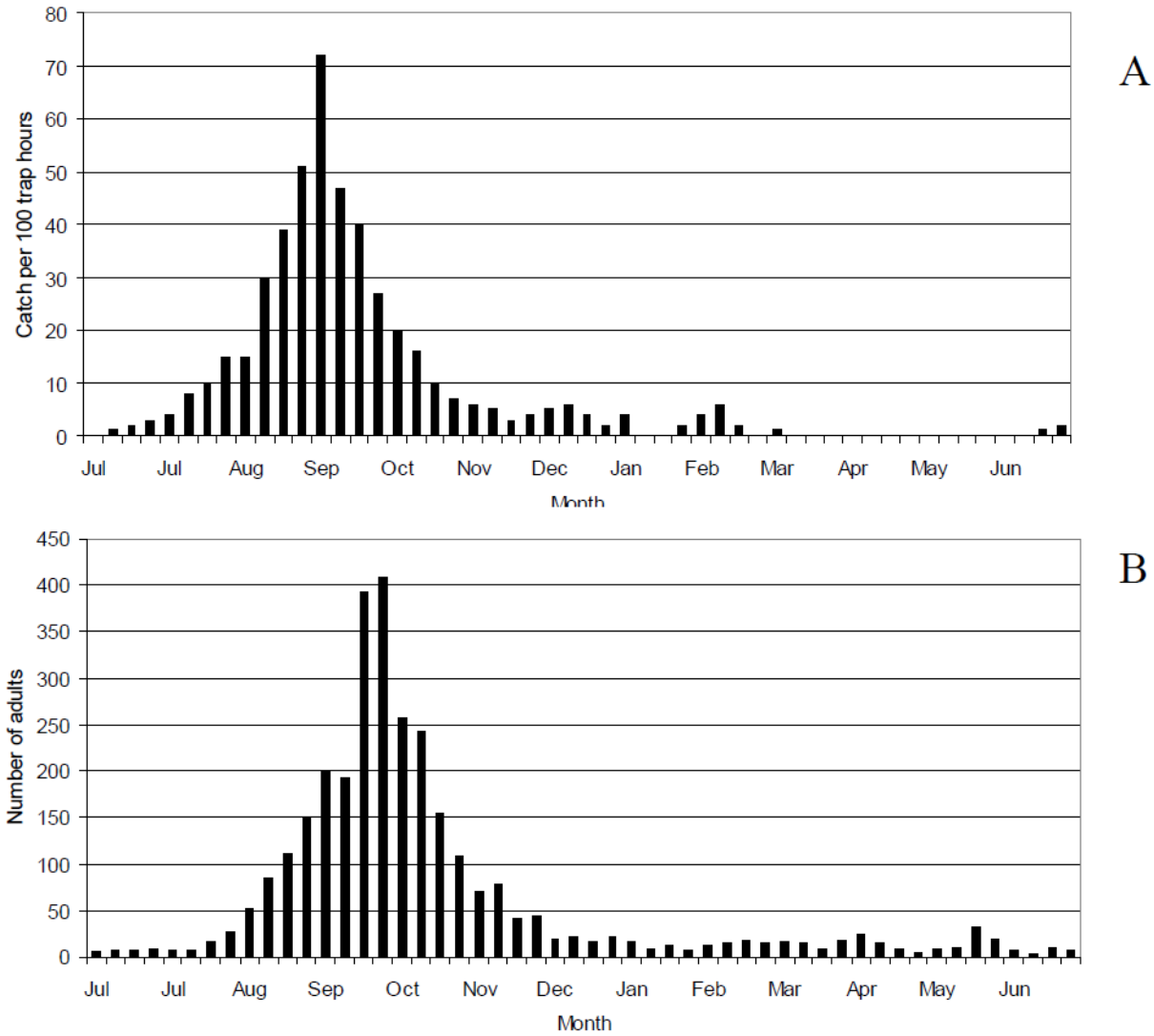


Figure 22: Typical anchoring mounts for hydroacoustic transducers and receivers used to secure devices to channel bottom.

Enclosure 2

Magnuson-Stevens Fishery Conservation and Management Act

ESSENTIAL FISH HABITAT CONSERVATION RECOMMENDATIONS

I. IDENTIFICATION OF ESSENTIAL FISH HABITAT

The Magnuson-Stevens Fishery Conservation and Management Act (MSA), as amended (16 U.S.C. § 1801 *et seq.*), requires that Essential Fish Habitat (EFH) be identified and described in Federal fishery management plans (FMPs). Federal action agencies must consult with NOAA's National Marine Fisheries Service (NMFS) on any activity which they fund, permit, or carry out that may adversely affect EFH. NMFS is required to provide EFH conservation and enhancement recommendations to the Federal action agencies.

