UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
650 Capitol Mall, Suite 5-100
Sacramento, California 95814-4700

FEB 6 2014

In response refer to:
2011/05043

Scott Hamelburg, Project Leader
U.S. Fish and Wildlife Service
Coleman National Fish Hatchery Complex
24411 Coleman Fish Hatchery Road
Anderson, California 96007

Dear Mr. Hamelburg:

This letter transmits NOAA's National Marine Fisheries Service's (NMFS) biological opinion (Enclosure 1) based on our review of the artificial propagation programs at the Coleman National Fish Hatchery and Livingston Stone National Fish Hatchery (Coleman NFH Complex) project in Shasta County, California, and its effects on listed species and designated critical habitats, in accordance with section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*). This biological opinion is based on information provided in the biological assessment, the draft biological opinion, discussions between NMFS and U.S. Fish and Wildlife Service (USFWS) staff, 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 the Coleman NFH Complex project is not likely to jeopardize the continued existence of federally listed endangered Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*), threatened Central Valley spring-run Chinook salmon (*O. tshawytscha*), threatened California Central Valley steelhead (*O. mykiss*), or threatened Southern distinct population segment (DPS) of North American green sturgeon (*Acipenser medirostris*), and is not likely to destroy or adversely modify their designated critical habitats. NMFS has also included an incidental take statement with reasonable and prudent measures and non-discretionary terms and conditions that are necessary and appropriate to avoid, minimize, or monitor incidental take of listed species associated with the project.

Please contact Ms. Naseem Alston at (916) 930-3655, or via email at Naseem.Alston@noaa.gov if you have any questions or require additional information concerning this project.

Sincerely,

for William W. Stelle, Jr.
Regional Administrator

Enclosures

cc: Copy to File - ARN #151422SWR2000SA5806
Mr. James Smith, U.S. Fish and Wildlife Service, 10950 Tyler Road, Red Bluff, CA, 96080

Enclosure

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
650 Capitol Mall, Suite 5-100
Sacramento, CA 95814-4700

BIOLOGICAL OPINION

ACTION AGENCY: United States Fish and Wildlife Service, Sacramento District

ACTIVITIES: Coleman National Fish Hatchery Complex Artificial Propagation Programs

CONSULTATION CONDUCTED BY: National Marine Fisheries Service, West Coast Region

FILE NUMBER: **151422SWR2000SA5806**

DATE ISSUED: FEB 6 2014

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I. BACKGROUND AND CONSULTATION HISTORY

This biological opinion constitutes NOAA's National Marine Fisheries Service (NMFS) consultation with the U.S. Fish and Wildlife (USFWS) regarding the effects of fish propagation programs at the Coleman National Fish Hatchery (CNFH) and effects of collection of natural-origin late fall-run Chinook salmon at Livingston Stone NFH (the CNFH Complex consists of the CNFH and the Livingston Stone NFH) on the federally listed endangered Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*) and threatened Central Valley spring-run Chinook salmon (*O. tshawytscha*) evolutionarily significant units (ESUs) and their designated critical habitats; threatened California Central Valley steelhead (*O. mykiss*) distinct population segment (DPS) and its designated critical habitat; threatened Southern DPS of North American green sturgeon (*Acipenser medirostris*) and its critical habitat; and endangered Southern Resident killer whale DPS (*Orcinus orca*). The hatchery programs are operated to mitigate for impacts resulting from the construction and operation of Shasta and Keswick dams. USFWS owns and operates the CNFH and Livingston Stone NFH facilities and U.S. Bureau of Reclamation (Reclamation) funds annual maintenance and operations.

This biological opinion has been prepared in accordance with section 7 of the Endangered Species Act (ESA) of 1973 as amended (16 U.S.C. 1531 *et seq*.) and in compliance with the Data Quality Act (§ 515 of Public Law 106-554). It is based on information provided in a Biological Assessment (BA) and additional information submitted to NMFS by USFWS, on published and unpublished scientific information on listed fishes in the action area, and on other sources representing the best available scientific information. This consultation has incorporated information from several ongoing processes, including the development of NMFS' Central Valley Salmon and Steelhead Recovery Plan, the Battle Creek Restoration Project, the development of Central Valley-wide monitoring plans for salmon and steelhead, the implementation of a constant fractional marking program in the Central Valley, and the development of Hatchery and Genetic Management Plans (HGMP) in accordance with regulations promulgated under ESA section 4(d) (50 CFR 223.203(b)(5); subsequently referred to as "4(d) rule"). Additional actions which have provided a context for this consultation include the *CDFG-NMFS Joint Hatchery Review Committee* (2001), NMFS' hatchery listing policy adopted in 2005 (70 FR 37204; June 28, 2005), the 2005 NMFS status review of Pacific coast salmon and steelhead (Good *et al.* 2005), the Hatchery Scientific Review Group report (HSRG 2012), and the 2011 NMFS status reviews (NMFS 2011a, 2011b, 2011c). A copy of the administrative record for this consultation is on file with the California Central Valley Area Office.

The 4(d) rule (65 FR 42422, July 10, 2000) does not prohibit the take of ESA-listed fish for a variety of hatchery purposes if a state or Federal agency develops an HGMP and NMFS approves it (September 22, 2000 Southwest and Northwest Region 4(d) Rule Implementation Binder for Threatened Salmon and Steelhead on the West Coast). The USFWS has structured the BA for the CNFH Complex after the format of an HGMP so that it serves the purpose of completing ESA section 7 consultation as well as meeting most of the criteria of limit 5 of the 4(d) rule. Through HGMPs, hatcheries will be managed according to the listed fishes' status. This will be determined using the concept of "viable salmonid population" (VSP). Hatchery activities will be scaled to the degree of risk the listed fish face. An HGMP must address the specific criteria outlined in the 4(d) rule. Specifically, an HGMP must: (1) specify the goals and

objectives for the hatchery program; (2) specify the donor population's "critical" and "viable" threshold levels; (3) prioritize broodstock collection programs in a manner that benefits listed fish; (4) specify the protocols that will be used for spawning and raising the fish in the hatchery; (5) determine the genetic and ecological effects arising from the hatchery program; (6) describe how the hatchery operation relates to fisheries management; (7) ensure that the hatchery facilities can adequately accommodate listed fish if they are collected for the program; (8) monitor and evaluate the HGMP to ensure it accomplishes its objectives; and (9) be consistent with tribal trust obligations. Templates for an HGMP can be found at: http://www.nwr.noaa.gov/Salmon-Harvest-Hatcheries/Hatcheries/HGMP-Template.cfm.

HGMPs for hatchery propagation programs submitted to NMFS under limit 5 of the 4(d) rule may be developed and approved in the following manner. A fish management agency develops an HGMP that meets the 4(d) rule criteria. They send it to NMFS who then requests public review and comment, and determines the National Environmental Policy Act (NEPA) process. The public input is used to revise the HGMP, if necessary and NMFS writes a letter of approval to the agency that developed the HGMP. The HGMP is then implemented and, as provided in the 4(d) rule, the prohibitions of ESA section 9(a)(1) do not apply to the hatchery program addressed by the HGMP. NMFS then monitors and evaluates the activities covered under the HGMP. Hatchery propagation programs for species listed as endangered, such as CNFH Complex's winter-run Chinook salmon program, go through a similar process, but are covered under ESA section 10(a)(1)(A) through issuance of a research and enhancement permit, as opposed to coverage under the 4(d) rule. The USFWS and NMFS have determined the HGMP for winter-run Chinook salmon will be completed with the addition of the information in the 2013 renewal of the ESA section 10 permit, and associated ESA section 7 biological opinion for the renewal of the permit. The ESA section 10 permit and associated ESA section 7 biological opinion will cover take of winter-run Chinook salmon for the purpose of propagation at Livingston Stone NFH as well as incidental take of other listed species as a result of that hatchery propagation program. Therefore, these activities are not part of the proposed action for this biological opinion. CNFH is not currently including listed natural-origin fish in the steelhead program, however, the CNFH produced steelhead are also considered part of the federally listed DPS, although there is not currently a take prohibition for adipose-fin clipped hatchery steelhead; therefore, an HGMP for adipose fin clipped hatchery steelhead does not need to be authorized under the 4(d) rule. However, NMFS agrees with the recent HSRG report (2012) recommendation that all Federal/State hatchery programs submit an HGMP. For the CNFH Complex, this biological opinion will serve as part of the review process for HGMPs for the propagation of fall-run and late fall-run Chinook salmon and adipose-fin clipped hatchery steelhead in addition to any review that the USFWS must complete under NEPA, including public review and comment.

The USFWS has determined that the proposed action is likely to affect federally listed salmon, steelhead, and their designated critical habitats; that federally listed green sturgeon and its critical habitat may also be affected; and that federally listed killer whales may also be affected. Therefore, this biological opinion will address these federally listed species and designated critical habitat. USFWS determined that the proposed action will have no effect to critical habitat designated for killer whales. Based on this determination, and since critical habitat designated for federally listed killer whales is outside the action area, this biological opinion will

not include any further discussion of critical habitat for killer whales. The likelihood and magnitude of impacts from the fish propagation programs that are part of the proposed action depend on overlap of project activities with each species' spatial and temporal distributions, habitat and resource needs, and life-history requirements. The framework used by NMFS to assess impacts from fish propagation programs focuses on those areas of significant resource and life-history commonality, as these are the areas where impacts are most likely and foreseeable. Impacts to federally listed Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon and California Central Valley steelhead were evaluated for the following ten general areas of risk: (1) Hatchery Facilities and Facility Operations (which includes hatchery failure, fish entrainment, hatchery water withdrawals, and discharge of hatchery effluent); (2) Broodstock Collection; (3) Genetic Introgression; (4) Disease; (5) Competition/Density-Dependent Effects (including ocean competition); (6) Predation; (7) Fisheries; (8) Masking; (9) Nutrient Cycling; and (10) Monitoring and Evaluation. Risk assessment of impacts of propagation programs conducted at the CNFH to North American green sturgeon was initially considered in all areas of potential impact, but was subsequently focused to possible effects of predation by hatchery fish upon juvenile green sturgeon, as this is the area of potential impact based on life-history overlap. Impacts to Southern Resident killer whales is probable only in the area of prey availability, with fishes produced at the CNFH likely contributing a beneficial effect to prey availability. Detrimental impacts could occur in the event of a broodstock production failure.

A. Recent history of ESA Consultation of the Proposed Project

On August 28, 2000, USFWS requested an extension of the 1999 CNFH biological opinion (NMFS 1999c), which covered the California Central Valley steelhead, and fall-run and late fall-run Chinook salmon programs, in order to complete work on the BA (and to include effects to the newly listed threatened spring-run Chinook salmon (September 1999), which also was to serve as a template for HGMPs for programs at both CNFH and Livingston Stone NFH.

On December 19, 2000, NMFS received a summary from USFWS, dated December 14, 2000, of comments, modifications and revisions resulting from the agency review process of the BA. These modifications were incorporated into the BA draft prior to public distribution. USFWS extended the public review comment period on the BA to January 29, 2001.

On December 27, 2000, NMFS extended coverage of the 1999 CNFH biological opinion through March 31, 2001. No additional impacts to listed fish or critical habitat over those previously addressed were expected to occur as a result of this extension.

On March 12, 2001, USFWS requested an extension of the 1999 CNFH biological opinion, in order to incorporate public comments into the BA. On March 19, 2001, NMFS granted the extension of the biological opinion through September 12, 2001.

On June 13, 2001, NMFS received the BA for the CNFH and Livingston Stone NFH artificial propagation and captive broodstock programs (which added the endangered winter-run Chinook salmon program at Livingston Stone NFH), including the request from USFWS to review a draft biological opinion prior to finalizing the document. On June 27, 2001, NMFS received a copy of

key appendices to the BA from USFWS, for insertion to the final document. The BA was developed following the format of a HGMP template.

On October 22, 2001, NMFS extended the ESA coverage of the 1999 CNFHCNFH biological opinion through December 31, 2001. The biological opinion was further extended through March 1, 2002, in order to allow NMFS time to complete their analysis of the effects of the proposed hatchery actions on listed salmonids.

On December 20, 2001, NMFS received an addendum to the June 2001 BA, dated December 5, 2001, from USFWS explaining its intent to allow passage of adult hatchery steelhead above the CNFHCNFH barrier weir in Battle Creek as a population supplementation action to be incorporated into the Battle Creek Fishery Management Plan.

On December 21, 2001, NMFS received a description from USFWS of the proposed collection and tissue sampling protocol for non-marked steelhead at CNFHCNFH, for purposes of genetic monitoring using microsatellite deoxyribonucleic acid (DNA) techniques, and for comparison with CNFHCNFH steelhead to determine the potential for using the hatchery stock in restoration efforts in Battle Creek.

In letters to USFWS dated January 23, 2002, and February 5, 2002, NMFS clarified the Federal non-listed status of CNFHCNFH steelhead, and the need for a scientific basis regarding further hatchery steelhead supplementation in Battle Creek.

On February 7, 2002, NMFS received a letter from USFWS dated January 24, 2002, informing NMFS of the commitment by USFWS to re-initiate formal consultation for operation of CNFHCNFH and Livingston Stone NFH upon completion of the Battle Creek Salmon and Steelhead Restoration Project. This action was prompted by concerns of the Battle Creek Working Group (BCWG) regarding the timing of future ESA section 7 consultations for CNFH compared with restoration actions in Battle Creek.

On April 15, 2002, USFWS requested NMFS' participation in a multi-agency meeting to investigate and recommend a strategy for managing returning steelhead adults in excess of broodstock needs at CNFH, for the 2002-2003 spawning season. A letter of confirmation for the meeting, dated May 9, 2002, was received by NMFS on May 13, 2002.

On May 15, 2002, representatives from USFWS, Reclamation, California Department of Fish and Game (CDFG), and NMFS met to discuss potential strategies for managing excess adult CNFH steelhead during the 2002-2003 spawning season. Eleven management alternatives were suggested, and a decision tree was developed to further discuss the alternatives at a planned future meeting.

On June 11, 2002, NMFS extended ESA incidental take coverage of the 1999 biological opinion through September 1, 2002, in order to analyze the effects of incorporating natural steelhead as hatchery broodstock on the continued existence of threatened and endangered salmonid species in the upper Sacramento River basin.

On July 11, 2002, representatives from USFWS, Reclamation, CDFG, and NMFS met to discuss potential options related to passing adult hatchery steelhead above the CNFH barrier weir. Discussion focused on current natural steelhead abundance, the carrying capacity of Battle Creek, the broodstock history of CNFH steelhead, current genetic information, and development of a study plan regarding the passing of hatchery steelhead into upper Battle Creek.

On August 16, 2002, NMFS received a draft monitoring and evaluation plan from USFWS for CNFH steelhead in excess of hatchery broodstock needs. On September 4, 2002, USFWS submitted a letter of justification to NMFS on the proposal to allow passage of surplus hatchery steelhead above the CNFH barrier weir, based on the origin and genetic relationship of the hatchery steelhead to the natural steelhead population in Battle Creek.

On September 24, 2002, a consensus decision was reached among USFWS, Reclamation, CDFG, and NMFS to release adult hatchery steelhead above the CNFH during the 2002-2003 migration and spawning season, and on October 31, 2002, NMFS co-signed a letter of support for this action with USFWS, Reclamation, and CDFG.

In a letter to NMFS dated July 30, 2003, USFWS initiated Essential Fish Habitat (EFH) consultation on the facilities and operations of the CNFH and Livingston Stone NFH.

On September 11, 2003, representatives of USFWS, CDFG, the NMFS Protected Resources Division, and the NMFS Southwest Fisheries Science Center (SWFSC) attended a Battle Creek steelhead genetics and CNFH operations meeting. A presentation was given on the 2002-2003 Battle Creek steelhead genetic tissue analysis results, and discussion was held on a draft steelhead monitoring and evaluation plan and proposed amendment to hold natural steelhead broodstock at CNFH prior to spawning.

On October 1, 2003, NMFS received a modification to the 2001 BA from USFWS for the collection of natural steelhead by CNFH for incorporation as broodstock for the hatchery steelhead program.

On October 8, 2003, NMFS gave a presentation to the California Bay-Delta Authority (CALFED) at the Battle Creek Workshop on the issues expected to be addressed in the CNFH and Livingston Stone NFH biological opinion at the Battle Creek Workshop.

On December 16, 2004, NMFS received a letter from USFWS, dated December 13, 2004, on a modification to the broodstock collection strategy for natural origin late fall-run Chinook salmon (*O. tshawytscha*) at CNFH.

On January 6, 2004, NMFS approved a December 23, 2003, request from USFWS, for authorization of tissue collection from incidentally trapped steelhead at Keswick Dam, for the purpose of genetic analysis of upper mainstem Sacramento River, Battle Creek and CNFH steelhead.

In a letter dated January 28, 2005, USFWS informed NMFS of a modification to their fish salvage plan for CNFH through an experimental "real-time" fish rescue effort that was conducted in May, June, and August of 2005.

In a letter dated June 20, 2005, USFWS informed NMFS of the results of planting CNFH steelhead into Keswick Reservoir. Based upon steelhead escapement from the reservoir and their recapture downstream, USFWS discontinued the outplanting effort to prevent impact to the natural anadromous steelhead in the upper Sacramento River.

In a letter to NMFS, dated April 7, 2006, USFWS provided a revised estimate of incidental take of ESA-listed anadromous salmonids at the CNFH water intakes, precipitated by a forced change in hatchery operations. Damage to the Pacific Gas & Electric Company's (PG&E) Coleman Powerhouse on December 2, 2005, prevented routing of stream flow through the powerhouse and made the hatchery's primary water supply intake (Intake 1) non-functional. CNFH relied on its unscreened backup water supply, Intake 2, until the repairs were completed and Intake 1 was made functional again.

In a letter to NMFS, dated December 1, 2008, USFWS informed NMFS of a modification to the CNFH late fall-run Chinook salmon release strategy, by the timing of releases with high flow events and peak late fall-run smoltification. USFWS would initiate a study concurrent with implementation of the modified release strategy to evaluate effects to natural-origin salmonids in the Sacramento River.

In a letter sent to NMFS in February 2009, USFWS provided notice of a temporary change to the strategy of releasing general production fall-run Chinook salmon (*O. tshawytscha*). USFWS intended to transport a portion (approximately 1.5 million fish, 10.7 percent of total production) of the hatchery's general production fall-run Chinook salmon to the San Pablo Bay, where they would be acclimated for a short period of time and then released. An attachment to the letter provided an analysis of effects to ESA-listed salmonids.

In a letter dated March 25, 2010, USFWS informed NMFS of the use of an unscreened water intake at the CNFH for the period February 8, 2010, through March 31, 2010. Attached to that letter were estimates of entrainment of ESA-listed salmonids and a description of planned efforts to salvage entrained fishes.

In a letter dated July 12, 2010, USFWS informed NMFS of the planned use of an unscreened hatchery intake from July 22, 2010, to September 22, 2010. Use of the unscreened, back up intake would be necessitated by the scheduled maintenance of the PG&E powerhouse, which would dewater the hatchery's primary intake. Attached to the letter were estimates of entrainment of listed salmonids in Battle Creek. Based on the low numbers of fishes emigrating from Battle Creek at that time of year and the relatively high amount of effort required to conduct an effective salvage operation, USFWS proposed to not implement a salvage effort.

On July 15, 2010, USFWS sent NMFS a report of fish salvage at the CNFH canal associated with the operation of an unscreened hatchery water intake for the period February 8, 2010, through March 31, 2010.

In a letter dated December 22, 2010, USFWS requested from NMFS a one-year variance to the production limit for steelhead to be released from the CNFH in 2011. The estimated production of brood year 2010 steelhead was approximately 27,000 over the upper production limit, as defined in the 1999 biological opinion for the CNFH artificial production programs. Included with the request was a risk analysis, which concluded that there would be negligible risks to listed salmon and steelhead in the upper Sacramento River.

On July 27, 2011, USFWS submitted an updated Biological Assessment for the CNFH Complex, and requested formal consultation.

From April 2012 through August, 2013, periodic discussions were held between UFWS and NMFS to clarify elements of the proposed action, effects analysis, scope of incidental take and other elements related to the incidental take statement.

II. DESCRIPTION OF THE PROPOSED ACTION

The CNFH Complex consists of the CNFH and the Livingston Stone NFH. The CNFH, authorized by the Central Valley Project (CVP), was constructed by Reclamation to partially mitigate for the loss of 187 miles of salmonid spawning and rearing habitat that was blocked after the construction of Shasta Dam (Skinner 1958; USFWS 2001b). The hatchery was constructed in 1942 on Battle Creek, near the city of Anderson, Shasta County, 5.8 river miles (RM) from the confluence with the Sacramento River (Figure 1), and fish culture operations began in 1943. During its history, CNFH has implemented propagation programs for winter-, spring-, fall- and late fall-run Chinook salmon and steelhead. Currently, CNFH manages two integrated-harvest programs: the non-listed fall-run Chinook salmon and late fall-run Chinook salmon programs, and one segregated program: the listed steelhead program. USFWS produces fall- and late fall-run Chinook salmon primarily to contribute to harvest in the ocean commercial fishery, the ocean sport fishery, and the freshwater sport fishery. Steelhead are produced primarily for harvest in the freshwater sport fishery. In addition, fish may also be reared for the purpose of research. CNFH is operated by USFWS.

The Livingston Stone NFH was constructed in 1997 at the base of Shasta Dam to assist recovery efforts for endangered winter-run Chinook salmon. Assuring that hatchery origin winter-run Chinook salmon would return to the upper Sacramento River to supplement the natural population resulted in the need to relocate the program from CNFH on Battle Creek to a location directly on the Sacramento River. Thus, Livingston Stone NFH was constructed in 1997. Reclamation is responsible for the funding of operations related to salmon and steelhead propagation at the CNFH and the Livingston Stone NFH. As described in the Background and Consultation History section of this biological opinion, renewal of the ESA section 10 permit and associated ESA section 7 biological opinion will cover take of winter-run Chinook salmon

for the purpose of propagation at the Livingston Stone NFH as well as incidental take of listed species as a result of that hatchery propagation program. Therefore, these activities are not part of the proposed action for this biological opinion. For the Livingston Stone NFH, the following discussion of hatchery facilities and operations focuses on collection of natural-origin late fall-run Chinook salmon that may occur at the Keswick Dam fish trap located on the Sacramento River.

A. Hatchery Facilities

1. Overview

a. *CNFH*

CNFH facilities include the main hatchery building containing incubation stacks and trays and fiberglass tanks for early-rearing; the administration building; the feed storage building; the garage, warehouse and storage buildings; the spawning building; the maintenance shop; the electrical sub-station and generator buildings; the ozone water treatment plant and associated structures; and three staff residences. Other structures for fish propagation include: twenty-eight 15-feet (ft) by 150-ft concrete raceways; thirty 8-ft by 80-ft concrete raceways; a pollution abatement pond, and facilities for congregating, collecting, holding, and spawning broodstock (Figure 2). Additionally, the USFWS California-Nevada Fish Health Center uses four buildings located on the hatchery property, including two used for office/laboratories and one wet lab. There is also on-station housing for hatchery staff.

