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 10, 2012

In response refer to:
2011/05837

Kathleen A. Dadey, Ph.D.
Chief, California South Branch
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 construction and operation of the 2012 Georgiana Slough non-physical barrier study (GSNPB study) in Sacramento County for the 2012 study proposed by the California Department of Water Resources (DWR), 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 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, 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 GSNPB Study in a letter dated October 24, 2011, upon listed salmonids, green sturgeon, and their designated critical habitats. NMFS received this request from the Corps on November 1, 2011.

This biological opinion is based on information presented in the *Biological Assessment of the 2012 Georgiana Slough Non-physical Barrier Study for NMFS-Managed Species* which was prepared by the project environmental consultant ICF International, additional information provided by the California Department of Water Resources (DWR), and an extensive literature review completed by NMFS staff. 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 Georgiana Slough non-physical barrier study, including the construction and operation of the non-physical barrier, 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 construction of the Georgiana Slough non-physical barrier and the associated operations of the barrier for the 2012 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 Central Valley 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 Chu E Yu

Rodney R. McInnis
Regional Administrator

Enclosures (2)

cc: NMFS-PRD, Long Beach, CA.
Katherine Kelly, Chief, Bay-Delta Office, California Department of Water Resources, 1416 9th Street, Room 215-37, Sacramento, CA 95814
Mark Holderman, Chief, Temporary Barriers and Lower San Joaquin, California Department of Water Resources, 1416 9th Street, Sacramento, CA 95814
Ryan Olah, U.S. Fish and Wildlife Service, Cottage Way, Sacramento, California
Copy to file: 151422SWR2011SA00060

Enclosure 1

BIOLOGICAL OPINION

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

ACTIVITY: Formal consultation for the Department of Water Resources 2012 Georgiana Slough non-physical barrier study

CONSULTATION CONDUCTED BY: Southwest Region, National Marine Fisheries Service

FILE NUMBER: **151422SWR2011SA00060 (TN 2011/05837)**

DATE ISSUE: **February 10, 2012**

I. CONSULTATION HISTORY

On August 2, 2011, An electronic mail (email) was sent to the NOAA's National Marine Fisheries Service (NMFS) from ICF-International containing attached documents for the August 4, 2011, pre-application meeting with the United States Army Corps of Engineers (Corps) and the California Department of Water Resources (DWR) regarding the 2012 Georgiana Slough Non-Physical Barrier study (GSNPB study). The U.S. Fish and Wildlife Service (FWS), California Department of Fish and Game (DFG), and the California Regional Water Quality Control Board (Regional Board) were copied on the email.

On August 4, 2011, a pre-application meeting was held at the Corps' office to discuss the 2012 GSNPB study.

On October 12, 2011, an email was sent from DWR to NMFS with a copy of the final version of the Biological Assessment for the 2012 GSNPB study that was sent to the Corps as part of the project initiation package.

On November 1, 2011, an initiation package requesting formal section 7 consultation under the Endangered Species Act (ESA) was received by NMFS from the Corps for the 2012 GSNPB study.

On November 4, 2011, the Corps sent copies of an email from the FWS to DWR requesting information regarding the removal of the barrier following completion of the study.

On November 8, 2011, the Corps sent copies of an email from the FWS to DWR requesting information regarding the locations of the hydrophones to be deployed in the upstream and downstream locations in the Sacramento River, as well as the location of the Georgiana Slough hydrophones deployed downstream of the barrier location.

On November 10, 2011, the Corps sent copies of an email from the FWS to DWR requesting information regarding the locations of deployment of the hydrophones used in estimating survival through the Delta waterways of acoustical tagged Chinook salmon used in the 2012 GSNPB study.

On November 17, 2011, the Corps sent copies of an email from the FWS to DWR requesting information regarding the Hazardous Material Management Plan (HMMP) and the Storm Water Pollution Prevention Plan (SWPPP) used in the 2011 GSNPB study.

On December 1, 2011, NMFS sent an email request to the Corps to clarify which nationwide permit(s) were being sought by DWR for the 2012 GSNPB study.

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

II. DESCRIPTION OF THE PROPOSED ACTION

A. General Overview

1. Introduction

On June 4, 2009, NMFS issued the Biological Opinion (BiOp or Opinion) for the Central Valley Project (CVP) and the State Water Project (SWP) Operations and Criteria Plan (OCAP) (National Marine Fisheries Service 2009a). This Opinion included a Reasonable and Prudent Alternative (RPA), divided into several separate actions, that NMFS believes will avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat. The RPA was divided into suites of actions related to the geographic areas affected by the project. Actions within suite IV are intended to focus on the Sacramento-San Joaquin River Delta (Delta) portion of the project. RPA Action IV.1.3 requires that the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) and/or DWR consider engineering solutions to further reduce the diversion of juvenile salmonids into the interior and southern Sacramento–San Joaquin River Delta (Delta), and reduce exposure of the emigrating fish to SWP and CVP export facilities. This action is based on salmon migration studies that have shown losses of approximately 65 percent of outmigrating fish that are diverted from the mainstem Sacramento River into the waterways of the internal Delta. Diversion into the internal Delta increases the likelihood of predation, entrainment, and mortality associated with the SWP and CVP export facilities in the south Delta.

As directed by RPA Action IV.1.3 and described above, DWR plans to investigate engineering alternatives to reduce the diversion of juvenile salmonids into the interior Delta. One such proposed alternative is the installation and operation of a non-physical barrier (NPB) consisting of a bio-acoustic fish fence (BAFF) at the divergence of Georgiana Slough from the Sacramento River. Several laboratory studies as well as information collected at a similar barrier installed at the head of Old River in the San Joaquin River basin in 2009 and 2010, and information collected in the spring of 2011 from the pilot study for this proposed project, indicate that the non-physical barrier has the potential to meet the requirement set forth in the OCAP RPA action. The 2011 pilot study tested the non-physical barrier concept at the Georgiana Slough location under field conditions. DWR is proposing a second year of study in 2012 at the Georgiana Slough field site, called the 2012 Georgiana Slough non-physical barrier study (2012 GSNPB study). Data from the 2012 study season will be used with data collected in 2011 to test the effectiveness of the barrier using BAFF techniques in the Georgiana Slough location. Additionally, DWR believes that the 2012 GSNPB study benefits would include:

1. Potentially reduce the impacts of the SWP and CVP operations on outmigrating salmon smolts by keeping them in the Sacramento River system and preventing them from entering the central and south Delta via Georgiana Slough;

2. maintaining SWP compliance with the federal Endangered Species Act (ESA); and

3. increasing the likelihood of successfully implementing improved through-Delta conveyance options.

2. Regulatory Framework

This Opinion is required as part of the Corps permitting of the proposed 2011 GSNPB Project under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act. The nationwide permits (NWPs) associated with this project are NWP 4, Fish and Wildlife Harvesting, Enhancement, and Attraction Devices and Activities, and NWP 6, Survey Activities 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 Central Valley steelhead (*O. mykiss*) distinct population segment (DPS), and the Southern DPS of the North American green sturgeon (*Acipenser medirostris*). The Corps also determined that the project will 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.

3. Project Purpose

The 2012 GSNPB Project will install and operate a non-physical barrier at the divergence of Georgiana Slough and the Sacramento River (Figure 1). The barrier is intended to create a behavioral deterrent for outmigrating juvenile salmonids that prevents entry into Georgiana Slough using sound, bubbles, and lights. In order to evaluate the efficacy of the barrier as a fish deterrent at this location, the 2012 study protocol calls for a series of controlled experimental releases of acoustically-tagged juvenile salmon smolts into the Sacramento River upstream of the Georgiana Slough barrier. According to the experimental design, fish will be released approximately 3 to 6 miles upstream of the barrier over the operational period of the study. Multiple hydroacoustic listening arrays will continuously monitor the area surrounding the barrier for the presence of the acoustically tagged fish, their position within the river channel, and their passage and fate through the study area. BAFF construction would begin in mid- to late January 2012. Following installation, the barrier would be operated for up to 60 days beginning as early as February 1, 2012. Upon completion of the experimental studies, the entire barrier structure and associated support structures and equipment would be removed completely from the river channel no later than June 30, 2012.

B. Project Actions

1. Barrier Design

The barrier employs the same technology that was used in the 2011 Georgiana Slough non-physical barrier study, with a few minor modifications to the design of the barrier. The barrier to be installed at the divergence of the Sacramento River and Georgiana Slough is a multi-stimulus fish barrier that combines high-intensity light-emitting diode (LED) Modulated Intense Lights (MILs), an air bubble “curtain”, and sound at frequencies and levels that are repellent to Chinook salmon (Bowen et al. 2009; Bowen and Bark 2010). The sound system and MIL flash rate can be tuned to known sensitivities of various fish species. Investigations have indicated that the most effective acoustic deterrents for multiple fish species fall within the sound frequency range of 5 to 600 hertz (Hz) (Bowen and Bark 2010). Studies with Chinook salmon and delta smelt (*Hypomesus transpacificus*) have shown that when the sound and strobe light flash rate were tuned according to these species’ sensitivities, the barrier was particularly effective as a deterrent for Chinook salmon smolts (Bowen et al. 2008). Based on these studies, it has been hypothesized that the sound is the predominant deterrent. The sound is trapped by refraction within the bubble curtain, producing a sharply defined sound field that fish do not detect until they are within a few meters of the barrier. The flashing MILs are aligned such that the light beam projects onto the bubble curtain, creating a visual shape that is readily detectable by the fish. This helps identify the bubble curtain as the source of the sounds. The narrow, vertical MIL beam minimizes light saturation within the experimental area.

The proposed barrier for the 2012 study may be slightly modified from that which was constructed in the 2011 study. The 2011 non-physical barrier was approximately 630 feet long, comprised of 16 separate, approximately 39.4-foot frame sections held in place by 15 piles. The proposed design for 2012 includes 18 sections and up to 19 pilings to allow minor adjustments to the orientation of the barrier to the river channel. Each frame section would have approximately six sound projectors, 12 MILs, and a perforated “bubble” pipe (Figure 2). The bubble pipe would be positioned along each frame below and upstream of the sound projectors. A bubble curtain would be created by passing compressed air into the perforated pipe. Air flow rate would typically be 1.38 cubic feet per minute (cfm) per linear foot length of barrier. The MILs would be powered from an “accumulator” positioned on each frame section. A mounting plate would be attached to the support tray to house the accumulators. The junction of each frame section can pivot with the adjacent section, and where needed each frame section can be supported at either end with a piling or support column to a pier block. The frame sections could be adjusted vertically at the pile attachments to adjust for the uneven river bed contour. The sections would be positioned along the barrier line such that as much of the barrier as possible is at a depth where the high tide bubble curtain is less than 12 feet. In the main portion of the channel, this is approximately 12 feet from the channel bottom. The top of the frame sections will be at least 8 feet from the water surface elevation at low tide. The interior barrier frames will be supported by up to 17, one-foot diameter (nominal) steel piles driven into the river bottom. The outside barrier frame ends would be secured to formed, streamlined concrete pier blocks. Piles may be used in shallower water closer to the shore to ensure that the system remains in alignment if the bottom composition appears unstable. Up to 38 concrete anchors may be used for construction purposes such as anchoring docks, signs, buoys, or fish tracking equipment.

The barrier will be situated at the head of Georgiana Slough, where the slough diverges from the Sacramento River in a southerly direction. The barrier alignment will have a slight curvature to it, extending out into the channel of the Sacramento River to the north. The barrier will extend from the southern bank of the Sacramento River just upstream of the mouth of Georgiana Slough, across the channel of Georgiana Slough, and then to the opposite bank, in a south westerly direction (see Figure 3).

2. Acoustic Telemetry Tracking System

The acoustic tag tracking system would consist of acoustic tags implanted in a projected 1,500 to 6,000 juvenile late fall-run Chinook salmon produced in the United States Fish and Wildlife Service (FWS) Coleman National Fish Hatchery, placement of underwater hydrophones, onshore receivers, data loggers, and data processing and storage computers. In addition, 50 to 75 predatory fish (e.g., striped bass [*Morone saxitalis*], catfish [Ictaluridae], and smallmouth bass [*Micropterus dolmieu*]) would also be caught, tagged, released, and tracked throughout the study (DWR 2012).

Each acoustic tag transmits an underwater sound signal (i.e., an acoustic "ping") that sends identification information about the tagged fish to the hydrophones. In 2011, 38 hydrophones were used in the study. Thirty hydrophones were deployed at specific locations in the vicinity of the Georgiana Slough barrier, both immediately upstream and downstream of the barrier location in the two river channels. The hydrophones were deployed at defined locations near the barrier with optimal spacing of the hydrophones to provide three-dimensional (3D) tracking of tagged fish within the area proximal to the barrier. Resolution of fish movement near the barrier was in the sub-meter range. Eight hydrophones were also deployed in pairs approximately 8 miles upstream of the BAFF in the Sacramento River and approximately 2-miles downstream of the BAFF in both Georgiana Slough and the Sacramento River in order to evaluate survival of those fish that successfully passed the barrier location.

The 2012 hydrophone configuration will consist of up to 50 hydrophones deployed in the vicinity of the Georgiana Slough Barrier location as well as in other Delta locations. Approximately 30 of these hydrophones will be deployed in close proximity to the barrier, such as was done in the 2011 experiment. The hydrophones will be strategically placed both horizontally and vertically to maximize the 3-D resolution of acoustically tagged fish moving through the instrumented area. As in 2011, a total of 8 hydrophones will be deployed in pairs approximately 6 miles upstream of the Georgiana Slough study area (2 pairs) and 2 miles downstream of the of the BAFF location in both the Sacramento River and Georgiana Slough (1 pair each location). Each hydrophone would be connected by cable to a receiver. Hydrophones in the immediate vicinity of the barrier would be connected to multi-port receivers housed in the equipment trailer, and other hydrophones would be connected to individual receivers in small utility boxes located on the banks of the waterway. Included in the 50 hydrophones proposed for the 2012 study, is a fish tracking component that will help to clarify the survival of tagged fish through the Delta after encountering the BAFF at the Georgiana Slough location. Hydrophones will be located at various channel junctions within the delta. Junctions under consideration for hydrophone deployment include sloughs adjacent to Ryer Island, Prospect Island, Hastings Tract, Sutter Island, Merrit Island, Andrus Island, Brannan Island, Grand Island, and Staten Island. No more than 12 receivers will be included in this portion of the 2012 study. However, if insufficient funding or other impediments to the implementation of this survival tracking portion of the 2012 study are encountered, then this portion of the study may be abandoned by DWR, and the number of receiver locations reduced accordingly.

Approximately 44 of the 50 proposed hydrophones will be positioned below the surface of the water in a mid-water column configuration (24 hydrophones for the 3D array, eight peripheral hydrophones, and 12 survival hydrophones) which would be deployed in the Sacramento River and Georgiana Slough channels. Surface signs and buoys would indicate the general area of all or some of the below surface hydrophones to alert boat traffic of their locations and their potential hazard to navigation. Some below surface hydrophones will be attached to steel cables secured to concrete anchors positioned on the bottom. The concrete anchors are approximately two feet wide, four feet long, and two feet thick or, alternatively, steel weights approximately two to three feet long by eight inches wide may be used to secure the hydrophones in place on the bottom of the river channel. A floating buoy would be attached to the other end of the cable so that the cable is pulled tight between the weight and the buoy. The buoy may be positioned to float on the water's surface, or it may be fixed at some distance below the water surface so that there is no surface presence of the buoy and cable. In addition, guy wires may be attached to the buoy and extended diagonally to anchor points on the river bottom to minimize hydrophone movement in the water currents present in the river. The approximate locations of the concrete or steel anchoring points are given in Figure 3 and correspond to the locations of the below surface hydrophone locations.

In addition to the concrete or steel anchor points described above, the below surface hydrophones may also be attached to small steel frames or fabricated steel structures, typically referred to as "tower" or "pound-in" mounts. The steel structure would be lowered by a boat-mounted winch or by hand to the river bottom. Hydrophone cables and structure recovery cables would be routed along the river bottom to shore receivers and anchor points.

Hydrophones may also be attached to nearby physical shore structures (e.g., docks or marina pilings) or to the temporary piles (shown on Figure 3) used to construct the barrier. The hydrophones would be positioned near the channel bottom with the cables running down the pile to the channel bottom and routed to shore facilities. The temporary piles would extend above the water surface and be clearly marked with signals and lights to alert all boat traffic of their locations as prescribed by the U.S. Coast Guard regulations.

Besides the sub-surface hydrophones, approximately 6 of the 50 proposed hydrophones would be surface hydrophones. These would be deployed near the physical structure of the BAFF, in both an upstream and downstream configuration (see Figure 3 for approximate locations). Surface signs and buoys would be attached to all of the surface hydrophones to alert boat traffic to their locations. Surface oriented hydrophones would be attached to the temporary piles below the lowest anticipated water surface elevation with the cables running down the pile to the channel bottom and then routed to shore side receiver locations. The temporary piles would extend above the water surface and be clearly marked with signals and lights as prescribed by the U.S. Coast Guard to alert all boat traffic to their locations.

If temporary piles are not a viable option for a particular surface hydrophone location, then the surface hydrophones will be attached to small floating buoys or boats tethered to concrete anchors placed on the river bottom (Figure 4 shows a typical concrete anchor). Each hydrophone would be attached to the buoy or boat device at the required depth below the water surface and the hydrophone cable would be routed down the tether to the river bottom and then to the shore side receiver unit.

3. Visual Tracking System

DWR currently owns a Dual-Frequency Identification Sonar (DIDSON) camera that has been used successfully in making observations of predator and prey fish within the Delta. As part of the 2012 experimental study it has been proposed that a DIDSON camera (supplied by DWR or through lease) will periodically be deployed immediately upstream of the non-physical barrier. The camera would be placed on a pile near the shore and the downstream terminus of the barrier (see Figure 3). The detection cone will be aimed along the outside edge of the barrier air bubble curtain. The DIDSON would record data prior to and after the barrier is turned on or off as well as during other times that visual tracking benefits the experiment. Results of the DIDSON observations will be qualitative but will be used as part of the overall experimental design to provide additional information on the occurrence and behavior of predatory fish immediately associated with the barrier.

4. Construction of Barrier

In 2011 construction of the proposed barrier took a total of 35 days: 14 days for initial site setup and staging, and 21 days for in-water work (including pile driving and BAFF assembly & installation). However, the number of piles proposed for the 2012 BAFF is greater than in the 2011 study, and the nature of in-water work makes it highly dependent on weather and flow conditions as to whether construction activities can be conducted. Wet weather, high river flows, and increased pile driving requirements have the potential to make in-water work conditions unsafe during the construction period, thus halting work and delaying the completion of the construction phase of the project. In anticipation of these potential delays and to account for the increased number of piles, the applicant (DWR) has predicted that a total of 42 construction days are required between December 12, 2011, and March 31, 2012, to complete the construction phase of the study. The initial site setup and staging is anticipated to take no more than 14 days to complete and will occur between December 12, 2011, and March 2, 2012. DWR is planning for the potential of an extended in-water work period of 28 days to occur between January 1 through March 31, 2012, to conduct BAFF construction, and scientific equipment deployment activities. Construction and related site cleanup activities would occur during daylight hours, up to 12 hours per day, seven days per week, during the proposed construction period.

As previously indicated above, in-water construction activities and system startup and testing would require approximately 28 working days from January 1 to March 31, 2012. The barrier construction would begin with installation of the steel piling BAFF foundation and concrete pier block supports. Between sixteen and twenty-six, 12-inch-nominal-diameter steel piles (15 to 19 piles for the BAFF support frame, 0 to 6 piles for mounting surface hydrophones, and 1 pile for mounting the DIDSON camera) would be driven with a barge mounted vibratory pile driver in the wetted river channel. The total surface area of river bottom affected by installation of the piles would be approximately 26 square feet (<0.001 acre). Up to four concrete pier block supports would be placed on the river bank below the ordinary high water mark. Each concrete pier block support has a base area of approximately 18 square feet; the total surface area of river bank below the ordinary high water mark temporarily filled by the concrete blocks would be approximately 72 square feet (0.002 acre).

Repositioning the barge and loading each pile prior to vibratory pile driving is estimated to take up to one hour. Positioning the pile into the predetermined location for the support structure may take an additional 30 minutes. Piles that were driven during the 2011 project took an average of 5 minutes of vibratory driving per pile (see Table 1). It is assumed that pile driving in 2012 will also require an average of approximately 5 minutes of vibratory driving per pile to achieve 25 feet of embedment into the river bed substrate.

The installation of all of the proposed piles would occur over a period of up to 21 days within the proposed 28-day in-water construction period. Following installation of the piles, the frames of the BAFF structure will be installed. Each of the barrier frame sections will be assembled on land and would then be lowered into the water over the pilings with a barge-mounted crane. Divers would attach each of the frame segments to the piles (or concrete pier blocks where necessary), and then attach the airlines and cables supplying power to the barrier components. Surface buoys will be attached to each sub-surface pile and will remain in place throughout the duration of the study. Removal of the barrier following completion of the study will take approximately 21 working days and would begin as soon as practicable after operations cease. Complete removal of the barrier will occur no later than June 30, 2012.

Construction of the 2012 GSNPB will require the use of both land based and in-water equipment. It is expected that the following types of equipment will be utilized to install the barrier during the construction and removal phases of the study: flatbed trucks with trailers, tractors or backhoes, pickup trucks, fork lifts, a work barge with spuds, a barge mounted crane, a vibratory pile driver, work boats and skiffs, an air compressor, and a diesel powered generator to supply electrical power. The barge and workboats will be stored adjacent to the land-based staging areas either on the Sacramento River or Georgiana Slough side of the project. The final location will depend on the barge operator’s decision of which moorage location is safer for the vessel. A floating dock may be temporarily positioned adjacent to the river bank to allow for the safe loading of personnel and equipment into the workboats. The dock is expected to measure approximately 10 feet by 40 feet and will be anchored to the bank and extend out into the river channel.

5. Barrier Operations

DWR, the project proponent, has stated that the 2012 GSNPB experimental study will comply with the biological opinion issued by NMFS regarding the operations of the Federal and State water projects and studies associated with those operations. Furthermore, the project proponent has indicated that they will attempt to coordinate with other agencies conducting similar efforts to track acoustically tagged fish movements in the Delta during the same time period. Such cooperation may include the detection of acoustically tagged fish from other studies by the receiver array deployed around the Georgiana Slough site as well as fish released in this study being detected by other receivers in the Delta affiliated with other studies.

During the 2011 study, the non-physical barrier was operated for 45 days. Consecutive daily operation was not possible due to unexpected high flow conditions on the Sacramento River and barrier equipment failures caused by debris impacting the structure and damaging barrier components. The 2012 barrier operation period is planned for no more than 60 days to commence soon after construction has been completed: as soon as February 1, 2012, depending on construction and permitting schedules and ending no later than May 31, 2012.

Shore based diesel generators will supply the power necessary to run the air compressor, the sound generators, and the LED lights for the barrier to function. The generator will be located on a trailer in the construction staging area. The staging area encompasses approximately 0.25 acres on the south bank of the Sacramento River at the western bank of Georgiana Slough (see Figure1). The air compressor required to run the bubble curtain will be housed in a separate trailer located on the same site. Storage containers that can be locked and secured will house the control units for the barrier as well as signal generators, amplifiers, and necessary electronic and computer equipment for the barrier operation. A separate trailer containing sleeping quarters for on-site staff conducting 24-hour monitoring will also be co-located on the site. All trailers will be towed to the staging site and will not require the construction or improvement of any roads beyond minor gravel augmentation to reduce the pooling of rainwater at the staging area site.

The barrier would be operated in conjunction with the release of approximately 1,500 to 6,000 acoustic-tagged late fall-run Chinook salmon. To support the barrier monitoring study, the barrier would be turned on and off at specific times relative to these releases to collect data about the deterrence of fish by the operational barrier compared to conditions without the barrier in operation. In addition, it is intended that the barrier would be "on" and "off" over a range of light and tidal conditions; two full tidal cycles are completed every 25 hours, and this period also covers the full range of light conditions. The experimental design for the 2012 non-physical barrier tests is based on a comparative analysis of the response of tagged juvenile salmon that migrate downstream in the Sacramento River and encounter the divergence with Georgiana Slough either when the barrier is on or when the barrier is off. The experimental design has been based on a random sequence for determining initial barrier on and barrier off test conditions. Randomly selecting the barrier on and barrier off operations reduces the risk of a systematic bias in river flows or other conditions that could adversely affect test results. Results from the detection record of the tagged fish will allow the calculation of the deterrence efficiency, the protection efficiency, and the overall efficiency of the barrier (DWR 2011).