EFH is defined as those waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity. For the purposes of interpreting the definition of EFH, "waters" includes aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include areas historically used by fish where appropriate; "substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities; "necessary" means habitat required to support a sustainable fishery and a healthy ecosystem; and, "spawning, breeding, feeding, or growth to maturity" covers all habitat types used by a species throughout its life cycle. The U.S. Army Corps of Engineers (Corps) requested consultation under the MSA for potential EFH impacts to Pacific salmon within the action area of the study. The proposed project site is within the region identified as EFH for Pacific salmon in Amendment 14 of the Pacific Salmon FMP. NMFS did not find that EFH for groundfish under Amendment 11 to the Pacific Coast Groundfish FMP (starry flounder, *Platicthys stellatus*) or coastal pelagics (northern anchovy, *Engraulis mordax*) under Amendment 8 of the Northern Anchovy Fishery Management Plan (Coastal Pelagics species FMP) would occur within the action area and thus would not be affected by the proposed study, therefore NMFS will confine its analysis to Pacific salmon EFH effects.

The Pacific Fishery Management Council (PFMC) has identified and described EFH, Adverse Impacts and Recommended Conservation Measures for salmon in Amendment 14 to the Pacific Coast Salmon FMP (PFMC 1999). Freshwater EFH for Pacific salmon in the California Central Valley includes waters currently or historically accessible to salmon within the Central Valley ecosystem as described in Myers *et al.* (1998), and includes the CALWATER Sacramento Delta (Delta) hydrologic unit (*i.e.*, number 5510). Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*), Central Valley spring-run Chinook salmon (*O. tshawytscha*), and Central Valley fall-/late fall-run Chinook salmon (*O. tshawytscha*) are species managed under the Salmon Plan that occur in the Delta unit.

Factors limiting salmon populations in the Delta include periodic reversed flows due to high water exports (drawing juveniles into large diversion pumps), loss of fish into unscreened agricultural diversions, predation by introduced species, and reduction in the quality and quantity of rearing habitat due to channelization, pollution, riprapping, *etc*. (Dettman *et al.* 1987; California Advisory Committee on Salmon and Steelhead Trout 1988, Kondolf *et al.* 1996a, 1996b). Factors affecting salmon populations in Suisun Bay include heavy industrialization within its watershed and discharge of wastewater effluents into the bay. Loss of vital wetland habitat along the fringes of the bay reduces rearing habitat and diminishes the functional processes that wetlands provide for the bay ecosystem.

A. Life History and Habitat Requirements

Pacific Salmon

General life history information for Central Valley Chinook salmon is summarized below. Information on Sacramento River winter-run and Central Valley spring-run Chinook salmon life histories is summarized in the preceding biological opinion for the proposed project (Enclosure 1). Further detailed information on Chinook salmon Evolutionarily Significant Units (ESUs) are available in the NMFS status review of Chinook salmon from Washington, Idaho, Oregon, and California (Myers *et al.* 1998), and the NMFS proposed rule for listing several ESUs of Chinook salmon (63 FR 11482, March 9, 1998).

Adult Central Valley fall-run Chinook salmon enter the Sacramento and San Joaquin Rivers from July through December and spawn from October through December while adult Central Valley late fall-run Chinook salmon enter the Sacramento and San Joaquin Rivers from October to April and spawn from January to April (U.S. Fish and Wildlife Service [FWS] 1998). Chinook salmon spawning generally occurs in clean loose gravel in swift, relatively shallow riffles or along the edges of fast runs (NMFS 1997).

Egg incubation occurs from October through March (Reynolds *et al.* 1993). Shortly after emergence from their gravel nests, most fry disperse downstream towards the Delta and into the San Francisco Bay and its estuarine waters (Kjelson *et al.* 1982). The remaining fry hide in the gravel or station in calm, shallow waters with bank cover such as tree roots, logs, and submerged or overhead vegetation. These juveniles feed and grow from January through mid-May, and emigrate to the Delta and estuary from mid-March through mid-June (Lister and Genoe 1970). As they grow, the juveniles associate with coarser substrates along the stream margin or farther from shore (Healey 1991). Along the emigration route, submerged and overhead cover in the form of rocks, aquatic and riparian vegetation, logs, and undercut banks provide habitat for food organisms, shade, and protect juveniles and smolts from predation. These smolts generally spend a very short time in the Delta and estuary before entry into the ocean. Whether entering the Delta or estuary as fry or juveniles, Central Valley Chinook salmon depend on passage through the Delta for access to the ocean.