2. Water Supply

a. *CNFH*

CNFH has water rights to withdraw up to 122 cubic feet per second (cfs) from Battle Creek, including 13 cfs that is diverted through the hatchery intake and delivered to downstream water users. Three intake structures and associated conveyance facilities are used to divert and convey water directly from the Coleman Powerhouse tailrace and Battle Creek (Figure 4). USFWS monitors water use at the hatchery to ensure compliance with the water rights.

The CNFH primary intake (Intake 1) is located in the tailrace of the PG&E Coleman Powerhouse, which empties into Battle Creek approximately 1.6 miles upstream of the hatchery property. Intake 1 is unscreened, however, it is inaccessible to anadromous salmonids from the downstream direction by a juvenile fish barrier and an adult salmonid exclusion weir, which prevent listed salmonids from accessing an area where they could become entrained. CNFH Intake 2 (unscreened) is located on the south bank of Battle Creek, in close proximity to Intake 1. Intake 2 draws water directly from Battle Creek, and is used as an emergency back-up to Intake 1. The design of Intake 2 prevents diversion of water simultaneous with Intake 1. Intake 2 supplies water to the hatchery only during periods when water cannot be supplied through Intake 1 (*e.g.*, emergency (failure of canal) or powerhouse maintenance). Intake 3 is screened and draws water directly from Battle Creek, approximately 0.4 miles downstream of Intake 2, and 1.2 miles upstream of the hatchery.

Water from all three intakes can be shunted to the ozone water treatment facility or sent directly to various fish-rearing areas at CNFH. The water delivery system at CNFH has numerous piping interconnections between facilities. These interconnections allow water to be diverted from the canal to the sand traps, to bypass the water treatment system, and to be reused from the 15-ft by 150-ft raceways to the 8-ft by 80-ft raceways.

The water delivery system and water treatment plant at CNFH are equipped with numerous alarms to alert hatchery staff in the event of power outages or low water supply.

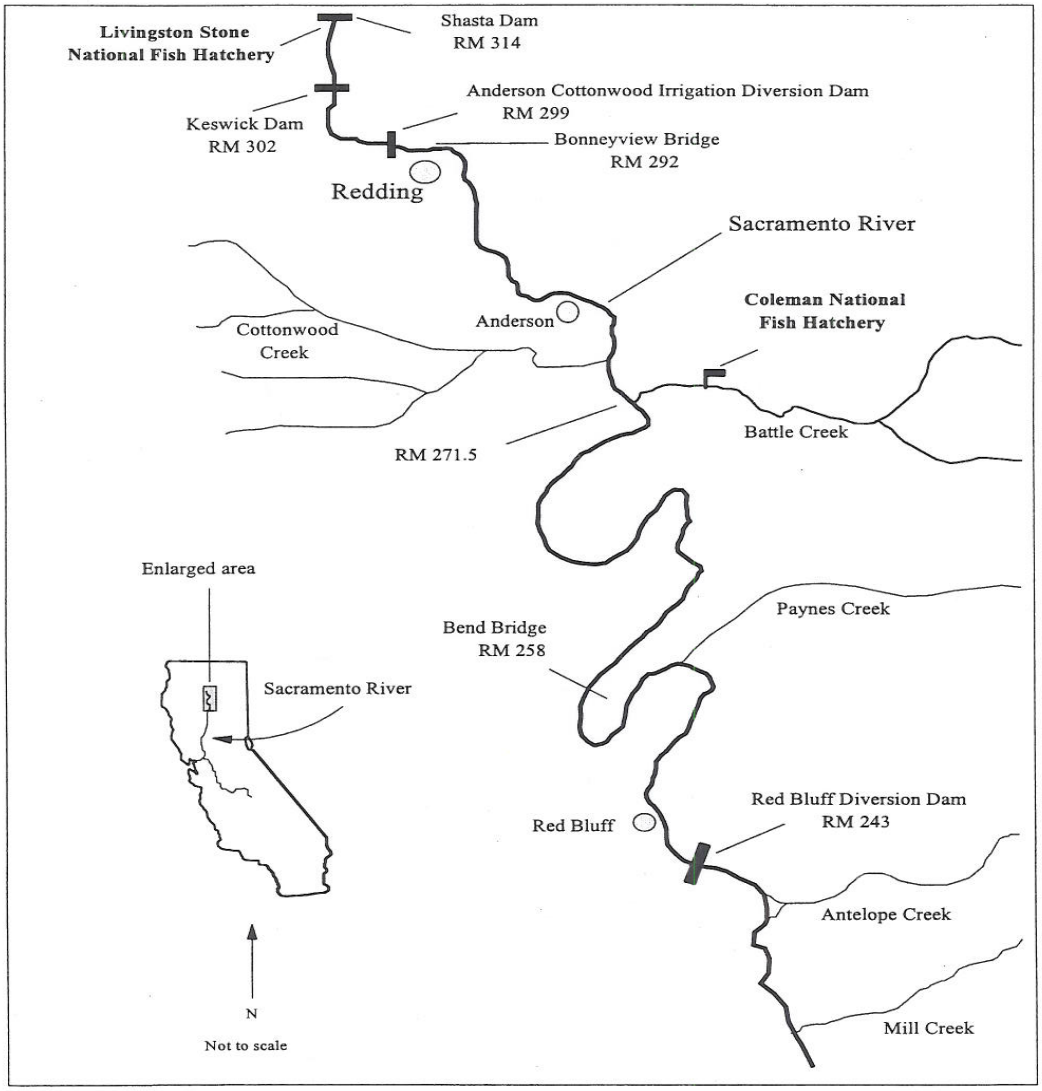

Figure 1. Location of the CNFH.

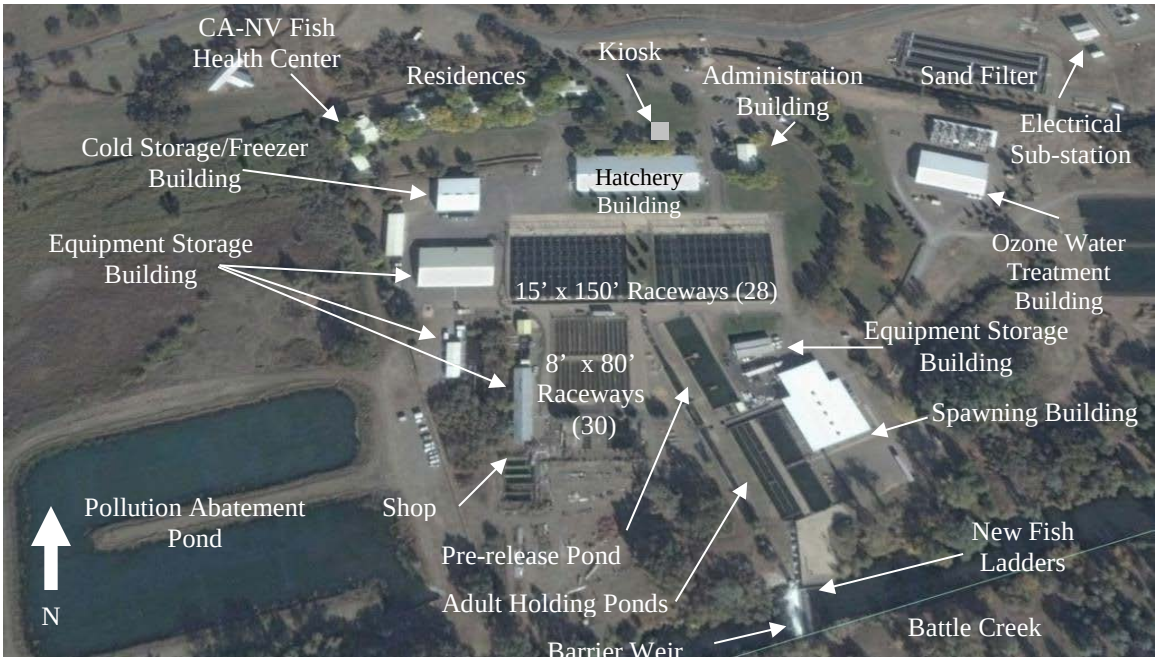

Figure 2. Physical layout of hatchery facilities at CNFH.

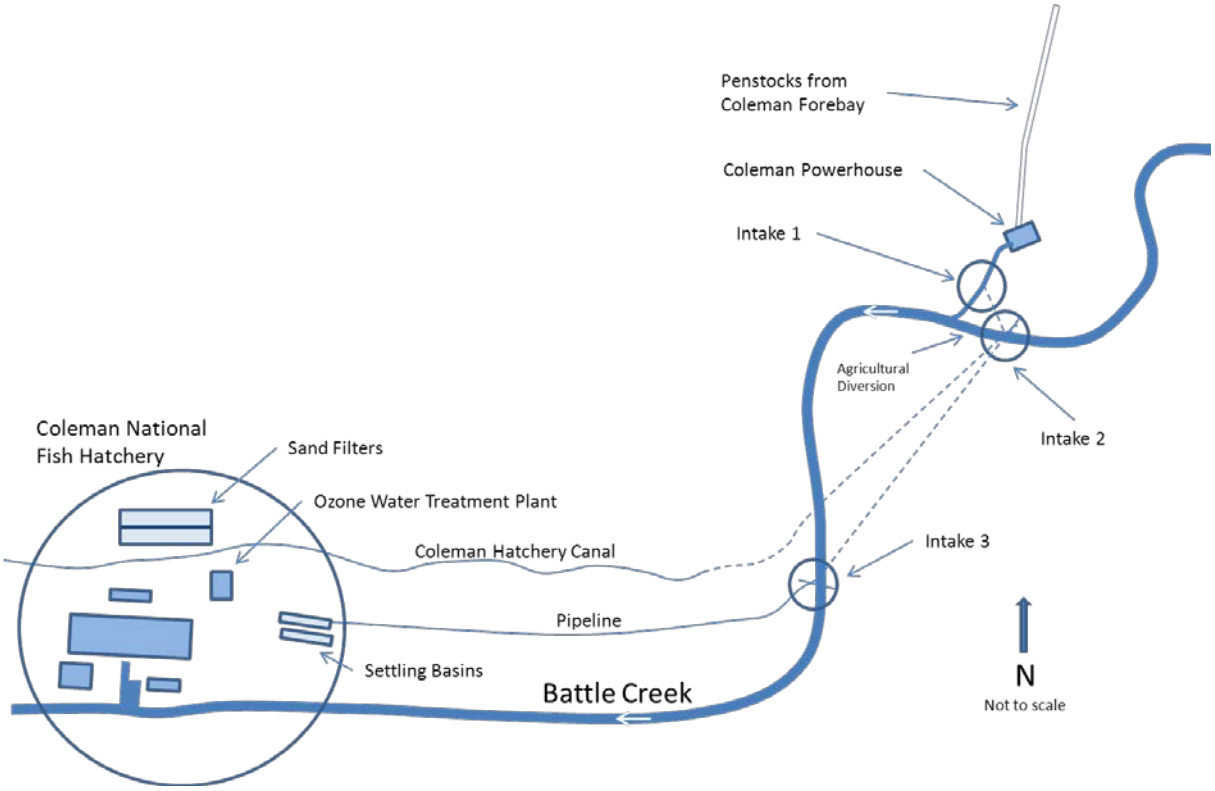

Figure 3. Schematic of the water delivery system at the CNFH.

In 2009, USFWS completed modifications to the CNFH intakes and water conveyance systems to improve protection for natural-origin fish in Battle Creek and improve efficiency, reliability, and flexibility of water deliveries for hatchery operations. The diversion capacity of Intake 1 was increased from 50 to 122 cfs, and a new 400-ft pipeline was extended downstream to discharge into the pipeline from Intake 3. The increased capacity of Intake 1 enables, under normal operations, the full allotment of water to the CNFH to be diverted from the tailrace of the PG&E powerhouse (*i.e.,* water that has already been diverted through the PG&E hydroelectric project system), thereby reducing the need for additional diversions directly from Battle Creek. Intake 3 was rebuilt with a new fish screen that meets the screening criteria of NMFS and CDFG. The screening of Intake 2, a secondary back-up to intakes 1 and 3, will be completed as a second phase of the project, contingent on funding. The intake and water delivery modifications completed in 2009 afford improved protections for naturally produced fish in Battle Creek and provide a reliable supply of high-quality water to satisfy operational needs at CNFH.

USFWS has developed a salvage plan for rescuing fish from the water delivery canal and sand traps following the recommendations in the 1999 CNFH Biological Opinion (NMFS 1999c). Fish rescues are carried out by CNFH staff or the Red Bluff Fish and Wildlife Office (RBFWO), who notify NMFS when there is a powerhouse emergency or planned maintenance action that would necessitate the use of unscreened Intake 2. Annual maintenance of the PG&E powerhouse is coordinated with CNFH, and generally occurs during two weeks of low flow when few anadromous fishes are emigrating from Battle Creek into the Sacramento River.

Fish salvage of the delivery canal takes place when water demand can be supplied fully by Intake 3 and fish rescue in the settling basins must be conducted when Intake 3 is not in use. The canal and traps require some draining and dewatering, and fish rescue is often complicated by sediment and submerged vegetation. Rescue techniques may include the use of dip nets, fyke nets, beach seines, and electroshocking.

3. Water Treatment

a. *CNFH*

The water supply at CNFH is treated with a combination of settling, filtration, and ozonation to remove silt, sediment and pathogens that impact fish reproduction and health. To reduce sediment in the hatchery water supply and to alleviate recurrent disease problems, CNFH uses a water treatment facility capable of filtering 45,000 gpm and ozonating 30,000 gpm. Ozone treatment kills viral, bacterial, and protozoan organisms that could infect fish being reared in the hatchery. Operation of the ozone water treatment facility has substantially reduced the occurrence of disease in hatchery production and the potential for disease transmission to naturally-produced stocks. Since 1999, the year that near-production capacity of the new ozone facility was first achieved, juvenile salmonids propagated at CNFH have been reared and released with no incidence of disease.

4. Water Discharge

a. *CNFH*

CNFH follows a *Monitoring and Reporting Program* and operates under a *Best Management Practices* (BMPs) *Plan* to meet its waste discharge management requirements under a National Pollution Discharge Elimination System permit (NPDES No. CAG135001) issued by the California Regional Water Quality Control Board (CRWQCB). CNFH directs 3.3 million gallons per day (mgd) of its daily 40.8 mgd flow-through effluent into its pollution abatement pond for filtering out large particulate matter associated with raceway cleaning. Water that is not diverted to the pollution abatement pond is discharged directly into Battle Creek through an overflow channel, the fish ladder, and a separate wastewater ditch. Effluent released from the hatchery must meet requirements for water temperature, pH (the measure of the acidity or basicity of an aqueous solution), suspended solids, and chemical oxygen demand (CDO) in the receiving stream's mixing zone (USFWS 2001b). CNFH has also developed and follows a *Spill Prevention Control and Countermeasure Plan*.

5. Broodstock Collection Facilities

a. *CNFH*

The facilities for congregating and collecting broodstock at the CNFH consist of a barrier weir, fish ladder, and holding ponds. The CNFH barrier weir and fish ladder are located approximately six miles up from Battle Creek's confluence with the Sacramento River. The weir is permanent and extends across the full width of Battle Creek (approximately 90 ft). The primary purpose of the barrier weir is to congregate salmonids and divert them into the hatchery's adult collection and holding ponds. USFWS, working cooperatively with Reclamation, completed modifications to the CNFH barrier weir and fish ladder in September 2008. The modification to the barrier weir is intended to improve the capability of controlling fish migration in Battle Creek. Modifications included the addition of a 2-foot-wide, lipped cap to the crest of the barrier weir and an overshot gate, which is used to regulate attraction flows at the entrance of the fish ladder. A new bifurcated fish ladder was also constructed; one fork leads directly to the existing CNFH adult holding ponds and the other provides access to Battle Creek upstream of the barrier weir. Additional modifications were included to enable lamprey (*Lampetra* spp.) to migrate through the fish ladder. A monitoring vault and viewing window is also included to support monitoring of fish passing above the hatchery. The reconstructed barrier weir was designed to block the passage of upstream migrating salmonids at flows up to 800 cfs and the new fish ladder was designed to efficiently attract and pass fish upstream, using criteria equivalent to that of upstream fish ladders associated with the Battle Creek Salmon and Steelhead Restoration Project.

b. *Livingston Stone NFH*

In addition to broodstock collection in Battle Creek, natural-origin late fall-run Chinook salmon may be collected at the Keswick Dam fish trap located on the Sacramento River and transported for propagation at the CNFH. The Keswick Dam fish trap and associated structures are located in the center of the dam between the powerhouse and the spillway. Broodstock collection facilities consist of a twelve-step fish ladder, a brail-lift, and a 1,000-gallon fish-tank elevator.

6. Adult Holding and Spawning Facilities

a. *CNFH*

Adult holding and spawning facilities at CNFH consist of five holding ponds of various configurations and a fully-mechanized facility for crowding, sedating, sorting, and spawning collected adults. Upon ascending the hatchery's adult collection ladder and lower part of Pond 2, salmonids ultimately enter Pond 3, which measures 200-ft by 36-ft (a volume of 30,600 cubic-ft [ft^3]). Fishes collected in Pond 3 are routed into the spawning building using mechanized crowders. The spawning building includes a spawning and sorting facility. A hydraulic lift located in the spawning building raises fish into a sedation tank infused with carbon dioxide (CO_2). Non-target fish can be returned immediately to Battle Creek during the initial sorting process by diverting them down a tube emptying into Battle Creek above the CNFH barrier weir. Hatchery broodstock can either be spawned immediately (*e.g.*, if fully mature) or shunted to Pond 3, Pond 4 or Pond 5 until they're ready for spawning. Ponds 4 and 5 measure 81.5-ft by 41-ft each (23,390 ft^3) and are also enclosed in the spawning building. Pond 1, also called the pre-release pond, measures 201-ft by 60-ft, and is used to hold post spawn steelhead during the recondition of those fish. Pond 1 has concrete sides and a gravel bottom.

7. Incubation and Indoor Rearing Facilities

a. *CNFH*

Egg incubation facilities are located in the hatchery building. Incubation units consist of 178 sixteen-tray vertical fiberglass incubators (Heath Incubation Trays). The top tray of each incubation stack is not used to limit the exposure of incubating eggs to light and silt. Also located in the hatchery building are sixty-seven 16-ft by 3.33-ft fiberglass tanks used for early-rearing of steelhead.

8. Outdoor Rearing Facilities

a. *CNFH*

Outdoor rearing units include twenty-eight 15-ft by 150-ft raceways and thirty 8-ft by 80-ft outdoor raceways. The raceways are constructed of concrete, surrounded by fencing, and covered with a network of wire to reduce terrestrial and avian predation. The 15-ft by 150-ft raceways are approximately 4 ft deep at the upstream end and 4 ft 9 inches deep at the downstream end, containing approximately 5,600 ft^3. The 8-ft by 80-ft raceways hold approximately 1,148 ft^3 of water.

9. Fish Transportation Equipment

a. *CNFH*

CNFH has two trucks that are used to transport fish; a 2002 Freightliner (tank capacity of 2,000 gallons) and a 1998 Freightliner (tank capacity of 1,500 gallons). Distribution trucks are used for transporting steelhead trout to the Sacramento River at Bend Bridge (RM 258) and for transporting a portion (approximately 10 percent) of the fall-run Chinook salmon to the San Pablo Bay for release. Occasionally, fall and late fall-run Chinook salmon are transported to alternative off-site release locations as part of various research projects. These trucks are also

used to transport natural-origin late fall-run Chinook salmon from the Keswick Dam fish trap to CNFH.

B. Artificial Propagation Activities

1. Overview

a. *CNFH*

The fall- and late fall-run Chinook salmon and steelhead propagation programs at the CNFH are intended to partially mitigate for the impacts of Shasta Dam on anadromous Chinook salmon and steelhead. Fall- and late fall-run Chinook salmon propagation programs are *integrated-harvest* type programs. The goal of the fall and late fall-run Chinook salmon programs is to contribute to *harvest* in the Sacramento River sport fishery and sport and commercial ocean fisheries. The steelhead propagation program at the CNFH is currently operated as a segregated-harvest type program. The CNFH steelhead program is intended to contribute to sport fisheries in the Sacramento River and Sacramento-San Joaquin Delta (Delta). The annual production goals are 12 million Central Valley fall-run Chinook salmon smolts, 1 million Central Valley late fall-run Chinook salmon smolts, and 600,000 steelhead smolts (Table 1).

Table 1. Annual propagation targets at the Coleman and National Fish Hatchery are presented, including number of adults spawned, initial egg take, and number of juveniles released. Also shown are target release timing, life stage and size, and release location.

			Release		
	# of Adults (1 ♀ : 1 ♂)	Production Target[1]	Month	Size	Location
Fall-run Chinook salmon	5,200	**12,000,000**	April	75 mm. 90 / lb 88 mm. 60 / lb.	90 percent - Battle Creek 10 percent - San Pablo Bay
Late fall-run Chinook salmon	540	1,000,000	December	135 mm. 13 / lb	Battle Creek
Steelhead	400-800[a]	600,000	January	200 mm. 4 / lb	Sacramento River at Bend (RM 258)

a the range of 400 to 800 fish is the minimum number required for meeting the production objectives

2. Broodstock Collection

a. *CNFH*

[1] Actual production may differ from release targets by +/- 15 percent, due to variations in fecundity and survival (Service 2001b).

The Coleman barrier weir and its associated fish ladders are located approximately 5.8 miles upstream from the confluence of Battle Creek and the Sacramento River. The weir is permanent, and extends across the full width of Battle Creek (approximately 90 ft). The barrier weir obstructs passage of adult salmonids to the ladder leading to upper Battle Creek (upstream of the hatchery) during broodstock collection and diverts them to a fish ladder leading to the hatchery's adult holding ponds. This method of broodstock collection is believed to provide a representative (unbiased) sample of all adults attempting to ascend Battle Creek past the CNFH. Upstream passage is blocked at the CNFH barrier weir from August 1 through February 28. From March through July, fish are allowed to ascend Battle Creek past the barrier weir using a fish ladder. To obtain a representative sample of each broodstock, fall- and late fall-run Chinook salmon are collected at CNFH throughout the duration of arrivals at the hatchery. Collection of fall-run Chinook salmon begins in early-October and continues through mid- to late-November. Late fall-run Chinook salmon are collected from mid-December through late-February. Collection of steelhead broodstock occurs concomitant with fall- and late fall-run Chinook salmon, extending from early-October through February.

Fall-run Chinook salmon broodstock are collected from a comingled population of natural and hatchery adults in Battle Creek. Because all hatchery-origin juveniles are not marked prior to release (a constant fractional marking rate of 25 percent is followed), unmarked adults returning to Battle Creek cannot be differentiated from hatchery- or natural-origin Chinook salmon. In the event of a deficit of fall-run Chinook salmon adults returning to Battle Creek, fall-run Chinook salmon broodstock could be also collected at the Keswick Dam fish trap; however, this option is rarely exercised. The most recent collections of fall-run Chinook salmon broodstock at the Keswick Dam fish trap occurred in 1986.