C. Conservation Measures

DWR, the project proponent, has indicated that they believe this action will result in the incidental take of listed salmonids and green sturgeon. DWR has proposed the following conservation measures be implemented to reduce and minimize the effects of this action:

1.) Construction personnel will participate in a NMFS-approved worker environmental awareness program. Under the proposed program, workers will be informed about the presence of federally listed salmonids and green sturgeon and the habitat associated with these species and that unlawful take of these fish or destruction of their habitat is a violation of the Federal Endangered Species Act. Prior to construction activities, a qualified biologist(s) approved by NMFS will instruct all construction personnel about the life history of Sacramento River winter and Central Valley spring-run Chinook salmon, Central Valley steelhead, and the southern DPS of green sturgeon. The workers will be informed of the terms and conditions of this opinion. Proof of instruction will be submitted to the Sacramento Office of NMFS.

2.) DWR will conduct all pile driving using a vibratory hammer to minimize to the greatest extent possible the noise generated by the pile driving activities. Compared to the standard impact or percussive pile driving hammer, a vibratory hammer reduces the distance that generated noise exceeds the thresholds determined by NMFS to be injurious to exposed fish. By reducing the radius of the noise field in which excessive levels of acoustic energy are present, fewer fish will be exposed to the adverse effects of the pile driving activities while moving through the action area.

3.) An Erosion Control Plan will be prepared prior to the initiation of construction activities that will result in ground disturbance. Site specific plans to control erosion, prevent spills within the construction area, and control sedimentation and runoff from the construction site will be developed and implemented as part of the Erosion Control Plan.

4.) DWR will prepare a Hazardous Materials Management Program (HMMP) that identifies the hazardous materials to be used during construction; describes measures to prevent, control, and minimize the spillage of hazardous substances; describes transport, storage, and disposal procedures for these substances; and outlines procedures to be followed in case of a spill of a hazardous material. The HMMP will require that hazardous and potentially hazardous substances stored onsite be kept in securely closed containers located away from drainage courses, storm drains, and areas where stormwater is allowed to infiltrate. It will also stipulate procedures, such as the use of spill containment pans, to minimize the potential for hazardous materials to infiltrate the ground during onsite fueling and servicing of construction equipment. Finally, the HMMP will require that adjacent land uses be notified immediately of any substantial spill or release.

5.) DWR will monitor turbidity levels in the Sacramento River and Georgiana Slough during ground-disturbing activities, including all pile-driving activities. Monitoring will be conducted by measuring upstream and downstream of the disturbance area to determine if the change in ambient turbidity exceeds 20 percent of the background turbidity, a threshold derived from the Sacramento and San Joaquin Rivers Basins Plan (Central Valley Regional Water Quality Control Board 1998). If so, DWR contractors will adjust work activities to ensure that turbidity levels do not exceed the 20 percent threshold.

6.) If riparian impacts are unavoidable, such as pruning of vegetation to facilitate equipment setup, DWR will return the disturbed riparian habitat (0.01 acres) to pre-2012 GSNPB Study conditions. This will consist of restoring the unstable bank area at the downstream end of the barrier and planting native riparian vegetation in the disturbed area.

7.) The construction contractor will implement the following applicable basic and enhanced control measures to reduce construction-related fugitive dust during site grading.

    a.) Water all exposed surfaces two times daily. Exposed surfaces include, but are not limited to soil piles, graded areas, unpaved parking areas, staging areas, and unpaved access roads.

    b.) Use wet power vacuum street sweepers to remove any visible trackout mud or dirt onto adjacent public roads at least once a day. Use of dry power sweeping is prohibited.

    c.) Limit vehicle speeds on unpaved roads to 15 miles per hour (mph).

    d.) Minimize idling time either by shutting equipment off when not in use or reducing the time of idling to 5 minutes (required by California Code of Regulations, Title 13, sections 2449[d][3] and 2485). Provide clear signage that posts this requirement for workers at the entrances to the site.

    e.) Maintain all construction equipment in proper working condition according to manufacturer's specifications. The equipment must be checked by a certified mechanic and determined to be running in proper condition before it is operated.

8.) As part of the standard DIDSON monitoring for predatory fish that is undertaken in the 3 hours prior to and after the barrier is turned on or off, as well as during other times that visual tracking benefits the experiment, observers will also examine the DIDSON output for signs of non-predatory fish such as adult Chinook salmon circling or congregating in the vicinity of the barrier for extended periods of time, i.e., greater than 1 hour. Should such behavior be observed while the barrier is operational, the barrier shall be switched off until the fish have dispersed from the site of the barrier.

9.) Navigational buoys, lights, and signage will be installed in both the Sacramento River and Georgiana Slough up- and down-stream of the barrier to inform boaters of the presence of the barrier and maintain navigation along both waterways. DWR will coordinate with the U.S. Coast Guard on the positioning of signage and buoys. Navigational aids and signage will be maintained during the study to ensure the safety of boaters and reduce the potential for accidents in the study location.

D. 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 divergence of Georgiana Slough from the main channel of the Sacramento River as well as the riparian banks and upland areas surrounding the channel divergence influenced by the staging and construction activities (Latitude 38.23947^o, Longitude -121.51726^o, nearest town Walnut Grove, Sacramento County, California). The staging area is described as the point of land bounded by the western bank of Georgiana Slough and the southern bank of the Sacramento River at the divergence of the channels (Figure 1). Placement of hydrophones will occur in the river channel immediately adjacent to the location of the non-physical barrier as well as at locations several miles upstream and downstream of the barrier on the Sacramento River (*i.e.*, near Steamboat Slough and the town of Ryde, California), and approximately 2.5 miles downstream of the barrier on Georgiana Slough. The impacted area will encompass the water column upstream and downstream of the barrier in which the sound generated by the acoustic generators exceeds the measurable ambient background noise in the river. This may extend for several hundred feet into the river channel beyond the location of the non-physical barrier.

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 GSNPB 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 GSNPB 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 GSNPB 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 GSNPB 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^{o}F for adult Chinook salmon migration, and Lindley *et al.* (2004) report that adult migration is blocked when temperatures reach 70^{o}F, and that fish can become stressed as temperatures approach 70^{o}F. Reclamation reports that spring-run Chinook salmon holding in upper watershed locations prefer water temperatures below 60^{o}F; although salmon can tolerate temperatures up to 65^{o}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°F [Moyle 2002]). A significant reduction in egg viability occurs at water temperatures above 57.5°F and total embryo mortality can occur at temperatures above 62°F (NMFS 1997). Alderdice and Velsen (1978) found that the upper and lower temperatures resulting in 50 percent pre-hatch mortality were 61°F and 37°F, respectively, when the incubation temperature was held constant. As water temperatures increase, the rate of embryo malformations also increases, as well as the susceptibility to fungus and bacterial infestations. The length of development for Chinook salmon embryos is dependent on the ambient water temperature surrounding the egg pocket in the redd. Colder water necessitates longer development times as metabolic processes are slowed. Within the appropriate water temperature range for embryo incubation, embryos hatch in 40 to 60 days, and the alevins (yolk-sac fry) remain in the gravel for an additional 4 to 6 weeks before emerging from the gravel.

During the 4 to 6 week period when alevins remain in the gravel, they utilize their yolk-sac to nourish their bodies. As their yolk-sac is depleted, fry begin to emerge from the gravel to begin exogenous feeding in their natal stream. The post-emergent fry disperse to the margins of their natal stream, seeking out shallow waters with slower currents, finer sediments, and bank cover such as overhanging and submerged vegetation, root wads, and fallen woody debris, and begin feeding on zooplankton, small insects, and small aquatic invertebrates. As they switch from endogenous nourishment to exogenous feeding, the fry's yolk-sac is reabsorbed, and the belly suture closes over the former location of the yolk-sac (button-up fry). Fry typically range from 25 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 mainstems of larger rivers, juveniles tend to migrate along the channel margins and avoid the elevated water velocities found in the thalweg of the channel. When the channel of the river is greater than 9 feet to 10 feet in depth, juvenile salmon tend to inhabit the surface waters (Healey 1982). Migrational cues, such as increasing turbidity from runoff, increased flows, changes in day length, or intraspecific competition from other fish in their natal streams may spur outmigration of juveniles when they have reached the appropriate stage of maturation (Kjelson *et al.* 1982, Brandes and McLain 2001).

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

Fry and parr may rear within riverine or estuarine habitats of the Sacramento River, the Delta, and their tributaries. In addition, Central Valley spring-run Chinook salmon juveniles have been observed rearing in the lower reaches of non-natal tributaries and intermittent streams in the Sacramento Valley during the winter months (Maslin *et al.* 1997, Snider 2001). Within the Delta, juvenile Chinook salmon forage in shallow areas with protective cover, such as intertidal and subtidal mudflats, marshes, channels, and sloughs (McDonald 1960, Dunford 1975).

Cladocerans, copepods, amphipods, and larvae of diptera, as well as small arachnids and ants are common prey items (Kjelson *et al.* 1982, Sommer *et al.* 2001, MacFarlane and Norton 2002). Shallow water habitats are more productive than the main river channels, supporting higher growth rates, partially due to higher prey consumption rates, as well as favorable environmental temperatures (Sommer *et al.* 2001). Optimal water temperatures for the growth of juvenile Chinook salmon in the Delta are between 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 2 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 2. The temporal occurrence of adult (a) and juvenile (b) Sacramento River winter-run Chinook salmon in the Sacramento River. Darker shades indicate months of greatest relative abundance.

a) Adult migration

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

b) Juvenile migration

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

KL = Knights Landing

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

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

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 3 in text and Appendix B: Figure5). 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.

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 red 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.

Table 3. 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)

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 7 and 8).

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 9).

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 6).

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 4 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).

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).

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

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

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

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

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)

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 5 in text and Appendix B: Figure 10). 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^{o}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.

Table 5. 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

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 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 11 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 6 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.

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).

Table 6. 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	L	L	L	L	L	L						L	L	L	L	M	M	H	H	M	L	L	L	L
[2,3]Sac R at Red Bluff	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	M	M	H	M	L	L	L	L
[4]Mill, Deer Creeks	M	M	H	M	M	L	L	L	L	L	L	L							M	H	H	M	M	M
[6]Sac R. at Fremont Weir	L	L	L	L											M	M	H	H	M	M	L	L	L	L
[6]Sac R. at Fremont Weir	L	L	L	L											M	M	H	H	M	M	L	L	L	L
[7]San Joaquin River	H	H	M	M	L	L							L	L	L	L	M	M	M	M	M	M	H	H

(b) Juvenile migration

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

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

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 12). 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 13 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 14). 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 15).

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 16). 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.* 2009, 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 7 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^{o}C and 23^{o}C. When ambient temperatures in the river dropped in autumn and early winter (<10^{o}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^{o}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°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.

Table 7. 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]	Low	Low	Medium	Medium / High	High	High / Medium	Medium	Medium	Medium	Low	Low	Low
SF Bay Estuary[d,h,i]	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low	Low

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

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

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

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

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

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

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

* 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 (2007)

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

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 (CDFG, 2002) indicating they are approximately 3 to 4 weeks old (Van Eenennaam *et al.* 2001, Deng *et al.* 2002). Taken together, the average length of larvae captured at the two monitoring sites indicate that fish were hatched upriver of the monitoring site and drifted downstream over the course of 2 to 4 weeks of growth. According to the CDFG document commenting on the NMFS proposal to list the southern DPS (CDFG 2002), some green sturgeon rear to larger sizes above RBDD, or move back to this location after spending time downstream. Two sturgeon between 180 mm and 400 mm TL were captured in the 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 8 and Appendix B Figures 17a and 17b). 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, 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. Critical Habitat for the Southern DPS of North American Green Sturgeon

Critical habitat was designated for the Southern DPS of North American green sturgeon on October 9, 2009 (74 FR 52300). Critical habitat for Southern DPS green sturgeon includes the stream channels and waterways in the 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 mainstems 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. Water Development

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. Water Conveyance and Flood Control

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. Land Use Activities

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 9).

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. <u>Hatchery Operations and Practices</u>

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 figure18). 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***

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. Environmental Variation

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 10 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 11 and 12). 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 (73 percent) enter the action area during the proposed construction window (January 1, through March 31, 2012). Presence of adult Chinook salmon are 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 28-day construction period occurring sometime between January 1, and March 31, 2012, approximately 55 percent of the adult winter-run spawning population is expected to pass through the action area. During the proposed 60 day study implementation period occurring sometime between February 1, and May 31, 2012, approximately 86 percent of the adult spawning population will move through the action area. During the deconstruction phase of the project (May–June, 2012), 17 percent of the adult winter-run spawning population is expected to migrate through the action area (see Appendix A: Table 13) (CDWR 2011).

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 construction period (January 1, through March 31, 2012) it is estimated that approximately 56 percent of the annual spring-run juvenile population will move into the Delta waterways within the action area. During the proposed 60 day study implementation period (occurring sometime between February 1, and May 31, 2012), approximately 97 percent of the annual juvenile spring-run Chinook salmon population will have moved into and through 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 11, 12, and 13). During the proposed construction window, less than 2 percent of the estimated annual adult escapement population will have moved upriver through the action area. During the proposed 60 day study implementation period, it is estimated that approximately 7 percent of the adult escapement will move upriver through the Delta waterways associated with the action area. During deconstruction of the barrier, an additional 11 percent of the annual adult escapement population is expected to move through the Delta waterways surrounding the action area during June. 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 11 and 12). 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 mainstem of the San Joaquin River upstream from the City of Stockton routinely catch low numbers of outmigrating 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 97 percent of the juvenile steelhead emigrants will move into and through the action area during the construction window (January through March). The proposed 60 day study period will occur sometime between February and May and will affect approximately 92 percent of the juvenile smolt outmigration into the action area from upriver (Appendix A: Table 12). Adult steelhead are expected to move through the action area during construction and study implementation periods, but the peak of upriver immigration is expected to occur earlier (August through November on the Sacramento River) than the construction and study implementation period (January through May). 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. Status of Critical Habitat Within the Action Area

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, 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 (Reynolds *et al*. 1993) in these tailwater sections.

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 project generally will affect more juvenile fish than adult fish. The larger effects to the juvenile population, in terms of numbers of juveniles subjected to project activities compared to adults, will result in a lower 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 project on juvenile abundance could affect the cohort replacement rate by decreasing the contributing juvenile portion of the population. Similarly, because of the high fecundity of North American green sturgeon and relatively high abundance of juveniles expected in the action area, the impacts of the project on juvenile green sturgeon also are expected to be less severe than the impacts to adults.

B. Assessment

1. <u>Construction Impacts</u>

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 construction activities for the 2012 GSNPB will occur for a scheduled 28-days from approximately mid-January through March 31, 2012, for the installation of the barrier, and then again in late May through the end of June over a period of 21-days for the removal of the barrier structure. The effects of construction activities as well as the exposure of each listed salmon and sturgeon based on life stage to each activity is described further below.

a. *Pile Driving*

(1) *Effects of sound on fish.* The installation of steel piles with a vibratory pile driving hammer is expected to result in adverse effects to listed salmonids due to high levels of underwater sound that will be produced. Although adverse effects to fish from elevated levels of underwater sound are well documented for explosives (Gaspin 1975, Keevin and Hempen 1997a) and air guns (Pearson *et al.* 1992, Engas *et al.* 1996, McCauley *et al.* 2003, Popper *et al.* 2005), there was initially little information regarding the effects on fish from underwater sound pressure waves generated during the installation of piles (Caltrans 2001, Vagle 2003). Laboratory research on the effects of sound on fish has used a variety of species and sounds (Hastings *et al.* 1996, Popper and Clarke 1976, Scholik and Yan 2002, Turnpenny *et al.* 1994). Experimental data found in the literature concerning the effects of sound on aquatic animals are not reported in a consistent manner, and most of these studies did not examine the type of sound generated by pile driving.

The degree to which an individual fish exposed to underwater sound will be affected (from a startle response to immediate mortality) is dependent on a number of variables such as the species of fish, size of the fish, presence of a swimbladder, sound pressure intensity and frequency, shape of the sound wave (rise time), depth of the water around the pile and the bottom substrate composition and texture. It has long been known that underwater explosives can cause injury and mortality to fish. The Department of the Navy conducted a series of experiments to determine the effects on fish from underwater explosions (Goertner *et al.* 1994, Gaspin 1975) which resulted in significant differences in effects to fish depending on whether or not they had swimbladders. Thus, it is the swimbladder, inflated with gas, which rapidly compresses under the overpressure wave and then expands as the pressure wave passes through the fish and is replaced by the underpressure wave that likely causes the observed injuries to internal organs (Keevin and Hempen 1997a). An important characteristic of the underwater sound that causes injury is the frequency. During pile installation, most energy is contained within the frequency range (100–1,000 Hertz) which results in reverberation of the swimbladder. Studies have shown that the most susceptible tissues that are injured during exposure to underwater sound produced from pile driving are the soft-tissue organs surrounding the swimbladder, such as the liver and kidney (Caltrans 2001, Abbott and Bing-Sawyer 2002, Caltrans 2003).

There are two types of swimbladders: physostomous, in which the organ is thin, membranous and connects to the esophagus through a pneumatic duct, and physoclistous, in which the organ is thick-walled and connected to the blood stream (Smith 1982). Both salmonids and sturgeon possess physostomous swimbladders (Smith 1982). As indicated by Keevin and Hempen (1997b) fish with physoclistous swimbladders are believed to be most sensitive to blast pressures, however, species with both types of swimbladders are more susceptible to injury than fish which lack swimbladders. In addition, sturgeon are known to have large swimbladders (Nelson 1994).

Although underwater sound pressure waves generated during pile driving are different in several ways from those generated during explosions, the mechanism of injury (*i.e.*, swimbladder expansion) may be similar. The most important differences between the two are the repetitive nature of pile driving and the overpressure-underpressure oscillations within the pile driving signal. When fish are exposed to multiple strikes, the repetitive oscillations and the resultant pressure waves will cause the swimbladder to act like a drum, and although any single pulse (depending on its magnitude) may not result in acute injury to the internal organs, the repetitive nature of the sound produced during pile driving is likely to result in injury due to the repetitive flexure of the organ membrane, particularly if the membrane experiences resonance.

NMFS uses the sound exposure level (SEL) metric, expressed as the square of the time integrated sound-pressure-level measured in decibels over the duration of the sound exposure (decibels are referenced to one micropascal (μPa) of pressure; one pascal is equivalent to 1 Newton of force per square meter[1]), to correlate physical injury to fish from underwater sound pressure produced during the installation of piles (Hastings and Popper 2005). This metric allows for the summation of energy over multiple pulses (strikes). Using SEL, the exposure of fish to a total amount of energy (*i.e.,* dose) can be used to determine a physical injury response.

NMFS must make some assumptions as to the behavior of the fish and the recovery time of tissue being affected in order to determine the response (*i.e.*, avoidance, injury, death) of the fish. Sonalysts (1997) suggested that although fish (including Atlantic salmon) exhibit a startle response during the first few acoustic exposures, they do not move away from areas of very loud underwater sounds and can be expected to remain in the area unless they are carried away by

[1] In the remainder of this document, SELs are referenced to one micropascal squared-second.

currents or normal movement patterns. Therefore, NMFS will assume that fish will remain in the vicinity of a construction site unless currents or behavior patterns unrelated to loud underwater sound avoidance would indicate that salmonid movement is likely to occur. Although there may be some tissue recovery between strikes, NMFS believes that cumulative injury impacts are likely to occur with repeated exposure to sound pressure waves from pile strikes. Therefore, NMFS will use accumulated energy over all strikes to determine potential physical effects to listed salmonids and sturgeon. There is also a question of the time interval between each pile being installed. Typically, several piles are installed on any given day, with tens of minutes between the completion of one pile and the initial driving of the next. Although there may be some tissue recovery between the completion of one pile and the beginning of pile driving at the next, given the level of uncertainty that exists, NMFS will sum the underwater sound energy produced during the installation of all piles on any given day to determine potential physical effects to listed salmonids and sturgeon (described below). NMFS will assume that normal behavior patterns will move migrating salmonids and green sturgeon out of the affected area within one day, and therefore underwater sound energy will not be summed across separate days. This would not be the case if the construction site were located in an area where either adult salmonids or sturgeon were spawning or juveniles were rearing for extended periods of time in the action area.

Sound is a major form of underwater communication for fish, so a functioning auditory system is essential for fish to survive. The structure of the fish inner ear is similar to that of other vertebrates: each ear has three semicircular canals and three otolithic organs, the utricle, saccule, and lagena. The semicircular canals and otolithic chambers are interconnected and filled with endolymphatic fluid. The swimbladder may act somewhat as an eardrum by responding to the sound pressure waves, depending on the species of fish. The motion of the swimbladder radiates a secondary signal to the inner ear. This provides the necessary particle movement for otolithic/auditory nervous stimulation, especially in species having the shortest distance between the swimbladder and the auditory apparatus (pars inferior). Popper (2005) reviews literature regarding sturgeon hearing and sound production. According to a limited amount of published information on the topic, it appears several species of *Acipenser* are believed to make sounds during spawning (Popper 2005).

The literature indicates damage to hearing by intense sound depends on auditory threshold and will vary from species to species (Popper and Fay 1973). Damage to hearing is normally measured in sound pressure levels expressed as root mean squared (RMS) decibels re 1 micropascal[2]. Some fish have hearing thresholds as low as 50 decibels RMS (dB_{rms}) while others have thresholds as high as 150 dB_{rms}. Enger (1981) exposed 26 Atlantic cod (*Gadus morhua*) to continuous tones of 180 dB_{rms} at frequencies from 50 to 400 Hertz (Hz) for one to five hours and found destruction of auditory hair cells in the saccule. The cod has a hearing threshold of 75-80 dB_{rms} between 100 and 200 Hz (Chapman and Hawkins 1973), so 180 dB_{rms} is about 100 dB above threshold. For Atlantic salmon (*Salmo salar*), Hawkins and Johnstone (1978) reported best sensitivity of 95-100 dB_{rms} between 100 and 200 Hz. Since the 100-200 Hz is the bandwidth of best sensitivity for both cod and Atlantic salmon, Hastings (2002), in support of the Caltrans BA of the Benicia-Martinez New Bridge Project, stated she would expect to see damage

[2] In the remainder of this document, rms pressure levels are referenced to one micropascal.

of auditory hair cells in salmon occurring with exposure to continuous sound at about 200 dB_{rms}. The peak pressure associated with a continuous sound of 200 dB_{rms} is equivalent to 203 dB_{peak}, thus Hastings (2002) concludes hearing damage to the sensory hearing cells of salmon onsets at a sound level of 203 dB_{peak}.

Hastings (1995) found destruction of auditory sensory cells when she and her colleagues exposed goldfish (*Carassius auratus*) to continuous tones of 189, 192, and 204 dB_{peak} at 250 Hz and 197 dB_{peak} at 500 Hz for approximately two hours. Four fish were exposed to each set of conditions and destruction of ciliary bundles was found to correlate with sound pressure level at a 95 percent confidence level. Hastings *et al.* (1996) also found destruction of sensory cells in the inner ear of oscars (*Astronautus ocellatus*) four days after being exposed to continuous sound for one hour to 180 dB_{peak} at 300 Hz. The authors found no damage in fish allowed to survive for only one day after exposure, suggesting that damage may develop slowly in the sensory cells of the fish's inner ears. NMFS is not aware of any similar studies conducted with green sturgeon or salmonids, however, the impacts are assumed to be similar given the relative similarity of the anatomical structure of the inner ear within fish.

Sonalysts (1997) reported that they performed reaction testing with caged Atlantic salmon at a wide range of sound pressure levels and frequencies. They stated that although some avoidance was noted at certain specific levels and frequencies, no avoidance response was seen when the sound pressure levels (likely RMS) were over 180 decibels (dB). The report also included a brief discussion of previously unreported studies that show that beyond a brief startle response associated with the first few acoustic exposures, fish do not move away from areas of very loud noises and are expected to remain in the area unless they are carried away by currents.

To determine the level of underwater sound that would elicit a behavioral response, Turnpenny *et al.* (1994) exposed a variety of fish species to varying levels of sound and frequency. No significant avoidance was found for trout at exposure levels (metric not specified) of up to 150 dB, although a reaction threshold of around 170 dB was observed. The authors used pure tone bursts, which cause an effect at a lower sound pressure level due to the higher duty cycle of the signal.

In the early 1990s, pile driving operations in Puget Sound were reported to disrupt juvenile salmon behavior (Feist *et a*l. 1992). Though no underwater sound measurements are available from that study, comparisons between juvenile salmon schooling behavior in areas subjected to pile driving/construction and other areas where there was no pile driving/construction indicate that there were fewer schools of fish in the pile-driving areas than in the non-pile driving areas. The results were not conclusive, but suggest that pile-driving operations may result in a disruption in normal migratory behavior.

During the construction of the Benicia-Martinez Bridge Project in April 2002, observations were made during pile driving that suggest small fish subject to the exposure of elevated underwater sound pressure levels can be vulnerable to predation. The stomach of a piscivorous striped bass killed by high underwater sound pressure levels was examined and found to contain several freshly consumed juvenile herring (R. Blizard, Caltrans, pers. comm. May 2002 to D. Woodbury, NMFS). Although necropsies were not performed on the juvenile herring (*Clupea harengus*), the consensus of the biologists present at the site was that the striped bass were feeding heavily on killed, injured, or stunned herring prior to swimming into the zone of lethal sound pressure levels.