II. PROPOSED ACTION

The proposed action is described in section II (*Description of the Proposed Action*) of the preceding biological opinion for endangered Sacramento River winter-run Chinook salmon, threatened Central Valley spring-run Chinook salmon, Central Valley steelhead (*O. mykiss*), threatened southern DPS of North American green sturgeon, and critical habitat for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead and southern DPS green sturgeon (Enclosure 1).

III. EFFECTS OF THE PROJECT ACTION

The effects of the proposed action on salmonid habitat are described at length in section V (*Effects of the Action*) of the preceding biological opinion, and generally are expected to apply to Pacific salmon EFH.

IV. CONCLUSION

Based on the best available information, NMFS believes that the proposed Georgiana Slough non-physical barrier study in 2012 may adversely affect EFH for Pacific salmon during its construction and operation.

V. EFH CONSERVATION RECOMMENDATIONS

NMFS recommends that the following conservation measures be implemented in the project action area, as addressed in Appendix A of Amendment 14 to the Pacific Coast Salmon Plan (PFMC 1999).

Riparian Habitat Management: In order to prevent adverse effects to riparian corridors, the Corps should:

- Maintain riparian management zones of appropriate width along Old River;
- Reduce erosion and runoff into waterways within the project area; and
- Minimize the use of chemical treatments within the riparian management zone to manage nuisance vegetation along the levee banks.

Bank Stabilization: The installation of riprap or other streambank stabilization devices can reduce or eliminate the development of side channels, functioning riparian and floodplain areas and off channel sloughs. In order to minimize these impacts, the Corps should:

- Use vegetative methods of bank erosion control whenever feasible. Hard bank protection should be a last resort when all other options have been explored and deemed unacceptable;

- Determine the cumulative effects of existing and proposed bio-engineered or bank hardening projects on salmon EFH, including prey species, before planning new bank stabilization projects; and

- Develop plans that minimize alterations or disturbance of the bank and existing riparian vegetation.

Conservation Measures for Construction/Urbanization: Activities associated with urbanization (*e.g.*, building construction, utility installation, road and bridge building, and storm water discharge) can significantly alter the land surface, soil, vegetation, and hydrology and subsequently adversely impact salmon EFH through habitat loss or modification. In order to minimize these impacts, the Corps and the applicant should:

- Plan development sites to minimize clearing and grading;

- Use Best Management Practices in building as well as road construction and maintenance operations such as avoiding ground disturbing activities during the wet season, minimizing the time disturbed lands are left exposed, using erosion prevention and sediment control methods, minimizing vegetation disturbance, maintaining buffers of vegetation around wetlands, streams and drainage ways, and avoid building activities in areas of steep slopes with highly erodible soils. Use methods such as sediment ponds, sediment traps, or other facilities designed to slow water runoff and trap sediment and nutrients; and

- Where feasible, reduce impervious surfaces.

Wastewater/Pollutant Discharges: Water quality essential to salmon and their habitat can be altered when pollutants are introduced through surface runoff, through direct discharges of pollutants into the water, when deposited pollutants are resuspended (*e.g.*, from dredging), and when flow is altered. Indirect sources of water pollution in salmon habitat includes run-off from streets, yards, and construction sites. In order to minimize these impacts, the Corps and the applicant should:

- Monitor water quality discharge following National Pollution Discharge Elimination System requirements from all discharge points;

- For those waters that are listed under Clean Water Act section 303 (d) criteria (*e.g.*, the Delta), work with State and Federal agencies to establish total maximum daily loads and develop appropriate management plans to attain management goals; and

- Establish and update, as necessary, pollution prevention plans, spill control practices, and spill control equipment for the handling and transport of toxic substances in salmon EFH

(*e.g.*, oil and fuel, organic solvents, raw cement residue, sanitary wastes, *etc.*). Consider bonds or other damage compensation mechanisms to cover clean-up, restoration, and mitigation costs.

VI. STATUTORY REQUIREMENTS

Section 305 (b) 4(B) of the MSA requires that the Federal lead agency provide NMFS with a detailed written response within 30 days, and 10 days in advance of any action, to the EFH conservation recommendations, including a description of measures adopted by the lead agency for avoiding, minimizing, or mitigating the impact of the project on EFH (50 CFR '600.920[k]). In the case of a response that is inconsistent with our recommendations, the Corps must explain its reasons for not following the recommendations, including the scientific justification for any disagreement with NMFS over the anticipated effects of the proposed action and the measures needed to avoid, minimize, or mitigate such effects.

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