Late fall-run Chinook salmon broodstock are collected from hatchery adults from Battle Creek and from natural adults captured at the Keswick Dam fish trap on the Sacramento River. Broodstock selection for fall- and late fall-run Chinook salmon occurs randomly from ripe Chinook salmon of a length indicative of being adults (*i.e.*, equal or greater than age-3). Fish less than an identified cut-off, typically 650 millimeters (mm), are identified as "jacks" (age-2), and incorporated at the rate which they return to Battle Creek, up to a maximum of 5 percent of the total broodstock. Unmarked adult Chinook salmon collected from Battle Creek during late fall-run spawning season are bypassed upstream of the CNFH barrier weir immediately at the time of initial broodstock sorting (USFWS 2010).

Steelhead broodstock are selected from hatchery-origin adults entering the CNFH. Because all juvenile steelhead are marked by clipping the adipose fin prior to release from the hatchery, adult steelhead encountered in Battle Creek can be positively identified to origin based on this distinguishing mark. Unmarked, natural-origin steelhead are released upstream of the CNFH barrier weir immediately at the time of initial sorting of broodstock.

b. *Livingston Stone NFH*

Most broodstock are collected using the fish trap at Keswick Dam. The fish trapping facilities are located in the center of the dam, between the powerhouse and the spillway. The trapping facilities consist of a twelve-step upstream fish ladder, a brail-lift, and a 1,000 gallon elevator. The fish ladder is approximately 170 ft long and 38 ft wide. Weirs spaced every 13 ft 7 inches

create pools in the ladder. Fish approaching Keswick Dam are attracted to the fish ladder by means of a 340 cfs jet pump supplying water to the trap and fish ladder. Additional attraction is supplied through water diffusers in the ladder floor. The top of the ladder leads to a fyke weir. After passing through the fyke weir, adult salmonids are contained in a large fiberglass brail enclosure. When the trap brail is raised, trapped fish are directed into a 1,000-gallon fish tank elevator which transports them up the face of the dam. The fish tank elevator is then emptied into a vehicle equipped with a distribution tank and transported to Livingston Stone NFH. The design of the Keswick Dam fish trap allows fish collected at that site to remain in water at all times.

3. Fish Sorting

a. *CNFH*

Sorting of broodstock collected at the CNFH is accomplished by crowding fishes from the adult collection pond into a channel that leads to the spawning building, where they are sedated in water infused with CO_2 and manually sorted. "Green" (unripe) fish entering CNFH may be detained at the facility until they are ready for spawning. Chinook salmon are sorted at least weekly during broodstock collection. Steelhead enter the hatchery interspersed amongst Chinook salmon and are netted from the sedation tank first to avoid the potential for injury by larger bodied Chinook salmon. Sorting of natural-origin late fall-run Chinook salmon broodstock collected at the Keswick Dam fish trap is accomplished by transporting collected fishes to the Livingston Stone NFH, where they are sedated with CO_2 in the transportation truck and manually sorted prior to transportation to the CNFH. Migration timing and physical characteristics (*e.g.*, the presence of fungus, fish coloration and condition, degree of ripeness, and the presence of marks or clips) assist in distinguishing overlapping salmon runs during the process of sorting and selecting hatchery broodstock.

4. Fish Transportation

a. *CNFH*

Most hatchery broodstock for the CNFH are collected at the hatchery and do not require transportation. When necessary, transportation of adult broodstock from points of collection to spawning and rearing facilities or relocation areas is accomplished with the use of aerated 250-gallon or 2,000-gallon insulated fish hauling trucks. Salt, artificial slime (to protect the natural slime coat), and ice may be added to transport water to reduce fish stress during truck transport. Transport from Keswick Dam to CNFH, including sorting of fish at the Livingston Stone NFH, may take up to 4 hours.

5. Fish Spawning

a. *CNFH*

Fall-run Chinook salmon are spawned from early October to late November and late fall-run Chinook salmon spawning occurs from late December to early March. Steelhead are spawned from late December to early March. Salmon and steelhead are typically pair-spawned (1 male:1 female), however, gametes from more than one male may be used to fertilize the eggs of an

individual female, if needed. The minimum spawning targets are 5,200 fall-run Chinook salmon, 540 late fall-run Chinook salmon, and 400 steelhead. However, the USFWS describes that the actual number of proposed fall-run Chinook salmon spawned may be greater than the minimum target to maintain genetic diversity in the hatchery production (USFWS 2011).

6. Carcass Disposal

a. *CNFH*

Chinook salmon carcasses from the CNFH may be transferred, through agreements, to representatives of local Native American tribes or through a seafood processor to the California Emergency Food-link. Chinook salmon carcasses not suitable for use as food are transported to a rendering plant. Hatchery-origin steelhead are live-spawned and then "reconditioned" prior to release into Battle Creek in the spring. Reconditioning refers to post spawning captivity of the spawned steelhead adults (kelts) designed to achieve a state of health that will enable the kelts to emigrate from the freshwater system. Following spawning, *O. mykiss* kelts are placed into circular tank for about one week to afford assessment of near immediate post spawn mortality. At the end of this period, the kelts are placed into a 9.1×15.2 m concrete and earthen holding pond where they are maintained on a diet of salmon eggs and commercial fish pellets until their release in March/April. The time spent in captivity post-spawning is also designed to discourage attempts to spawn in the natural environment.

7. Fish Incubation

a. *CNFH*

Newly fertilized Chinook salmon and steelhead eggs are disinfected and water hardened in iodophor solution prior to transfer to the incubation building. Tray loading densities vary by species and life stage. Initial tray loading densities, from the point of fertilization to eye-up, are 10,000–11,000 eggs for fall-run and 9,000–10,000 eggs for late fall-run, and 15,000–22,000 eggs for steelhead. Tray loading densities from eye-up to hatchery are 7,800 eggs for fall and late fall-run Chinook salmon and 11,000–14,000 eggs for steelhead. Eggs are treated with formalin to deter fungus, and dead eggs are removed after the eye-up stage. Eggs may be excessed to meet hatchery production targets. Eggs and sac-fry remain in incubation for approximately two to three months. Following incubation, swim-up fry are combined into production-sized rearing units according to spawning date. Fry may be reared initially in indoor fiberglass tanks (steelhead) or moved directly into outdoor raceways (Chinook salmon).

8. Fish Rearing

a. *CNFH*

Each outdoor raceway at the CNFH is supplied with single-pass water and has a sun shade. Fish handling is limited to reduce stress, however, handling may be required to separate large groups of juvenile fish into multiple rearing units to accommodate each growth stage. Rearing units are observed daily for any dead and moribund fish, which are then removed. Fish health is

monitored and treatment is carried out as needed. Fish are fed on a semi-moist or dry pellet diet. Feed rations are based on percent body weight per day.

9. Fish Marking

a. *CNFH*

Fall-run Chinook salmon production are adipose fin-clipped and CWT at a 25 percent mark rate and late fall-run Chinook salmon are fin-clipped and CWT at a 100 percent rate. Funding for fall- and late fall-run Chinook salmon is obtained on a year-to-year basis and continued funding is uncertain. The CNFH steelhead production is adipose fin-clipped at a 100 percent rate. Funding for continued marking of steelhead can be reasonably assured to continue into the future.

The USFWS has committed to provide continued funding for the marking of steelhead and marking and coded-wire tagging of winter-run Chinook. Funding requirements for these two projects are modest (e.g., approximately $25,000 total), and can be accomplished within existing funding levels provided annually to the Hatchery Evaluation Program at the RBFWO (through CNFH) by Reclamation. Marking of all steelhead produced at the CNFH and all other hatcheries in the Central Valley was initiated in 1998 per agreement with the CDFG (now CDFW), which enabled changes in harvest management to implement a selective fishery. Marking and tagging of all winter Chinook produced at the Livingston Stone NFH is expected to be required with renewal in 2013 of the ESA section 10 permit for this propagation program, and provides a means to evaluate effects and effectiveness of the hatchery supplementation program.

Funding for the marking and tagging of fall and late-fall Chinook is dissimilar to that of steelhead and winter Chinook in that it cannot be accommodated from existing mitigation funding from Reclamation. Funding to implement the Constant Fractional Marking program for only fall-run Chinook at the CNFH requires approximately $500,000 annually, plus additional funds to recover and process tags from returning adults. Additionally, a selective fishery has not been implemented for Chinook salmon in California and so 100 percent marking is not required for harvest management.

10. Fish Releases

a. *CNFH*

Fall-run Chinook salmon are released into Battle Creek in two groups during April, when fish are approximately 75mm fork length (FL). An additional 1.2 million fish (approximately 10 percent of total fall-run Chinook salmon production) are trucked to the San Pablo Bay for release during May. Late fall-run Chinook salmon are released as yearlings into Battle Creek during December. Late fall-run Chinook salmon releases will coincide with smolting and will attempt to coincide with storm events resulting in increased flow and turbidity in the Sacramento River. Steelhead are released as yearlings in January into the Sacramento River at the Bend Bridge (Sacramento River; RM 258).

III. ENVIRONMENTAL BASELINE and STATUS of the SPECIES and CRITICAL HABITAT

The environmental baseline provides a reference condition, to which we add the effects of the proposed action, to consider the effects of the proposed Federal actions within the context of other factors that impact the listed species. The effects of the action are considered within the context of the status of the species and together with the environmental baseline and cumulative effects, and a determination is made as to whether the proposed action reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species or result in the destruction or adverse modification of critical habitat. 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).

This biological opinion has been organized such that the status of listed species, and their designated critical habitats, are described separately for Battle Creek and other portions of the action area. The first part of each species' status description is the status throughout the range of the evolutionarily significant unit (ESU) or distinct population segment (DPS), followed by a description of status in Battle Creek. This format is consistent with how USFWS presented the status of salmonid populations in the Biological Assessment of the CNFH Complex, and provides a logical context to assess impacts of hatchery facilities and operations. Because the CNFH is located on Battle Creek, we would expect that the mechanisms and relative magnitude of impacts from hatchery facilities and operations will differ between Battle Creek and other locations of the action area. Battle Creek is also important because it is the focus of ongoing habitat restoration actions focused primarily to provide benefits to ESA-listed salmonids. In this section we also provide a description of the condition of the species and critical habitat in the action area. This has been included to provide an understanding of the historical potential of these habitats, and the effects to listed species caused by the current stress regime.

A. Action Area

The action area is defined as all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02). The action area for this biological opinion is that portion of the range of the listed fishes that is directly and indirectly affected by hatchery facilities and operations. This includes spawning and rearing areas and the migration corridor of Chinook salmon and steelhead produced at the CNFH, including the mainstem of Battle Creek, from its confluence at RM 271.5 of the Sacramento River, upstream to the first permanent barrier structure of Eagle Canyon Diversion Dam on North Fork Battle Creek, and the current first permanent barrier structure of Coleman Diversion Dam on South Fork Battle Creek; the mainstem and lower tributaries of the Sacramento River from the Golden Gate Bridge upstream to RM 302 at Keswick Dam, and throughout the Delta, beginning with the Delta Cross Channel (DCC) to the confluence of the San Joaquin River basin; the San Francisco estuary from the confluence of the Sacramento and San Joaquin Rivers to the Golden Gate Bridge and inclusive of the Suisun Marsh and San Pablo Bay; and ocean habitat

(those areas utilized in off-shore and open waters adjacent to the northeastern Pacific Ocean coastline). The action area represents the migratory corridor, marine and freshwater rearing habitat, and spawning habitat utilized by CNFH production releases and returns.

B. Endangered Species Act Listing Status and Critical Habitat

The following federally listed species and designated critical habitats occur in the action area and may be affected by the proposed action:

Sacramento River winter-run Chinook salmon ESU (*Oncorhynchus tshawytscha*) endangered (January 4, 1994, 59 FR 440)

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

Central Valley Spring-run Chinook salmon ESU (*O. tshawytscha*) 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 (*O. mykiss*) threatened (January 5, 2006, 71 FR 834)

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

Southern DPS of North American green sturgeon (*Acipenser medirostris*) threatened (April 7, 2006, 71 FR 17757)

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

Southern Resident killer whales (*Orcinus orca*) endangered (November 18, 2005, 70 FR 69903).

NMFS has recently completed an updated status review of five Pacific salmon ESUs and one steelhead DPS, including Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon and California Central Valley steelhead, and concluded that the species' status should remain as previously listed (76 FR 50447; August 15, 2011). The 2011 Status Reviews (NMFS 2011a, 2011b, 2011c) additionally stated that, although the listings should remain unchanged, the status of these populations have worsened over the past five years since the 2005/2006 reviews and recommended that status be reassessed in two to three years as opposed to waiting another five years. The status reviews in 2005 and 2006 had also concluded that the species' status should remain as previously listed (70 FR 37160 and 71 FR 834).

C. Sacramento River Winter-run Chinook salmon

1. History of Listing Action

Sacramento River winter-run Chinook salmon were listed as threatened under ESA emergency listing procedures on August 4, 1989 (54 FR 32085) and again on April 2, 1990 (55 FR 12191) . A final rule to list winter-run Chinook salmon as a threatened species was published on November 5, 1990 (55 FR 46515). NMFS designated critical habitat for winter-run Chinook salmon on June 16, 1993 (58 FR 33212). The Sacramento River winter-run Chinook salmon ESU was reclassified as endangered in a final rule published on January 4, 1994 (59 FR 440) due to continuing decline and increased variability of run sizes since their listing as a threatened species, expected weak returns as a result of two small year classes in 1991 and 1993, and continuing threats to the population. The draft winter-run Chinook salmon recovery plan (NMFS 1997) recommended the implementation and continuation of several conservation measures, including the continued development of an enhancement program. The winter-run Chinook salmon ESU includes both naturally spawned winter-run Chinook salmon and the hatchery produced component of the population produced at Livingston Stone NFH. The abundance of the Sacramento River winter-run Chinook salmon population increased significantly leading into the early 2000s, prompting NMFS to propose reclassification of the ESU to "threatened" status in their review of 27 West Coast salmonid ESUs (69 FR 33102; June 14, 2004). However, the proposal to reclassify winter-run Chinook salmon was ultimately withdrawn because substantial concerns remained regarding the adequacy and benefits of ongoing and planned protective efforts. The Sacramento River winter-run Chinook salmon ESU retained its "endangered" listing status as described in the final rule (70 FR 37160; June 28, 2005). Beginning in 2007, the abundance of Sacramento River winter-run Chinook salmon again declined, likely resulting from poor environmental conditions at the time juveniles entered the marine environment (Lindley *et al*. 2009).

2. Life History

Winter-run Chinook salmon exhibit characteristics of both stream- and ocean-type races (Healey 1991). Adults enter freshwater in winter-run or early spring, and delay spawning until early summer (stream-type). However, juvenile winter-run Chinook salmon migrate to sea after only 4 to 7 months of river life (ocean-type). Adult winter-run Chinook salmon enter San Francisco Bay from November through June (Hallock and Fisher 1985), enter the Sacramento River basin between December and July, the peak occurring in March (Figure 5; Yoshiyama *et al.* 1998, Moyle 2002), and migrate past the Red Bluff Diversion Dam (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 (Yoshiyama *et al*. 1998, Moyle 2002). Spawning occurs primarily from mid-April to mid-August, with the peak activity typically occurring in June in the Sacramento River reach between Keswick Dam and Red Bluff (Vogel and Marine 1991). The majority of winter-run Chinook salmon spawners are 3 years old.

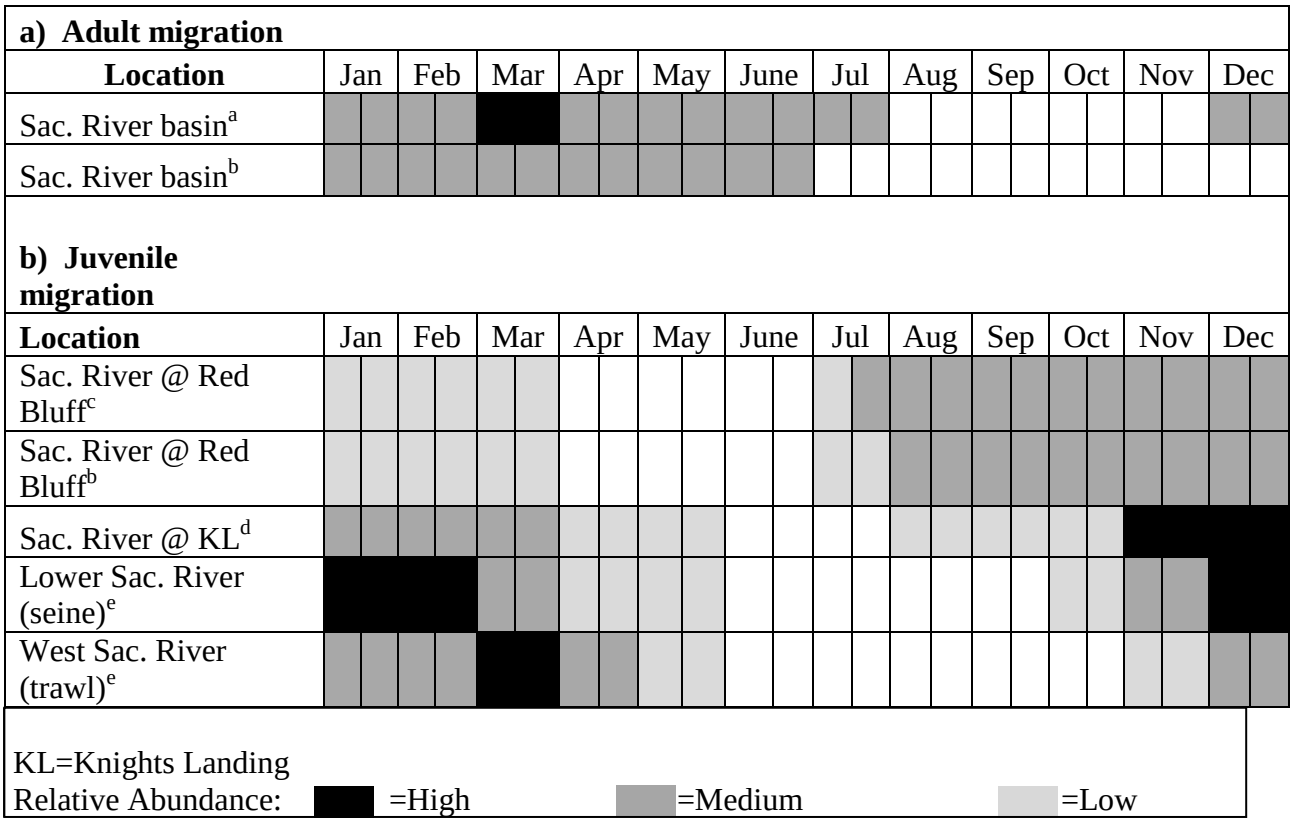

Figure 4. The temporal occurrence of (a) adult and (b) juvenile winter-run in the Sacramento River. Darker shades indicate months of greatest relative abundance. Sources: [a]Yoshiyama *et al*. (1998); Moyle (2002); [b]Myers *et al*. (1998); Vogel and Marine (1991) ; [c]Martin *et al.* (2001); [d]Snider and Titus (2000); [e]USFWS (2001a, 2001b)

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 winter-run Chinook salmon past RBDD may begin as early as mid-July, typically peaks in September, and can continue through March (Vogel and Marine 1991, NMFS 1997). From 1995 to 1999, all winter-run Chinook salmon emigrating as fry passed RBDD by October, and all pre-smolts and smolts passed RBDD by March (Martin *et al.* 2001). Juvenile 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, Gaines and Martin 2001). The timing of migration may vary somewhat due to changes in river flows, dam operations, and water year type. Winter-run Chinook salmon juveniles remain in the Delta until they reach a fork length of approximately 118 mm and are from 5 to 10 months of age, and then begin emigrating to the ocean as early as November and continue through May (Fisher 1994, Myers *et al.* 1998).

3. Range-Wide (ESU) Status and Trends

The historical distribution of winter-run Chinook salmon spawning and rearing occurred primarily in 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 suitable 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 permanently blocked access to all of these waters except Battle Creek, which had its own impediments to upstream migration (*i.e.*, hydroelectric facilities; Moyle *et al.* 1989; NMFS 1997, 1998a, 1998b). Approximately, 299 miles of spawning habitat in the upper Sacramento River watershed is now inaccessible to anadromous fish. Most facets of winter-run Chinook salmon life history (*e.g.*, spawning, incubation, freshwater rearing) have been compromised by habitat blockage in the upper Sacramento River. Until 1984, a small number of winter-run Chinook salmon also occurred in the Calavaras River, a tributary to the lower San Joaquin River. However, this group was eliminated by low flows below the New Hogan Dam during the drought of 1987–1992.

Lindley *et al.* (2004) theorized about the historical population structure of Central Valley salmon based on historical distributions, geography, hydrography, ecology, population genetics, life history information, and trends in abundance. The authors postulated that four geographically-based, independent populations comprised the historical Sacramento River winter-run Chinook salmon ESU, including: the Little Sacramento River, Pit River-Fall Creek-Hat Creek Basin, McCloud River, and Battle Creek. The single extant population of winter-run Chinook salmon, now confined downstream of Keswick Dam, was founded by some unknown combination of fish from these original populations (Lindley *et al.* 2004). The remnant winter-run Chinook salmon population is dependent on cold water releases from Shasta Dam.

Fisher (1994) estimated that the abundance of winter-run Chinook salmon may have been 200,000 fish in the late 1800s. By the late 1960s, a quarter century after the construction of Shasta Dam, the population size of winter-run Chinook salmon continued to exceed 100,000 (Good *et al.* 2005). A rapid decline occurred from 1969 to 1979, after completion of the RBDD. Over the next 20 years, the population was reduced to a low of only 186 adults in 1994. At that point, winter-run Chinook salmon were at a high risk of extinction, as defined in the most recent guideline for recovery of Central Valley salmonids (Lindley *et al*. 2007). Over the following decade several conservation measures were implemented to rebuild the run of winter-run Chinook salmon and to prevent its extinction, including the development and operation of a hatchery supplementation and captive broodstock program, construction of a temperature control device (TCD) on Shasta Dam, changes to the timing of seasonal operations at the RBDD, and restrictions of the ocean harvest. In the early 2000's population estimates of winter-run Chinook salmon rebounded, reaching a recent high of 17,296 in 2006 (Table 2). Following that peak, winter-run Chinook salmon abundance again declined, with an estimated return of 1,596 fish in 2010, and 827 in 2011 (Grandtab 2013). This recent population decline is coincident with a large-scale decline of Central Valley fall-run Chinook salmon, which has been attributed to unusually low ocean productivity at the time juvenile salmonids entered saltwater (Lindley *et al.*, 2009).

Estimates of winter-run Chinook salmon abundance and cohort replacement rates, which have fluctuated broadly since 1986, are shown in Table 2. Annual population estimates decreased nearly 93 percent between 1986 (2,596) and 1994 (186) and then increased by nearly two orders

of magnitude to 17,296 in 2006 before again declining by about 90 percent in 2010 (1,596). The 5-year moving average of population estimates shows a population increase from 491 in 1994 to 11,333 in 2006, followed by a sharp downturn extending into 2011, ending in a slight increase in 2012 with an estimate of 2,767. Cohort replacement rates (CRR) are the ratio of adult spawners divided by the number of spawners that produced those recruits. Because the majority of winter-run Chinook salmon spawners are 3 years old, NMFS calculated the CRR using the ratio of spawner abundance for a given year divided by the abundance of spawners three years prior. Between 1996 and 2008 the 5-year moving average of CRRs has been consistently above replacement level (*i.e.,* CRR greater than 1.0). The recent population decline has resulted in a CRR less than 1 since 2006.