It appears that physical damage to the auditory system of salmonids is likely to occur at levels at or above 200 dB_{rms}, which is near the SEL threshold at which physical injury to the organs adjacent to a fish's swimbladder is estimated to occur. A white paper written by Popper *et al.* (2006) proposes a dual metric approach, incorporating both SEL and peak pressure, in assessing potential physical injuries to fish from exposure to elevated levels of underwater sound produced during pile driving. The authors proposed interim single strike thresholds of 187 dB SEL and 208 dB peak. In a critique of the white paper, a NMFS scientist from the Northwest Fisheries Science Center in Seattle, Washington (Memorandum to Mr. Russ Strach and Mr. Mike Crouse, NMFS from Tracy Collier, NMFS, September 19, 2006) stated that exposure to multiple strikes must be considered in assessing impacts. They further stated that the method described in Hastings and Popper (2005) is appropriate. Specifically, to account for exposure to multiple impulses (strikes), the single strike SEL at a given distance from the pile is added to 10*log (number of strikes) to give a cumulative SEL. Thus, using the parameters set forth in the papers referenced above, an accumulated 187 dB_{SEL} is used to estimate the onset of physical injury to small fish. Given that larger fish can tolerate a larger dose before eliciting a similar response (Yelverton *et. al*.1975), 3 decibels are added to this threshold to obtain a threshold of 190 dB_{SEL} for adult salmonids and sturgeon. In response to this new information, an interagency working group, which included staff from NMFS, established interim criteria for evaluating underwater noise impacts from pile driving on fish. These criteria are defined in the document entitled "Agreement in Principal for Interim Criteria for Injury to Fish from Pile Driving Activities" dated June 12, 2008 (Fisheries Hydroacoustic Working Group 2008). This agreement identifies a peak sound pressure level of 206 decibels (dB) and an accumulated sound exposure level (SEL)[3] of 187 dB as thresholds for injury to fish. For fish less than 2 g, the accumulated SEL threshold is reduced to 183 dB. Although there has been no formal agreement on a "behavioral" threshold, NMFS uses 150 dB_{RMS} as the threshold for adverse behavioral effects (National Marine Fisheries Service 2009).

(2) *Effects of GSNPB pile Installation*

Pile driving of objects into the substrate of the river channel bottom is accomplished by transferring kinetic energy from the pile driving hammer into the object being driven into the bottom substrate. Energy transferred to the pile by the hammer is partially redirected as acoustic energy and heat as the pile loses energy to the surrounding medium (*i.e.,* soil or rock). As sound propagates away from the source, several factors change its amplitude (Burgess and Blackwell 2003). These factors include the spreading of the sound wave over a wider area (spreading loss),

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

losses to friction between water or sediment particles that vibrate with the passing sound wave (absorption), scattering and reflections from boundaries and objects in the sound's path and constructive and destructive interference with one or more reflections of the sound off "solid" surfaces such as the seafloor or water surface. The sound level measured at any given point along the path of the propagated sound wave includes all of these effects and is termed the received level. The sum of all of the propagation and loss effects on a signal is called the transmission loss and is the difference between the received level and the source level. In this consultation, NMFS will assess the sound propagation through the water column in a simple manner. NMFS acknowledges that the propagation of the sound in water is very complex and can include coupled transmission through the channel bottom substrate, reflections of sound waves off of hard surfaces and the boundary between the water and air at the river's surface, and the destructive and constructive interference of passing sound waves as they move through the liquid medium. These complex representations of the sound propagation are beyond the scope of this opinion because NMFS does not have enough information or expertise in the varied and specific fields of the physical sciences to determine the exact nature of these representations under the specific circumstances surrounding the implementation of the proposed project.

Pile driving under the proposed 2012 GSNPB Study would be done with a vibratory pile driver. Vibratory pile driving is accomplished by attaching a variable eccentric vibrator to the head of the pile to drive the pile into the substrate. The interim criteria were established specifically for impact pile driving and were not intended to be applied to vibratory driving. However, for this assessment the interim criteria will be evaluated along with new criteria that have been recently published for vibratory driving (Hastings 2010). Pile driving noise modeling was conducted with the NMFS Underwater Noise Calculation Spreadsheet model (National Marine Fisheries Service 2009). The Compendium of Pile Driving Sound Data (California Department of Transportation 2007) provides sound level data on a variety of pile sizes and driver types.

Based on information given in the Compendium of Pile Driving Sound Data, the 12-inch steel pile data are considered to be representative of the types of hollow, steel piles to be used in the GSNPB study and indicate the following acoustic energy source levels as measured at 10 meters from the pile for a vibratory hammer:

Peak[4] = 171 dB

RMS = 155 dB

Sound exposure level (SEL [for 1 second of vibratory driving]) = 155 dB.

In the absence of site-specific data, NMFS recommends using an underwater attenuation rate of 4.5 dB per doubling of distance (National Marine Fisheries Service 2009). It also supports the notion that sound levels of less than 150 dB do not contribute to the accumulated SEL for the purposes of assessing injury (National Marine Fisheries Service 2009). Using this assumption and attenuation rate, as well as 5 minutes of driving at each of up to 26 piles (5 minutes/pile * 60 seconds/minute*26 piles = 7,800 seconds total pile driving time, assuming 1 strike per second), the $SEL_{accumulated}$ is 194 dB at 10 meters (33 feet) and the calculated distance to each of the applicable thresholds is as follows:

[4] Peak sound pressure refers to the highest absolute value of a measured waveform (i.e., sound pressure pulse as a function of time).

Distance to 206 dB-peak = less than 1 meter (less than 3.3 feet)

Distance to 150 dB-RMS = 72 feet/ 22 meters

Distance to 187 dB-$SEL_{accumulated}$ = 72 feet/ 22 meters (for fish > 2 g)

Distance to 183 dB-$SEL_{accumulated}$ = 72 feet/ 22 meters (for fish < 2 g)

Based on these calculations, there is potential for behavioral modifications or injuries to fish that remain within a 72 foot radius of the pile being driven during installation of the 26 piles. The same results are obtained if as few as 10 piles are installed. Therefore, even if it is assumed that 50 percent of the piles are installed on one day and 50 percent on the following day, the 183-dB-$SEL_{accumulated}$ threshold distance remains the same over both days.

A second series of calculations were run using field data collected during the 2011 GSNPB project (see Table 1, from DWR 2011). Instantaneous peak sound pressures ranged from 192.4 dB (re: 1µPa) to 155 dB , measured 10m from the source. Average peak instantaneous sound pressures per pile driven ranged from 152 dB to 178 dB, with the daily average ranging from 162 dB to 178 dB. Average number of seconds required daily for the vibratory pile driver to set piles ranged from 142 seconds (2 piles) to 2,451 seconds (3 piles). The maximum number of piles installed in one day was 6 piles. Using the NMFS Underwater Noise Calculation Spreadsheet model for stationary fish, $SEL_{accumulated}$ ranged between 159 dB and 184 dB at 10 meters (33 feet) and the calculated distance to each of the applicable thresholds is as follows (see Table 14 in text below):

Table 14: Calculated distances to physical injury and behavioral effects for field data collected in the 2011 GSNPB Study.

Daily average peak (dB)	Physical Injury			Behavioral	Daily seconds of Vibratory Pile driving
	Peak	Cumulative SEL			
	206 dB	187 dB (≥ 2g)	183 dB (≤ 2g)	150 dB RMS	
175	< 1 m	6 m	10 m	63 m	2,451
162	< 1 m	<1 m	< 1 m	6 m	142
178	< 1 m	6 m	10 m	74 m	1,060
173	< 1 m	3 m	5 m	34 m	1,082
177	< 1 m	2m	5 m	63 m	381
173	< 1 m	1m	3 m	34 m	425

As discussed above, the interim criteria adopted by the Fisheries Hydroacoustic Working Group (2008) are most relevant to impact pile driving, rather than the vibratory pile driving technique to be used to install the pilings for the GSNPB at the entrance to Georgiana Slough. Recently proposed criteria for vibratory pile driving were based on findings that higher threshold levels specifically related to the effects caused by vibratory pile driving hammers are warranted (Hastings 2010). These preliminary criteria are:

Non-auditory tissue damage

Mass ≤ 0.6 g = 191 dB-$SEL_{accumulated}$

For fish between 0.6 and 102 g mass, cumulative SEL = 195.28 + 19.28*log10(mass)

Mass ≥ 102 g = 234 db-$SEL_{accumulated}$

Auditory tissue damage

Hearing generalists (e.g., salmonids): > 234 dB-$SEL_{accumulated}$

Hearing specialists (e.g., carp): 222 dB-$SEL_{accumulated}$

Temporary threshold shift (hearing loss)

Hearing generalists: 234 dB-$SEL_{accumulated}$

Hearing specialists: 185 dB-$SEL_{accumulated}$

For the smallest fish (≤ 0.6 g), the distance to the 191 dB-$SEL_{accumulated}$ threshold for non-auditory tissue damage would be slightly more than the distances calculated for the 183 dB-$SEL_{accumulated}$ threshold (i.e., 72 feet or 22 meters under the general parameters or approximately 1 to 10 meters for the calculated distances derived from the 2011 field data). However, juvenile salmonids and juvenile green sturgeon in the study area would be expected to be larger than 0.6 grams. Assuming a fish weight of 1 gram, the distance to the appropriate threshold for non-auditory tissue damage (i.e., 195.28 dB-$SEL_{accumulated}$) would be 11 meters (35 feet)(DWR biological assessment for 2011 study, DWR 2010a). Most juvenile salmonids and green sturgeon in the project area would be expected to be larger than the 1 gram, thus they would have to pass closer to the pile driving activities to sustain injury to non-auditory tissues than would be expected for the more sensitive smaller sized fish. Furthermore, it is not expected that the exposed fish would remain in the same location to experience the full duration of the pile driving due to river currents, tides, and behavioral movements.

b. *Turbidity Associated with Construction*

Increased turbidity and suspended sediment levels associated with construction may negatively impact fish populations temporarily through reduced availability of food, reduced feeding efficiency, and exposure to toxic sediment released into the water column. Fish responses to increased turbidity and suspended sediment can range from behavioral changes (alarm reactions, abandonment of cover, and avoidance) to sublethal effects (e.g., reduced feeding rate), and, at high suspended sediment concentrations for prolonged periods, lethal effects (Newcombe and Jensen 1996). Resuspension of contaminated sediment may introduce compounds into the overlying water column where they result in exposure risks to passing aquatic organisms, including listed salmonids and green sturgeon. The spatial and temporal extent of resuspended sediment associated with the pile driving activities is expected to be minimal due to the limited area of disturbance and short duration of those activities, respectively. It is anticipated that installation of the piles will take approximately 6 days based on 2011 data and removal in May will take a similar amount of time, the project description calls for 21-days of pile driving activity in 2012 to construct the barrier, with roughly the same number of piles (20 versus 26 piles) projected for the installation.

c. *Exposure Risk to Listed Species during Construction and Removal Phases of Barrier*

The installation and removal of the pilings associated with the non-physical barrier has the potential to adversely affect juvenile fish present in the general area of the construction activities. Construction associated with the installation of the barrier is scheduled to occur sometime from mid-January through the end of March with 28 days of in-water construction, with complete removal of the barrier scheduled to occur in late May/ June. Assuming that construction and removal activities take 28 days in the period between mid-January and the end of March and 21 days between mid-May and the end of June, and predicated on the assumption that migration is uniformly spread throughout each of these months, then the total proportion of downstream migrating salmonids potentially passing through the 2012 GSNPB Study area during the construction and deconstruction activities is as follows, based on the general proportion of the juvenile population entering the Delta in a given month (Table 12) and the duration of the actions over the 7 week period:

28 days of construction ÷ (15 days in January + 29 days in February + 31 days in March) = 37.3 percent of total time in the months construction is occurring. Deconstruction of the barrier is equal to 21 days of deconstruction ÷ (15 days in May + 30 days in June) = 47 percent.

Fall-run Chinook salmon: 18.7 percent during construction, 12.2 percent during deconstruction.

(37.3 percent) * (14 percent population passing in January + 13 percent in February + 23 percent in March) = 18.7 percent of population exposed during in-water construction.

47 percent * (26 percent passing in May + 0 percent in June) = 12.2 percent of population during deconstruction

Spring-run Chinook salmon: 20.9 percent during construction, 0.47 percent during deconstruction.

37.3 percent * (3 percent in January + 0 percent in February + 53 percent in March) = 20.9 percent of population exposed during in-water construction.

47 percent * (1 percent in May + 0 percent in June) = 0.47 percent of the population during deconstruction.

Winter-run Chinook salmon: 27.2 percent during construction, 0 percent during deconstruction.

37.3 percent * (17 percent in January + 19 percent in February + 37 percent in March) = 27.2 percent of population exposed during construction.

47 percent * (0 percent in May + 0 percent in June) = 0 percent of population during deconstruction.

Steelhead: 36.2 percent during construction, 0 percent during deconstruction.

37.3 percent * (5 percent in January + 32 percent in February + 60 percent in March) = 36.2 percent of population during construction.

47 percent * (0 percent in May + 0 percent in June) = 0 percent of population during deconstruction.

An alternative way of looking at exposure to construction is given in tables 15 and 16, in which the monthly emigration rates of the juvenile salmonids is spread evenly into fourths for each month (quartiles). The individual quartiles are then summed over the 4 week construction period or 3 week deconstruction period and the value displayed. The maximum exposure risk occurs in the month of March for in-water construction. If the 28-day in-water construction action occurs in March, assuming starting on March 1, then 23 percent of the fall-run Chinook salmon population, 53 percent of the annual spring-run Chinook salmon population emigration, 37 percent of the annual winter-run Chinook salmon population, and 60 percent of the steelhead population may be exposed to the construction activities proposed. The least exposure across the 4 different salmonid populations occurs if in-water construction is initiated in mid-January. Exposure risk for emigrating steelhead smolts increases with each week through the beginning of March, while the other 3 salmonid groups don't start increasing markedly unitl the beginning of February from the values seen in January

The proportion of the total adult Chinook salmon upstream migration that may pass through the 2012 GSNPB Study area in February and the early May is approximately as follows, based on passage above Red Bluff Diversion Dam (Vogel and Marine 1991; Table 13) and calculated in a manner analogous to the juvenile assessment:

Fall-run Chinook salmon: 0 percent of the population during construction and deconstruction.

(37.3 percent) * (0 percent population passing in January + 0 percent in February + 0 percent in March) = 0 percent of population exposed during in-water construction.

47 percent * (0 percent passing in May + 0 percent in June) = 0 percent of population during deconstruction

Late-fall-run Chinook salmon: 15.4 percent of the population during construction, 0 percent during deconstruction.

37.3 percent * (17.5 percent in January + 17.5 percent in February + 6.25 percent in March) = 15.4 percent of population exposed during in-water construction.

47 percent * (0 percent in May + 0 percent in June) = 0 percent of the population during deconstruction.

Spring-run Chinook salmon: 0.47 percent of the population during construction, 7 percent during deconstruction.

37.3 percent * (0 percent in January + 0 percent in February + 1.25 percent in March)= .47 percent of population exposed during in-water construction.

47 percent * (4.5 percent in May + 10.5 percent in June) = 7 percent of the population during deconstruction.

Winter-run Chinook salmon: 20.5 percent of the population during construction, 8 percent of the population during deconstruction.

37.3 percent * (3.75 percent in January + 13.75 percent in February + 37.5 percent in March) = 20.5 percent of population exposed during construction.

47 percent * (10 percent in May + 7 percent in June) = 8 percent of population during deconstruction.

An alternative way of looking at exposure to construction of adult Chinook salmon migrating upstream is given in tables 17 and 18, in which the monthly emigration rates of the adult Chinook salmon is spread evenly into fourths for each month (quartiles). The individual quartiles are then summed over the 4 week construction period or 3 week deconstruction period and the value displayed. The maximum exposure risk occurs in the month of March for winter-run Chinook salmon to in-water construction. If the 28-day in-water construction action occurs in March, assuming starting on March 1st, then 0 percent of the fall-run Chinook salmon population, 1.25 percent of the annual spring-run Chinook salmon population, 37.5 percent of the annual winter-run Chinook salmon population, and 6.25 percent of the late-fall-run Chinook salmon population may be exposed to the construction activities proposed. Exposure risk for migrating late-fall-run Chinook salmon adults is highest in January and February and then decreases with each week through the beginning of March. Conversely, winter-run Chinook salmon adults start entering the Delta in increasing numbers through the beginning of March and then start declining in April. For the deconstruction period, the Chinook salmon run at greatest risk to in-water activities are spring-run Chinook salmon adults. Nearly 8 percent of the spring-run Chinook salmon adult population may move through the action area during the 3 weeks of deconstruction actions from late May through the end of June.

These estimates assume that most migrating fish use the mainstem Sacramento River. This is not necessarily true as recent studies have shown that perhaps 30–40 percent of outmigrating juvenile Chinook salmon may enter Steamboat and Sutter Sloughs, upstream of the 2012 GSNPB Study area, and reenter the Sacramento River approximately 9.3 miles downstream of the 2012 GSNPB Study area (Perry and Skalski 2008, Perry et al. 2010). The Steamboat/Sutter Sloughs migration route is also available to upstream migrating adult salmonids. As noted above, adult steelhead also migrate upstream during the construction period, and may also use the Steamboat/Sutter Sloughs migration route. In addition, adult fish may migrate upstream within Georgiana Slough and encounter the barrier from the downstream side. As such, the actual percentage of fish in the Sacramento River during the construction and removal window is likely less than what is shown above. Note also that the actual period of time during which construction or removal is occurring is only a small proportion of the total work window (i.e., approximately 10 to 12 hour work days during the mid-January through March and the late May through June work windows).

These estimates also assume that fish pass through the action area with an equal probability of occurrence during the 24-hour daily period. However, since adult and juvenile salmonids move primarily during crepuscular periods (morning and evening low light conditions) and minimize their migrational movements during the day, then the proportion of fish moving through the action area during pile driving activities should decline. Under this scenario, daily pile driving activities should commence after the height of fish movement has ended in the morning and cease prior to the onset of fish movement in the evening. This effectively reduces the exposed fraction of fish. Likewise, the behavior of individual fish to anthropogenic noise is uncertain. If fish avoid areas with high levels of environmental noise either by actively avoiding it or leaving the vicinity of the noise once it starts (Feist *et al.* 1992), then the fish may reduce their exposure to the noise.

Since juvenile green sturgeon are expected to be rearing in the waterways of the Delta, including the action area on a year-round basis, they are expected to be in the vicinity of the GSNPB during the pile driving of the steel piles for the barrier during the 28-day installation period. Likewise, they are also expected to be present in May and June during the removal of the pilings following completion of the experiment. The percentage of the population present in the area is, however, unknown. There is not currently a reliable measure of juvenile green sturgeon population abundance in the Delta, nor is there a reliable estimate of the relative fraction of the population utilizing the action area during the construction and removal periods. Therefore, juvenile presence is assumed for both of these periods without quantification. Likewise, adult green sturgeon are likely to be migrating upstream during both the barrier installation in the January through March period and the barrier removal activities in May and June. There is also the potential that some adult green sturgeon may be moving back down river during the May-June period following their upstream movements.

d. *Effects of Barrier Construction on Critical Habitat*

The installation and removal of the barrier would temporarily impact less than 0.01 acre of channel bottom. The surface area affected by the piles would account for at most 20 square feet of channel substrate (113 square inches per pile * 26 piles ≈ 20 square feet), while the surface area beneath the 4 concrete pier blocks would total approximately 72 square feet. In addition, there would be temporary covering of benthic habitat by hydrophone anchoring structures, which are concrete blocks 2 by 4 feet by 24 inches in height; assuming 38 such blocks are needed, approximately 304 square feet of substrate would be covered. The barrier would only reduce the quantity of benthic channel habitat for approximately two to two and a half months, after which the barrier and the piles would be removed. The temporary occupation of the habitat by the barrier support structures would be of relatively minor importance to downstream migrating juvenile salmonids, which are generally in the uppermost portions of the water column (Quinn 2005, Kimmerer 2008). Installation and removal of the barrier would temporarily increase turbidity and suspended sediment, as described above, but this is likely to be a very minor impact. As such, there would be no substantial effects on Chinook salmon or steelhead critical habitat and any such modification of the habitat would be temporary in nature related to in-water construction activities.

There would be no hydrodynamic changes associated with the barrier presence in the channel. Shaded riverine aquatic habitat, an important component of freshwater rearing habitat, occurs in the 2012 GSNPB Study area but would be minimally disturbed by the temporary buildings housing barrier control and monitoring equipment or by the various cables and air supply pipes stretching from the land to the barrier. As described in the project description, the temporary housing and storage units would be trailer mounted and would be removed following the completion of the study. Any instream woody material, another important rearing habitat component, occurring in the 2012 GSNPB Study area would not be removed but would be minimally relocated if found to be obstructing any of the equipment required for barrier operation and installation.

The use of construction equipment near the river has the potential to impair water quality if hazardous chemicals (e.g., fuels and petroleum-based lubricants, hydraulic fluids, degreasers, etc.) were spilled and directly or indirectly entered the river. These potential effects are expected to be minimal because they would be quickly contained and cleaned up according to the proposed spill prevention and control plan to be implemented by DWR. The plan will ensure that equipment is properly maintained, hazardous materials are appropriately contained and secured, and construction personnel are trained in the avoidance and proper response to any accidental spills or releases. Additionally, DWR will adhere to the standard construction best management practices (BMPs) described in the current California Department of Transportation *Construction Site Best Management Practices Manual* (California Department of Transportation 2003).

NMFS designated critical habitat for North American green sturgeon (Southern DPS) in the Delta. PCEs for the Southern DPS of green sturgeon include the following six elements: food resources; water flow; water quality; migratory corridors; water depth; and sediment quality. The Delta includes PCEs concerned with: food resources; water flows sufficient to allow adults, sub-adults, and juveniles to orient to flows for migration; migratory corridors for all life-stages using the Delta; water depths to accommodate the needs of different life-stages in the estuary; and sediment with adequately low contaminant loads (National Marine Fisheries Service 2009a).

As previously described, green sturgeon food resources have the potential to be affected in the 2012 GSNPB Study area as a result of sediment disturbance during pile and concrete pier installation and removal needed for the barrier. However, this effect and the associated covering of benthic substrate is expected to have minimal impact on green sturgeon critical habitat because it is temporary and the total area impacted is very small area (less than 0.01 acre). Green sturgeon are believed to feed primarily upon benthic invertebrates such as clams, mysids, grass shrimp, and amphipods (Radtke 1966) and the aforementioned activities would temporarily disturb and reduce benthic habitat in the areas occupied by the barrier. However, because the affected areas are only a very small fraction of the total Delta area designated as critical habitat for green sturgeon, and because the effects would be temporary in nature, the overall impact to critical habitat would be minimal and not permanent.

e. *Summary of Construction Effects*

Based on the calculations for the duration of construction activities, a maximum of 37 percent of the emigrating juvenile winter-run Chinook salmon population is expected to enter the action area during the 28 days of construction activity if construction takes place only during March. If construction starts in mid-January, the fraction of the winter-run Chinook salmon population exposed to the construction actions falls to approximately 20 percent. Since very few winter-run Chinook salmon enter the Delta in May and essentially none in June, all of the juvenile winter-run Chinook salmon exposures to construction actions are expected to take place during the months of January through March. Averaged over the 75 days in the aforementioned work period, approximately 27 percent of the annual juvenile winter-run Chinook salmon population enters the Delta during the 28-day construction period, 0 percent during 21-day deconstruction period; but only 6 days will be associated with the actual vibratory pile driving actions, based on 2011's construction history to install the piles for the barrier. Thus, based on the assumptions discussed previously, approximately 5.8 percent of the winter-run Chinook salmon juvenile population is expected to be exposed to the effects of the pile driving actions over the 6 days of vibratory pile driving: (27 percent of winter-run Chinook salmon population * {6 days [vibratory pile driving] ÷ 28 days [construction window]} = 5.8 percent of the winter-run Chinook salmon population exposed to pile driving actions). This is probably an overestimate due to the alternative routes that emigrating fish may take through Sutter and Steamboat Sloughs and the potential that fish will only move through the action area during crepuscular periods when the likelihood of pile driving actions are low. Furthermore, only an estimated 130 minutes of actual pile driving will occur (5 minutes per pile, 26 piles) with approximately an hour between piles. Thus, the actual exposure to the sound generated by the vibratory hammer is considerably less than 6 days.