Although the winter-run Chinook salmon population showed a general positive trend from the early 1990s through 2006, winter-run Chinook salmon abundance and CRR's since that time have decreased, indicating a rapidly declining population. The population is presently below the recovery goals listed in the draft Central Valley Recovery Plan. Low abundance coupled with high levels of year-to-year variability of abundance and population growth rates are indicative of a population that is particularly susceptible to extinction by stochastic events. Poor ocean productivity in recent years has affected all Central Valley Chinook salmon runs to some extent, and the sharp drop in abundance of the winter-run Chinook salmon population since 2007 accentuates the vulnerability of this ESU. Since there is only one extant population of winter-run Chinook salmon, there are no other populations to buffer the effects of a catastrophe in the mainstem Sacramento River. Additionally, the winter-run Chinook salmon population is completely dependent on cold water releases from Shasta Dam in order to sustain the remnant population, and the entire ESU is therefore susceptible to a multi-year drought.

Estimates of abundance of naturally produced juvenile winter-run Chinook salmon generally track that of the adult parent population. Two current methods are utilized to estimate juvenile production of winter-run Chinook salmon: the Juvenile Production Estimate (JPE) method, and the Juvenile Production Index (JPI) method (Gaines and Poytress 2004). The JPE estimates juvenile abundance using estimated adult escapement from either fish counts at the RBDD or carcass surveys, whereas the JPI uses capture of juvenile winter-run Chinook salmon and trap efficiency relationships developed using rotary screw traps at the RBDD. The two methods show similar trends and there is generally a high degree of concordance between the estimates using the two methodologies. The average abundance of juvenile winter-run Chinook salmon fry passing the RBDD between 1995 and 2009 (excluding 2000 and 2001 for which there are no data) is 4,069,184 using the JPI (Bill Poytress, personal communication, USFWS, RBFWO, 2008). Using the JPE method, and estimates of adult abundance based on the Sacramento River carcass survey, provides an estimate of 4,721,436 (Bill Poytress, personal communication, USFWS, RBFWO, 2008).

The winter-run Chinook salmon ESU includes both naturally-spawned winter-run Chinook salmon and the hatchery-produced component of the population produced at the Livingston Stone NFH. USFWS conducts a conservation program for winter-run Chinook salmon at the Livingston Stone NFH. The winter-run Chinook salmon supplementation program at Livingston Stone NFH releases up to 250,000 smolts annually into the upper Sacramento River. The winter-run Chinook salmon hatchery operates under strict guidelines that limit spawning to no more

than 15 percent of the total run with a maximum of 120 fish and includes genetic-based run verification of each individual fish considered for broodstock. The program incorporates only broodstock of natural-origin to reduce the potential for perpetuating traits associated with domestication.

4. Battle Creek Status and Trends

The importance of Battle Creek as historical habitat for winter-run Chinook salmon is uncertain. Direct information is inadequate to conclusively determine the abundance or constancy of winter-run Chinook salmon in Battle Creek prior to the dramatic alterations of the watershed that occurred during the early 1900's. Scattered records do exist, however, to show that both juvenile and adult winter-run Chinook salmon inhabited the tributary at least occasionally. Rutter (1904) reported the capture of newly emerged salmon fry in Battle Creek during September and October, suggesting that winter-run Chinook salmon had spawned successfully in the tributary. Needham *et al.* (1941) observed salmon spawning in Battle Creek during May and June - a timeframe characteristic of winter-run Chinook salmon. In 1958, the CNFH broodstock collection efforts resulted in over 300 winter-run Chinook salmon captured from Battle Creek (USFWS 1963). These observations, along with the presence of suitable habitat features including, most notably, a constant supply of cool spring-fed water, support the inference that Battle Creek provided habitats at least occasionally suitable for winter-run Chinook salmon. Lindley *et al.* (2004) theorized about the historical population structure of winter-run Chinook salmon based on historical distribution, geography, hydrography, ecology, population genetics, life history, and trends in abundance. The authors postulated that Battle Creek was one of four independent populations comprising the historical Sacramento River winter-run Chinook salmon ESU, with the others being the Little Sacramento River, Pit River-Fall Creek-Hat Creek Basin, and the McCloud River.

Table 2. Winter-run Chinook salmon population estimates and corresponding Cohort Replacement Rate.

Year	Population Estimate[1]	5-Year Moving Average of Population Estimate	Cohort Replacement Rate (Age-3)	5-Year Moving Average of Cohort Replacement Rate
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	
1992	1,240	1,091	1.78	
1993	387	593	0.90	0.64
1994	186	491	0.88	0.77
1995	1,297	664	1.05	0.94
1996	1,337	889	3.45	1.61
1997	880	817	4.73	2.20
1998	2,992	1,338	2.31	2.48
1999	3,288	1,959	2.46	2.80
2000	1,352	1,970	1.54	2.90
2001	8,224	3,347	2.75	2.76
2002	7,441	4,659	2.26	2.26
2003	8,218	5,705	6.08	3.02
2004	7,869	6,621	0.96	2.72
2005	15,839	9,518	2.13	2.84
2006	17,296	11,333	2.10	2.71
2007	2,542	10,353	0.32	2.32
2008	2,830	9,275	0.18	1.14
2009	4,537	8,609	0.26	1.00
2010	1,596	5,760	0.63	0.70
2011	827	2,466	0.29	0.34
2012	2,767	2,511	0.61	0.39
median	**2,542**	**2,466**	**1.00**	**2.00**

Winter-run Chinook salmon were largely eliminated from Battle Creek early in the twentieth century as a result of hydropower dams that blocked suitable spawning and rearing habitats (Yoshiyama *et al.* 1998). Restoration actions planned and underway for Battle Creek are focused on establishing and improving the status of federally listed salmonids, including winter-run Chinook salmon, by restoring adequate stream flows and improving passage through the migration corridor to suitable holding and spawning habitat.

A conservation hatchery program for winter-run Chinook salmon was initiated at the CNFH in 1988. Winter-run Chinook salmon originating at the CNFH did not assimilate, however, into the intended natural population in the upper Sacramento River as intended (USFWS 1996). Monitoring in Battle Creek in the mid-1990s estimated approximately 200 hatchery-origin winter-run Chinook salmon were returning to that watershed. To remediate the situation, hatchery operations were moved in 1998 to the newly constructed Livingston Stone National Fish Hatchery on the upper Sacramento River, and subsequent to the relocation of the hatchery propagation program, returns of winter-run Chinook salmon to Battle Creek declined to near zero within a couple years. Since that time, winter-run Chinook salmon have been observed in only two years (2002 and 2006). In 2002, three natural-origin adults were estimated to pass upstream of the barrier weir at the CNFH, and in 2006, five adults (one natural-origin and four hatchery-origin fish) were observed at the CNFH barrier weir. These fish were likely strays from principal spawning areas of the upper Sacramento River. No other recent observations of winter-run Chinook salmon have been made in Battle Creek and winter-run Chinook salmon do not currently inhabit Battle Creek as a self-sustaining population.

D. Winter-run Chinook salmon Designated Critical Habitat

The designated critical habitat for the Sacramento River winter-run Chinook salmon ESU includes the Sacramento River from Keswick Dam (RM 302) downstream to Chipps Island (RM 0) at the westward margin of the Delta; all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge; and all waters of San Francisco Estuary to the Golden Gate Bridge north of the San Francisco/Oakland Bay Bridge (June 16, 1993, 58 FR 33212). In the Sacramento River, critical habitat includes the river water column, river bottom, and adjacent riparian zone (those areas above a streambank that provide cover and shade to the nearshore aquatic areas) 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 winter-run as part of their juvenile emigration or adult spawning migration.

In designating critical habitat, NMFS considers those physical and biological features that are essential to the conservation of a species and that may require special management considerations or protection, including, but not limited to: (1) space for individual and population growth, and for normal behavior; (2) food, water, air, light, minerals, or other nutritional or physiological requirements; (3) cover or shelter; (4) sites for breeding, reproduction, or rearing offspring; and, generally, (5) habitats that are protected from disturbance or are representative of the historic geographical and ecological distributions of a species [see 50 CFR 424.12(b)]. In addition, NMFS focuses on the known principal biological or physical constituent elements within the designated area that are essential to the conservation of the species (primary constituent elements). The final rule designating critical habitat for winter-run Chinook salmon (June 16, 1993, 58 FR 33212) identifies the following physical and biological features that are essential for the conservation of winter-run Chinook salmon: (1) access from the Pacific Ocean to appropriate spawning areas in the upper Sacramento River; (2) the availability of clean gravel for spawning substrate; (3) adequate river flows for successful spawning, incubation of eggs, fry development and emergence, and downstream transport of juveniles; (4) water temperatures between 42.5°F and 57.5°F for successful spawning, egg

incubation, and fry development; (5) habitat areas and adequate prey that are not contaminated; (6) riparian habitat that provides for successful juvenile development and survival; and (7) access downstream so that juveniles can migrate from spawning grounds to San Francisco Bay and the Pacific Ocean. All of these essential features of critical habitat have been affected by anthropogenic activities, thereby contributing to the decline of Sacramento River winter-run Chinook salmon.

1. Access to Spawning Areas in the Upper Sacramento River

Adult migration corridors should provide satisfactory water quality, water quantity, water temperature, water velocity, cover, shelter and safe passage conditions in order for adults to reach spawning areas. Adult winter-run Chinook salmon generally migrate to spawning areas during the winter-run and spring. At that time of year, the migration route is mostly free of obstructions. However, the value of the Sacramento River migratory corridor has been reduced when the gates at the RBDD are lowered to divert river water into the Tehama-Colusa and Corning canals, thereby delaying or blocking 15 percent of the tail end of the spawning migration. Reasonable and Prudent Alternative (RPA) actions of the 2009 NMFS biological opinion on the Long Term Operations of the Central Valley Project-State Water Project (CVP-SWP) provided a prescription for modified operations of the RBDD gates to reduce impacts on migrating winter-run Chinook salmon (NMFS 2009a). Construction of the pumping plant at the RBDD was completed in September of 2012 and replaced the need for lowering the RBDD gates, thereby providing unimpeded passage for winter-run Chinook salmon to available spawning areas. Beginning September, 2011, the gates of the RBDD have remained open year round.

2. The Availability of Clean Gravel for Spawning Substrate

Spawning habitat for winter-run Chinook salmon is restricted to the Sacramento River between Keswick Dam and RBDD; however, the vast majority of spawning occurs upstream of the Airport Road bridge in Anderson, a distance of only 13 miles of river. Available spawning habit is completely outside the historical range utilized by winter-run Chinook salmon for spawning. Because Shasta and Keswick dams preclude spawning gravel recruitment, Reclamation injects spawning gravel into various areas of the upper Sacramento River. With the supplemented gravel injections, the reach of the upper Sacramento River continues to support the current populations of winter-run Chinook salmon.

3. Adequate River Flows for Successful Spawning, Incubation of Eggs, Fry Development and Emergence, and Downstream Transport of Juveniles

All historical spawning habitats of Sacramento River winter-run Chinook salmon have been blocked by essentially permanent and impassable barriers. Remaining spawning areas are completely outside of the historical range of winter-run Chinook salmon spawning, and are completely dependent on releases of cold water from Shasta Dam.

An April 5, 1960, Memorandum of Agreement (MOA) between Reclamation and the CDFG originally established flow objectives in the Sacramento River for the protection and preservation of fish and wildlife resources. In addition, Reclamation complies with the flow releases required in Water Rights Order (WRO) 90-05. Additional measures to improve juvenile rearing habitat in

the lower Sacramento River and northern Delta are required through the NMFS biological opinion on the Long Term Operations of the CVP-SWP (NMFS 2009a).

4. Water Temperatures for Successful Spawning, Egg Incubation, and Fry Development

Summer flow releases from Shasta Reservoir for agriculture and other consumptive uses drive operations of Shasta and Keswick dams during the period of winter-run Chinook salmon migration, spawning, egg incubation, fry development, and emergence. However, cold water releases also benefit winter-run Chinook salmon. The extent to which winter-run Chinook salmon habitat needs are met depends on Reclamation's other operational commitments, including those to water contractors, State Water Resources Control Board Water Rights Decision 1641 (D-1641) regulations and criteria, and projected end of September storage volume. Based on these commitments and Reclamation's modeled February and subsequent monthly forecasts, Reclamation determines how far downstream 56°F can be maintained and sustained throughout the winter-run Chinook salmon spawning, egg incubation, and fry development stages. Although Water Rights Order (WRO) 90-05 and 91-1 require Reclamation to operate Keswick and Shasta dams, and the Spring-run Creek Power Plant, to meet a daily average water temperature of 56°F at RBDD, they also provide the exception that the water temperature compliance point (TCP) may be modified when the objective cannot be met at RBDD. In every year since the State Water Resources Control Board (SWRCB) issued WRO 90-05 and 91-1, operations plans have included modifying the RBDD compliance point to make best use of the cold water resources based on the location of spawning Chinook salmon. Once a TCP has been identified and established, it generally does not change, and therefore, water temperatures are typically adequate for successful egg incubation and fry development for those redds constructed upstream of the TCP. However, the annual change in TCP has degraded the conservation value of spawning habitat (based on water temperature). As part of the RPA for NMFS' biological opinion on the Long Term Operations of the CVP-SWP, a year-round temperature and Shasta reservoir storage management program to minimize effects to winter-run Chinook salmon spawning, egg incubation, and rearing is included (NMFS 2009a).

5. Habitat Areas and Adequate Prey that are not Contaminated

Current water quality conditions are better than in previous decades, however legacy contaminants such as mercury (and methyl mercury), polychlorinated biphenyls (PCB), heavy metals, and persistent organochlorine pesticides continue to be found in watersheds throughout the Central Valley. Although most of these contaminants are at low concentrations in the food chain, they continue to work their way into the base of the food web, particularly when sediments are disturbed and previously entombed compounds are released into the water column. Exposure to these contaminated food sources may create delayed sublethal effects that reduce fitness. Contaminants are typically associated with areas of urban development or other anthropogenic activities (*e.g.*, mercury contamination as a result of gold mining or processing). Areas with low human impacts frequently have low contaminant burdens, and therefore lower levels of potentially harmful toxicants in the aquatic system.

6. Riparian Habitat that Provides for Successful Juvenile Development and Survival

The channelized, leveed, and riprapped river reaches and sloughs that are common in the Sacramento River system typically have low habitat complexity, low abundance of food

organisms, and offer little protection from predators. Juvenile life stages of salmonids are dependent on the natural functioning of this habitat for successful survival and recruitment. Some complex, productive habitats with floodplains [*e.g.*, 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) remain in the system. Nevertheless, the current condition of riparian habitat for winter-run Chinook salmon is degraded.

7. Unobstructed emigration corridor from Spawning Grounds to the Pacific Ocean

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 mainstem of the Sacramento River.

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. Prior to 2012, when the gates were in, RBDD reduced the value of the migratory corridor for downstream migration. Predators of juvenile salmonids, such as striped bass (*Morone saxatilis*) and Sacramento pikeminnow (*Ptychocheilus grandis*), concentrated downstream of dam structures, resulting in increased mortality of juvenile Chinook salmon from predation.

Unscreened diversions that entrain juvenile salmonids are prevalent throughout the mainstem Sacramento River. Although actual entrainment rates are not known, the CVP-SWP operations biological assessment provided calculations of estimated entrainment of salmonids through unscreened diversions along the Sacramento River (Reclamation 2008). According to the calculations, over 7,000 juvenile winter-run Chinook salmon are lost to unscreened diversions annually.

Emigrating juvenile salmonid are also affected by diversion into the interior Delta through the DDCC. When the DCC gates are open during winter-run Chinook salmon outmigration, a portion of the flow, and therefore, a portion of the out-migrating winter-run Chinook salmon, is entrained through the DCC into the interior Delta, where their chances of survival and successful migration to San Francisco Bay and the Pacific Ocean are reduced.
D-1641 provides for 45 days of discretionary gate closures of the DCC between November 1 and January 31, which leaves the DCC gates open half the time during those three months. Additional gate closures to keep young fish out of artificial channels and to allow them to migrate safely towards the Ocean are included in the RPA of NMFS' biological opinion on the Long Term Operations of the CVP-SWP (NMFS 2009a).

Water pumping at the CVP-SWP export facilities in the South Delta causes reverse flows, further disrupting the emigration of juvenile winter-run Chinook salmon by attracting and diverting

them to the inner Delta, where they are exposed to increased rates of predation and entrainment at pumping stations. NMFS' biological opinion on the Long Term Operations of the CVP-SWP (NMFS 2009a) set limits to the strength of reverse flows in the Old and Middle Rivers, thereby keeping salmon away from areas of highest mortality.

Based on impediments caused by the RBDD (up until 2012), unscreened diversions, the schedule of DCC gates operations, and reverse flows in the Delta, the current condition of the freshwater migration corridor in the Sacramento River is much degraded during the emigration of Sacramento River winter-run Chinook salmon.

8. Summary of Sacramento River Winter-run Chinook salmon Critical Habitat

Critical habitat for winter-run Chinook salmon is composed of physical and biological features that are essential for the conservation of winter-run Chinook salmon, including upstream and downstream access, and the availability of certain habitat conditions necessary to meet the biological requirements of the species. Currently, many of these physical and biological features are impaired, and provide limited conservation value. Additional factors degrading the quality of the migratory corridor for juveniles include unscreened diversions throughout the mainstem Sacramento River, open DCC gates during the outmigration of winter-run Chinook salmon, and reverse flows in the Sacramento-San Joaquin Delta.

In addition, the annual change in the TCP has degraded the conservation value of available spawning habitats (based on water temperature). The current condition of riparian habitat for winter-run Chinook salmon rearing is degraded by the channelized, leveed, and riprapped river reaches and sloughs that are common in the Sacramento River system. However, some complex, productive habitats with floodplains remain in the system, including reaches of the Sacramento River with setback levees located upstream of the City of Colusa and flood bypasses (*i.e.*, Yolo and Sutter bypasses). Based on the impediments caused by unscreened diversions, annual changes to the temperature compliance point, diversions into the inner Delta when DCC gates are open, reverse flows in the Delta, and the degraded condition of spawning habitat and riparian habitat, the current condition of critical habitat of Sacramento River winter-run Chinook salmon is degraded, and has low value for the conservation of the species.

E. Central Valley Spring-run Chinook salmon

1. History of Listing Action

The Central Valley spring-run Chinook salmon ESU was listed as threatened on September 16, 1999 (64 FR 50394), and a final rule with protective regulations under ESA Section 4(d) for this ESU was published on January 9, 2002 (67 FR 1116). The Central Valley spring-run Chinook salmon ESU retained its threatened listing status in the 2005 final rule for the status review of West Coast Pacific salmonid ESUs (70 FR 37160; June 28, 2005). The Central Valley spring-run Chinook salmon ESU includes all naturally spawned populations of spring-run Chinook salmon (and their progeny) in the Sacramento River and its tributaries in California as well as the Feather River Fish Hatchery spring-run Chinook salmon program (70 FR 37160; June 28, 2005). The ESU includes spring-run Chinook salmon populations in the southern Cascades ecoregion, including those in Mill, Deer, and Butte creeks (NMFS 2003), and spring-run

Chinook salmon populations of the northern Sierra ecoregion, including those in the Yuba and Feather Rivers.

2. Life History

Historically, spring-run Chinook salmon occupied the upper and middle reaches (1,000 to 6,000 ft) of the San Joaquin, American, Yuba, Feather, Sacramento, McCloud, and Pit rivers, with smaller populations occurring in most tributaries with sufficient habitat for over-summering adults (Stone 1874, Rutter 1904, Clark 1929). Spring-run Chinook salmon exhibit a stream-type life history. Adults enter freshwater in the spring, hold over the summer, spawn in the fall, and the juveniles typically spend a year or more in freshwater before emigrating. Adult 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 (Figure 6; Yoshiyama *et al*. 1998, Moyle 2002). Lindley *et al*. (2004) indicate that adult spring-run Chinook salmon migrate from the Sacramento River into spawning tributaries primarily between mid-April and mid-June. Adequate streamflows are necessary to enable adults to pass into upstream holding habitat and to maintain suitable water temperature. The preferred temperature range for upstream migration is 38°F to 56°F (Bell 1991, CDFG 1998).

Upon entering fresh water, spring-run Chinook salmon are sexually immature and must hold in cold water for several months to mature. 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). Reclamation reports that spring-run Chinook salmon holding in upper watershed locations prefer water temperatures below 60°F, although salmon can tolerate temperatures up to 65°F before they experience an increased susceptibility to disease.

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 (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 spring-run Chinook salmon migrants to be fry occurring primarily from December through February, and that these movements appeared to be influenced by flow. Small numbers of spring-run Chinook salmon emigrated as yearlings later in the year, typically the next fall. 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 seek areas of shallow water and low velocities while they finish absorbing the yolk sac and transition to exogenous feeding (Moyle 2002).

Many fry 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).

Based on the available information, the emigration timing of Spring-run Chinook salmon appears highly variable (CDFG 1998). Some fish may begin emigrating soon after emergence from the gravel, whereas others reside in natal areas throughout the summer and emigrate as yearlings with the onset of intense fall storms (CDFG 1998). The emigration period extends from November to early May, with up to 69 percent of the young-of-the-year fish emigrating through the lower Sacramento River and Delta during this period (CDFG 1998). 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-run months (Maslin *et al.* 1997, Snider 2001). Peak movement of juvenile (yearling) spring-run Chinook salmon in the Sacramento River at Knights Landing occurs in December, and again in March and April for young-of-the-year juveniles. However, juveniles also are observed between November and the end of May (Snider and Titus 2000).

Spring-run Chinook salmon fry and fingerlings can enter the Delta as early as January and as late as June; a cohort's length of residency within the Delta is unknown but probably lessens as the season progresses into the late spring-run months (CDFG 1998). Shifts in juvenile salmonid abundance demonstrated with various sampling gear reflect discretionary use of the Delta by juvenile salmonids based on their size, age, and degree of smoltification.

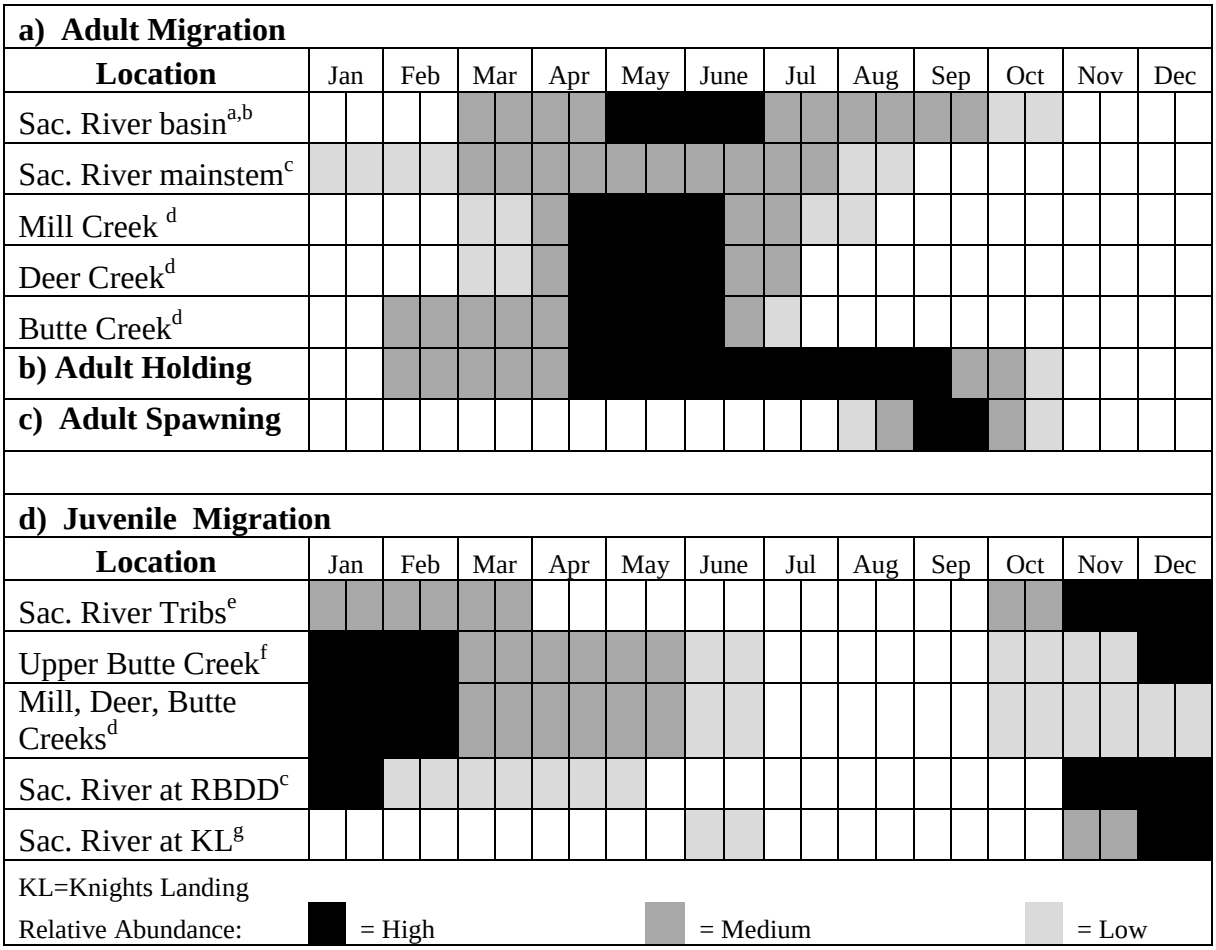

Figure 5. The temporal occurrence of adult (a-c) and juvenile (d) Central Valley Spring-run Chinook salmon in the Sacramento River. Darker shades indicate months of greatest relative abundance. Note: Yearling Spring-run Chinook salmon rear in their natal streams through the first summer following their birth. Downstream emigration generally occurs the following fall and winter. Young-of-the-year Spring-run Chinook salmon emigrate during the first spring-run after they hatch. Sources: [a]Yoshiyama *et al*. (1998); [b]Moyle (2002); [c]Myers *et al*. (1998); [d]Lindley *et al*. (2007); [e]CDFG (1998); [f]McReynolds *et al*. (2005); Ward *et al*. (2002, 2003); [g]Snider and Titus (2000).

3. Range-Wide (ESU) Status and Trends

Historically, spring-run Chinook salmon were the second most abundant salmon run in the Central Valley (CDFG 1998). The Central Valley drainage as a whole is estimated to have supported spring-run Chinook salmon runs as large as 600,000 fish in the late 1880s (CDFG 1998), after substantial habitat degradation had already occurred. Before the construction of Friant Dam, nearly 50,000 adults were counted in the San Joaquin River alone (Fry 1961). Construction of other low elevation dams in the foothills of the Sierras on the American, Mokelumne, Stanislaus, Tuolumne, and Merced rivers extirpated spring-run Chinook salmon from these watersheds. Naturally-spawning populations of 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). However, only Deer, Mill, and Butte creeks are considered to be independent spring-run Chinook salmon populations. The other tributary populations are considered dependent populations, which rely on the three independent populations for continued existence.

Existing independent populations of spring-run Chinook salmon show substantial declines from historic numbers, and a substantial portion of the existing Central Valley ESU is comprised of fish originating at the Feather River Fish Hatchery (FRFH). From 1986 to 2010, an average of 3,690 spring-run Chinook salmon returned to the FRFH compared to an average of 5,574 spring-run Chinook salmon for independent populations in Mill-Deer-Butte creeks. Coded-wire tag information from these hatchery returns indicates substantial introgression has occurred between FRFH spring-run and fall-run Chinook salmon populations, compromising the genetic integrity of both stocks. 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 natural spawning spring-run Chinook salmon in the Feather River is also questionable because of 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, and the importance of genetic diversity as one of the VSP parameters, the following discussion of spring-run Chinook salmon abundance will omit data associated with Feather River spring-run Chinook salmon, and focus on independent natural populations of spring-run Chinook salmon in Mill, Deer, and Butte creeks.

Recent abundance of spring-run Chinook salmon remains well below estimates of historic abundance (Table 3). The combined abundance of spring-run Chinook salmon in Mill, Deer and Butte creeks has fluctuated broadly since 1986, ranging from a low of 304 in 1987 to a high of 22,562 in 1998 (Table 3). Annual estimates of abundance show a generally increasing trend from 1993 to 2005, with a strong year class (1995) and subsequent cohorts exhibiting a substantial influence on the overall trend. Estimates of abundance calculated on a five-year moving average show a generally increasing trend from 1994 to 2002, relatively high and stable abundance through 2007, followed by a period of decreasing abundance to 2011. Abundance of the independent populations of spring-run Chinook salmon in Mill, Deer, and Butte creeks are dominated by returns to Butte Creek, which have comprised 73 percent of the escapement since 1986. During this same period, adult returns to Butte Creek have averaged 5,102 annually. Returns to Mill and Deer creeks have averaged 610 and 917, respectively. Age-3 CRRs since 1986 show a high amount of year-to-year variability, with the cohort failing to replace itself (*i.e.*, CRR greater than 1) in 12 of the twenty-two years. 2012, and 2013, abundance estimates for Mill, Deer, and Butte creeks increased, with 2013 the highest combined abundance since 1998, at 17,239.

In 2008, adult escapement of spring-run Chinook salmon declined dramatically in several of the region's watersheds. Butte Creek had an estimated 3,935 adults return to the watershed and returns to Mill and Deer creeks were 362 and 140, respectively. These fluctuations are likely attributable to poor conditions that existed in the ocean during the spring-run of 2006 when this cohort entered the ocean as smolts, a critical phase of their life history. This same factor has

been implicated as contributing to a concomitant decline of abundance for Central Valley fall and winter-run Chinook salmon. Additional factors that have limited adult spawning populations are in-river water quality conditions. In 2002 and 2003, mean water temperatures in Butte Creek exceeded 21°C for 10 or more days in July (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. This trend may indicate that the population in Butte Creek had reached its capacity for prevailing environmental conditions (Ward *et al.* 2003).

Recent actions by fishery management agencies have improved habitat conditions on Clear Creek for spring-run Chinook salmon. The Clear Creek population of spring-run Chinook salmon appears to be generally increasing in abundance, albeit modestly. Significant efforts have been made to enhance over-summer flows from Whiskeytown Dam, maintain suitable water temperatures in those reaches, enhance spawning habitat through gravel augmentation, and prevent genetic introgression with fall-run which utilize the same watershed. Although concern existed over the timing of the RBDD gate closures and whether this action delays spring-run Chinook salmon bound for Clear Creek to the extent that adults cannot access the watershed due to thermal barriers forming in the lower reaches of the creek near its confluence with the Sacramento River, migrational delays at the RBDD should not be an issue beginning in 2012, when the dam gates will be raised year-around in favor of new pumping facilities.

The extent of spawning by spring-run Chinook salmon in the mainstem of the upper Sacramento River is uncertain. Due to geographic overlap of fall and spring-run Chinook salmon ESUs and resultant hybridization since the construction of Shasta Dam, although Chinook salmon that spawn in the mainstem Sacramento River during September are likely to be spring-run Chinook salmon, they may also be early returning fall-run Chinook salmon. Estimates of abundance in the Sacramento River are based solely on spawn timing, and salmon spawning during September are considered to be spring-run Chinook salmon whereas salmon spawning in October are considered to be fall-run Chinook salmon. However, salmon redds observed in September could also be early spawning fall-run Chinook salmon, as there is no discernible peak for Sacramento River spring-run Chinook salmon spawn timing that can be used to separate the runs. In addition, since there is no spatial separation, early returning fall-run may hybridize with spring-run or superimpose on spring-run redds.

Very few spring-run Chinook salmon redds (less than 15 per year) were observed in the Sacramento River from 1989–1993, and none in 1994 during aerial redd counts (USFWS 2003). Recently, the number of redds in September has varied from 3 to 105 during 2001 through 2013 (CDFG unpublished data 2013), depending, at least in part, on the number of survey flights.

Table 3. Estimated abundance spring-run Chinook salmon in Mill-Deer-Butte creeks, from CDFG Grand Tab (April 2013; CDFW, personal communication, 2014) with corresponding cohort replacement rates for years since 1986.

Year	Deer/Mill/Butte Creek Spawning Escapement	5-Year Moving Average of Population Estimate	Cohort Replacement Rate (age-3)	5-Year Moving Average Cohort Replacement Rate (age-3)
1986	2,205			
1987	304			
1988	2,233			
1989	1947		0.88	
1990	1590	1,656	5.23	
1991	798	1,374	0.36	
1992	1,176	1,549	0.60	
1993	970	1,296	0.61	1.54
1994	1682	1,243	2.11	1.78
1995	9,115	2,748	7.75	2.29
1996	2,280	3,045	2.35	2.68
1997	1303	3,070	0.77	2.72
1998	22,562	7,388	2.48	3.09
1999	5,830	8,218	2.56	3.18
2000	5,299	7,455	4.07	2.44
2001	12,331	9,465	0.55	2.08
2002	12,574	11,719	2.16	2.36
2003	8,583	8,923	1.62	2.19
2004	9,192	9,596	0.75	1.83
2005	14,014	11,339	1.11	1.24
2006	8,013	10,475	0.93	1.31
2007	6,507	9,262	0.71	1.02
2008	4,437	8,433	0.32	0.76
2009	2,492	7,093	0.31	0.68
2010	1,904	4,671	0.29	0.51
2011	2,767	3,621	0.62	0.45
2012	9,941	4,308	3.99	1.11
2013	17,239	6,869	9.05	2.85
Median	3,602	6,981	1.00	2.00

4. Battle Creek Status and Trends

Spring-run Chinook salmon are native to Battle Creek; however, estimates of abundance prior to large-scale anthropogenic disturbances of the watershed are not available. Both North and South Fork Battle Creek historically contained habitats suitable for spring-run Chinook salmon spawning and rearing (CDFG 1993), and much of those areas likely were occupied prior to the

habitat perturbations associated with the hydropower project (Yoshiyama *et al.* 1998). Hydropower development of Battle Creek began in 1899, and has resulted in a substantial reduction in quality and quantity of salmonid habitat, due primarily to decreased stream flows and blocked migration corridors. By the late 1920s, Clark (1929) reported that spring-run Chinook salmon had been nearly extirpated in Battle Creek as a result of the near complete dewatering of the stream channel and impassable dams and fish ladders. Only limited natural spawning of spring-run Chinook salmon occurred within degraded and marginal habitats downstream of the lowermost dams. An artificial propagation program for spring-run Chinook salmon was initiated at the CNFH in 1943 but failed to restore a viable run due to lack of broodstock and high water temperatures. The spring-run Chinook salmon production program was discontinued in 1951. Annual estimates of spring-run Chinook salmon abundance in Battle Creek from 1943 to 1956 ranged from less than 500 to 2,000 adults (Fry 1961). From 1952 to 1956, CDFG estimated 1,700 to 2,200 spring-run Chinook salmon spawning in Battle Creek (CDFG 1961, as cited in Ward and Kier 1999) and stream surveys recorded spring-run presence in Eagle Canyon (1960s-1970s) and South Fork Battle Creek (1970s; CDFG 1966; 1970). No population estimates of spring-run Chinook salmon in Battle Creek were conducted between 1956 and 1994.

Battle Creek currently supports a remnant run of spring-run Chinook salmon. USFWS conducts annual estimates of salmon abundance in Battle Creek using a combination of methods, including direct counts of unmarked (presumably natural-origin) fish collected at the hatchery and released upstream of the CNFH barrier weir from January to February, and counts of fish passing through the fish ladder at the CNFH barrier weir from March to August. Total counts of unmarked salmon from March 1 through July are considered maximum potential spring-run Chinook salmon escapement to Battle Creek - a designation based primarily upon run timing. From 1995 to 2011, estimates of the maximum potential spring-run Chinook salmon escapement to Battle Creek range from 35 to 291. In 2012 and 2013, adult returns were the highest on record, at 799 and 608 respectively (Table 4).

Because of the overlapping periods of migration, a portion of the total Chinook salmon included in the maximum potential spring-run Chinook salmon estimates for Battle Creek likely belong to the other runs of Central Valley Chinook salmon. Since 2001, counts of maximum potential spring-run Chinook salmon have been adjusted using a genetically-based run assignment, which characterizes fish as to their most probable run type based on similarity to established genetic baselines for fall-run, late fall-run, winter-run, and spring-run Chinook salmon. A genetic baseline has not yet been developed specifically for Battle Creek spring-run Chinook salmon, so fish are categorized according to baselines for spring-run Chinook salmon in Mill-Deer Creeks, Butte Creek, and the Feather River. Genetically-based abundance estimates of spring-run Chinook salmon in Battle Creek ranged from 67 to 154 (mean of 106, standard deviation [std.] of 36).

Table 4. Estimated abundance of "maximum potential" spring-run Chinook salmon and genetically identified spring-run Chinook salmon in Battle Creek, upstream of the CNFH barrier weir, 1995-2013 (Newton and Stafford 2011; Grand Tab 2013; Laurie Earley, USFS, personal communication 2014).

Maximum Potential Spring-run Chinook salmon		5 Year Moving Average of Population Estimate	Genetically Identified Spring-run Chinook salmon Population Estimate
Return Year	Population Estimate		
1995	66		
1996	35		
1997	107		
1998	178		
1999	73	92	
2000	78	94	
2001	111	109	100
2002	222	132	144
2003	221	141	100
2004	90	144	70
2005	73	143	67
2006	221	165	154
2007	291	179	
2008	105	156	
2009	194	177	
2010	172	197	
2011	157	184	
2012	799	285	
2013	608	386	
Median	157	156	100

F. Spring-run Chinook salmon Designated Critical Habitat

Critical habitat was designated for spring-run Chinook salmon on September 2, 2005 (70 FR 52488), and includes watersheds along the Sacramento River and its tributaries and the Sacramento-San Joaquin Delta, in the following counties: Tehama, Butte, Glenn, Shasta, Yolo, Sacramento, Solano, Colusa, Yuba, Sutter, Trinity, Alameda, San Joaquin, and Contra Costa. 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 bank-full 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 one to two years on the annual flood series; Bain and Stevenson 1999; September 2, 2005, 70 FR 52488).

In designating critical habitat, NMFS considers those physical and biological features that are essential to the conservation of a species and that may require special management considerations or protection, including, but not limited to: (1) space for individual and population growth, and for normal behavior; (2) food, water, air, light, minerals, or other nutritional or physiological requirements; (3) cover or shelter; (4) sites for breeding, reproduction, or rearing offspring; and, generally, (5) habitats that are protected from disturbance or are representative of the historic geographical and ecological distributions of a species [see 50 CFR 424.12(b)]. In addition to these factors, NMFS focuses on the known principal biological or physical constituent elements within the designated area that are essential to the conservation of the species (primary constituent elements). These primary constituent elements may include, but are not limited to, spawning sites, food resources, water quality and quantity, and riparian vegetation.

Within the areas of designated critical habitat for the Central Valley spring-run Chinook salmon ESU, the primary constituent elements (PCEs) are those sites and habitat components that support one or more life stages, including freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, and estuarine areas with certain conditions that are more completely described below. The following discussion describes the current conditions of the freshwater PCEs for Central Valley spring-run Chinook salmon.

1. Spawning Habitat

The final rule designating critical habitat for Central Valley spring-run Chinook salmon describes the PCEs to include freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation, and larval development (70 FR 52488; September 2, 2005). Many historic spring-run Chinook salmon spawning areas have been blocked upstream of permanent, impassable dams, and these areas were not designated as critical habitat. Extant populations of spring-run Chinook salmon spawn in tributaries such as Mill, Deer, and Butte creeks and the mainstem Sacramento River between RBDD and Keswick Dam; however, little spring-run Chinook salmon spawning activity has been recorded in the mainstem Sacramento River in recent years. Operations of Shasta and Keswick Dams on the mainstem Sacramento River, which are focused primarily to ensure an adequate quantity and quality of water winter-run Chinook salmon migration, holding, spawning, and incubation, may be limiting the amount of cold water available to ensure successful incubation of spring-run Chinook salmon eggs spawned on the mainstem Sacramento River. Likewise, habitat conditions in Butte Creek have limited the success of spring-run Chinook salmon spawning in that tributary; high water temperatures have caused disease outbreaks amongst over-summering adults, resulting in high levels of prespawn mortality.

2. Freshwater Rearing Habitat

The final rule designating critical habitat for Central Valley spring-run Chinook salmon describes the PCEs to include freshwater rearing sites 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 (70 FR 52488;

September 2, 2005). Both spawning areas and migratory corridors comprise rearing habitat for juveniles, which feed and grow before and during their outmigration. 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. The channelized, leveed, and riprapped river reaches and sloughs that are common in the Sacramento River system are much degraded, and typically have low habitat complexity, low abundance of food organisms, and offer little protection from either fish or avian predators. However, some complex, productive habitats with floodplains [*e.g.*, 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) remain in the system. These remnant habitats more closely resemble the complex habitats of the river system to which Central Valley salmonids have evolved, and likely function to benefit survival and recruitment of juvenile salmonids.

3. Freshwater Migration Corridors

The final rule designating critical habitat for Central Valley spring-run Chinook salmon describes the PCEs to include freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large woody objects, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival (70 FR 52488; September 2, 2005). These characteristics augment juvenile and adult mobility, survival, and food supply. Migratory corridors are downstream of the spawning areas and include the lower reaches of the spawning tributaries, the mainstem of the Sacramento River 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.

The lowering of the gates at the RBDD had created a seasonal migratory barrier. Approximately 10 percent of spring-run Chinook salmon spawn upstream of the RBDD. Of those, approximately 72 percent attempted to migrate past RBDD during the “gates in” period [Tehama-Colusa Canal Authority (TCCA) and Reclamation 2002]. Less than 1 percent of spring-run Chinook salmon juveniles were potentially impacted by passing under the dam during their downstream migration (TCCA and Reclamation 2002). Juvenile spring-run Chinook salmon that tried to migrate past RBDD in its gates down position were subjected to disorientation. In addition, predator fishes such as Sacramento pikeminnow and striped bass concentrated around the RBDD dam structures, and consumed out-migrating juvenile salmonids. The Reclamation and TCCA have recently completed a project constructing a new pumping plant at the site of the RBDD. Since completion in 2012, the project has resolved the fish passage issues at RBDD while simultaneously providing a long-term solution for delivering irrigation water.

Significant amounts of flow and many juvenile spring-run Chinook salmon enter the DCC (when the gates are open) and Georgiana Slough, especially during increased Delta pumping. Mortality of juvenile salmon entering the central Delta is higher than for those continuing downstream in

the Sacramento River. This difference in mortality could be caused by a combination of factors: the longer migration route through the central Delta to the western Delta, exposure to higher water temperatures, higher predation rates, exposure to seasonal agricultural diversions, water quality impairments due to agricultural and municipal discharges, and a more complex channel configuration making it more difficult for salmon to successfully migrate to the western Delta and the ocean. In addition, the State and Federal pumping facilities in the Delta, and other associated fish facilities, increase mortality of juvenile spring-run Chinook salmon through various means, including entrainment into the State and Federal canals, handling, trucking, and release.

Based on unscreened diversions, the schedule of DCC gates operations, and reverse flows in the Delta, the current condition of the freshwater migration corridor in the Sacramento River is much degraded for Central Valley spring-run Chinook salmon.

4. Estuarine Areas

The final rule designating critical habitat for Central Valley spring-run Chinook salmon describes the PCEs to include estuarine areas free of obstruction and excessive predation with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh and salt water; natural cover such as submerged and overhanging large woody material, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation (70 FR 52488; September 2, 2005).

The current condition of the estuarine habitat in the project area has been substantially degraded from historic conditions as a result of changes to land use. Over 90 percent of the fringing fresh, brackish, and salt marshes have been lost to human actions. This loss of the fringing marshes reduces the availability of forage species and eliminates the cycling of nutrients from the marsh vegetation into the water column of the adjoining waterways. The channels of the Delta have been modified by the raising of levees and armoring of the levee banks with stone riprap. This reduces habitat complexity by reducing the supply of woody debris and vegetative material into the nearshore area, reducing local variations in water depth and velocities and simplifying the community structure of the nearshore environment. Heavy urbanization and industrial actions have lowered water quality and introduced persistent contaminants to the sediments surrounding points of discharge (*e.g.*, refineries in Suisun and San Pablo bays, and creosote factories in Stockton).

Current estuarine areas have also been substantially degraded as a result of the operations of the CVP and SWP. Spring-run Chinook salmon smolts are drawn to the central and south Delta as they emigrate, and are subjected to the indirect (*e.g.*, predation, contaminants) and direct (*e.g.*, salvage, loss) effects of the Federal and State fish facilities. Within the central and southern Delta, net water movement is towards the pumping facilities, altering the migratory cues for emigrating fish in these regions. Operations of upstream reservoir releases and diversion of water from the southern Delta have been manipulated to maintain a “static” salinity profile in the western Delta near Chipps Island (“X2,” the site area of salinity transition in the Delta). In the area of salinity transition, the low salinity zone (LSZ), is an area of high productivity. Historically, this zone fluctuated in its location in relation to the outflow of water from the Delta

and moved westwards with high Delta inflow (*i.e.*, floods and spring-run runoff) and eastwards with reduced summer and fall flows. This variability in the salinity transition zone has been substantially reduced by the operations of the State and Federal water projects. The projects' long-term water diversions also have contributed to reductions in the phytoplankton and zooplankton populations in the Delta, as well as alterations in nutrient cycling within the Delta ecosystem.