Adult winter-run Chinook salmon will also have some exposure to the construction actions during the January through March construction period (up to approximately 37 percent, if all construction actions take place in March). Considerably less exposure to adults occurs during the deconstruction period from mid-May to the end of June (approximately 7 to 5 percent averaged over 3-week increments). It is estimated that approximately 21 percent of the annual adult spawning migration will pass upriver during the 28 days of construction in the mid-January through March work window. Using the same rationale for exposure to pile driving actions as taken for the juveniles, 4.5 percent of the adult winter-run Chinook salmon population will be exposed to these activities. In the mid-May through June period proposed for deconstruction, the proportion of the population of adults exposed to the construction actions to remove the barrier is approximately 8 percent of the total population based on the ratio of 21 days of in-water work and total time in the work window. In addition, using the more conservative acoustic energy levels provided in the CalTrans Compilation (CalTrans 2007), the calculated distances from the pile to the acute injury (peak) and cumulative injury (SEL) noise energy thresholds indicate that juvenile salmonids would have to be closer than 72 feet (22 meters) to encounter cumulative injury effects and within 1 meter of the pile to encounter acute injury levels due to excessive acoustic energy levels from the vibratory pile driving hammer action. If the field data calculations are used, the distances to physical injury and behavioral alterations are reduced. The distance across Georgiana Slough at the site of the barrier is approximately 325 feet, thus the diameter of cumulative injury effects (≈ 150 feet) will encompass about 46 percent of the channel width, leaving approximately 54 percent of the Georgiana Slough channel outside of the sublethal zone. If the criteria associated with the vibratory hammer is used (Hastings 2010), then the diameter of sound energy resulting in non-auditory tissue damage is only 22 meters (72 feet) and less than a quarter of the channel width is compromised by the impacts of the vibratory pile driving action. Since the channel of the Sacramento River is wider (approximately 425 to 450 feet) than the entrance into Georgiana Slough, the percentage of channel width compromised by the vibratory pile driving activities is less. It is expected that about 1/6 of the channel will have sound energy above the cumulative injury threshold of 183 dB, and therefore most of the channel should provide safe passage through the action area. It is not expected that the subtle increase in turbidity associated with the installation of the piles and their subsequent removal will be noticeable beyond the immediate vicinity of the actual pile itself. Ambient river currents should quickly dissipate the small plume of resuspended sediment associated with driving the piling into the channel bottom or in its removal later in May. Any contaminated material associated with the bottom substrate should be rapidly dispersed into the surrounding water column by river currents or tides, thus diluting the concentration of contaminants to which fish are exposed within the vicinity of the barrier. In regards to spills of hazardous materials from land or water based equipment, any impacts are expected to be low due to the safety measures that will be implemented under the proposed spill plan. Furthermore, the conservation measures proposed for the project will minimize risk associated with the project.

The impacts of the construction phase of the GSNPB should be relatively similar for juvenile Central Valley spring-run Chinook and juvenile Central Valley steelhead. Juvenile spring-run Chinook salmon are expected to be present during the construction phase of the project. It is estimated that 21 percent of the juvenile population will be present during the construction actions. Steelhead smolts will experience a higher level of exposure to the construction activities (36.2 percent of the emigrating population). Between 5 and 8 percent of the adult spring-run Chinook population is expected to pass through the action area during the removal phase of the GSNPB study. Few adult spring-run Chinook salmon are expected to pass upriver during the installation of the barrier (≈ 0.5 percent). Adult steelhead may be moving both upstream and downstream during the installation phase (January through March) and the removal phase in May and June, however more downstream migrants are expected since the peak of upstream migration in the Sacramento River basin occurs earlier than mid-January. Exposure to the vibratory pile driver actions will be shorter than the total construction period as explained above for winter-run Chinook salmon.

Both adult and juvenile green sturgeon are expected to be affected by the construction activities associated with the GSNPB study. Juvenile green sturgeon are expected to be present throughout the construction period as juveniles rear in the Delta for up to 3 years. The period between February and May also coincides with the upstream migration of adult green sturgeon from San Francisco Bay through the Delta and into the Sacramento River to spawn. The proportion of fish moving through the action area on a temporal basis is not well known. However due to the larger size of juvenile green sturgeon compared to salmonids, and the obviously larger size of the adults, the effects of the sound generated by the vibratory pile driving hammer are expected to be less severe than that for the smaller salmonids. The short duration of the vibratory pile driving actions to install the pilings for the project will also limit the amount of exposure incurred by green sturgeon in the action area.

The aquatic habitat is not expected to be permanently affected to any demonstrable level as a result of the construction activities. Impacts will be minor due to the small footprint of the 26 piles and the non-permanent nature of the barrier structure itself. Complete removal of all physical structures related to the project will be completed no later than the end of June, and no permanent impacts to the aquatic habitat, including the PCE's of the designated critical habitat for the salmonids and green sturgeon, are expected to occur.

2. Impacts of the Barrier Operations on Fish

a. *Chinook Salmon and Central Valley Steelhead*

Operations of the non-physical barrier would occur for up to 60 days beginning as early as February 1, 2012, and concluding no later than May 31, 2012. The total proportion of downstream migrating juvenile salmonid populations potentially passing through the GSNPB Study area in February, March, April and May is given below. Like the assessment for juvenile fish exposure to the pile driving actions, this assumes that all juvenile fish use the Sacramento River migration corridor and do not the use alternative routes through the northern Delta such as Sutter and Steamboat Sloughs. Percentages were summed for the 4 month period based on the juvenile migration patterns presented in Table 12 (see also National Marine Fisheries Service 2009a: 633). The migratory information is a synthesis of several fish monitoring programs that occur in the lower Sacramento River and within the northern and central Delta:

Juvenile salmonid exposure to barrier operations:

Fall-run Chinook salmon: 34 percent : (13 percent February + 23 percent March + 6 percent April + 26 percent May = 68 percent) * (60 days of operations/121 days in 4 month period) = 34 percent run exposure to operations.

Spring-run Chinook salmon: 48.5 percent: (0 percent February + 53 percent March + 43 percent April + 1 percent May = 97 percent) * (60 days of operations/121 days in 4 month period) = 48.5 percent run exposure to operations

Winter-run Chinook salmon: 28.5 percent (19 percent February + 37 percent March + 1 percent April + 0 percent May = 57 percent) * (60 days of operations/121 days in 4 month period) = 28.5 percent run exposure to operations

Steelhead: 46 percent (32 percent February + 60 percent March + 0 percent April + 0 percent May = 92 percent) * (60 days of operations/121 days in 4 month perod) = 46 percent run exposure to operations

To assess the exposure of adult salmonids, NMFS made similar assumptions for adult fish migrating upstream that were made for the juvenile fish migration. NMFS assumed that all fish passed upstream within the Sacramento River/ Georgiana Slough channels and moved through the action area adjacent to the barrier location and did not move upstream through the alternate pathways previously described. The biological assessment calculated the monthly proportion of adult fish moving through the Delta using data derived from Vogel and Marine (1991) and passage of adult fish past the Red Bluff Diversion Dam (RBDD)(see Table 13). The biological assessment assumed that the swimming speed of migrating salmon would be 25 kilometers per day and that migrating salmon would have passed through the Delta approximately 2 weeks earlier than their observed presence at the RBDD if swimming speed remained consistent. Based on this rationale, the proportion of the total adult Chinook salmon upstream migration that is expected to pass through the 2012 GSNPB Study area during barrier operations from February 1 to May 31, 2012 is as follows:

Fall-run Chinook salmon: 0 percent (0 percent February + 0 percent March + 0 percent April + 0 percent May = 0 percent) * (60 days of operations/121 days in 4 month period) = 0 percent run exposure to operations

Late-fall-run Chinook salmon: 12.5 percent (17.5 percent February + 6.25 percent March + 1.25 percent April + 0 percent May = 25 percent) * (60 days of operations/121 days in 4 month period) = 12.5 percent run exposure to operations

Spring-run Chinook salmon: 3.5 percent (0 percent February + 1.25 percent March + 1.25 percent April + 4.5 percent May = 7 percent) * (60 days of operations/121 days in 4 month period) = 3.5 percent run exposure to operations

Winter-run Chinook salmon: 43 percent (13.75 percent February + 37.5 percent March + 25 percent April + 10 percent May = 86 percent) * (60days of operations/121 days in 4 month perod) = 43 percent run exposure to operations

By March, the peak adult steelhead migration upriver into the Sacramento River basin has greatly diminished as suggested by McEwan (2001)(see Figure 20), with even fewer fish migrating upriver in April. By March and April most adult fish have ascended the Sacramento and are well upstream of the Delta. As mentioned for the construction impacts, there is the potential for adult steelhead kelts (post spawned fish) moving back downstream during March and April from their spawning areas upstream. However, the exact timing and numbers moving back downstream are not known with any certainty.

Since the barrier is of a non-physical type, relying on air bubbles, lights, and sound to deter fish and not a physical blockage of the channel, it is not expected that the barrier structure comprised of the pilings and frame work will block or impede the flow of water into Georgiana Slough from the Sacramento River to any demonstrable level. Therefore, NMFS does not anticipate that there will be any significant hydrodynamic changes in the natural flow split between Georgiana Slough and the Sacramento River and thus, there should be no impacts to fish related to changes in the ambient flow patterns or distribution of water associated with the operation of the barrier beyond the very localized effects seen immediately adjacent to the pilings or framework. It is anticipated that the physical presence of the pilings and framework will create small eddies immediately down current (*i.e.*, behind) the structure as water moves past it. Likewise the actions of the bubbles will create a localized vertical current along the face of the bubble curtain as the less dense bubbles move upwards towards the surface, carrying a fraction of the water within the air-bubble mixture with it towards the surface. At the river surface, the air-water mixture is expected to flow downstream with the prevailing current in the river channel. There is the potential that small fish could be entrained with this vertical movement of water towards the surface and this movement could be disorienting to those fish so entrained making them more vulnerable to predators. It is unlikely that there will be any demonstrable changes in measured water quality, local water elevations, or general water velocities in the larger area surrounding the barrier location that might alter fish distribution due to the operation of the barrier. Changes in salmonid distribution are believed to be primarily caused by the behavioral deterrence of the functioning barrier. Predator distribution may be altered by the barrier due to the fine scale environment surrounding the physical barrier. The creation of structure may enhance the ability for the predator to hold station in the mid-channel location as it orients to the hard structure in the water column (predator attraction to physical structure) and takes advantage of the small velocity breaks associated with the physical structure. This may be more of a problem when the air bubbles, sound, and light components of the barrier are turned off during the cycling of the barrier for the experimental study. The experimental design, which includes the fine scale determination of movements of the tagged late fall-run Chinook salmon study fish, should indicate the level of deterrence associated with the barrier in the operating phase and the interactions with any predators associated with the barrier. In addition, the experimental design includes tagging of predatory fish within the locale of the barrier, and observing their movements during the study, including whether these fish associate with the barrier structure or are influenced by the operation of the barrier.

The upstream migration of adult Chinook salmon and steelhead could also be affected by barrier operation. Adult salmon and steelhead are sensitive to the stimuli emitted by the barrier, and they may be deterred or delayed by the barrier's operation. Although it is expected that most adult salmonids from the Sacramento River basin would probably be migrating up the main stem of the Sacramento River, some may be migrating up through Georgiana Slough after entering the San Joaquin River system. When the barrier is turned on, fish in the Sacramento River could avoid the barrier after first contact by swimming away from it towards the opposite bank (northern bank), and thus avoiding or reducing their exposure to the barrier's bubbles, light, and sound properties. Fish moving upstream in Georgiana Slough would encounter the functioning barrier from the downstream side and would have to swim through or under the bubble curtain, wait for the bubble curtain to be turned off, or return down Georgiana Slough and find a different pathway to enter the Sacramento River main stem channel. The vertical distribution of upstream migrating adult Chinook salmon and steelhead in the Central Valley is not well known, but data from other locations suggest that fish move more frequently at depths that are shallower than the depth of the barrier (Gray and Haynes 1977; Quinn 2005). In contrast, observations by local biologists and models of depths at which migration energy costs are reduced (Hughes 2004) suggest that fish use waters very close to the bottom during their upstream migration and therefore would pass upstream below the depth of the barrier framework. Other factors such as water temperatures, local velocity profiles, and light penetration could affect the distribution of adults in the water column (Quinn 2005).

It is unlikely that the barrier would delay upstream migrating salmonids to any great extent. This conclusion is inferred from tracking studies of adult fall-run Chinook salmon conducted as part of earlier Georgiana Slough acoustic deterrent studies (Hanson *et al*. no date). Hanson *et al.* found that there was no significant delay in upstream passage time and only a 9 percent decrease in passage time when considering both upstream and downstream passage. They concluded that such a delay would not be considered significant in the context of reaching spawning grounds in good condition. In the proposed study, the barrier will be operated for 60 days in the 4-month period that includes February, March, April, and May. Water temperatures and dissolved oxygen are not expected to be limiting at this time, thus a minor delay in the upstream migration of adult winter-run and spring-run Chinook salmon should not result in any demonstrable adverse effects related to the delay. Furthermore, the acoustic barrier used in the Hanson *et al.* studies had a much wider potential area of effect on non-target species or life stages than the current barrier because there was no bubble curtain to contain the sound; resulting in the detection of elevated sound pressure levels up to 0.25 miles away (Hanson *et al.* [no date] as reported in the BA for the GSNPB, DWR 2010). It is therefore assumed that the minimal effect observed on adult salmonids from the earlier Hanson *et al.* studies is applicable to the present barrier, although there would be some uncertainty due to the differences in the barrier designs and operations. Monitoring with the DIDSON camera during the current barrier operations will be used to ascertain whether there are obvious delays in the passage of adult salmonids through the action area as a result of the barrier operations. It will also determine whether adults will swim through the barrier or below it during its operation, or wait until the barrier is turned off before swimming upstream past the barrier structure.

The barrier has the potential to reduce the likelihood that juvenile outmigrating salmon during the period of barrier operations (*e.g.*, spring-run Chinook salmon, winter-run Chinook salmon, fall-run Chinook salmon, and Central Valley steelhead) would follow the natural flow split into Georgiana Slough and thence into the waterways of the interior Delta. The probability that a juvenile Chinook salmon or steelhead smolt would successfully migrate to Chipps Island is lower via the interior Delta routes than for a fish that remains in the main steam channel of the Sacramento River (Perry et al. 2010). The non-physical barrier is intended to serve as a beneficial guide to juvenile salmon migrating downstream in the Sacramento River. It guides fish away from Georgiana Slough, causing the fish to remain in the Sacramento River. In doing so it has the potential to increase smolt survival because it keeps fish away from the interior Delta waterways where they have an increased risk of predation and increased vulnerability to entrainment at the SWP and CVP export facilities.

In contrast to the discussion above of adult salmonids migrating upstream, juvenile salmonids, such as Chinook salmon, are assumed to occupy the upper 4 meters (13 feet) of the water column (referenced in DWR [2012] based on an assumption made in Kimmerer (2008) using the depth of trawl nets used in fish monitoring studies, his "Z" variable in equation 7) and thus most fish will encounter the bubble curtain when it is operating. However, some fish may pass beneath the barrier, which will have its lowest point at a depth of approximately 8–12 feet beneath the surface (see Figures 2 and 3). This will allow a fraction of the naturally occurring distribution of fish in the water column to be below the depth of the bubble curtain. This fraction of fish could pass undeterred beneath the curtain and into the channel of Georgiana Slough. Passage of fish under the barrier may increase during the night when fish have been observed to disperse in the water column compared to daytime behavior. The study is designed to measure the fraction of the tagged fish passing beneath the barrier. The fine scale resolution capabilities provided by the acoustic listening array equipment will allow depth determination of the tagged fish as it encounters the bubble curtain and therefore whether fish at deeper depths pass through the barrier at higher rates than fish at shallower depths. Those fish that do encounter the barrier at shallower depths may also pass through the bubble curtain. Based on the results of the 2009-2010 testing at the HOR non-physical barrier (Bowen et al. 2009, Bowen and Bark 2010), deterrence could be over 80 percent with a smaller fraction passing through the barrier. This high rate of deterrence however may not always translate into increased survival if predators are attracted to the barrier support structure in the water. Bowen and Bark (2010) observed that striped bass (*Morone saxitalis*) swam parallel to the bubble curtain, immediately adjacent to the HOR barrier infrastructure. The striped bass preyed upon tagged juvenile Chinook salmon that were deterred by the barrier's bubbles and sound and were swimming downstream along the barrier. A further complication of this particular study at the Head of Old River is the presence of a large scour hole at the downstream end of the Head of Old River Barrier. Salmon that were deterred effectively by the barrier were directed towards the deep scour hole where predators were congregated. Predation of the redirected smolts was high and overall survival was diminished (Bowen et al. 2009). A similar scour hole is present near the Georgiana Slough barrier that is analogous to the scour hole at the Head of Old River. It is anticipated that this hole will also harbor predators such as striped bass, which are expected to feed upon some of the deterred fish. The level of predation will likely depend on the hydrodynamic conditions experienced during the study, e.g., lower predation may occur with higher Sacramento River flows (Bowen and Bark 2010) or the distribution of fish across the entire Sacramento River channel at the site of the barrier in relation to tidal effects may reduce the apparent concentration of fish along the barrier. Determining the level of survival of the fish bearing acoustic tags passing through the action area will allow the role of predation to be examined further, as will tracking of tagged predators and DIDSON camera monitoring of the barrier vicinity for predators in the 3 hours before and after turning the barrier on or off.

b. *Southern DPS of North American Green Sturgeon*

Juvenile, sub-adult, and adult green sturgeon are expected to be present in the Sacramento River and Georgiana Slough from February through May, the period when the experimental study utilizing the barrier is to be conducted. Adult green sturgeon are expected to be moving upriver during this 4-month period to reach their spawning grounds in the upper Sacramento River. Juveniles and sub-adults are expected to be within the waters of the Delta, which includes the action area, using it as a migratory corridor and rearing area. The non-physical barrier at Georgiana Slough has been designed to have a clearance from the bottom of the support framework to the channel bottom of approximately eight to twelve feet. Therefore, adult, sub-adult, and juvenile green sturgeon are expected to easily pass beneath the structure if they choose to do so. Green sturgeon are generally benthically oriented (Moyle 2002), but may also be found swimming high in the water column (Kelly *et al.* 2007). Based on auditory studies conducted with other Acipenseridae, Lovell *et al.* (2005) concluded that acipenserids did not have the hearing sensitivity of teleost fish considered to be hearing specialists to pressure dominated sound fields such as used in the non-physical barrier. However, the comparisons done in that study were between hearing specialists (non-native Asian carp) and the endemic shovelnose sturgeon (*Acipenser fulvescens*) and paddlefish (*Polyodon spathula*). Since salmonids are hearing generalists, the level of separation between hearing thresholds of salmonids and green sturgeon may not be as substantial as would be expected from the Lovell *et al.* (2005) study where hearing sensitivities between the native shovelnose and paddlefish were compared to the non-native silver carp (*Hypopthalmichthys molitrix*) and bighead carp (*Aristichthysc nobilis*). Acipenseridae possess large swim bladders, and may use sound as a form of communication (Johnston and Phillips 2003, Popper 2005). Acipenseridae also may have the ability to detect electrical currents in the water (Teeter *et al*., 1980), and the electrical field surrounding the barrier apparatus when electrical current is flowing to the lights and sound generators may affect the behavior of sturgeon. However, when the barrier is in the "off" configuration there is no electrical current flowing to the lights and sound generators, and the barrier does not produce sound, lights or bubbles that may interfere with sturgeon behavior.

c. *Effects to Critical Habitat from the Operations of the Non-Physical Barrier*

The effects of the non-physical barrier operation on designated critical habitat for the endangered Sacramento River winter-run Chinook salmon ESU, the threatened Central Valley spring-run Chinook salmon ESU, the threatened Central Valley steelhead DPS, and the Southern DPS green sturgeon is expected to be minimal. The barrier will be operated for only 60 days during a 4-month study window and will be cycled on and off during that period according to the experimental protocol of the study. The deterrence effect of the sound generated as part of the barrier operations will obstruct portions of the migratory corridors utilized by the emigrating salmonids and green sturgeon. However, this deterrence effect is the intention of the non-physical barrier and its operation is designed to enhance the ultimate survival of emigrating salmonids through the Delta. This will be accomplished by reducing the diversion of juvenile Chinook salmon and steelhead into Georgiana Slough and thus reducing access to the Delta interior and the waterways of the central and southern Delta. Numerous studies have shown that survival is lower in the Delta interior and the waterways of the central and southern Delta (Brandes and McLain 2001, Newman and Brandes 2010, Perry *et. al*. 2010). Fish that remained in the Sacramento River system had higher survival rates to the western Delta (Chipps Island) than those fish that entered the Delta interior. Fish that entered the Delta interior via Georgiana Slough also had a higher vulnerability to entrainment at the CVP and SWP pumping facilities compared to fish that remained in the Sacramento River (Newman and Brandes 2010). While the barrier will limit access to designated critical habitat for Central Valley steelhead in the central and southern Delta, it is believed that the fish from the Sacramento River basin will ultimately benefit by having higher survival rates to the western Delta. Winter-run and spring-run Chinook salmon do not have designated habitat in the central and southern Delta or in Georgiana Slough. Therefore, preventing fish from entering Georgiana Slough will not affect critical habitat, because Georgiana Slough was not designated as critical habitat for these ESUs, nor were the waters of the central and southern delta.

The waters of the Delta (north, central, western, and southern Delta, and essentially all accessible waters within the legal Delta with only a few exceptions) were designated as critical habitat for the southern DPS of green sturgeon. The operation of the non-physical barrier may impede some movements of green sturgeon within these waters, but it is not considered a total blockage of the migratory corridors. As discussed above, ample space is present beneath the structure's supporting framework to provide passage through the location of the barrier. It is not expected that the sound generated by the barrier will deter green sturgeon to the same extent as the salmonid species due to the intrinsic qualities of the hearing thresholds of sturgeon. Based on the Lovell *et al.* (2005) studies, sturgeon species appear to require higher thresholds for provoking deterrence responses than hearing specialist (*i.e.*, such as the silver and big headed carp) in a sound pressure dominated sound field. The sturgeon species tested were responsive to sound ranging in frequency from 100 to 500 Hz. It also is expected that green sturgeon should be able to pass beneath the barrier with minimal delay during the barrier operations as no physical obstruction is present. Furthermore, the barrier will be cycled from operation to non-operation on a continual basis during the duration of the experiment, thus any behavioral deterrence due to sound, light, or electroception of the electric current driving the barrier operation will be intermittent and will allow passage during the "off" cycle. Thus there will be multiple periods each day when the barrier is turned off and there should be no sustained deterrence effect from the barrier to green sturgeon.

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 operation of the GSNPB by DWR will occur over a 5 ½ month period, mid-January through June 2012. The effects will be temporary since the barrier will be completely removed in May 2011, following the completion of the experimental study.

B. Summary of Effects of the Proposed Action

The proposed project, the Georgiana Slough non-physical barrier and the associated experimental study using acoustically tagged late-fall Chinook salmon 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 GSNPB is designed to allow water to enter the Georgiana Slough channel at the head, while also serving as a deterrent to emigrating salmonids that would try to enter the channel during their downstream emigration, and guiding them to remain in the main channel of the Sacramento River through the Delta. The interior of the Delta has low survival rates for salmonids. Most are presumed to be eaten by predators within the waterways of the central and southern Delta, but other stressors such as contaminants, migrational delays, or entrainment by the export facilities are other potential sources of mortality.

1. Sacramento River Winter-Run Chinook Salmon

The exposure of juvenile and adult winter-run Chinook salmon to the effects of construction related activities will amount to 28 days between mid-January and March 31, 2012, and 21 days between mid-May and June 30, 2012. It is calculated that approximately 27.2 percent of the juvenile population and 20.5 percent of the adult population will be exposed to the construction actions. Pile driving will occur over a 6 day period, and the fraction of the population that will be exposed to the effects of pile driving is approximately 5.8 percent of the juveniles and 4.4

percent of the adult population. The fraction may even be less if fish move downstream through either Steamboat or Sutter Sloughs rather than within the main channel of the Sacramento River. Furthermore, fish moving at night would avoid pile driving operations. Pile driving would not occur at night. The actual percentage of fish that might incur injury is probably less than the fraction of the population exposed due to the limited range that excessive sound levels extend away from the pile into the river channel during the pile driving actions. The range to tissue injury is at most 72 feet (based on the spreadsheet model and criteria derived from percussive pile drivers: 206 dB peak and 187 dB $SEL_{accumulated}$ for fish > 2 grams) and as little as 35 feet if the vibratory pile driving hammer criteria (Hastings 2010) are used instead (195.28 dB $SEL_{accumulated}$ for fish >0.6 grams). Acute tissue injury from peak sound pressure of 206 dB would occur at distances of 1 meter or less from the pile during the pile driving actions using the vibratory hammer. The distance across Georgiana Slough at the site of the barrier is approximately 325 feet, thus the diameter of cumulative injury effects (≈ 150 feet) will encompass about 46 percent of the channel width, leaving approximately 54 percent of the Georgiana Slough channel outside of the tissue injury zone. If the criteria associated with the vibratory hammer is used (Hastings 2010), then the diameter of sound energy resulting in non-auditory tissue damage is only 22 meters (72 feet) and less than a quarter of the channel width is compromised by the impacts of the vibratory pile driving action. Since the channel of the Sacramento River is wider (approximately 425 to 450 feet) than the entrance into Georgiana Slough, the percentage of channel width compromised by the vibratory pile driving activities is less. It is expected that about 1/6 of the channel will have sound energy above the cumulative injury threshold of 183 dB, and therefore most of the channel should provide safe passage through the action area. Since adult fish are larger, it takes a greater level of sound intensity to cause injury. Therefore, the ranges described here would be conservative estimates for the effects on adult fish.