Non-native invasive species (NIS) have also altered the native food webs that once existed in Central Valley Estuarine areas. The arrival of Asiatic freshwater clams *Corbicula fluminea* and *Potamocorbula amurensis* have disrupted the normal benthic community structure and depressed phytoplankton levels in the estuary due to highly efficient filter feeding of the introduced clams (Cohen and Moyle 2004). The decline in the levels of phytoplankton reduces the abundance of zooplankton that feed upon them, and hence reduces the forage base available to salmonids transiting the Delta and San Francisco estuary. This reduction of forage base can adversely impact the health and physiological condition of salmonids as they emigrate to the Pacific Ocean.

5. Summary of Central Valley Spring-run Chinook salmon Critical Habitat

Spring-run Chinook salmon critical habitat has suffered similar types of degradation as winter-run Chinook salmon critical habitat. The current condition of spring-run Chinook salmon critical habitat is substantially degraded, and does not provide the conservation value necessary for the recovery of the species.

G. California Central Valley steelhead

1. History of Listing Action

The California Central Valley steelhead DPS was listed as threatened on March 19, 1998 (63 FR 13347), and a final rule with protective regulations under ESA Section 4(d) for this DPS was published on July 10, 2000 (65 FR 42422). The DPS includes all naturally-spawned populations of steelhead (and their progeny) in the Sacramento and San Joaquin Rivers and their tributaries, excluding steelhead from San Francisco and San Pablo Bays and their tributaries, as well as including the CNFH and FRFH steelhead hatchery programs (71 FR 834; January 5, 2006).

2. Life History

California Central Valley steelhead begin their upstream migration from August through April (Busby *et al.* 1996) and spawn from December through April, with a peak between January and March (Figure 7). Spawning areas are typically small streams and tributaries where cool, well oxygenated water is available year-round (Hallock *et al.* 1961, McEwan and Jackson 1996). Timing of upstream migration is correlated with higher flow events, such as freshets or sand bar breaches at river mouths, which typically create conditions of elevated turbidity and decreased water temperature. Van Woert (1964) and Harvey (1995) observed that in Mill Creek, the steelhead migration is continuous and 60 percent of the run had migrated to upstream spawning areas by December 30.

Steelhead spawning occurs during winter-run and spring-run months. Unlike Pacific salmon, steelhead are iteroparous, or capable of spawning more than once before death (Barnhart 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. The length of time it takes for steelhead eggs to hatch depends mostly on water temperature; hatching requires about 30 days at 51°F.

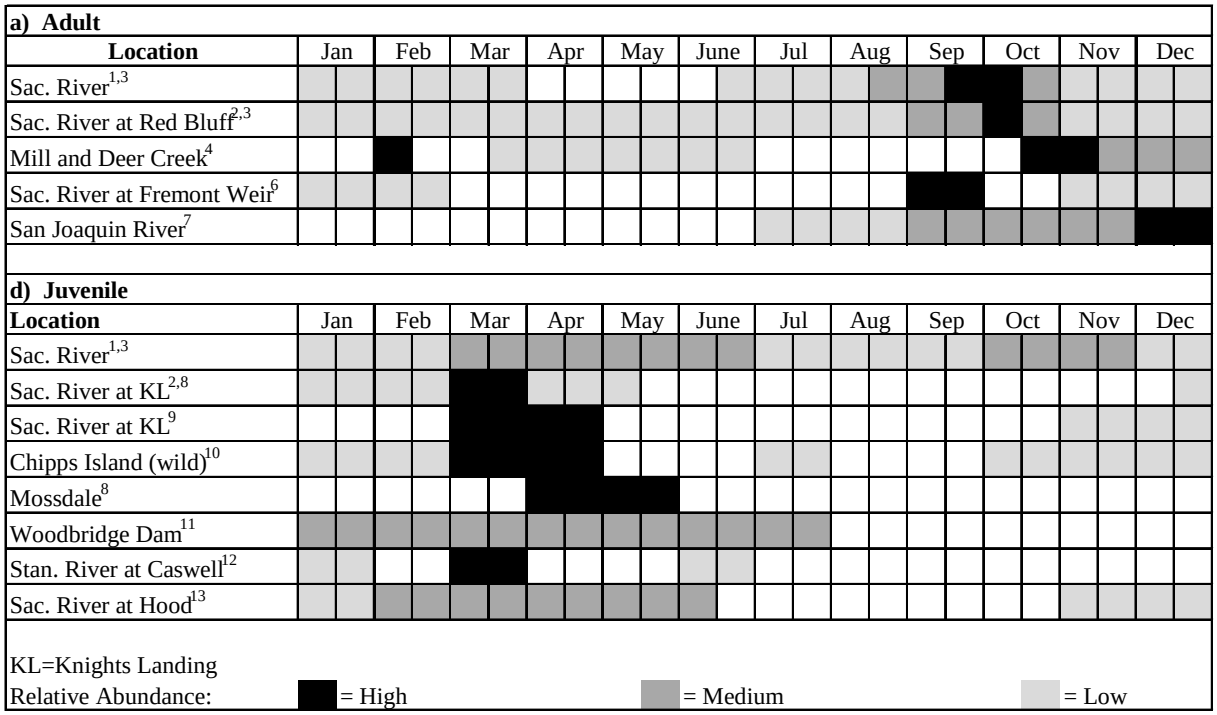

Figure 6. The temporal occurrence of (a) adult and (b) juvenile California Central Valley steelhead in the Central Valley. Darker shades indicate months of greatest relative abundance. Sources: [1]Hallock *et al.* (1961); [2]McEwan (2001); [3]Hallock 1989; [4]CDFG (1995); [5]Hallock *et al.* (1957); [6]Bailey (1954); [7]CDFG Steelhead Report Card data (CDFG 2007); [8]USFWS (unpublished data 1994-2011); [9]Snider and Titus (2000); [10]Nobriga and Cadrett (2003); [11]Jones & Stokes Associates, Inc. (2002); [12] S.P. Cramer and Associates, Inc. (2000, 2001); [13] Schaffter (1980, 1997).

Steelhead fry emerge from the gravel usually about four to six weeks after hatching, but factors such as redd depth, gravel size, siltation, and temperature can affect emergence timing (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-the-year also are abundant in glides and riffles. Productive steelhead habitat is characterized by complexity, primarily in the form of 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 high flow events during the fall, winter, and spring. Emigrating California Central Valley steelhead use the lower reaches of the Sacramento River and the Delta for rearing and as a migration corridor to the ocean. Juvenile California Central Valley steelhead feed mostly on drifting aquatic organisms and terrestrial insects and will also take invertebrates off of the stream bed (Moyle 2002). Some juvenile steelhead may utilize tidal marsh areas, non-tidal freshwater marshes, and other shallow water areas in the Delta as rearing areas for short periods prior to their final emigration to the sea. Hallock *et al.* (1961) found that juvenile steelhead in the Sacramento River basin migrate downstream during most months of the year, but the peak period of emigration occurred in the spring, with a much smaller peak in the fall. Nobriga and Cadrett (2003) verified these temporal findings based on analysis of captures at Chipps Island, Suisun Bay.

3. Range-Wide (DPS) Status and Trends

Steelhead historically were distributed throughout the Sacramento and San Joaquin Rivers (Busby *et al.* 1996). Steelhead were found from the upper Sacramento and Pit River systems, south to the Kings and possibly the Kern River systems, and in both east- and west-side Sacramento River tributaries (Yoshiyama *et al.* 1996). Hallock *et al.* (1961) estimated an average of 20,540 adult steelhead through the 1960s in the Sacramento River, upstream of the Feather River. Over the past 30 years, the naturally-spawned steelhead populations in the upper Sacramento River have declined substantially (Figure 7).

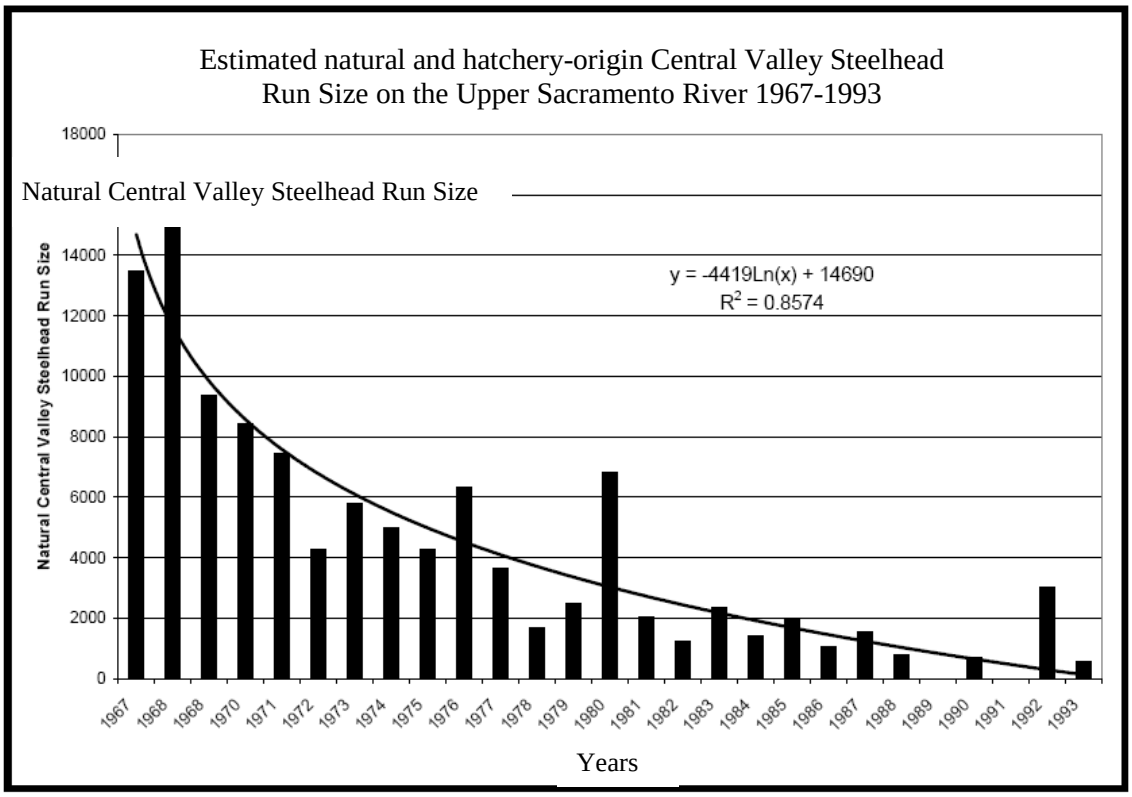

Figure 7. Estimated California Central Valley steelhead escapement in the upper Sacramento River based on RBDD counts. Note: Steelhead escapement surveys at RBDD ended in 1993 (McEwan and Jackson 1996).

The present distribution of California Central Valley steelhead has been greatly reduced (McEwan and Jackson 1996). Existing wild steelhead stocks in the Central Valley are confined mostly to the upper Sacramento River and its tributaries, including Battle, 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). Until recently, steelhead were thought to be extirpated from the San Joaquin River system. Recent monitoring has detected self-sustaining populations of steelhead in the Stanislaus, Mokelumne, Calaveras, and other streams previously thought to be void of steelhead (McEwan 2001). It is possible that naturally-spawning populations may also exist in many other streams but are undetected due to lack of monitoring programs (Interagency Ecological Program (IEP) Steelhead Project Work Team 1999). Reliable and consistent estimates of steelhead abundance are limited to the direct counts in Battle Creek at CNFH and the CNFH fish weir, FRFH, and Nimbus Hatchery weir (McEwan 2001).

Prior to 1993, reliable estimates of steelhead abundance upstream of Red Bluff were generated by enumerating passage through the fish ladders at RBDD. Steelhead counts at the RBDD include both hatchery-origin adults produced at the CNFH and naturally produced steelhead originating from the mainstem Sacramento River and its tributaries. Counts of steelhead at the RBDD declined from an average annual count of 11,187 for the period 1967 to 1976 to an average of 2,202 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). Seasonal counts of steelhead at the RBDD ended in 1993, when operations of the dam and fish ladders were changed, resulting in decreased opportunity to conduct passage counts.

Good *et al.* (2005) estimated a steelhead spawning population of about 3,600 females annually in the entire Central Valley based on catch ratios of coded-wire tagged (hatchery-origin) and untagged (wild-origin) steelhead smolts collected in the Chipps Island trawl. 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 Cottonwood, Battle, Antelope, Deer, and Mill creeks and the Yuba River. Populations may also 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 2008) indicate that steelhead are present in Clear Creek (Giovannetti *et al.* 2009, Good *et al.* 2005) as well as monitoring from 2005 to 2009 in Battle Creek (Newton and Stafford 2011). Monitoring has detected small, self-sustaining populations (*i.e.*, non-hatchery origin) of steelhead in the Stanislaus, Mokelumne, and Calaveras rivers, and other streams previously thought to be devoid of steelhead (McEwan 2001; S.P. Cramer and Associates Inc. 2000, 2001). Zimmerman *et al.* (2009) used otolith microchemistry to confirm that *O. mykiss* in the Stanislaus, Tuolumne and Merced rivers included anadromous life forms.

It is possible that naturally-spawning steelhead 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 juvenile steelhead have occurred on the Tuolumne and Merced Rivers during fall-run monitoring activities, indicating that steelhead are widespread throughout accessible streams and rivers in the Central Valley (Good *et al*. 2005). CDFG staff have prepared catch summaries for juvenile migrant California Central Valley steelhead on the San Joaquin River near Mossdale, which represents migrants from the Stanislaus, Tuolumne, and Merced rivers. Based on trawl recoveries at Mossdale between 1988 and 2002, as well as rotary screw trap efforts in all three tributaries, CDFG (2003) 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”. The documented returns on the order of single fish in these tributaries suggest that existing populations of California Central Valley steelhead on the Tuolumne, Merced, and lower San Joaquin rivers are severely depressed.

4. Battle Creek Status and Trends

Historical run-size estimates of steelhead do not exist for Battle Creek; however, steelhead are believed to have historically inhabited Battle Creek and nearly all tributaries of the upper Sacramento River. Similar to winter-run and spring-run Chinook salmon, the natural steelhead population in Battle Creek was likely severely impacted in the early twentieth century by the Battle Creek hydropower system. Circumstantial evidence suggests the Battle Creek steelhead run was relatively small in the 1940s when the steelhead propagation program was initiated at the CNFH. Founding broodstock for the steelhead propagation program were not collected from Battle Creek but, rather, they were collected from the Sacramento River at the Keswick Dam fish

trap. An on-site captive rearing program was used to supply hatchery broodstock until the 1950's when returns of hatchery-origin steelhead to Battle Creek were sufficient to meet the hatchery's spawning goals.

Most of the steelhead adults returning to the Battle Creek watershed originate at the CNFH, and they constitute a significant portion of the California Central Valley steelhead DPS. The abundance of returning hatchery- and natural-origin steelhead in Battle Creek has been more reliably estimable since 2002/2003, when the first full cohort of mass marked hatchery fish returned to the CNFH, although spawning reports have occurred since 1988 (Kevin Niemela, USFWS, personal communication, 2014). Prior to 2002, hatchery and natural-origin steelhead in Battle Creek were not differentiable, and all steelhead were managed as a single, homogeneous stock, although USFWS believes the majority of returning fish in years prior to 2002 were hatchery-origin. Abundance estimates of natural-origin steelhead in Battle Creek began in 2001, although a portion of these fish were likely of hatchery-origin. USFWS data from 2001 to 2009 ranged from 222 to 545 (mean of 387, std. of 101; Figure 8; USFWS 2011). Hatchery-produced steelhead that were 100 percent adipose-fin-clipped began returning to CNFH in 2003. The abundance of hatchery-origin steelhead returning to CNFH from 2003 to 2009 ranged from 1,004 to 3,193 (mean of 1,993, std. of 763; Figure 8; USFWS 2011). These estimates of steelhead abundance include all variants of life history types of the species *O. mykiss*, including ocean-going fish commonly referred as "steelhead" and nonanadromous types commonly referred as "rainbow trout." During recent years there has been a marked paucity of larger-sized natural-origin *O. mykiss* observed in Battle Creek (K. Niemela, USFWS, personal communication, 2010). This decline of larger-sized *O. mykiss* may indicate selection against an anadromous life history type.

H. California Central Valley steelhead Designated Critical Habitat

Critical habitat was designated for California Central Valley steelhead on September 2, 2005 (70 FR 52488). California Central Valley steelhead critical habitat was designated for watersheds along the Sacramento-San Joaquin corridor, including the following counties: Tehama, Butte, Glenn, Shasta, Yolo, Sacramento, Solano, Yuba, Sutter, Placer, Calaveras, San Joaquin, Stanislaus, Tuolumne, Merced, Alameda, and Contra Costa. Critical habitat includes the stream channels within the designated stream reaches, and their lateral extent as defined by the ordinary high-water line (33 CFR 329.11) or the full bank elevation. Critical habitat in estuarine reaches is defined by the perimeter of the water body as displayed on standard 1:24,000 scale topographic maps or the elevation of the extreme high water mark, whichever is greater. Within the areas of designated critical habitat for the California Central Valley steelhead DPS, the primary constituent elements (PCEs) are those sites and habitat components that support one or more life stages, including freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, and estuarine areas with certain conditions that are more completely described below. The following discussion describes the current conditions of the freshwater PCEs for California Central Valley steelhead.

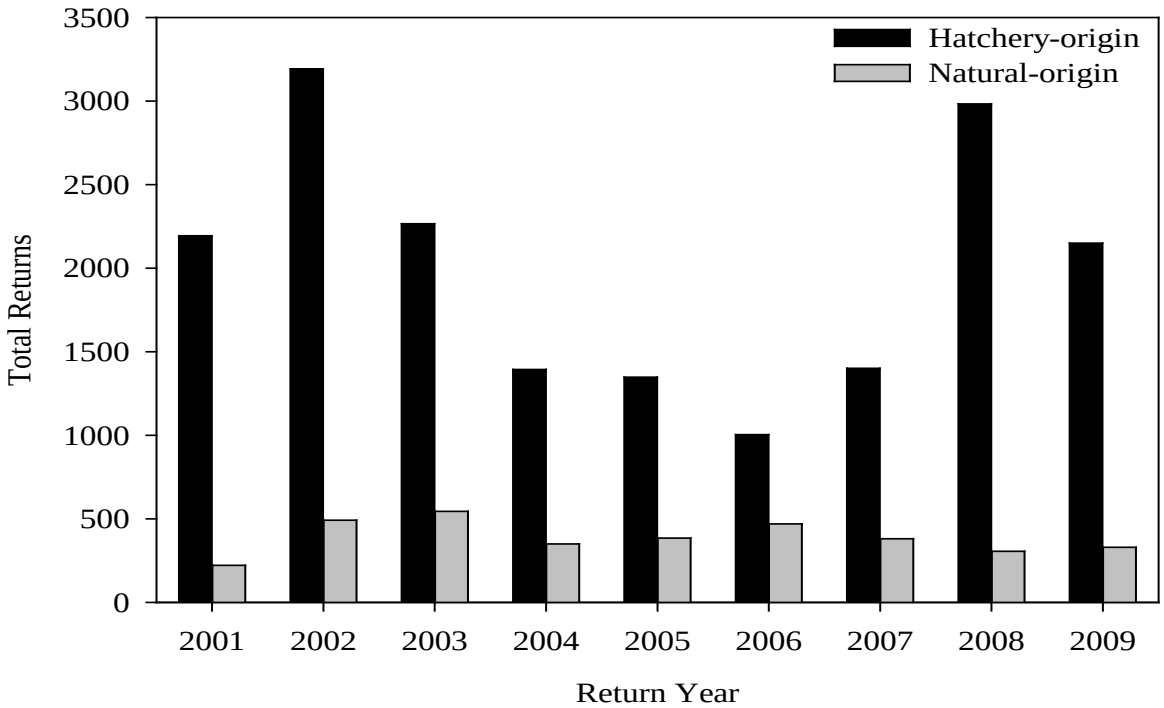

Figure 8. Returns of natural- and hatchery-origin *Oncorhynchus mykiss* to Battle Creek for return years 2001-2009.

1. Spawning Habitat

The final rule designating critical habitat for California Central Valley steelhead describes the PCEs to include freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation, and larval development (70 FR 52488; September 2, 2005). The vast majority of spawning habitat for California Central Valley steelhead has been blocked by impassable dams, and these areas were not designated as critical habitat. Most existing spawning habitat in the Central Valley for steelhead is located in areas directly downstream of dams containing suitable conditions for spawning and incubation. These reaches can be subjected to manipulations of flows and temperatures, particularly during summer months, which can have negative effects upon salmonids downstream.

2. Freshwater Rearing Habitat

The final rule designating critical habitat for California Central Valley steelhead describes the PCEs to include freshwater rearing sites 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 (70 FR 52488; September 2, 2005). Both spawning areas and migratory corridors comprise rearing habitat for juveniles, which reside in freshwater for an extended period of time prior to their outmigration. 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 [*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) remain in the system. Non-natal, intermittent tributaries also may be used for juvenile rearing. However, the channelized, leveed, and riprapped river reaches and sloughs that are common in the middle and lower Sacramento River system typically have low habitat complexity, low abundance of food organisms, and offer little protection from either fish or avian predators. Steelhead are generally considered more susceptible to the negative effects of degraded rearing habitat, because they rear in freshwater longer than winter-run and spring-run Chinook salmon.

3. Freshwater Migration Corridors

The final rule designating critical habitat for California Central Valley steelhead describes the PCEs to include freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large woody objects, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival (70 FR 52488; September 2, 2005). Migratory corridors are downstream of the spawning areas and include the lower mainstem of the Sacramento and San Joaquin rivers and the Delta. These corridors allow the upstream passage of adults, and the downstream emigration of 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. Up until 2012, RBDD gates impeded steelhead emigration during a portion of each adult and juvenile cohort. Juvenile California Central Valley steelhead that tried to migrate past RBDD when its gates were down were subjected to disorientation. In addition, although predators of juvenile California Central Valley steelhead are prominent throughout the Sacramento River and Delta, they concentrate around structures, and therefore, a higher concentration of striped bass, and especially Sacramento pikeminnow, resided downstream of RBDD and would prey on emigrating juvenile salmonids.

Juvenile California Central Valley steelhead that emigrate from the San Joaquin River tributaries are exposed to degraded migration corridors, degraded water quality in the lower San Joaquin River basin and the Stockton Deep Water Shipping Channel (DWSC). Significant flow and many juvenile California Central Valley steelhead from the Sacramento River enter the Delta Cross Channel (when the gates are open) and Georgiana Slough and pass into the central Delta. Likewise, some juvenile California Central Valley steelhead from the San Joaquin River are diverted into the southern Delta through Old River and Turner and Columbia Cuts. Mortality of juvenile California Central Valley steelhead entering the central Delta is higher than for those continuing downstream in the Sacramento and San Joaquin rivers. This difference in mortality could be caused by a combination of factors, such as: the longer migration route through the central Delta to the western Delta, exposure to higher water temperatures, exposure to seasonal agricultural diversions, exposure to increased predation, water quality impairments due to agricultural and municipal discharges, and a more complex channel configuration making it more difficult for California Central Valley steelhead to successfully migrate to the western Delta and the ocean. In addition, the State and Federal pumps in the Delta, and associated fish facilities, increase mortality of juvenile California Central Valley steelhead through various

means, including entrainment into the State and Federal facilities, handling, trucking, and release. The current condition of freshwater migration corridors in the Sacramento River, San Joaquin River, and Delta are very degraded.

4. Estuarine Areas

The final rule designating critical habitat for California Central Valley steelhead describes the PCEs to include estuarine areas free of obstruction and excessive predation with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh and salt water; natural cover such as submerged and overhanging large woody material, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation (70 FR 52488; September 2, 2005). Current estuarine areas are degraded as a result of the operations of the CVP and SWP. California Central Valley steelhead smolts are drawn to the central and south Delta as they out-migrate, and are subjected to the indirect (*e.g.*, predation, contaminants) and direct (*e.g.*, salvage, loss) effects of the Delta and both the Federal and State fish facilities.

The location of X2 has also been modified from natural conditions. Historically, the Delta provided the transitional habitat for California Central Valley steelhead to undergo the physiological change to salt water. However, as X2 was modified to control Delta water quality, and competing species' needs (*e.g.*, delta smelt), the Delta served more as a migratory corridor for emigrating anadromous salmonids. The current condition of the estuarine area has been described in the preceding section for spring-run Chinook salmon critical habitat.

5. Summary of California Central Valley steelhead Critical Habitat

Steelhead already have been extirpated from most of their historical range in the Central Valley. Concerns regarding existing steelhead critical habitats in this DPS focus on the widespread degradation, destruction, and blockage of freshwater habitat within the region, and water allocation problems. The current condition of California Central Valley steelhead critical habitat is degraded, and does not provide the conservation value necessary for the recovery of the species. California Central Valley steelhead critical habitat has suffered similar types of degradation as that of winter-run Chinook salmon. In addition, the Sacramento-San Joaquin River Delta, as part of California Central Valley steelhead designated critical habitat, has impaired functionality for juvenile California Central Valley steelhead rearing and physiological transition to salt water.

I. Southern DPS of North American Green Sturgeon

1. History of Listing Action

Several environmental organizations petitioned for listing the North American green sturgeon under the Endangered Species Act in June 2001. A study of the species' status determined that North American green sturgeon is comprised of two DPSs: the northern DPS and the southern DPS. The Northern DPS of green sturgeon consists of populations north of and including the Eel River. The Southern DPS of green sturgeon consists of populations originating from coastal watersheds south of the Eel River and the Central Valley of California. In 2003, NMFS determined that listing was not warranted, but both DPSs were added to the list of candidate

species (68 FR 4433; January 29, 2003). Because of remaining uncertainties about the structure of the population and status of the species, NMFS added both the northern and southern DPS to the list of Species of Concern (69 FR 19975: April 15, 2004). A subsequent status review of the two DPSs resulted in a NMFS proposal to list the southern DPS of green sturgeon, but NMFS reaffirmed its earlier determination that the northern DPS did not warrant listing (70 FR 17386; April 6, 2005). The Southern DPS of green sturgeon was listed as threatened on April 7, 2006 (71 FR 17757), and a final rule with protective regulations under ESA Section 4(d) for this DPS was published on June 2, 2010 (75 FR 30714).

2. Life History

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. Sexually mature female green sturgeon are typically 13 to 27 years old and have a total body length (TL) ranging between 145 and 205 cm (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 at 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.

Adults begin their upstream spawning migrations into freshwater in late February with spawning occurring 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).

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 adult 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 (Moyle *et al.* 1992, Van Eenennaam *et al*. 2001). At an average of 4.3 mm, the eggs are the largest of any sturgeon, and the volume of yolk ensures an ample supply of energy for the developing embryo. The outside of the eggs are adhesive, and are more dense than those of white sturgeon (Kynard *et al.* 2005, Van Eenennaam *et al.* 2009).

Kelly *et al.* (2007) indicated that green sturgeon enter the San Francisco Estuary during the spring-run and remain until autumn. 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 (more than 5 meters), low gradient reaches or off channel sloughs or coves of the river during summer months when water temperatures were between 15 degrees-Celsius (°C) and 23°C. When ambient temperatures in the river dropped in autumn and early winter-run (less than 10°C) and flows increased, fish moved downstream and into the ocean. Erickson *et al.* (2002) surmised that this holding in deep pools was to conserve energy and utilize abundant food resources. Benson *et al.* (2007) found similar behavior on the Klamath and Trinity River systems with adult sturgeon acoustically tagged during their spawning migrations. Most fish held over the summer in discrete locations characterized by deep, low velocity pools until late fall or early winter-run 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). Recent acoustic tag data indicate that adult green sturgeon migrate upstream as far as the mouth of Cow Creek, near Deschutes Bridge, in May. Adults prefer deep holes at the mouths of tributary streams, where they spawn and rest on the bottom.

After spawning, the adults hold over in the upper Sacramento River between RBDD and GCID until November (Heublein *et al.* 2009). Heublein *et al.* (2006 and 2009) has documented the presence of adults in the Sacramento River during the spring-run and through the fall into the early winter-run 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 and decreasing water temperatures, and occurs rapidly once initiated. Some adults rapidly leave the system following their suspected spawning activity and re-enter the ocean 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.

Green sturgeon larvae hatch from fertilized eggs after approximately 169 hours at a water temperature of 15°C (Van Eenennaam *et al.* 2001, Deng *et al.* 2002), which is similar to the sympatric white sturgeon development rate (176 hours). Van Eenennaam *et al.* (2005) indicated that an optimum range of water temperature for egg development ranged between 14°C and 17°C. Newly hatched green sturgeon are approximately 12.5 to 14.5 mm in length and have a large ovoid yolk sac that supplies nutritional energy until exogenous feeding occurs. At 10 days of age, the yolk sac has become greatly reduced in size and the larvae initiates exogenous feeding through a functional mouth.

Green sturgeon larvae do not exhibit the initial pelagic swim–up behavior characteristic of other *Acipenseridae*. They are strongly oriented to the bottom and exhibit nocturnal activity patterns. After six 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 behavioral 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 8°C, downstream migrational behavior diminished and holding behavior increased. This data suggests that 9 to 10 month old fish would hold over in their natal rivers during the ensuing winter following hatching, but at a location downstream of their spawning grounds. Green sturgeon juveniles tested under laboratory conditions had optimal bioenergetic performance (*i.e.* growth, food conversion, swimming ability) between 15°C and 19°C 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 4°C to approximately 24°C. The Sacramento River has similar temperature profiles and, like the previous two rivers, is a regulated system with dams controlling flows on its mainstem (Shasta and Keswick dams), and its tributaries (*e.g.*, Whiskeytown, Oroville, Folsom, and Nimbus dams).

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 (Crustacea: Decapoda spp.) (Moyle *et al.* 1992). It is unknown what forage species are consumed by adults in the Sacramento River upstream of the Delta.

3. Range-Wide (DPS) Status and Trends

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 indicate that North American green sturgeon are migrating considerable distances up the Pacific coast into other estuaries, particularly the Columbia River estuary. This information also agrees with the results of previous green sturgeon tagging studies (CDFG 2002), where CDFG tagged a total of 233 green sturgeon in the San Pablo Bay estuary

between 1954 and 2001. A total of 17 tagged fish were recovered: 3 in the Sacramento-San Joaquin Estuary, 2 in the Pacific Ocean off of California, and 12 from commercial fisheries off of the Oregon and Washington coasts. Eight of the 12 commercial fisheries recoveries were in the Columbia River estuary (CDFG 2002).

Abundance of the Southern DPS of green sturgeon is described in NMFS status reviews (Adams *et al*. 2002, NMFS 2005). Limited information of population abundance comes from incidental captures of North American green sturgeon while monitoring white sturgeon during the CDFG's 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 in 1993 to more than 8,421 in 2001, and averaged 1,509 fish per year. Unfortunately, there are many biases and errors associated with these estimates, and CDFG does not consider these estimates reliable because they are based on small sample sizes, intermittent reporting, and are drawn from inferences made from incidental catches while monitoring catch of white sturgeon.

Larval and juvenile sturgeon have been caught in traps at two sites in the upper Sacramento River: at the RBDD (RM 342) and the GCID pumping plant (RM 205, CDFG 2002). Salmonid monitoring efforts at RBDD and GCID on the upper Sacramento River have captured between 0 and 2,068 larvae and juvenile green sturgeon per year (Adams *et al*. 2002). Larvae captured at the RBDD site are typically only a few days to a few weeks old, with lengths ranging from 24 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 and late August, with the peak of recoveries occurring in June (1995-1999 and 2003-2008 data). The mean annual total length of post-larval green sturgeon captured in the GCID RST, 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. Recent data indicate that very little production took place in 2007 and 2008 (13 and 3 larval green sturgeon captured in the RST monitoring sites at RBDD, respectively; Poytress 2008, Poytress *et al*. 2009).

Collections of juvenile green sturgeon at the John E. Skinner Fish Collection Facility between 1968 and 2001 can be used to make inferences on the abundance of the Southern DPS green sturgeon. The average number of Southern DPS green sturgeon entrained per year at the State Facility prior to 1986 was 732. From 1986 to 2001, 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 of green sturgeon is declining. 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). Catches of sub-adult and adult Northern and Southern DPS green sturgeon, primarily in San Pablo Bay, by the IEP ranged from 1 to 212 green sturgeon per year between 1996 and 2004 (212 occurred in 2001). However, the portion of the Southern DPS of

green sturgeon is unknown. Recent spawning population estimates using sibling-based genetics by Israel (2006) indicate spawning populations of 32 spawner pairs in 2002, 64 in 2003, 44 in 2004, 92 in 2005, and 124 in 2006 above RBDD (with an average of 71).

Available information on green sturgeon indicates that, as with winter-run Chinook salmon, the mainstem Sacramento River may be the only remaining viable spawning habitat for the Southern DPS of green sturgeon (Good *et al.* 2005). 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, the mainstem Sacramento River.

4. Battle Creek Status and Trends

North American green sturgeon are not native to Battle Creek, nor do they currently inhabit that tributary.

J. Southern DPS of Green Sturgeon Critical Habitat

Critical habitat for the Southern DPS of green sturgeon was designated on October 9, 2009 (74 FR 52300). Critical habitat for Southern DPS of green sturgeon includes approximately 320 miles of riverine habitat, including the Sacramento River, lower Feather River, lower Yuba River, and the Sacramento-San Joaquin Delta. Also included in designated critical habitat are 1,058 square miles of estuarine habitat in California, Oregon, and Washington, and 11,421 square miles of coastal marine habitat within 60 fathoms depth off California, Oregon, and Washington within the geographical area presently occupied by the Southern DPS of green sturgeon. In addition, approximately 135 square miles of habitat within the Yolo and Sutter bypasses, adjacent to the Sacramento River, California, are designated. Critical habitat for Southern DPS of green sturgeon is defined as specific areas that contain the PCE and physical habitat elements essential to the conservation of the species. The PCEs of critical habitat essential for the conservation of the Southern DPS of green sturgeon in riverine and estuarine systems are: food resources, substrate type or size (for riverine systems only), water flow, water quality, migratory corridor, depth, and sediment quality. The specific PCEs essential for the conservation of the Southern DPS in coastal marine areas are: migratory corridor, water quality, and food resources. These PCEs are described more completely below and in the final rule designating critical habitat for the Southern DPS of green sturgeon (74 FR 52300; October 9, 2009).

1. Access to Spawning Areas in the Upper Sacramento River

Adult migration corridors should provide satisfactory water quality, water temperature, water flow, water depth, and a migratory pathway necessary for safe and timely passage in order for adults to reach spawning areas. Adult Southern DPS green sturgeon begin their migration from the ocean to freshwater beginning in late-February. Spawning occurs from March to July, with peak activity from mid-April to mid-June. The migration route up the Sacramento River corridor is mostly free of obstructions. However, the value of the Sacramento River migratory corridor has been reduced when the gates at the RBDD were lowered to divert river water into the Tehama Colusa and Corning canals, thereby delaying or blocking a portion of the spawning

migration. Modifications to the timing of RBDD gate operations that began in 1996 are believed to have provided substantial increases in green sturgeon spawning habitat. Reasonable and Prudent Alternative (RPA) actions of the OCAP biological opinion provide a prescription for additional changes to the operations of the RBDD gates that will further reduce impacts on migrating green sturgeon (NMFS 2009a). Recent completion of a pumping plant at the RBDD has eliminated the need for lowering the RBDD gates beginning in 2012, thereby providing unimpeded passage to available spawning areas upstream to the ACID Dam.

Green sturgeon adults that migrate upstream in April, May, and June are completely blocked by the ACID diversion dam. Therefore, 5 miles, or 12 percent, of potential spawning habitat are inaccessible upstream of the diversion dam. It is unknown if spawning is occurring in this area. Adults that pass upstream of ACID dam before April are forced to wait 6 months until the stop logs are pulled before returning downstream to the ocean.

2. Spawning Substrate

Spawning habitat for Southern DPS green sturgeon is restricted to the Sacramento River between Hamilton City and Keswick Dam. Spawning occurs in deep, fast-moving water over substrates ranging from clean sand, to bedrock, with preferences for gravel, cobble, or bolder substrates. Eggs likely adhere to substrates, or settle into crevices between substrates (Deng 2000, Van Eenennaam *et al.* 2001, Deng *et al.* 2002). Suitable spawning substrates are free of excessive silt and debris that could smother eggs and have interstices, or irregular surfaces, that function to "collect" eggs and provide protection from predators. Because Shasta and Keswick dams preclude spawning gravel recruitment, Reclamation injects spawning gravel into various areas of the upper Sacramento River, primarily for the benefit of salmonids. Recent stream surveys by USFWS and Reclamation biologists have identified approximately 54 suitable holes and pools between Keswick Dam and approximately GCID that would support spawning or holding activities for green sturgeon, based on the identified physical criteria. Many of these locations are at the confluence of tributaries with the mainstem Sacramento River or at bend pools. Observations of channel type and substrate compositions during these surveys indicate that appropriate substrate is available in the Sacramento River between Keswick Dam and GCID.

3. Adequate River Flows and Water Quality for Successful Spawning, Incubation of Eggs, and Fry Development

Adequate water quality, including temperature, salinity, oxygen content, and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages are required for the proper functioning of the freshwater habitat. Spawning in the Sacramento River is believed to be triggered by increases in flow to about 14,000 cfs (average daily flow during spawning months: 6,900 to 10,800 cfs). Post-spawning downstream migrations are also triggered by increased flows, ranging from 6,150 to 14,725 cfs in the late summer (Vogel 2005) and greater than 3,550 cfs in the winter-run (Erickson *et al.* 2002, Benson *et al.* 2007). The current suitability of these flow requirements in the Sacramento River is almost entirely dependent on releases from Shasta Dam. Sufficient flow is also needed to reduce the incidence of fungal infestations of the eggs, and to flush silt and debris from cobble, gravel, and other substrate surfaces to prevent crevices from being filled in and to maintain surfaces for feeding.

Development of early life stages is also affected by water temperature. Suitable water temperatures include: stable water temperatures within spawning reaches (wide fluctuations could increase egg mortality or deformities in developing embryos); temperatures within 11-17°C (optimal range is 14 to 16°C) in spawning reaches for egg incubation from March to August (Van Eenennaam *et al.* 2005); temperatures below 20°C for larval development (Werner *et al.* 2007); and temperatures below 24°C for juveniles (Mayfield and Cech 2004, Allen *et al.* 2006). Due to the temperature management of the releases from Keswick Dam for winter-run Chinook salmon in the upper Sacramento River, water temperatures in the upper river reaches utilized currently by green sturgeon appear to be suitable for proper egg development and larval and juvenile rearing. A Memorandum of Agreement (MOA) between Reclamation and CDFG originally established flow objectives in the Sacramento River for the protection and preservation of fish and wildlife resources. In addition, Reclamation complies with the flow releases required in Water Rights Order (WRO) 90-05. Additional measures to manage releases from Shasta Reservoir are provided through the NMFS biological opinion on the Long Term Operations of the CVP-SWP (NMFS 2009a).

Suitable salinity levels range from fresh water [less than 3 parts per thousand (ppt)] for larvae and early juveniles [about 100 days post hatch (dph)] to brackish water (10 ppt) for juveniles prior to their transition to salt water. Juvenile green sturgeon rear and feed in fresh and estuarine waters from 1 to 4 years prior to dispersing into coastal marine waters. Prolonged exposure to higher salinities may result in decreased growth and activity levels and even mortality (Allen and Cech 2007). Salinity levels are suitable for green sturgeon in the Sacramento River and freshwater portions of the Delta for early life history stages. Adequate levels of dissolved oxygen (DO) are needed to support oxygen consumption by early life stages (ranging from 61.78 to 76.06 milligram (mg) O_2 per hour per kilogram for juveniles, Allen and Cech 2007). Current mainstem DO levels are suitable to support the growth and migration of green sturgeon in the Sacramento River.

4. <u>Habitat Areas and Adequate Food Resources that are not Contaminated</u>

Abundant and uncontaminated food resources in riverine, estuarine, and marine habitats are necessary for growth and development across all life stages of green sturgeon. Juvenile green sturgeon most likely feed on benthic invertebrates, including fly larvae, amphipods, and bivalves. The channelized, leveed, and riprapped river reaches and sloughs that are common in the Sacramento River system typically have low habitat complexity and low abundance of food. Juvenile life stages of green sturgeon are dependent on the natural functioning of this habitat for growth, survival, and recruitment. Some complex, productive habitats with floodplains [*e.g.*, 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) remain in the system. Nevertheless, the current condition of riparian habitat for green sturgeon is degraded.

Prey species for juvenile, subadult, and adult green sturgeon within bays and estuaries primarily consist of benthic invertebrates and fish, including crangonid shrimp (*Crangon sp*.), callianassid shrimp, burrowing thalassinidean shrimp (*Decapoda: Thalassinidea*), Phylum *Arthropoda*: amphipods, isopods, clams, annelid worms, crabs; sand lances (*Ammodytes hexapterus*) and anchovies (*Engraulis mordax*). These prey species are critical for the rearing, foraging, growth, and development of juvenile, subadult, and adult green sturgeon within the bays and estuaries.

Currently, the estuary provides these food resources, although annual fluctuations in the population levels of these food resources may diminish the contribution of one group to the diet of green sturgeon relative to another food source. The recent spread of the Asian overbite clam (*Potamocorbula amurensis*) has shifted the diet profile of white sturgeon to this invasive species. The overbite clam now makes up a substantial proportion of the white sturgeon's diet in the estuary. NMFS assumes that green sturgeon have also altered their diet to include this new food source based on its increased prevalence in the benthic invertebrate community. The overbite clam is known to bioaccumulate selenium, a toxic metal to which sturgeon are highly sensitive, that enters the system through agricultural practices in the San Joaquin Valley (CDFG 2002; Linville *et al.* 2002).

Exposure to contaminated water and food sources may disrupt normal development of embryonic, larval, and juvenile stages of green sturgeon. Legacy contaminants such as mercury (and methyl mercury), polychlorinated biphenyls (PCB), heavy metals, and persistent organochlorine pesticides continue to be found in watersheds throughout the Central Valley. Although most of these contaminants are at low concentrations in the food chain, they continue to work their way into the base of the food web, and accumulate in the tissues of higher-level predators, such as green sturgeon. Exposure to these contaminated food sources may create delayed sublethal effects, including adverse impacts on growth, reproductive development, and reproductive success (*e.g*., reduced egg size and abnormal gonadal development, and abnormal embryo development during early cleavage stages (Fairey *et al.* 1997, Foster *et al.* 2001a, Foster *et al.* 2001b, Kruse and Scarnecchia 2002, Feist *et al.* 2005, and Greenfield *et al.* 2005). Contaminants are typically associated with areas of urban development or other anthropogenic activities (*e.g.*, mercury contamination as a result of gold mining or processing).

5. <u>Emigration corridor from Spawning Grounds to the Pacific Ocean</u>

Freshwater migration corridors should provide a migratory pathway necessary for safe and timely passage, with water quantity and quality conditions that enhance migratory movements. Migratory corridors of Southern DPS green sturgeon are downstream of the spawning areas in the mainstem of the upper Sacramento River.

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. Unscreened diversions that can entrain juvenile green sturgeon are prevalent throughout the Sacramento River system. Currently, safe and unobstructed passage has been diminished by human actions in the Delta and bays. The CVP and SWP water projects alter flow patterns in the Delta due to export pumping and create entrainment issues in the Delta at the pumping and Fish Facilities. Power generation facilities in Suisun Bay create risks of entrainment and thermal barriers through their operations of cooling water diversions and discharges. Installation of seasonal barriers in the South Delta and operations of the radial gates in the DCC facilities alter migration corridors available to green sturgeon. Water pumping at the CVP-SWP export facilities in the South Delta causes reverse flows, disrupting the natural orientation cues used by juvenile fishes and attracting and diverting them to the inner Delta where they are exposed to entrainment at pumping stations. RPA actions

in the NMFS biological opinion on the Long Term Operations of the CVP-SWP provides limits to the strength of reverse flows in the Old and Middle Rivers (NMFS 2009a), thereby keeping salmon away from areas of highest mortality. Entrainment numbers at the Delta pumping facilities have decreased since the mid-1980s for unknown reasons.

Based on impediments caused by the RBDD up until 2012, unscreened diversions, and reverse flows in the Delta, the current condition of the freshwater migration corridor in the Sacramento River is much degraded during the emigration of Southern DPS green sturgeon.

6. Summary of Southern DPS of North American Green Sturgeon Critical Habitat

The current condition of critical habitat for the Southern DPS of green sturgeon is degraded. It does not provide the full extent of conservation values necessary for the recovery of the species, particularly in the upstream riverine habitat. The habitat values proposed for green sturgeon critical habitat have suffered similar types of degradation as already described for winter-run and spring-run Chinook salmon critical habitat. In addition, the alterations to the Sacramento-San Joaquin River Delta may have a particularly strong impact on the survival and recruitment of juvenile green sturgeon due to the protracted rearing time in the delta and estuary. Loss of individuals during this phase of the life history of green sturgeon represents losses to multiple year classes rearing in the Delta, which can ultimately impact the potential population structure for decades to come.

K. Southern Resident Killer Whales

1. History of Listing Action

The Southern Resident killer whale DPS was designated as “depleted” under the Marine Mammal Protection Act (MMPA; May 29, 2003, 68 FR 31980) in May 2003, because it was below its optimum sustainable population. The Southern Resident killer whales DPS was listed as endangered under the ESA on November 18, 2005 (70 FR 69903). A Recovery Plan for Southern Resident killer whales (NMFS 2008a) was published in January 2008.

2. Life History

Four distinct communities of resident killer whale have been identified off the west coast of the United States: Southern, Northern, Southern Alaska, and Western Alaska. Resident killer whales are distributed in the U.S. from central California to Alaska. Groups of related matrilines form pods. The Southern Resident DPS consists of three pods, identified as J, K, and L pods, that reside for part of the year in the inland waterways of Washington State and British Columbia. The geographic ranges of Southern and Northern Residents overlap considerably; however, genetic analysis indicates that these social groupings are most likely reproductively isolated from each other (Hoelzel *et al.* 1998, Barrett-Lennard 2000, Barrett-Lennard and Ellis 2001). Clans are composed of pods with similar vocal dialects. All three pods of the Southern Residents are part of the J clan.