The percentage of juvenile winter-run Chinook salmon exposed to the barrier operations during the 60-day study occurring between February 1 and May 31 (121 days) will amount to 28.5 percent of the emigrating population, assuming all fish utilize the Sacramento River channel as their migratory corridor. As explained previously, a fraction of the emigrating population will likely use Sutter and Steamboat Slough to move downstream so the estimate of exposure is likely an overestimate as those fish taking the alternative routes will not be exposed to the barrier at Georgiana Slough. The percentage of the adult winter-run Chinook salmon population exposed to the barrier operations over the 4-month period is 43 percent. The barrier is designed as a deterrent and the intensity of the sound emitted by the barrier is below the thresholds for physical injury to salmonids. Therefore the barrier operations will not cause injury by themselves. Barrier operations however may increase vulnerability of fish moving parallel to the face of the bubble curtain to predation. The magnitude of the potential increase in predation is unknown at this time. However, it should be compared to the potential benefits in survival derived from reducing the diversion of fish into Georgiana Slough and keeping more fish within the mainstem of the Sacramento River. Estimates of the ratio of survival of fish migrating through the interior Delta compared to the survival of fish remaining in the Sacramento River migratory corridor are less than 1:2 (mean value 35 percent, Newman and Brandes 2010) and survival of tagged juvenile Chinook salmon in the Georgiana Slough migratory corridor is approximately 33 percent. (Perry *et al*. 2010). Adult fish are not expected to be substantially affected by the barrier operation, with slight migratory delays being the most likely effect created by the barrier operation. Passage through the barrier location is likely to occur when the barrier is cycled to the "off" configuration.

2. Central Valley spring-run Chinook salmon

The exposure of juvenile and adult spring-run Chinook salmon to the effects of construction related activities will amount to 28 days between mid-January and March 31, 2012, and 21 days between mid-May and June 30, 2012. It is calculated that approximately 21 percent of the juvenile population and 0.5 percent of the adult population will be exposed to the construction actions. Pile driving will occur over a 6 day period, and the fraction of the population that will be exposed to the effects of pile driving is approximately 4.5 percent of the juveniles and 0.1 percent of the adult population (see Tables 12 and 13). In contrast, during the 60-day study occurring between February 1 and May 31 (121 days), approximately 48.5 percent of the juvenile spring-run Chinook salmon population will move through the action area and potentially face exposure to the barrier operations. The estimated proportion of the adult population of spring-run Chinook salmon moving upstream during this 121 day period is 3.5 percent of the population. As described earlier for winter-run Chinook salmon, these are probably overestimates since alternative routes such as Sutter and Steamboat Sloughs exist and not all of the migrating population is likely to use the Sacramento River migratory corridor. Juvenile spring-run Chinook salmon are expected to face the same general risks as winter-run Chinook salmon to the operations of the barrier. In comparison to the winter-run Chinook salmon population, nearly all of the juvenile spring-run Chinook salmon population (97 percent) will emigrate through the Delta during the 4-month study period, compared to only 57 percent of the winter-run Chinook salmon juvenile population.

3. Central Valley Steelhead

During the construction phase of the project approximately 9.8 percent of the emigrating steelhead smolt population from the Sacramento River basin will be exposed to construction activities over the 28 days between mid-January and March 31, 2012, and 21 days between mid-May and June 30, 2012 (see Table 12). It is calculated that approximately 36.2 percent of the juvenile population and less than 10 percent of the adult population will be exposed to the construction actions. Pile driving will occur over a 6 day period, and the fraction of the population that will be exposed to the effects of pile driving is approximately 7.8 percent of the juvenile population and less than 2 percent of the adult population. Like the winter-run and spring-run Chinook salmon migrations, alternative routes for migration through Sutter and Steamboat Sloughs exist for steelhead, and the prospect that all of the emigrating steelhead will move through the Sacramento River route is unlikely. Thus, the risk of Sacramento River basin steelhead smolt exposure to the construction actions is liable to be less than the numbers given above. It is very unlikely that steelhead smolts from the Mokelumne River system or from the San Joaquin River basin, including the Calaveras River system, will have any exposure to the GSNPB study as their migratory corridors are in the San Joaquin River system and do not overlap with the action area. In regards to the 60-day operational period of the barrier over the 4-month period between February 1, 2012, and May 31, 2011, there is a high likelihood that a substantial fraction of the downstream emigrating steelhead smolt population will be present in the action during this time. Approximately 92 percent of the juvenile emigration occurs during the 4-month period between February and May. As previously described for winter-run and spring-run Chinook salmon, the operation of the barrier should not lead directly to fish being harmed by the sound or bubbles generated by the barrier itself. Barrier operations however may increase vulnerability of fish moving parallel to the face of the bubble curtain to predation. How much predation will be changed is currently unknown, but will be one of the focuses of the proposed experimental study. As described previously for the winter-run Chinook salmon, the change in predation rates associated with the barrier operations will be compared to the change in overall survival of the fish that remain in the Sacramento channel and migrate downstream towards the western Delta. Higher survival of steelhead is expected for that proportion of the population that remains in the Sacramento River system compared to those which move into Georgiana Slough and the Delta interior.

Adult migration of steelhead into and out of the Sacramento River Basin may be occurring during the construction periods between mid-January and March 31, 2012, but likely represents a small fraction of the adult population (< 10 percent). Likewise, some adults may be migrating during the 4-month operational phase of the study (February through May). As previously described, the peak of upriver migration occurs earlier in the year, with most fish moving upstream in fall and early winter (see Table 6 and Figure 20) and spawning from December through April with peaks in spawning from January though March in small streams and tributaries throughout the basin. Thus, most fish would already be upriver near their spawning reaches during this time (February through May). Those fish that returned downriver following spawning (kelts) may be passing through the action area, but information for this life history stage is not clear or abundant. It is not expected that adult steelhead would be demonstrably affected by the operations of the bubble curtain. Delay of migration may occur, but will likely be of short duration since fish could continue their upstream migration when the barrier is cycled to the "off" configuration during the experiment. In addition, due to the large gap between the bottom of the barrier framework and the channel bottom, adult fish could just as easily pass beneath the bubble curtain as wait for it to turn off. Predation of adult steelhead is not expected to be a concern since most adult fish are large enough to avoid being eaten by other predatory fish. A potential concern would be if aquatic mammals such as sea lions or river otters congregated in close proximity to the barrier and preyed upon fish that were congregated in the area due to potential delays created by the barrier operations.

4. Southern DPS Green Sturgeon

Little is known about the migratory habits and patterns of either adult or juvenile green sturgeon in the Delta region. Adults begin their upstream spawning migrations into freshwater in late February with spawning occuring between March and July in locations in the upper Sacramento River below Keswick Dam (CDFG 2002. Heublin 2006, Heublin *et al.* 2009, Vogel 2008). Peak spawning is believed to occur between April and June in the stretch of the Sacramento River between Red Bluff and Keswick Dam. After spawning, adults return downstream and re-enter the Delta towards late summer and fall based on the behavior of tagged sturgeon in the Sacramento River system. Juvenile and larval green sturgeon begin to show up in rotary screw trap catches along the Sacramento River starting in summer (Beamesderfer et al. 2004) and could be expected to reach the Delta by fall, but are more likely to enter the next spring based on lines of evidence related to their behavior in relation to water temperature and the size of fish captured at the CVP and SWP fish salvage facilities. Kynard *et al*.'s (2005) laboratory studies indicated that juvenile fish continued to migrate downstream at night for the first 6 months of life. When ambient water temperatures reached 46.4°F, downstream migrational behavior diminished and holding behavior increased. 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 construction and operational phases of the project. Exposure to the construction phase is expected to be brief; 28 days between mid-January and March 31 and 21 days between May 15, and June 30, 2012, with a much briefer period of exposure to the pile driving actions with the vibratory hammer (6 days). Due to their larger size compared to salmonids, sturgeon are expected to be more resistant to any physical effects associated with the pile driving actions. Exposure of fish to the operational phase will be for a much longer period, but effects to juveniles, sub-adults, and adults are expected to be minimal. Green sturgeon should be able to swim below the barrier with minimal delays in their movements. The acoustic sensitivity studies conducted by Lovell *et al.* (2005) indicate that green sturgeon (as referenced to the other Acipenseridae surrogate species) may be relatively insensitive to the frequencies and intensity of sound employed by the barrier as a deterrent, at least as compared to other teleost fish. Predation is not expected to be an issue with green sturgeon as their size and protective scutes afford a measure of protection against most predators.

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 26 pilings that will be driven into the channel of the Sacramento River adjacent to the mouth of Georgiana Slough will only impact 20 ft^2 of substrate. An additional 72 ft^2 of bottom will be covered by the 4 concrete piers used to support the bottom of the framework in shallow water. The 38 concrete blocks used to anchor the hydrophone arrays will cover approximately 304 ft^2 of additional bottom substrate. The total in-channel footprint for the barrier is approximately 0.01 acres. This will result in only a temporary disturbance of the channel substrate as the barrier will be completely removed from the channel, including all piers, concrete anchors, and pilings following the completion of the study. The operation of the barrier will introduce sound, light, and a bubble curtain into the aquatic environment. These elements will lead to a migratory blockage of Georgiana Slough when the barrier is in operation. As such, there will be a project related impediment to free migratory movement of fish within the designated critical habitats for Central Valley steelhead and green sturgeon. The impediment to free migration is intentional and is a project purpose. The barrier is designed to deter listed salmonids from entering Georgiana Slough and subsequently the waters of the Delta interior, including the central and southern Delta. By doing so, it is hypothesized that overall survival will be enhanced for these listed salmonid populations by reducing the fraction of the population that migrates into Georgiana Slough and that is subsequently lost. Several studies, as previously mentioned above, have clearly shown that survival is typically lower for Chinook salmon smolts migrating through the waterways of the central and southern Delta compared to those fish that remain in the Sacramento River migratory corridor. By reducing the fraction of fish that migrate into Georgiana Slough and redirecting these fish back into the Sacramento River route, more fish are likely to survive to the western Delta, thus theoretically increasing the number of fish that will make it successfully to the ocean through the estuary. By increasing the number of fish successfully entering the marine phase of their life history, more future adult fish should eventually return to spawn. The potential for predation losses will be examined as part of the study and the potential for increased smolt loss due to the barrier operations will be weighed against the increase in overall survival of fish through to the western Delta. As mentioned earlier, the barrier is temporary with full removal by the end of June. Thereafter there will be no impediment to migration. During the experimental study, the barrier will be cycled on and off. During the "off" cycle there should be no impediment to normally occurring migration patterns as currently observed in the action area. Some alteration to predation rates may occur, but the magnitude and character of the change is not known at this time with certainty. One of the experimental goals of the study is to characterize the nature of predation associated with the installation and operation of the non-physical barrier and compare overall survival through the action area with the barrier operating and when it is off.

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 GSNPB study, and the cumulative effects, it is NMFS' biological opinion that the GSNPB 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 will 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 juvenile Sacramento River winter-run Chinook salmon, juvenile Central Valley spring-run Chinook salmon, adult and juvenile Central Valley steelhead and juveniles from the Southern DPS of North American green sturgeon, resulting from (1) the construction and removal of the non-physical barrier between the months of mid-January and March 31, 2012, and May 15 and June 30, 2012, respectively, due to the generation of underwater noise associated with the process of installing and removing the barrier including noise associated with pile driving; (2) increased vulnerability to predation during the construction process and barrier operations; and (3) the impedance of free migratory movements within the channels of Georgiana Slough and the Sacramento River during the operational period of the Georgiana Slough non-physical barrier. Incidental take of juvenile and adult Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and Southern DPS green sturgeon is expected to occur during the 28-day construction period occurring between mid-January and March 31, 2012, and from the 21-day period between May 16 and June 30, 2012, when individuals from these four populations could potentially be present in the action area during construction activities and during the 60-days of barrier operations from February 1 through May 3, 2012.

Only the level of acoustic noise generated during the construction and deconstruction phases of the project can be accurately and consistently measured, thus providing a quantifiable metric for determining incidental take of listed fish. Therefore, the measurement of acoustic noise during the construction and deconstruction phases, and in particular the vibratory pile driving of the steel piles described in the proposed project, will serve as a physically measurable proxy for the incidental take of listed fish species. NMFS assumes that the project proponent will adhere to the project description provided for the purposes of the section 7 consultation, and will not depart from that description in any meaningful or demonstrable way.

The analysis of the effects of the proposed GSNPB anticipates that the installation of the barrier will use up to 26 steel piles, each 12 inches in diameter. The number, size, and material of the pilings will affect the amount of sound energy generated during the driving of the pilings that was analyzed for this project. Likewise, pile driving must be conducted using a vibratory hammer. Different methodologies or types of pile driving equipment will alter the characteristics of the acoustic noise generated during the installation of the pilings, which in turn affects the physiological and behavioral response of the exposed receptors (*i.e.,* listed fish species) present in the vicinity of the construction activities. Based on the effects analysis conducted for this consultation, the amount of generated sound associated with the pile driving actions shall not exceed 206 dB peak at 1 meter from the pile being driven at any time, 183 dB SEL at 22 meters (72 feet) from the pile at any time, and a value of 155 dB RMS as measured 75 meters (246 feet) from the pile at any time. Based on data collected in 2011, these values should not be exceeded during the installation of the pilings. Using these metrics, the calculated distances from the pile to the acute injury (peak) and cumulative injury (SEL) noise energy thresholds indicate that juvenile salmonids would have to be closer than 72 feet (22 meters) to encounter cumulative injury effects and within 1 meter of the pile to encounter acute injury levels due to excessive acoustic energy levels from the vibratory pile driving hammer action.

If any of these proxies are exceeded, the proposed 2012 GSNPB 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 measures are 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 DWR avoids or minimizes construction related impacts associated with the implementation of the GSNPB 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 GSNPB study.

2.) The Corps shall ensure that DWR monitors the projected weather patterns and river conditions and real time fish monitoring data prior to initiation of construction to protect listed fish.

3.) The Corps shall ensure that DWR implements all conservation measures described in the project description for the GSNPB 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 measures described above and outline prescribed reporting/monitoring requirements. These terms and conditions are non-discretionary:

1.) The Corps shall ensure that DWR avoids or minimizes construction related impacts associated with the implementation of the GSNPB 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 GSNPB study.

a.) The GSNPB study shall be constructed at the location described in the project description. The barrier shall cross the mouth of Georgiana Slough at the following coordinates: Latitude 38.23947^{o}, Longitude -121.51726^{o}, near the town of Walnut Grove, CA. Any variance from this location will constitute the need to reinitiate consultation with NMFS.

b.) Construction impacts shall be confined to the minimum area necessary to complete the GSNPB barrier. No more than 26 steel piles shall be used for the barrier. No more than 0.01 acres of in-water habitat shall be affected by the physical footprint of the barrier project.

c.) Stockpiling of construction materials including piles, cables, concrete anchors, portable equipment, vehicles, and supplies, including chemicals and chemical containers, shall be restricted to the designated construction staging areas on the western bank of Georgiana Slough and avoid to the greatest extent possible riparian areas. Staging of these materials may begin on or after January 1, 2012, for the installation of the barrier in 2012. Removal and cleanup of the staging area will be completed within 30 days of the completion of the experimental study, but no later than June 30, 2012. Exposed soils shall be reseeded with native plants and/or grasses to prevent erosion following completion of the decommissioning of the staging area.

d.) In water construction for the installation of the barrier shall commence no earlier than January 15, 2012, and last no more than 28 days as described in the project description. Construction shall be completed prior to March 31, 2012. Complete removal of the barrier shall be accomplished no later than June 30, 2012. Construction activities to remove the barrier shall last no more than 21 days.

e.) Monitoring of underwater sound generated by the vibratory hammer during piling installation shall be conducted to verify that sound level criteria are not being exceeded as calculated in the project description. If levels are exceeded, NMFS will be notified and work halted until corrective actions are instituted to achieve sound level criteria.

f.) The experimental study utilizing the GSNPB shall not exceed 60 days of operation between February 1, 2012, and May 31, 2012.

g.) All heavy equipment shall be fueled, maintained, and stored at a safe distance from any adjacent waterways. Standard construction best management practices (BMPs), as described in the current California Department of Transportation Construction Site Best Management Practices Manual (Caltrans 2003), shall be implemented so that no oil, grease, fuel or other fluids contaminate the waterways around the work sites.

h.) The trailer housing the power supply and equipment to operate the GSNPB shall be placed on the berm adjacent to Georgiana Slough installation site (western bank of Georgiana Slough). 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 GSNPB. 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.

i.) Erosion control measures that prevent soil or sediment from entering the river during construction, or as a result of construction, shall be implemented and maintained throughout construction, or as needed as described in the Caltrans Construction Site BMP Manual. If precipitation events occur during construction or the experimental study period, the staging and storage site will be monitored for sediment runoff to the adjacent waterways and corrective actions implemented if such sediment runoff is observed or reasonably predicted.

j.) Any Chinook salmon, steelhead or green sturgeon found dead or injured within 0.25 mile upstream or downstream of construction sites during barrier installation 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 carcass or injured specimen was found, a color photograph, 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.) Within 30 days of completing any construction activity associated with the GSNPB, DWR shall submit a report to the Corps and NMFS describing the work that was performed, the starting and ending dates of the construction actions, any observed adverse effects to aquatic habitats and their duration (*i.e*., increased suspended sediment levels or turbidity, instances of pollution, unusual animal behaviors in adjacent waters, *etc*.), any problems encountered during construction activities, and any adverse effects to Chinook salmon, steelhead, or green sturgeon associated with the construction activities that was not previously considered.

2.) The Corps shall ensure that DWR monitors the projected weather patterns and river conditions and real time fish monitoring data prior to initiation of construction to protect listed fish.

a.) The Corps shall ensure that DWR monitors weather patterns and river forecasts for the period preceding the start of construction. If precipitation events or increases in river levels and flows are predicted to occur immediately prior to the start of construction, DWR shall notify NMFS prior to initiating construction and consult with NMFS to determine if construction actions are still feasible as previously considered. Sudden increases in river flows, imminent precipitation events that will create changes in river stage in the Sacramento Valley, or observed sudden increases in turbidity in the Sacramento River above the Delta may initiate a pulse of salmonid migration into the Delta.

b.) The Corps shall ensure that DWR monitors the recovery of salmonids in the fishery monitoring programs currently being employed on the Sacramento River and northern Delta. If increasing presence of listed salmonids are detected in these monitoring efforts at Moulton Weir, Tisdale Weir, Knights Landing, and Sacramento Area mid-water trawl and beach seines, DWR shall immediately contact the Sacramento Area Supervisor for NMFS. NMFS and DWR will confer to determine if construction actions will place fish at additional risk within the action area.

3.) The Corps shall ensure that DWR implements all conservation measures described in the project description for the GSNPB study.

a.) The Corps shall ensure that DWR minimizes the potential for harm, harassment, injury, death, or other forms of take of federally listed species resulting from actions related to the GSNPB study by implementing all of the *Conservation Measures* as described in the *Project Description* section of this biological opinion. Conservation measures may be modified by the terms and conditions of this document to enhance and further the protection of listed species.

b.) The Corps shall ensure that DWR, through the terms of the issued nationwide permit, requires all contractors and personnel involved with this project to be educated and informed of the *Terms and Conditions* of this biological opinion and the *Conservation Measures* described in the project description.

c.) The Corps shall ensure that DWR develops and delivers a worker environmental awareness training program to NMFS prior to initiating project activities for NMFS approval. Following NMFS approval of the training program, DWR shall provide written documentation of environmental training of all personnel involved in the construction of the project.

d.) All biologists engaged in the implementation of the GSNPB Conservation Measures shall be qualified to carry out their duties. All biologists shall present their qualifications to NMFS for approval prior to engaging in project activities.

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 DWR 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 DWR 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 DWR 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 DWR 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 Georgiana Slough Non-physical Barrier Program for 2012. 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.

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Appendix A: Tables

Table 1: Underwater Noise Level Measurements of Vibratory Hammer Pile Driving During the 2011 GSNPB Study (at 10 meters from pile)

Date	Time of Day		Pile	Depth (feet)[1]	Number of Seconds of	Peak[2] (dB)	Average Peak[3] (dB)	Daily Number of Seconds of Vibratory	Daily Average Peak[3]	SEL$_{accumulated}$ (dB)	
	Start	End								Stationary Fish	Moving Fish
2-24-2011	10:36:28	13:55:24	15	5	1,070	180.7	168	2,451	175	184	169
	14:38:02	14:43:22	14	5	321	159.3	155				
	16:28:57	16:58:42	13	8	1,060	190.0	183				
2-25-2011	14:18:45	14:20:36	13	8	112	171.8	162	142	162	159	--
	14:34:36	14:35:05	14	5	30	171.0	163				
2-26-2011	15:26:50	16:07:52	12	8	1,060	177.8	178	717	178	174	--
2-28-2011	8:19:51	9:08:01	11	8	252	178.3	159	1,082	173	178	--
	9:49:34	9:55:42	10	10	369	171.4	158				
	10:32:47	10:39:41	9	10	105	168.3	159				
	11:25:31	11:29:40	18	10	65	182.3	173				
	12:35:25	12:38:57	8	10	85	181.3	167				
	13:13:06	13:18:48	7	10	206	192.4	177				
3-2-2011	16:29:21	16:33:15	17	10	75	187.5	177	381	177	177	173
	17:13:48	17:21:44	6	10	306	188.3	176				
3-3-2011	8:27:54	8:31:51	16	10	114	186.9	175	425	173	174	--
	9:11:26	9:15:26	5	10	57	175.9	164				
	9:54:08	9:56:40	4	10	55	187.2	177				
	10:32:26	10:35:36	3	10	94	155.0	152				
	11:08:35	11:09:27	2	8	48	187.6	173				
	11:58:22	9:15:26	1	5	57	182.6	170				

Notes: dB = decibel; SEL$_{accumulated}$ = daily accumulated sound exposure level.

[1] Depth of hydrophone in water body.

[2] Peak sound pressure refers to the highest absolute value of a measured waveform.

[3] Average of peak sound pressure levels measured during pile installation.

Source: Underwater measurements conducted by AECOM in 2011, National Marine Fisheries Service Underwater Noise Calculation Spreadsheet 2011.

Table 8: 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 9: 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 10. 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
<u>Central Valley</u>	***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 Ravines	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, and 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	UCDavis
		Suisun Marsh	Gill netting	Suisun Marsh Salinity Control Gates	Fish passage	Variable, Jun - Dec	CDFG

Table 11: 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 12: 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 13: 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 15: Cumulative exposure for 4 consecutive weeks during juvenile emigration period for salmonids. Emigration values are from Table 12. Highlighted area is the proposed construction period spanning the mid-January through end of March time frame. Each numerical value represents the cumulative sum of the next 4 monthly quartiles (approximately 1 week per quartile) during which in-water construction would occur (28 days ≈ 4 weeks or quartiles).

Month	Week (Monthly quartile)	Juvenile Salmonid Run			
		Fall-run	Spring-run	Winter-run	Steelhead
Jan	1	14	3	17	5
	2	14	2	18	12
	3	14	2	18	19
	4	13	1	19	25
Feb	1	13	0	19	32
	2	16	13	24	39
	3	18	27	28	46
	4	21	40	33	53
Mar	1	23	53	37	60

Table 16: Cumulative exposure for 3 consecutive weeks during juvenile emigration period for salmonids. Emigration values are from Table 12. Highlighted area is the proposed deconstruction period spanning the mid-May through end of June time frame. Each numerical value represents the cumulative sum of the next 3 monthly quartiles (approximately 1 week per quartile) during which in-water deconstruction would occur (21 days ≈ 3 weeks or quartiles).

Month	Week (Monthly quartile)	Juvenile Salmonid run			
		Fall-run	Spring-run	Winter-run	Steelhead
May	1	19.5	0.75	0	0
	2	19.5	0.75	0	0
	3	13	0.75	0	0
	4	6.5	0.75	0	0
June	1	0	0.75	0	0
	2	0	0.75	0	0
	3	0	0.5	0	0
	4	0	0.25	0	0

Table 17: Cumulative exposure for 4 consecutive weeks during adult emigration period for salmonids. Emigration values are from Table 13. Highlighted area is the proposed construction period spanning the mid-January through end of March time frame. Each numerical value represents the cumulative sum of the next 4 monthly quartiles (approximately 1 week per quartile) during which in-water construction would occur (28 days ≈ 4 weeks or quartiles).

Month	Week (Monthly quartile	Adult Salmonid Run			
		Fall-run	Spring-run	Winter-run	Late-fall
Jan	1	0.00	0.00	3.75	17.50
	2	0.00	0.00	6.25	17.50
	3	0.00	0.00	8.75	17.50
	4	0.00	0.00	11.25	17.50
Feb	1	0.00	0.00	13.75	17.50
	2	0.00	0.31	19.69	14.69
	3	0.00	0.63	25.63	11.88
	4	0.00	0.94	31.56	9.06
Mar	1	0.00	1.25	37.50	6.25

Table 18: Cumulative exposure for 3 consecutive weeks during adult emigration period for salmonids. Emigration values are from Table 13. Highlighted area is the proposed deconstruction period spanning the mid-May through end of June time frame. Each numerical value represents the cumulative sum of the next 3 monthly quartiles (approximately 1 week per quartile) during which in-water deconstruction would occur (21 days ≈ 3 weeks or quartiles).

Month	Week (Monthly quartile)	Adult Salmonid run			
		Fall-run	Spring-run	Winter-run	Late-fall
May	1	0.00	3.38	7.50	0.00
	2	0.00	3.38	7.50	0.00
	3	0.00	4.88	6.75	0.00
	4	0.00	6.38	6.00	0.00
June	1	0.00	7.88	5.25	0.00
	2	0.00	7.88	5.25	0.00
	3	0.63	9.00	3.88	0.00
	4	1.25	10.13	2.50	0.00

Appendix B: Figures

Figure 1: Location of Georgiana Slough Non-physical Barrier Study Site

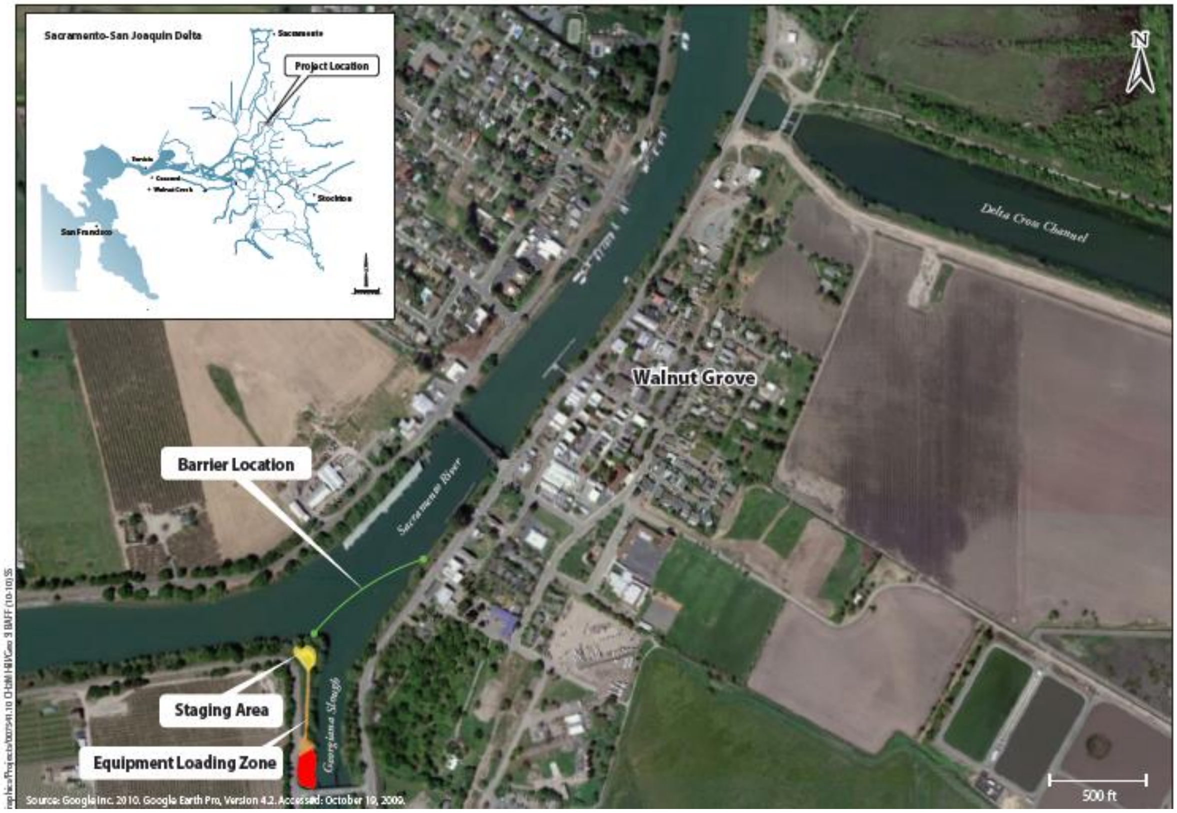
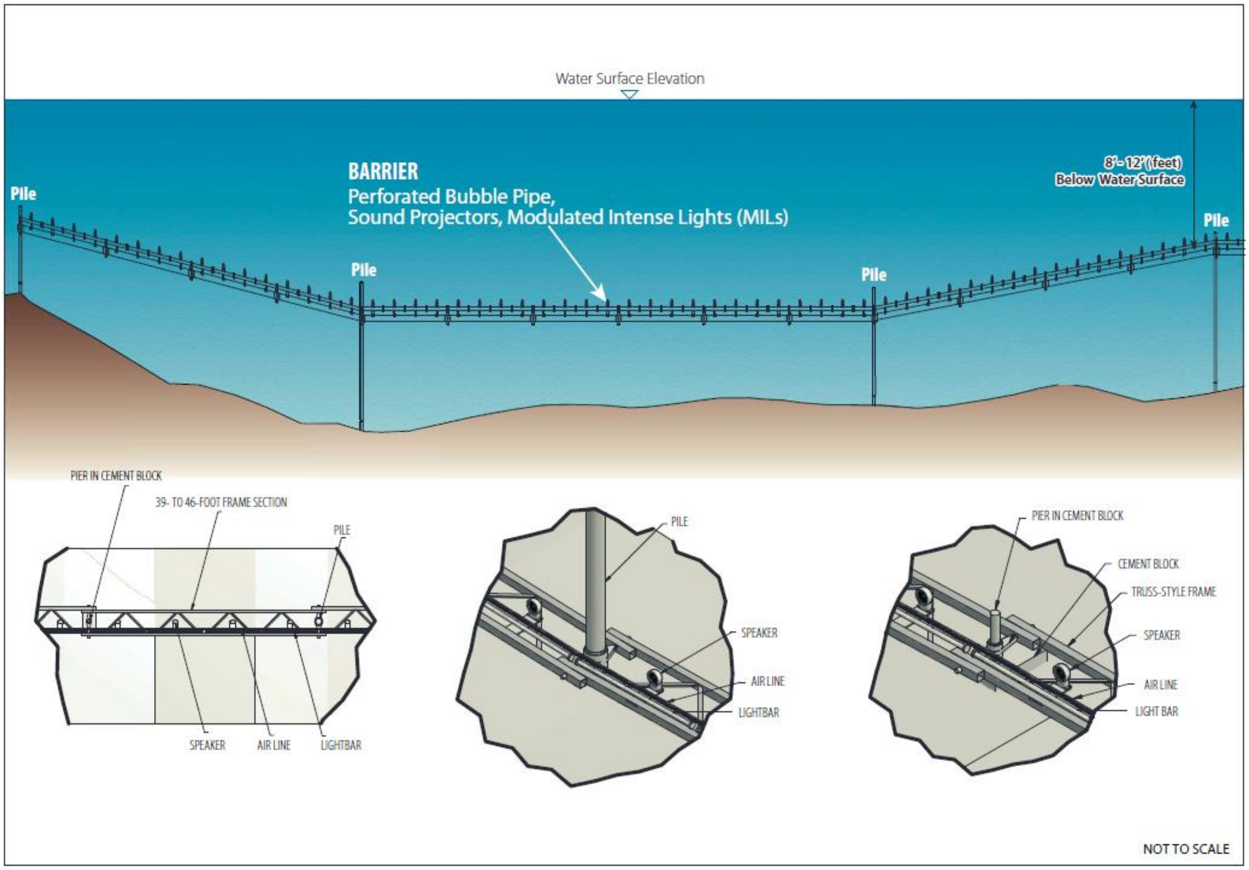


Figure 2: Conceptual Design of Georgiana Slough Non-physical Barrier



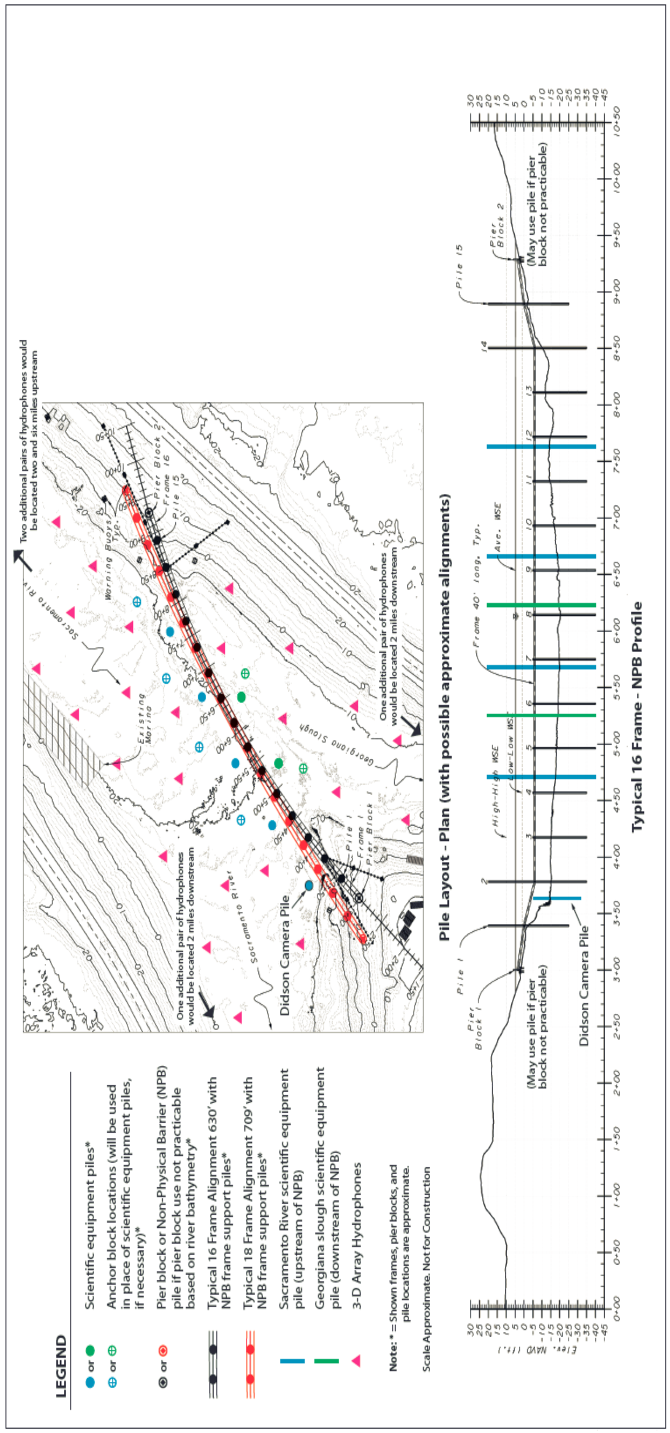


Figure 3: Alignment of Piles and Barrier in Sacramento River and Georgiana Slough

Figure 4: Typical plans for concrete blocks.

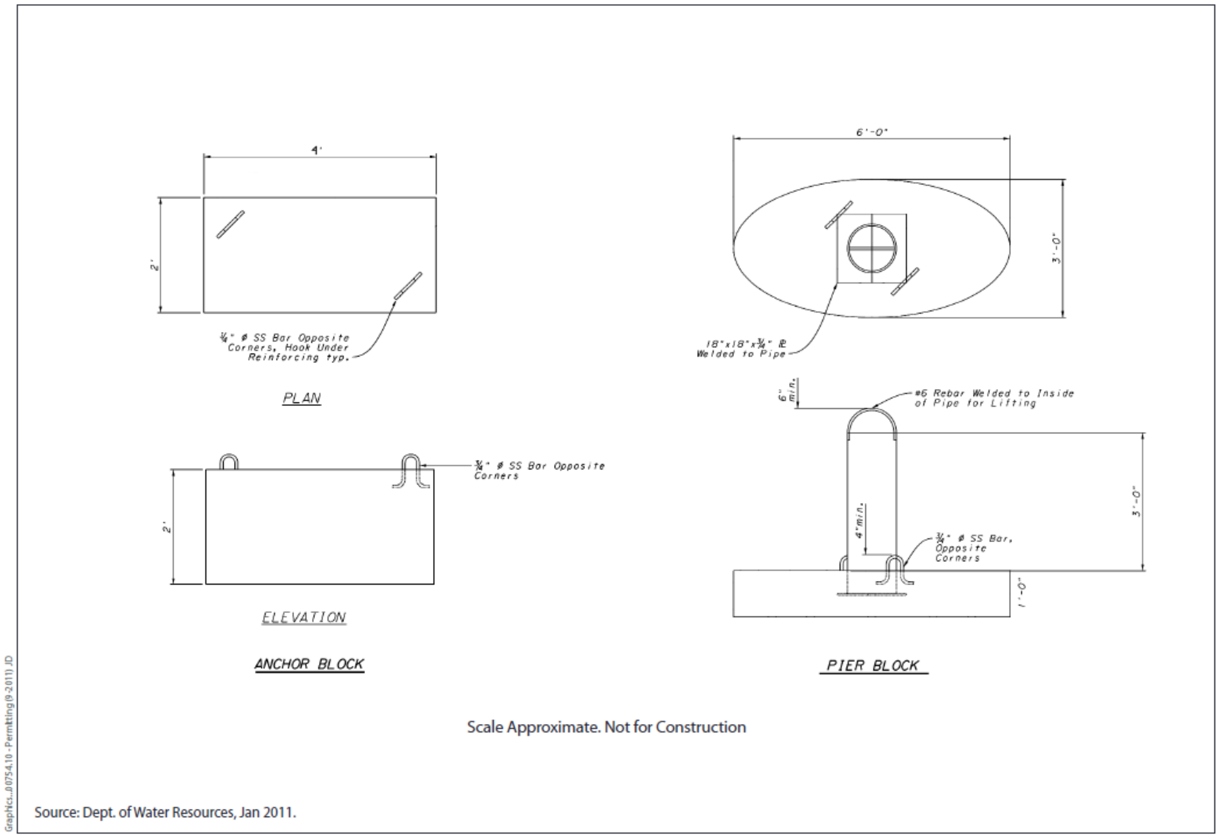


Figure 5: Annual estimated Sacramento River winter-run Chinook salmon escapement population 1970 through 2011. Sources: CDFG 2011 (Grand Tab February 1, 2011, CDFG 2011 survey data)

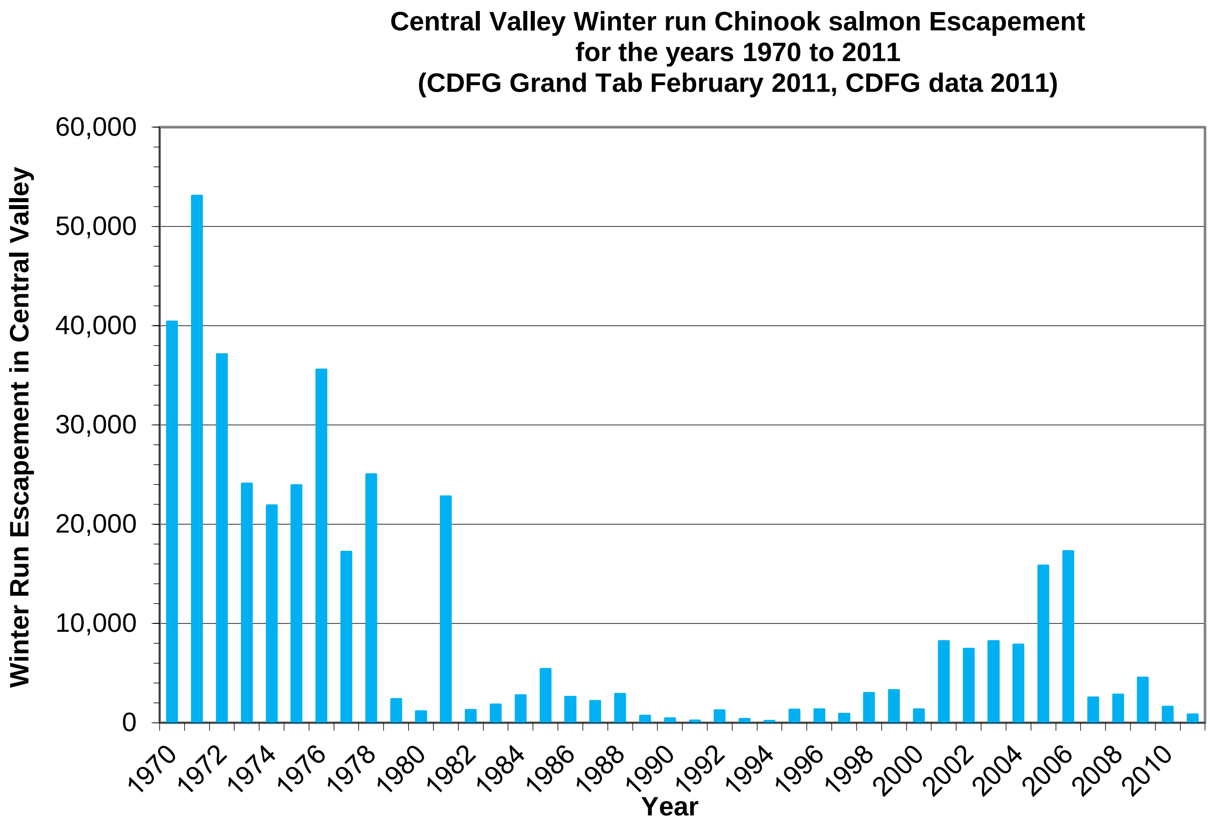


Figure 6: Annual Percentages of Sacramento River winter-run Chinook salmon adults spawning in the Sacramento River that are of hatchery origin (NMFS 2011a).

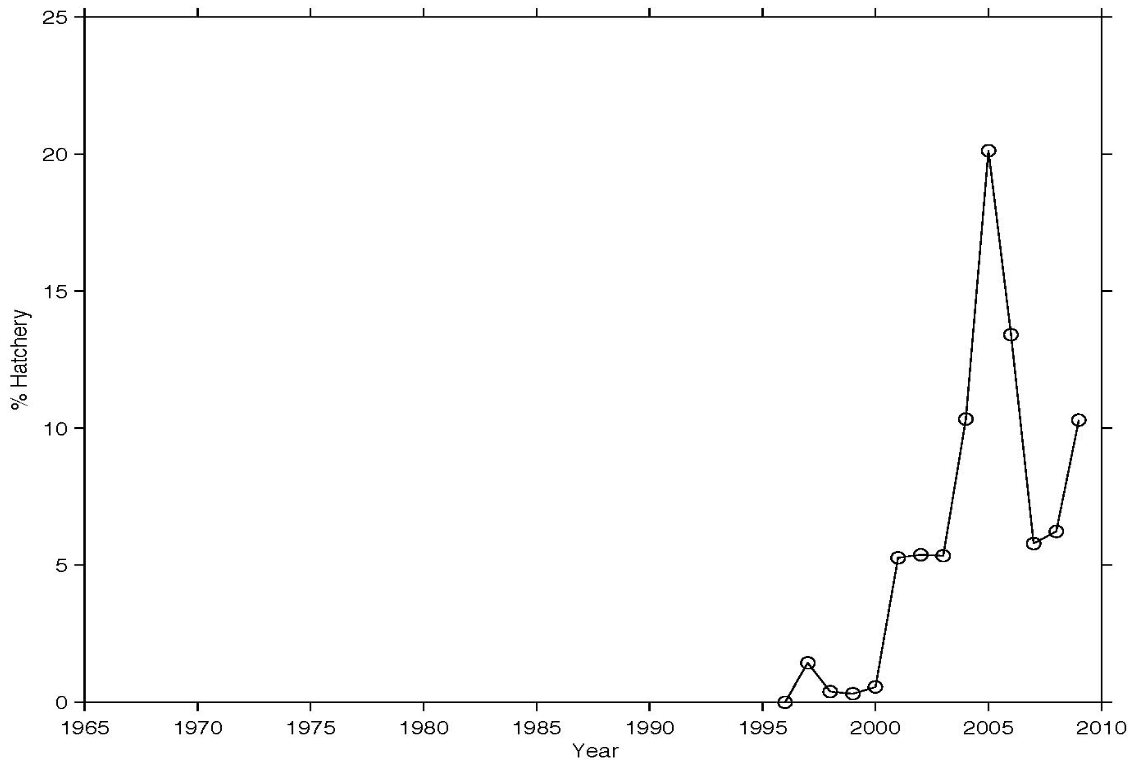


Figure 7: Adult winter-run escapement based on carcass surveys for the years 2005 through 2011 (NMFS 2011a, CDFG 2011 survey data).

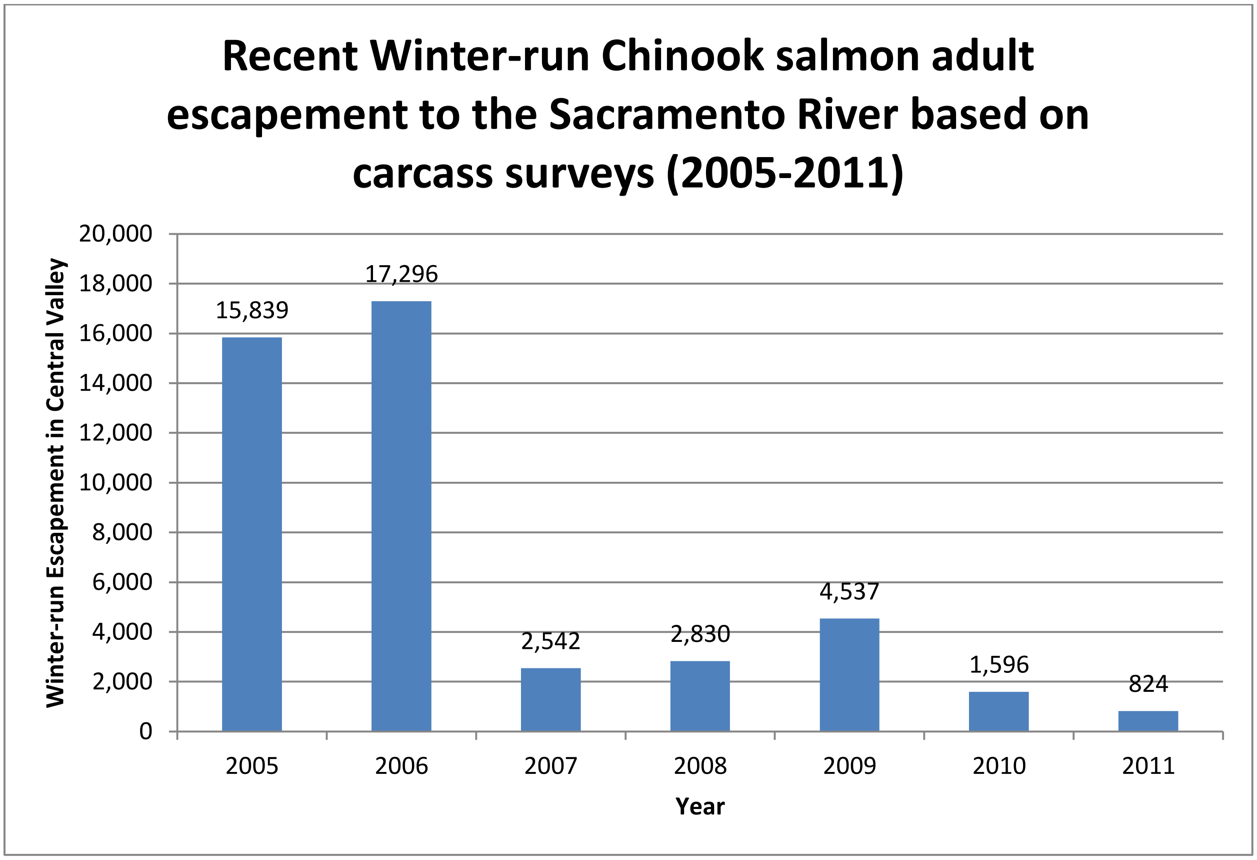


Figure 8: Annual cohort replacement rate for Sacramento River winter-run for the period 1999 to 2011 (NMFS 2011a, GrandTab February 1, 2011, CDFG survey data 2011).

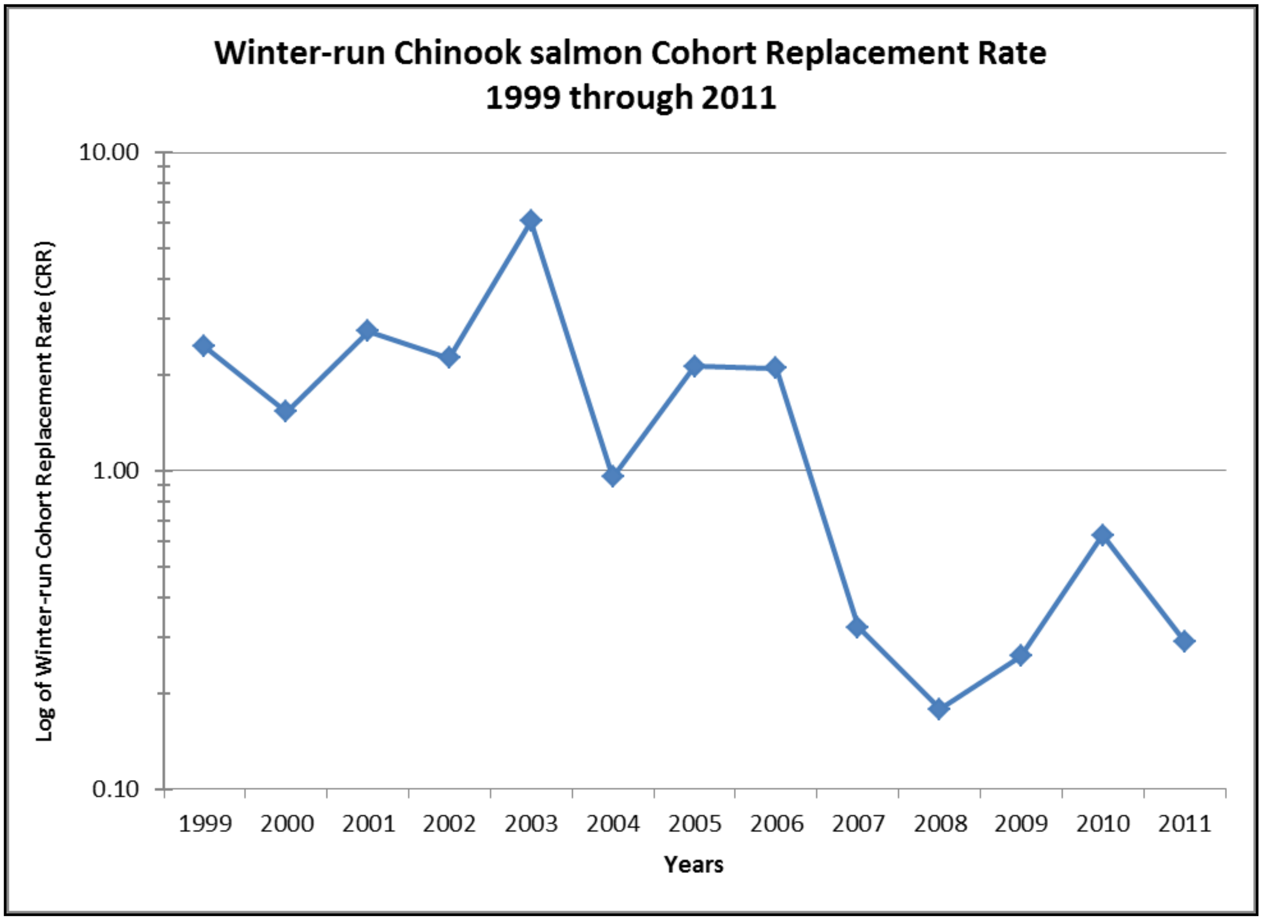


Figure 9: Current and historical distribution of Sacramento River winter-run Chinook salmon.

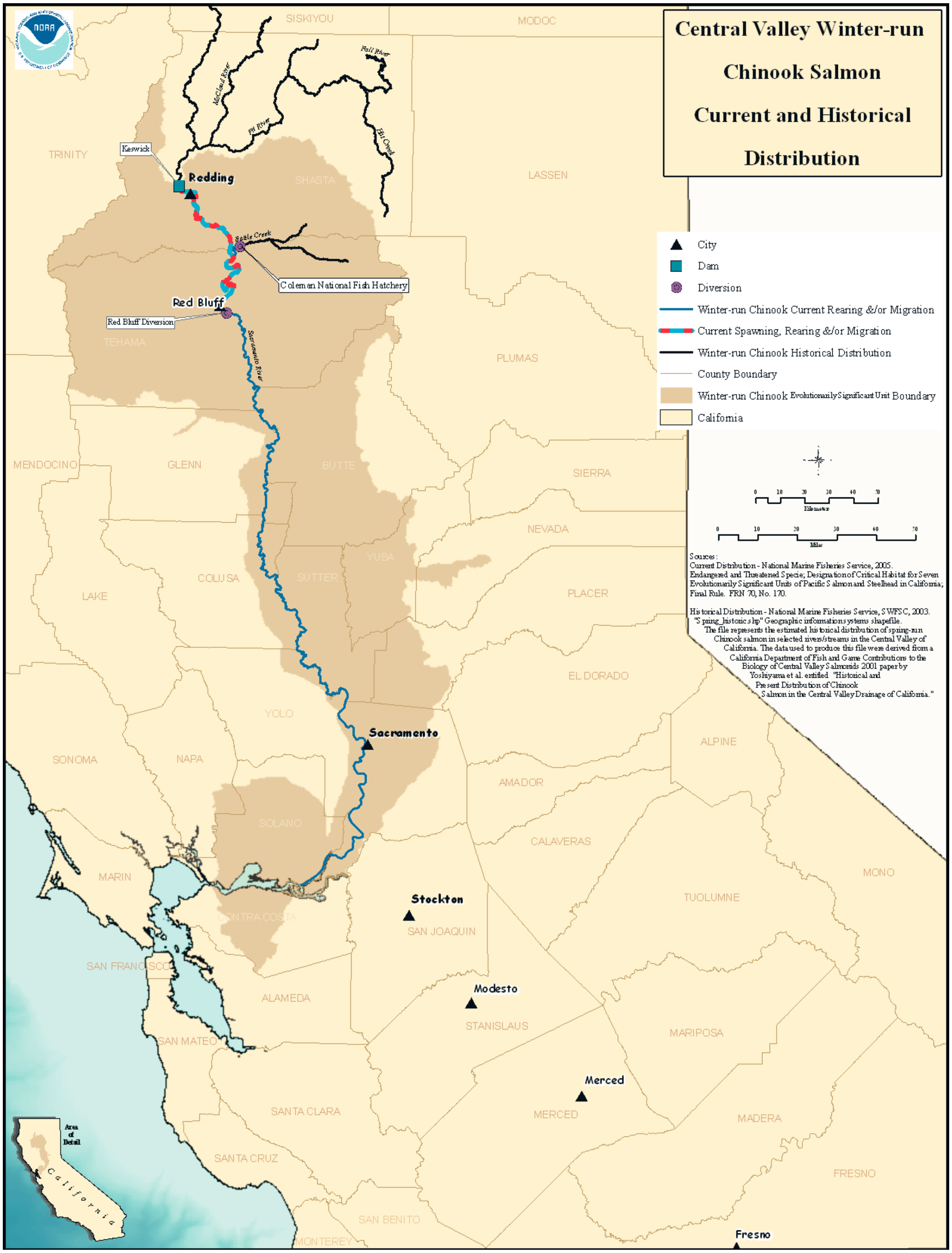


Figure 10: Annual estimated Central Valley in-river spring-run Chinook salmon escapement population for the Sacramento River watershed for years 1960 through 2011 (CDFG Grand Tab 2011).

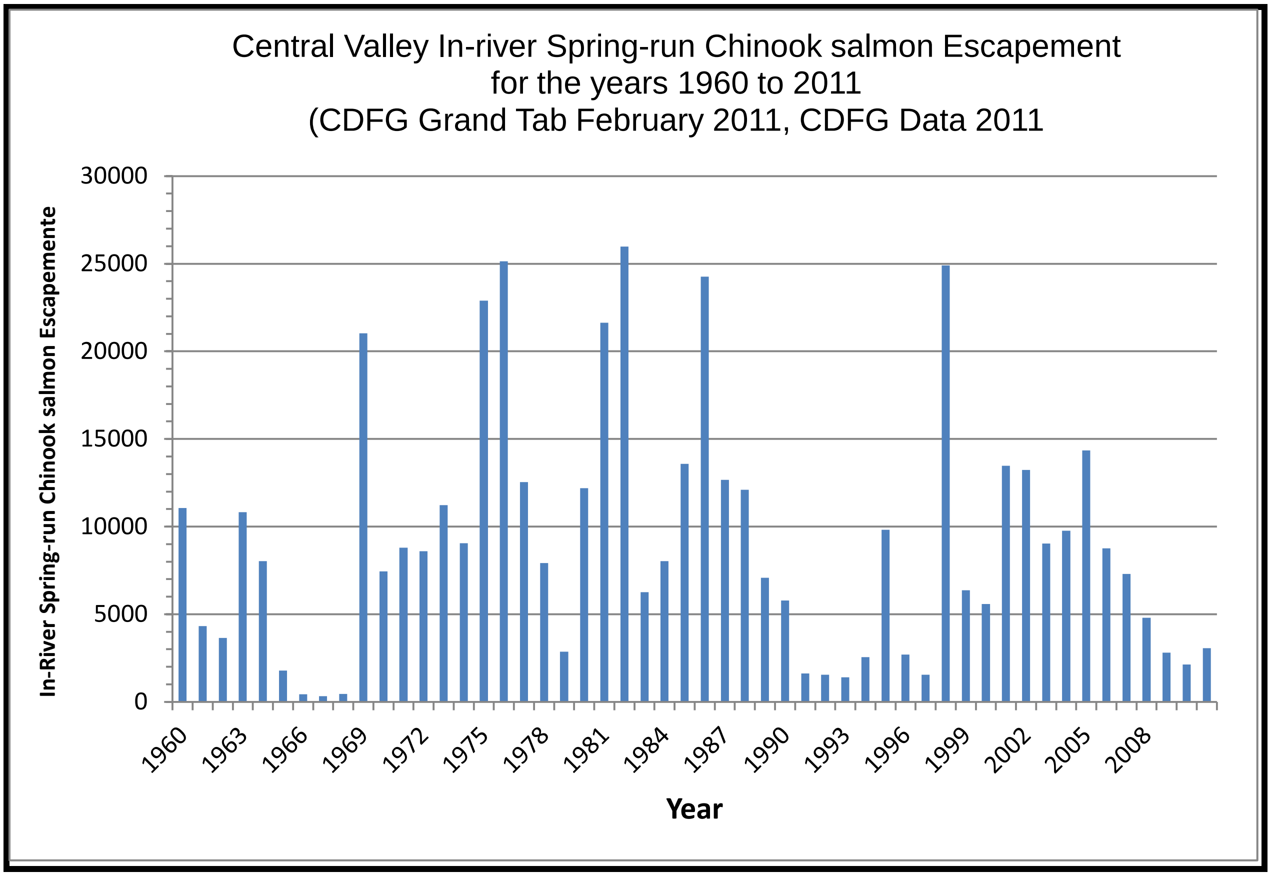


Figure 11: Adult escapement of Central Valley spring-run Chinook salmon for several tributary populations (1970 – 2010). Y-axis is in thousands of adult fish. Data from NMFS 2011b.

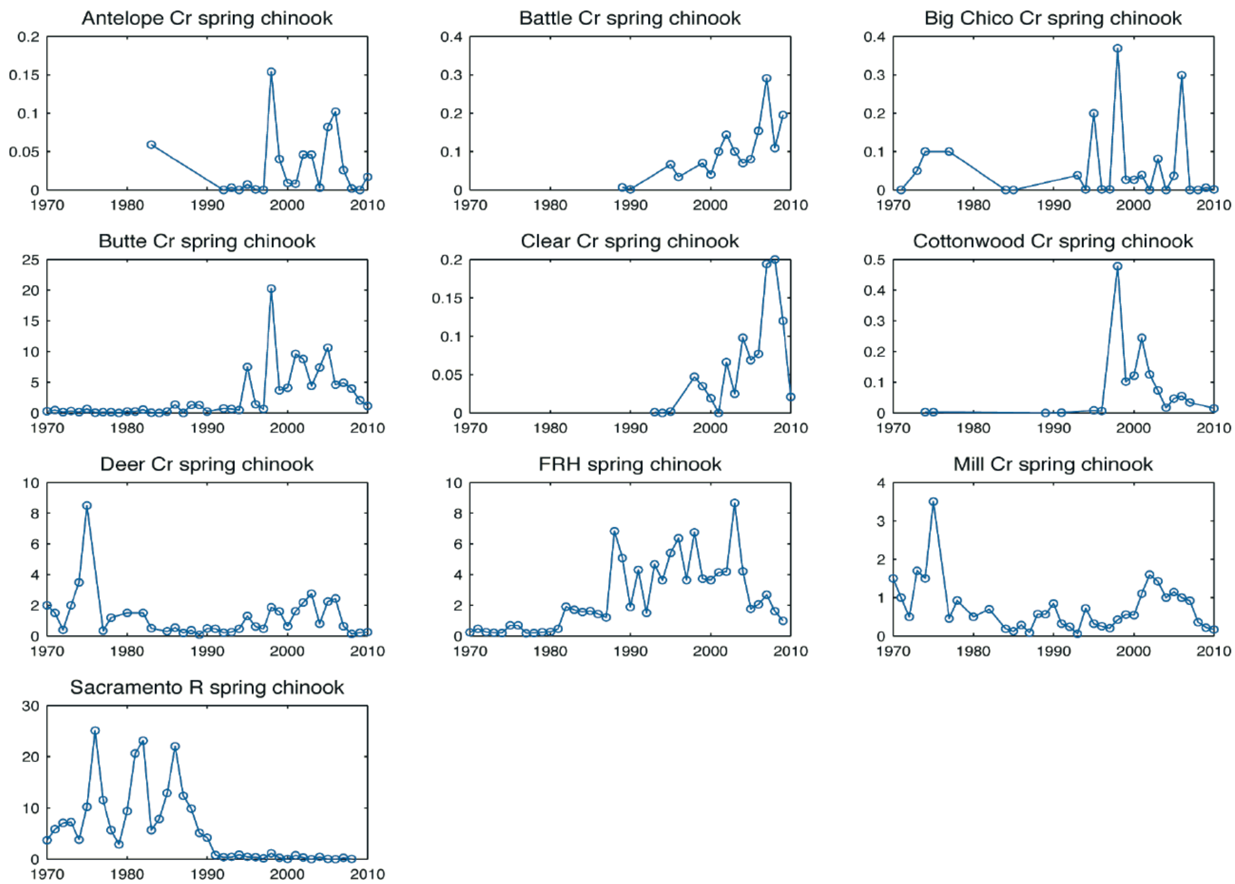
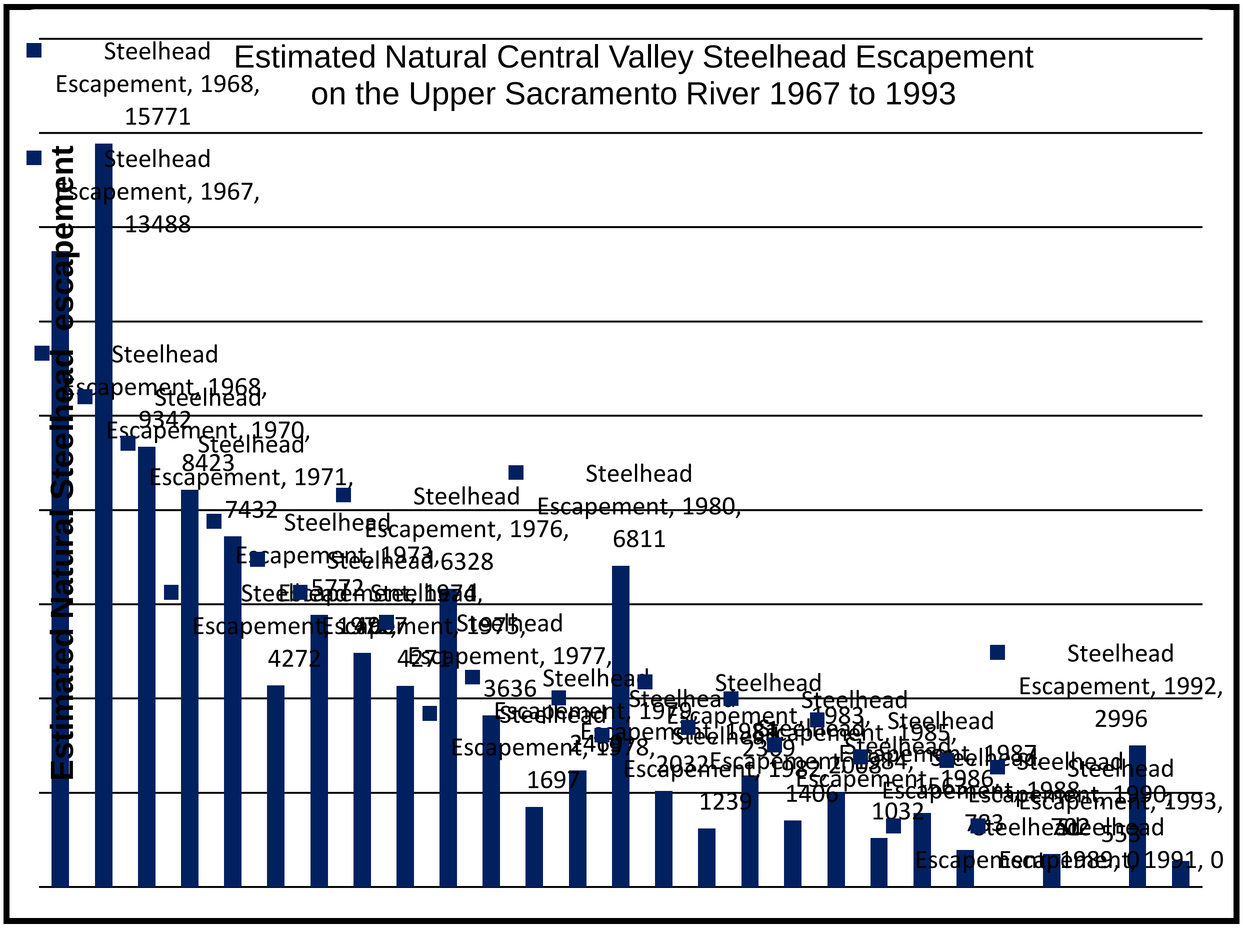


Figure 12: Estimated Central Valley natural steelhead escapement population in the upper Sacramento River based on RBDD counts.
Source: McEwan and Jackson 1996.



Note: Steelhead escapement surveys at RBDD ended in 1993

Figure 13: 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).

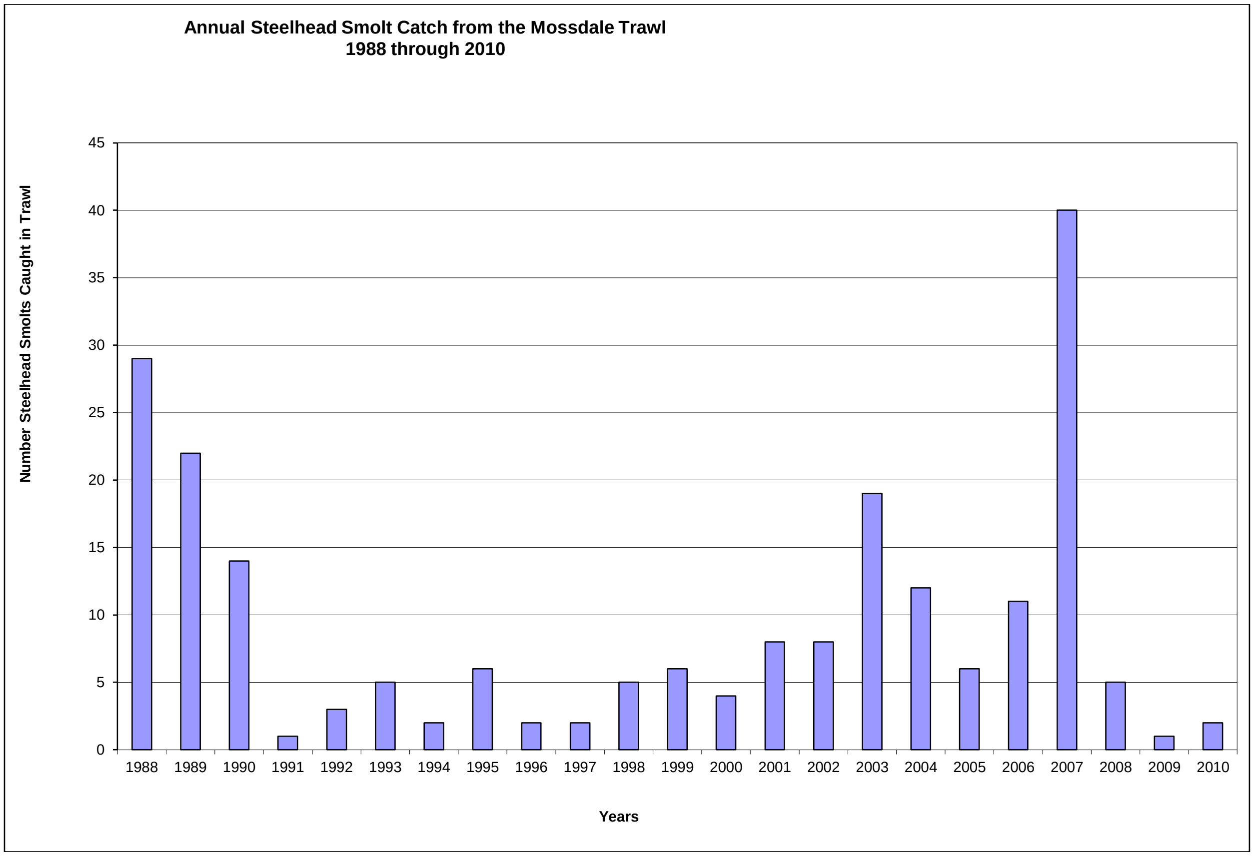


Figure 14: Top illustration - Catch of steelhead juveniles at Chipps Island by the USFWS midwater trawl survey from 1976 to 2010. Middle illustration – Fraction of the catch bearing an adipose fin clip. Vertical line denotes the start of 100% fin clipping of hatchery produced steelhead in 1998. Bottom illustration – Catch per unit effort in fish per million cubic meters of water swept through the survey nets.

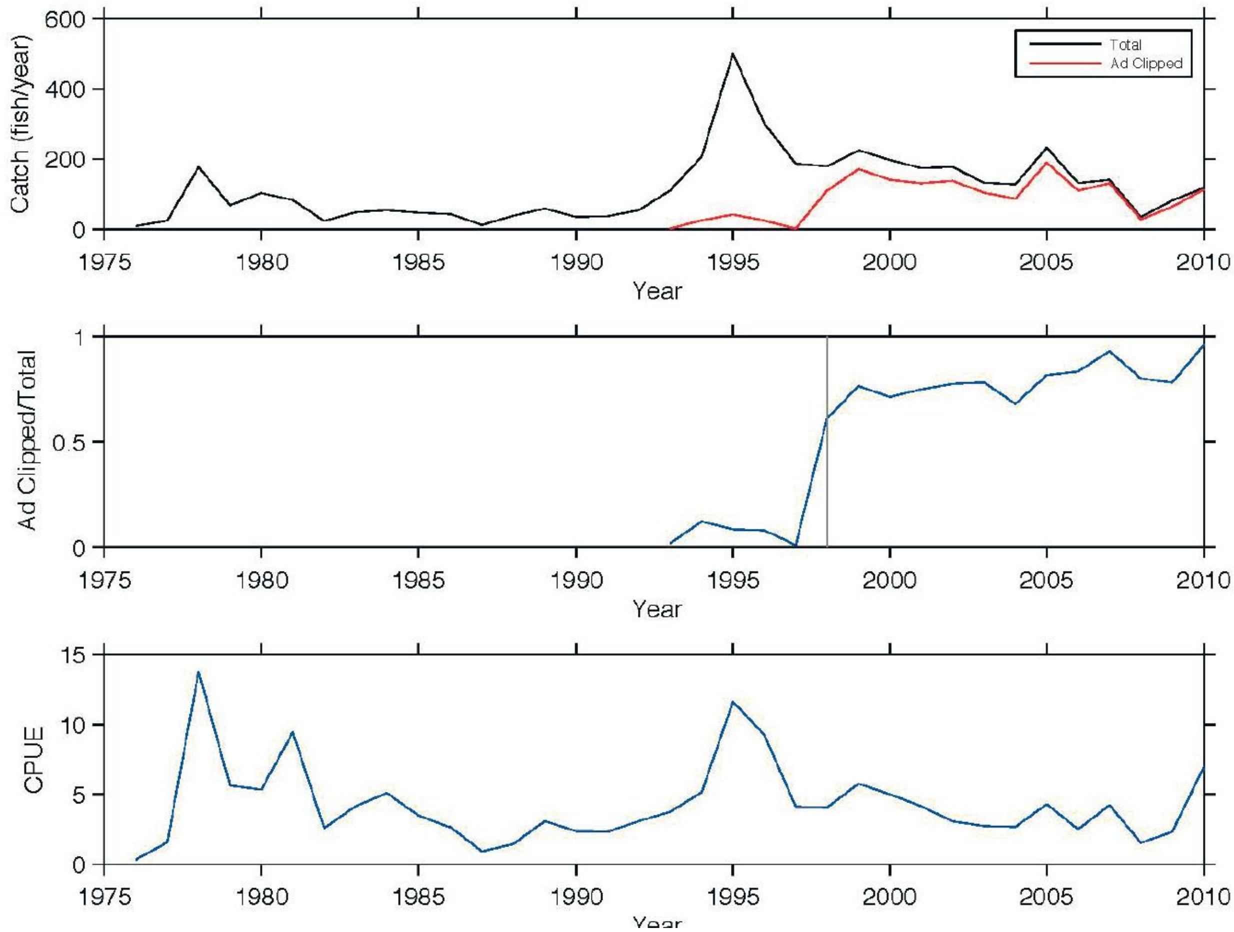


Figure 15: Steelhead salvaged in the delta fish collection facilities (CVP and SWP) from 1993 through 2010. All hatchery steelhead juveniles have been ad-clipped since 1998. Data from CDFG website: ftp.delta.dfg.ca.gov/salvage.

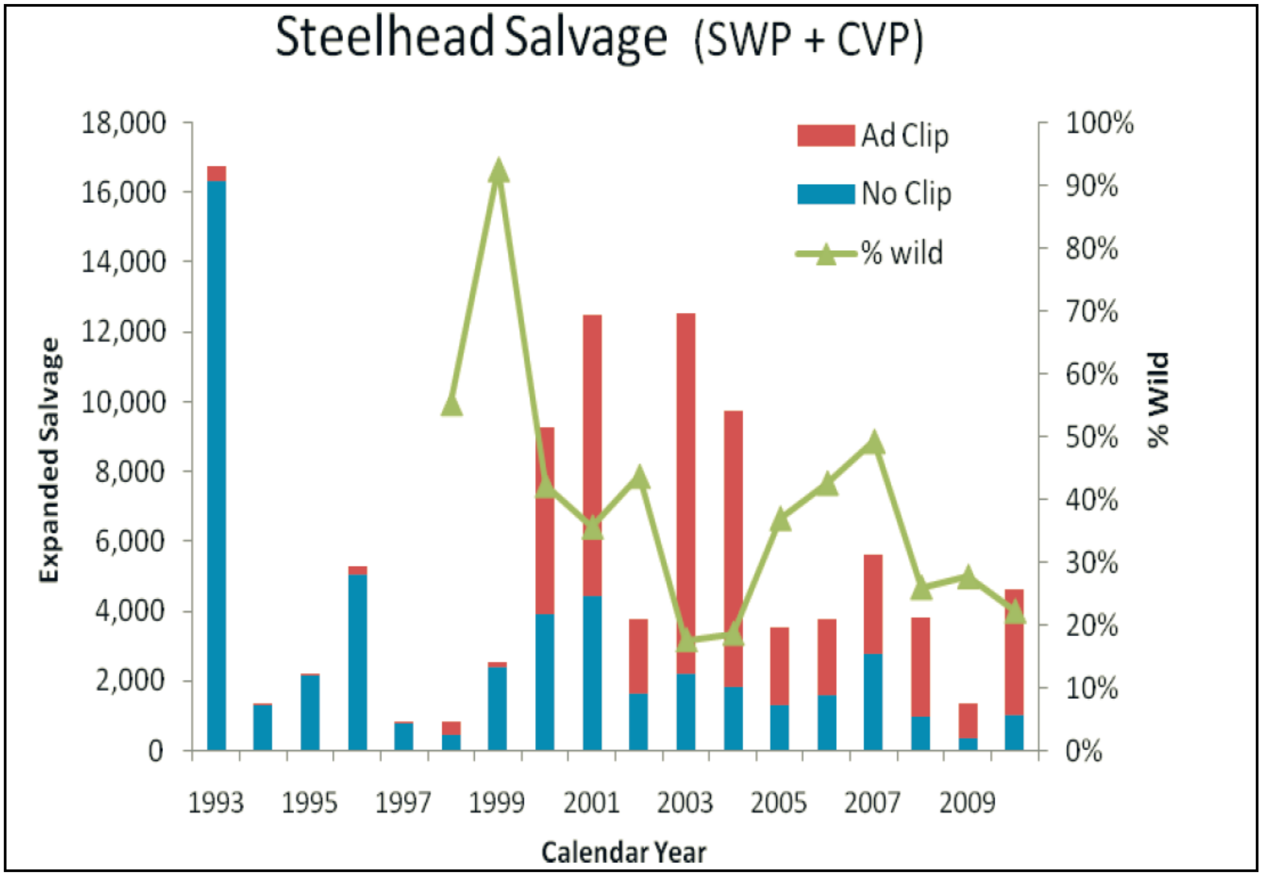


Figure 16: Annual return of adult steelhead to the Coleman National Fish Hatchery. Starting in 2003, fish were identified as either hatchery origin (ad-clipped) or naturally spawned (wild) fish. Data courtesy of USFWS as reported in NMFS 2011c.

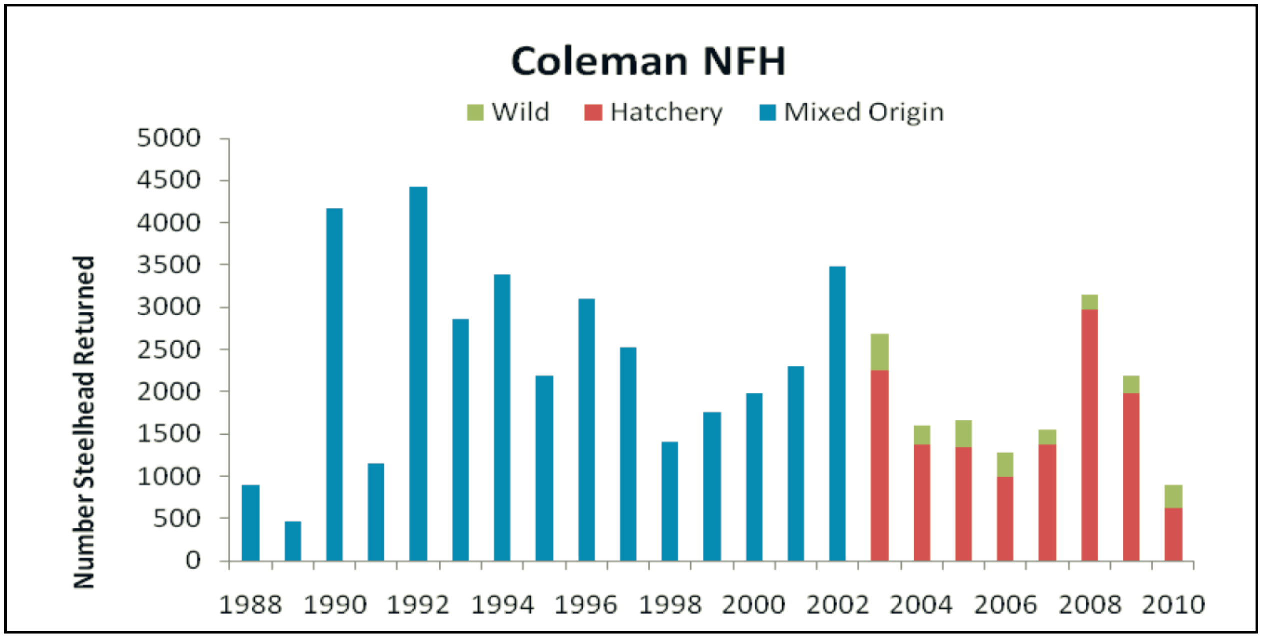


Figure 17a: Estimated number of North American green sturgeon (Southern DPS) salvaged from the State Water Project and the Central Valley Project fish collection facilities. Sources: Beamesderfer *et al.*, 2007, CDFG 2002, Adams *et al.* 2007.

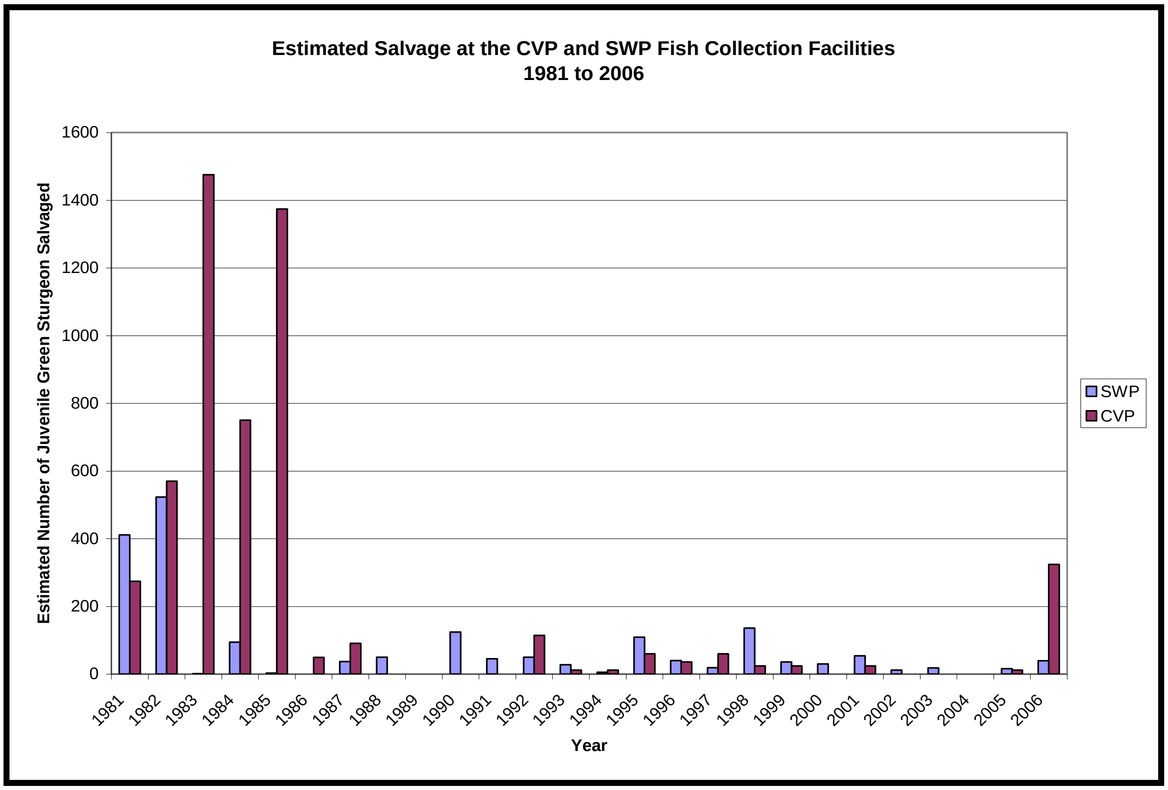


Figure 17b: Estimated number of North American green sturgeon (southern DPS) salvaged monthly from the State Water Project and the Central Valley Project fish collection facilities.

Source: CDFG 2002, unpublished CDFG records.

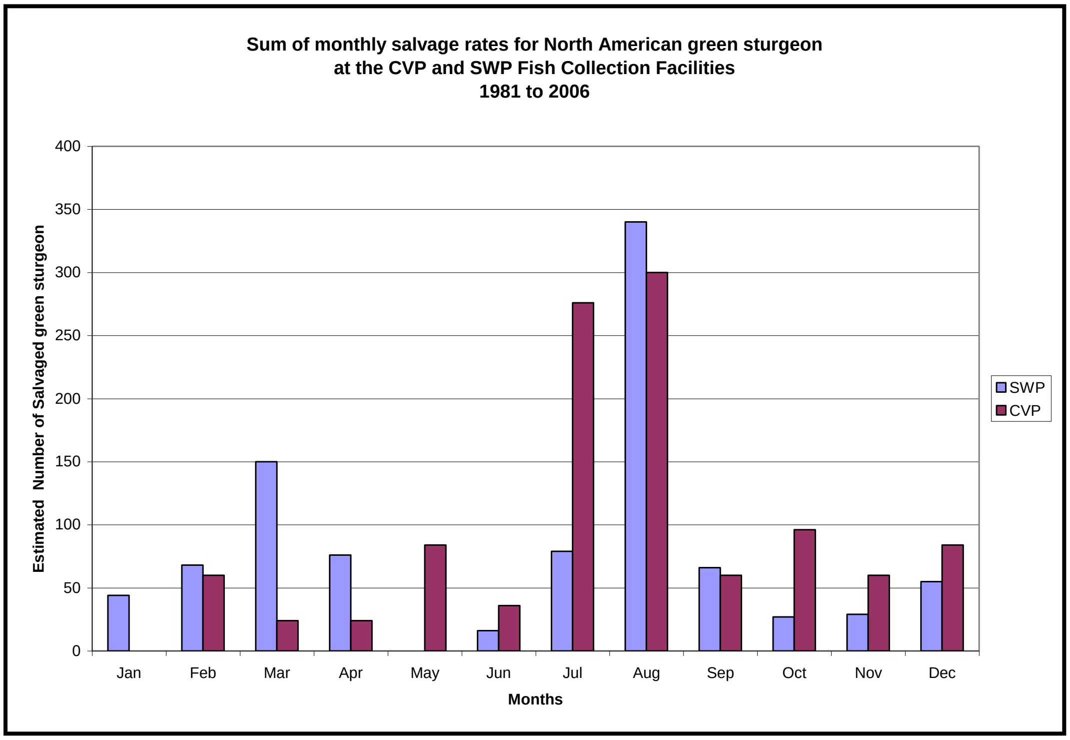


Figure 18: Sacramento winter-run Chinook salmon afe-3 ocean exploitation rate for the years 2000-2007. (O'Farrell *et al.* 2010).

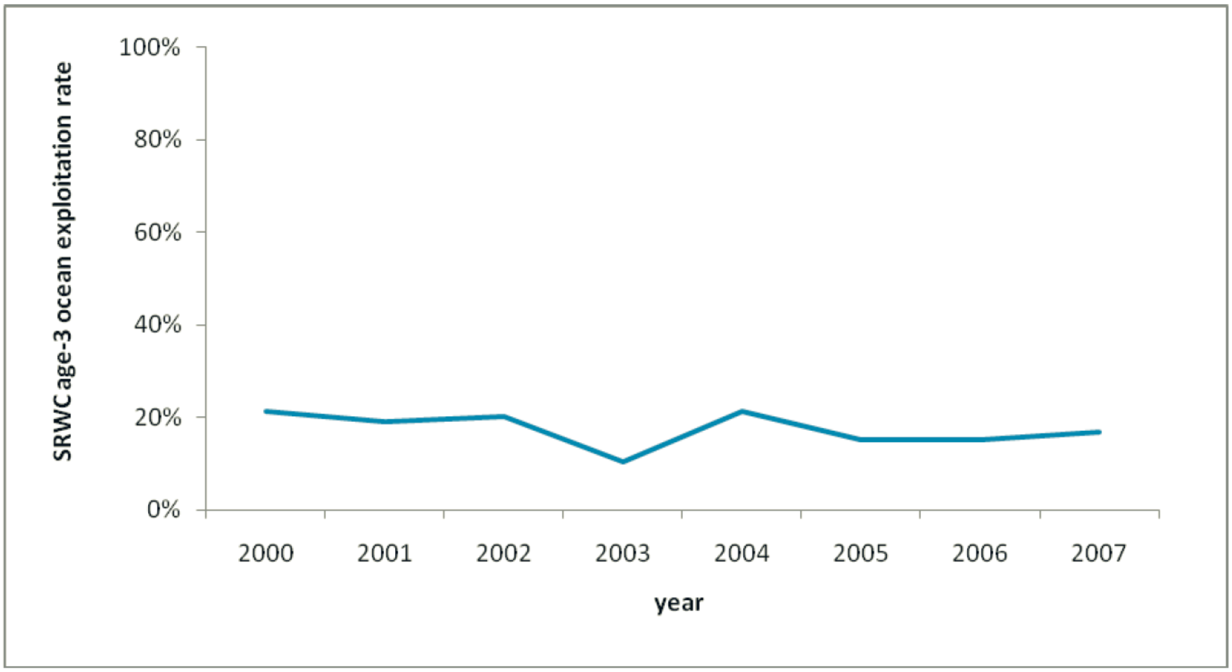


Figure 19: Sacramento River fall-run Chinook salmon ocean harvest rate index for the years 1983-2010. Data from PFMC 2010a,b, as reported in NMFS (2011b); 5-Year Review for Central Valley spring-run Chinook salmon ESU.

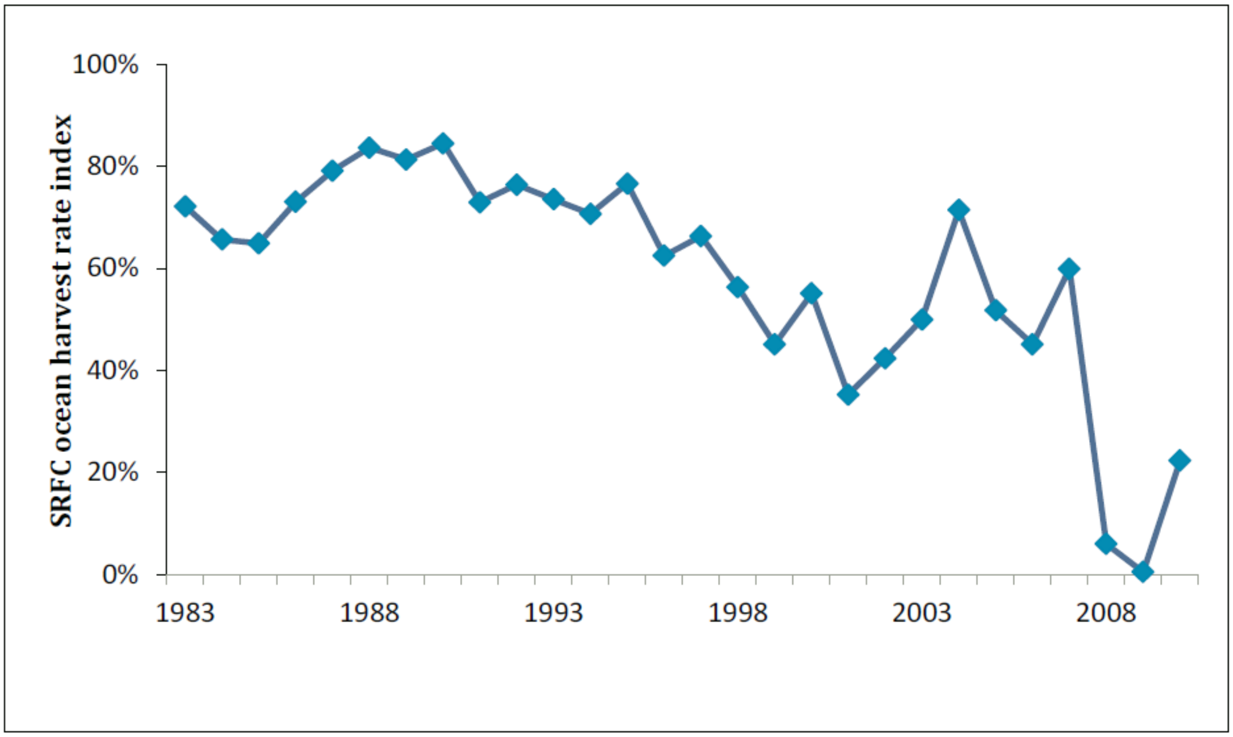
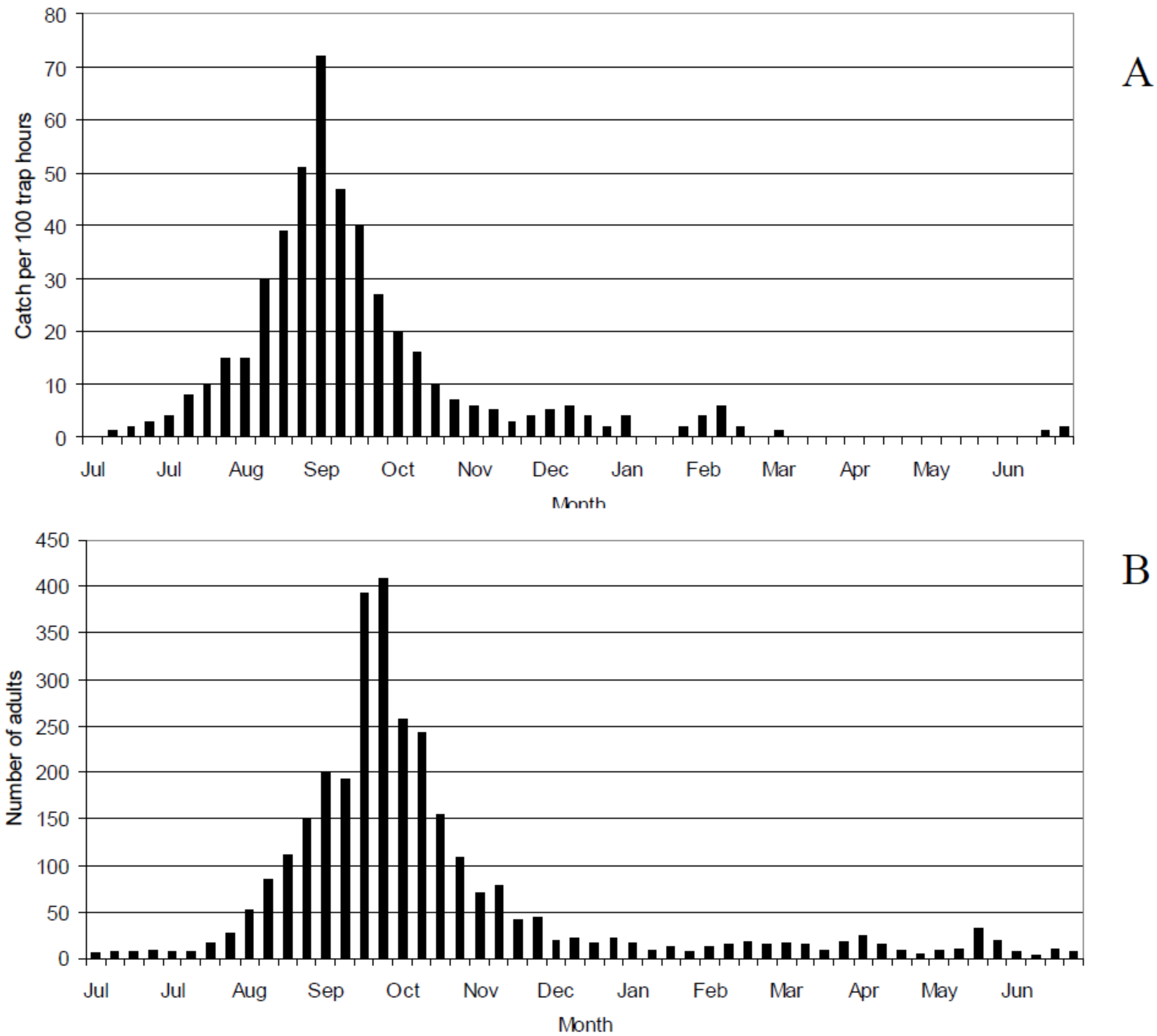


Figure 20: Time pattern of Sacramento River adult steelhead migration. Figure 2A shows migration timing from July through June of 1953 through 1959, determined by trapping upstream migrants in the Sacramento River just upstream of the confluence with the Feather River (from Hallock and others 1961). 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)



Enclosure 2

<u>Magnuson-Stevens Fishery Conservation and Management Act</u>

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 proposed project site is within the region identified as EFH for Pacific salmon in Amendment 14 of the Pacific Salmon FMP. The U.S. Army Corps of Engineers (Corps) requested consultation as under the MSA for potential EFH for starry flounder (*Platichthys stellatus*) under Amendment 11 to the Pacific Coast Groundfish FMP, and northern Anchovy (*Engraulis mordax*) under Amendment 8 of the Northern Anchovy Fishery Management Plan (Coastal Pelagics species FMP). NMFS did not find that EFH for groundfish (starry flounder, Platicthys stellatus) or coastal pelagics (northern anchovy, Engraulis mordax) in the action area would be affected by the proposed project and study, and 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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