Southern Residents are a long-lived species, with late onset of sexual maturity (review in NMFS 2008a). Maximum life span is estimated to be 80-90 years for females and 50-60 years for males (Olesiuk *et al.* 1990). Females produce a low number of calves over the course of their

reproductive life span (an average of 5.3 surviving calves over an average reproductive lifespan of 25 years; Olesiuk *et al*. 2005). Mothers and offspring-run maintain highly stable social bonds throughout their lives, which is the basis for the matrilineal social structure in the Southern Resident population (Bigg *et al*. 1990, Baird 2000, Ford *et al*. 2000).

Resident whales spend about 50 to 67 percent of their time foraging (Heimlich-Boran 1988, Ford 1989, Morton 1990, Felleman *et al.* 1991). Resident whales are known to consume 22 species of fish and one species of squid (*Loligo opalescens*), including salmon (*Oncorhynchus* spp.), rockfish (*Sebastes* spp.), Pacific herring (*Clupea pallasi*), lingcod (*Ophiodon elongates*), greenling (*Hexagrammos* spp.), and flatfish (families: *Pleuronectidae, Bothidae,*) (Scheffer and Slipp 1948, Ford *et al.* 1998, Ford and Ellis 2005, Saulitis *et al.* 2000). Published information of fish predation comes mostly from field observations focused primarily on Northern Residents, which showed that salmon represent over 96 percent of prey during summer and fall. Chinook salmon are selected preferentially over other species of salmon, presumably because of the species' large size and high fat and energy content. Southern Residents are large mammals with high energy requirements.

The seasonal timing of salmon spawning runs may influence the migratory patterns of Southern Residents to coincide with the congregations of salmon prior to their movement into freshwater. Southern Residents spend considerable time from late spring-run to early autumn in inland waterways of Washington State and British Columbia (Strait of Georgia, Strait of Juan de Fuca, and Puget Sound (Bigg 1982, Ford *et al*. 2000, Krahn *et al*. 2002). Typically, J, K and L pods are increasingly present in May or June and spend considerable time in the core area of Georgia Basin and Puget Sound until at least September. During this time, pods (particularly K and L) make frequent trips from inland waters to the outer coasts of Washington and southern Vancouver Island, which typically last a few days (Ford *et al*. 2000). Late summer and early fall movements of Southern Residents in the Georgia Basin have remained fairly consistent since the early 1970s, with strong site fidelity shown to the region as a whole; however presence in inland waters in the fall has increased in recent years (NMFS 2008a). During early autumn, J pod in particular expands their routine movements into Puget Sound, likely to take advantage of chum and Chinook salmon runs (Osborne 1999). Some sightings in Monterey Bay, California have also coincided with large runs of salmon, with feeding witnessed in 2000 (Black *et al*. 2001). However, when Southern Residents were sighted in Monterey Bay during 2008, salmon runs were expected to be very small. L pod was also seen feeding on unidentified salmon off Westport, Washington, in March 2004 during the spring-run Chinook salmon run in the Columbia River (Krahn *et al*. 2004). During late fall, winter, and early spring, the ranges and movements of the Southern Residents are less well known. Sightings through the Strait of Juan de Fuca in late fall suggest that activity shifts to the outer coasts of Vancouver Island and Washington (Krahn *et al*. 2002).

3. <u>Range-Wide Status and Trends</u>

The historical abundance of Southern Residents is estimated from 140 to 200 whales. The minimum estimate (~140) is the number of whales killed or removed for public display in the 1960s and 1970s added to the remaining population at the time of the captures. The maximum estimate (~200) is based on a recent genetic analysis of microsatellite DNA (May 29, 2003, 68 FR 31980). At present, the Southern Resident population has declined to essentially the same

size that was estimated during the early 1960s, when it was likely depleted (figure 4-13 in Olesiuk *et al*. 1990). Since censuses began in 1974, J and K pods steadily increased; however, the population suffered an almost 20 percent decline from 1996 to 2001, largely driven by lower survival rates in L pod. There were increases in the overall population from 2002 to 2007, however, the population declined in 2008 with 85 Southern Residents counted; 25 in J pod, 19 in K pod and 41 in L pod. Two additional whales have been reported missing since the 2008 census count. Representation from all three pods is necessary to meet biological criteria for Southern Resident killer whale down-listing and recovery (NMFS 2008a).

L. Factors affecting the Current Status of Listed Species

Profound alterations to the riverine habitat of the Central Valley began with the discovery of gold in the mid-1800s which resulted in stream bed alteration and increased sedimentation, reducing the quality and availability of spawning and rearing habitat from mining activities and other land uses. Subsequent human activities further contributed to the decline of Central Valley anadromous salmonids and the Southern DPS of green sturgeon, eventually leading to listing the species under the ESA. These activities, which are ongoing and continue to affect the species and their habitats, include: (1) dam construction and continued use that blocks previously accessible spawning and rearing habitat; (2) water development activities that affect flow quantity, timing, and water quality; (3) land use activities such as agriculture, flood control, urban development, mining, and logging that degrade aquatic habitat and decrease prey abundance; (4) hatchery operation and practices; and (5) harvest activities. Although the life histories and geographic extent of winter-run and spring-run Chinook salmon , California Central Valley steelhead, and the Southern DPS of green sturgeon are different, much of their freshwater habitat overlap, and therefore, most of the factors responsible for their current statuses are similar. Unless specified, the following discussion of factors that have affected the current status of listed species applies to Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, California Central Valley steelhead, and the Southern DPS of green sturgeon.

1. Dams and Habitat Blockage

Hydropower, flood control, and water supply dams of the CVP and SWP, and other municipal and private entities have permanently blocked or hindered access of anadromous fishes to historical spawning and rearing grounds. Keswick and Shasta Dams block access to historic spawning and rearing habitat in the upper Sacramento, McCloud, and Pit rivers. All, or nearly all of the historical spawning habitat of Sacramento River winter-run Chinook salmon was historically located upstream of Shasta Dam, and an estimated 70 percent of historical spring-run Chinook salmon spawning habitat (Yoshiyama *et al.* 1998). Coldwater releases from Shasta and Keswick dams are managed to support winter-run populations downstream of Shasta Dam, an area that did not historically support winter-run Chinook salmon spawning. On the Feather River, Oroville Dam and associated facilities block access to the upper Feather River watershed. Nimbus Dam blocks access to most of the American River basin and Englebright and Daguerre Point dams block access to the upper Yuba River. The completion of Friant Dam in 1942 blocked salmonid access to the upper San Joaquin River, and dramatically changed the hydrograph downstream of that point, resulting in severe impacts to the southernmost salmon run in North America. The upper watersheds of these primary Central Valley basins and numerous

additional subbasins that are now blocked by dams once comprised preferred spawning and rearing habitat for Sacramento River winter-run Chinook salmon, Central Valley Spring-run Chinook salmon, and California Central Valley steelhead. Clark (1929) estimated 6,000 linear miles of salmon habitat existed in the Central Valley system prior to European settlement, and that approximately 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. The percentage of habitat loss for steelhead is presumably greater, because steelhead were more extensively distributed upstream than Chinook salmon.

As a result of migrational barriers, winter-run and spring-run Chinook salmon and steelhead have been confined to lower elevation stream reaches, which historically were used only as corridors for migration and rearing. Because salmonids are now confined to spawn lower in the river system, juvenile salmonids are forced to rear for a longer period of time within the lower reaches of the river system. However, as will be discussed below, the lower Sacramento River no longer provides the habitat features necessary for rearing of listed anadromous fish species, especially for an extended duration of time. Salmonid populations have declined throughout the Central Valley due to decreased quantity, quality, and spatial distribution of spawning and rearing habitat (Lindley *et al*. 2009).

Dammed rivers can be progressively starved of gravel input, further decreasing the carrying capacity of spawning habitat and limiting potential salmonid productivity in accessible streams. Large storage dams also alter the natural hydrograph, decreasing fall, winter, and spring-run flows and increasing summer flows. Power operations can cause frequent and dramatic fluctuations in flow levels and river elevations, affecting fish movement and riparian ecology, and stranding fish in shallow areas. 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 19 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 spring-run Chinook salmon continue to occur in Big Chico, Antelope, Clear, Thomes, and Beegum creeks and the Yuba River, but rely on the extant independent populations for their continued survival. California 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, access to 80 percent of the historically available habitat has been lost due to dam construction and other factors.

Dams have also likely disconnected green sturgeon from historic spawning and rearing habitats. Current spawning of Southern DPS green sturgeon occurs only in the Sacramento River (Adams *et al.* 2002, Beamesderfer *et al.* 2004, Adams *et al*. 2007) downstream of Keswick and Shasta dams. Although historic spawning distributions of green sturgeon in the Central Valley are not known, suitable spawning habitats exist upstream of these barriers and, based on habitat assessments done for Chinook salmon, the geographic extent of spawning has likely been reduced due to the impassable dams. Green sturgeon spawning on the Feather River has also likely been reduced due to the presence of Oroville Dam. Spawning on the Feather River is

suspected to have occurred in the past based on the continued presence of adult green sturgeon in the river below Oroville Dam. This suggests that adult sturgeon are trying to migrate to upstream spawning areas now blocked by the dam, which was constructed in 1968. 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 the tributaries where the water courses left the foothills and entered the valley floor. These low elevation dams have blocked potentially suitable green sturgeon spawning habitats located further upstream for approximately a century. Additional potential migration barriers to adult green sturgeon in the Central Valley include Sacramento Deep Water Ship Channel locks, Fremont Weir, Sutter Bypass, and the Delta Cross Channel Gates on the Sacramento River, Shanghai Bench and Sunset Pumps on the Feather River, and up until 2012, the RBDD (70 FR 17386; April 6, 2005).

The cycle of marine nutrient input into freshwater and terrestrial ecosystems has been disconnected by the presence of dams. The anadromous life history provides nutrient subsidies to the natural system through deposition of fish carcasses. Young-of-year salmonids feed directly on carcasses, which provide nitrogen and phosphorous to support primary production (plankton) and secondary production (benthic micro- and macro-invertebrates), decomposers (bacteria and fungi), and consumers farther up the food chain (*e.g.*, invertebrate predators [insects, bugs, spiders], shellfish and fin fish, snakes, raccoons, skunks, bears, man). When the size of salmon runs is reduced, there is a corresponding effect in environmental productivity and dependent predator and scavenger populations (Polis *et al.* 1997). Mitigation hatcheries are typically located downstream of large-scale projects, and a substantial portion of their adult escapement return to the hatchery and do not contribute nutrients in the form of decaying carcasses.

Habitat blockage has also affected distributions of Chinook salmon and green sturgeon in the Delta. The Suisun Marsh Salinity Control Gates (SMSCG), located on Montezuma Slough, were installed in 1988, and are operated 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). As a result of the SMSCG fish passage study and a term and condition in NMFS' 2004 biological opinion on the Long Term Operations of the CVP-SWP, the boat lock has remained open since the 2001 to 2002 control season and adult fish passage has improved.

Since its construction in 1964, RBDD has impeded passage of adult salmonids. Although there are fish ladders at the right and left banks, and a temporary ladder in the middle of the dam, they are not efficient at passing fish. The range of effects resulting from upstream migrational delays at RBDD include delayed, but eventually successful spawning, to prespawn mortality and the complete loss of spawning potential in that fraction of the population. Beginning in 1985 the RBDD gates have been seasonally raised to improve passage for listed salmonids, primarily endangered winter-run Chinook salmon. However, the dam continued to impede a portion of the winter-run Chinook salmon migration and the fish ladders are completely ineffective at passing green sturgeon. The Reclamation and the TCCA have recently (2012) constructed a new pumping plant at the site of the RBDD, which should no longer be an impediment to migration.

Further efforts will need to involve more than restoration of currently accessible watersheds. The draft Central Valley Recovery Plan calls for reestablishing populations into historical habitats currently blocked by large dams, such as those underway to establish spring-run Chinook salmon production in the San Joaquin River downstream of Friant Dam, populations upstream of Shasta Dam, and to facilitate passage of fish upstream of Englebright Dam on the Yuba River, which are needed to make the ESU/DPS viable (NMFS 2009b). In addition, Battle Creek was identified in the draft Central Valley Recovery Plan as a Core 1 population (a population capable of reaching viable status and critical for recovery of the ESU/DPS) for all three species covered in the plan.

2. Water Development

The diversion and storage of natural flows by dams and diversion structures on Central Valley waterways have depleted streamflows 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. Highly managed and depleted flows have contributed to elevated temperatures, lower DO levels, and decreased recruitment of gravel and large woody debris (LWD) (Spence *et al.* 1996). The storage of unimpeded runoff in these large reservoirs has altered the normal hydrograph for the Sacramento and San Joaquin River watersheds. Historical seasonal flow patterns included high flows in the winter-run and spring-run with declining flows throughout the summer and early fall. The current hydrology has truncated peaks with a prolonged period of elevated flows (compared to historical levels) continuing into the summer dry season. More uniform flows year round have resulted in diminished natural channel formation, altered food web processes, and slower regeneration of riparian vegetation. Stable flow patterns have also reduced bedload 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.

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 survival in the Sacramento River is also directly related to June stream flow 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. 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). Likewise, most of the 370 water diversions operating in Suisun Marsh are unscreened (Herren and Kawasaki 2001). Depending on the size, location, and season of

operation, these unscreened diversions entrain and kill many life stages of aquatic species, including juvenile salmonids. The threat of screened and unscreened agricultural, municipal, and industrial water diversions in the Sacramento River and Delta to North American green sturgeon are largely unknown as juvenile sturgeon are often not identified, and the current CDFG and NMFS' screen criteria are not specifically designed to protect sturgeon. Based on the temporal occurrence of juvenile North American green sturgeon and the high density of water diversion structures along rearing and migration routes, the potential threat of these diversions are believed to be serious and in need of study (70 FR 17386; April 6, 2005).

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: (1) water diversion from the mainstem Sacramento River into the Central Delta via the DCC; (2) upstream or reverse flows of water in the lower San Joaquin River and southern Delta waterways; (3) entrainment at the CVP and 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* spp.) within the waterways of the Delta while moving through the Delta under the influence of CVP and SWP pumping.

Decreased flows during spring-run and early-summer are also believed to possibly contribute to the decline in green sturgeon; however, the full relationship between flow and North American green sturgeon has not been determined. Existing studies primarily involve the more abundant white sturgeon, and the threats to North American green sturgeon are assumed to be similar (70 FR 17386; April 6, 2005); however, they may differ in magnitude because white sturgeon spend a relatively greater portion of time in the riverine environment. Spawning requires sufficient instream flows for passage of reproductive adults and effective fertilization. Temperature, DO, and suitable in-river habitats influence larval survival. Ecological processes and stressors begin to influence green sturgeon immediately during their first summer. These stressors are cumulative to the effects of temperature, salinity, and flow during green sturgeon's first fall and winter. The CDFG (1992) found a strong correlation between mean daily freshwater outflow (April to July) and white sturgeon year class strength in the Sacramento-San Joaquin Estuary, suggesting that insufficient flow rates are likely to pose a significant threat to the Southern DPS of North American green sturgeon. It is postulated that low flows could dampen survival by hampering the dispersal of larvae, delaying the transport of larvae downstream of water diversions in the Delta, or decreasing nutrient supply to the nursery, thus stifling productivity (CDFG 1992).

3. <u>Anderson-Cottonwood Irrigation District Dam (ACID)</u>

The Anderson-Cottonwood Irrigation District (ACID) operates a diversion dam across the Sacramento River located 5 miles downstream from Keswick Dam. The ACID Dam is one of the 3 largest diversions on the Sacramento River and has senior water rights of 128 thousand acre ft (TAF) of water for irrigation along the west side of the northern Central Valley. The diversion dam is operated from April through October, and its installation and removal requires close coordination between Reclamation and ACID. Controlled releases of water from Keswick Dam are necessary to decrease river flow to the level needed to install or remove the flashboards. Reductions in Keswick releases are limited to 15 percent in a 24-hour period and 2.5 percent in

any 1 hour. Experience with real-time operations has shown that the most significant reductions occur during wet years when Shasta releases are higher than 10,000 cfs. During wet years, flows released from Shasta Dam are typically higher than in drier water year types; therefore, the amount of flow that needs to be reduced to get to safe operating levels for the installation of the flashboards at the ACID dam is greater and the wetted area reduction downstream of Keswick Dam is thus greater. Based on run timing, flow reductions associated with flashboard installation could impact winter, spring, and fall-run Chinook salmon and green sturgeon by dewatering redds, stranding juveniles, and increasing water temperatures. Redd dewatering would mostly likely affect spring-run and fall-run Chinook salmon in October, however, the reductions in flows are usually short-term, lasting less than 8 hours. Such short-term reductions in flows may cause some mortality of incubating eggs and loss of stranded juveniles.

Fish passage at the ACID diversion dam was improved in 2001 with the addition of new fish ladders and fish screens. Since upstream passage was improved a substantial shift in winter-run Chinook salmon spawning has occurred. In recent years, more than half of the winter-run redds have typically been observed above the ACID diversion dam. This makes flow fluctuations more a concern since such a large proportion of the run is spawning so close to Keswick Dam where flow decreases are not buffered by inflows of tributaries downstream.

Green sturgeon adults that migrate upstream in April, May, and June are completely blocked by the ACID diversion dam. Therefore, 5 miles of spawning habitat are inaccessible upstream of the diversion dam. It is unknown if spawning or holding is or would be occurring in this area. Upstream blockage at the ACID results in the reduction of approximately 12 percent of potentially available habitat between Keswick Dam and RBDD. Adults that pass upstream of the diversion dam before April would be forced to wait 6 months until the stop logs are pulled before returning downstream. Newly-emerged green sturgeon larvae that hatch upstream of the ACID diversion dam would be forced to hold for 6 months upstream of the dam or pass over it and be subjected to higher velocities and turbulent flow below the dam, thus rendering the larvae and juvenile green sturgeon more susceptible to predation.

4. Red Bluff Diversion Dam (RBDD)

As of 2012, the RBDD gates will no longer be lowered, as a result of construction of a new pumping plant with fish screens. Operations of the RBDD will allow unimpeded upstream and downstream passage for the five runs of anadromous salmonids and green sturgeon in the Sacramento River. However, a description of this recent major passage impediment is included here as it has affected migration and populations for many years.

RBDD is located 59 miles downstream of Keswick Dam and is owned and operated by Reclamation for purpose of diverting up to 328 TAF of water from the Sacramento River into the Corning and Tehama-Colusa canals for irrigation. RBDD consisted of a series of eleven gates that, when lowered, enable the diversion of water from the Sacramento River into the Corning and Tehama-Colusa canals to irrigate 150,000 acres of cropland. Constructed in the 1960s, the gates of the RBDD were initially lowered year-round to divert water continuously; however, beginning in the 1980s the diversion period was gradually reduced to improve passage of several salmonid species. There are three fish ladders on RBDD, one on each side and one temporary ladder in the middle of the dam; however, the RBDD fish ladders are not efficient at passing

adult salmonids due to the inability of salmon to find the entrances. Water released from RBDD flows under the gates, caused turbulent flows that confused fish and kept them from finding the ladders. The fish ladders were not designed to allow sufficient flow to attract adult salmonids towards them. Previous studies have shown that salmon could be delayed up to 20 days in passing the dam. These delays can reduce the reproductive success of adults and increase the chance of prespawn mortality as a result of expending limited reserves of energy fighting the flows beneath the gates. Additionally, delays in passage likely prevented some spring-run Chinook salmon adults (those that encounter gates down in May and June) from entering tributaries above RBDD that dry up or become warm in the spring-run (*e.g.*, Cottonwood Creek, Cow Creek). Passage delays at RBDD have the potential to prevent these fish from accessing summer holding pools in the upper areas of the creeks. The tailrace and lake created by the dam also provides habitat for species that prey on juvenile salmonids, reducing their overall survival rates.

The RBDD gates were seasonally raised to improve passage for listed salmonids, primarily endangered winter-run Chinook salmon; however, the RBDD continued to block or delay adult salmonids and sturgeon migrating upstream to various degrees, depending on species and run timing (Vogel *et al*. 1988; Hallock 1989; and CDFG 1998). The dam impeded a portion of the winter-run Chinook salmon migration and the fish ladders were completely ineffective at passing green sturgeon.

Green sturgeon adults that migrated upstream after the dam gates were down were completely blocked by the RBDD. Upstream blockage forced sturgeon to spawn downstream of RBDD. Adults that passed upstream of the diversion dam before dam gates were down were forced to either reside in the upper river until the gates were raised or to attempt to navigate under the openings below the dam gates. During recent years the carcasses of several adult sturgeon were recovered from beneath the dam gates, apparently entrained by hydraulic forces within an area too small for them to pass through. Newly-emerged green sturgeon larvae that hatch upstream of the ACID diversion dam would be forced to reside in the upper river until the RBDD gates were raised or to pass under the dam gates, where they would be subjected to higher velocities and turbulent flows, rendering the larvae and juvenile green sturgeon more susceptible to predation.

5. Water Conveyance and Flood Control

Juvenile Chinook salmon emigrating from the Sacramento River must pass through the Sacramento-San Joaquin Delta, where they are subject to numerous threats that can affect their growth and survival. Threats in the Delta ecosystem are associated with: (1) loss of habitat from increased freshwater exports; (2) increased salinity, dredging, diking and filling; (3) introduced aquatic species that have disrupted the food chain; (4) programs which employ chemical controls to contain exotic vegetation; and, (5) entrainment (movement of fish by currents) in Federal, State, and private water diversions (USFWS 1996). Channelized, leveed, and rip-rapped river reaches and sloughs that are common in the Delta typically have low habitat complexity, low abundance of food organisms, and offer little protection from either fish or avian predators. Changed pattern and timing of flows through the Delta, sport and commercial harvest, and interactions with hatchery stocks have all affected salmon and steelhead runs migrating through or past the Delta (USFWS 1996).

The development of the water conveyance system in the Delta has resulted in the construction of armored, rip-rapped levees on 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 several primary constituent elements of critical habitat, including: spawning habitat, freshwater rearing habitat, freshwater migration corridors, and estuarine habitat. The construction of levees disrupts the natural processes connecting the river and riparian areas, resulting in a multitude of habitat-related effects, including isolation of the watershed's natural floodplain behind the levee from the active river channel and its fluctuating hydrology.

The effects of levee creation, channelization, and riprapping include the alteration of river hydraulics and riparian cover along the bank as a result of changes in bank configuration and structural features (Stillwater Sciences 2002). Many levees use angular rock (riprap) to armor the bank from erosive forces. Simple slopes protected with rock revetment generally create nearshore 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, affecting the quantity and quality of nearshore habitat for juvenile salmonids (USFWS 2000, Schmetterling *et al.* 2001, Garland *et al*. 2002). 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 to escape from fast currents, deep water, and predators (Stillwater Sciences 2002). 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.

Riprapping also has the effect of reducing inputs of LWD, which is 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 generally reduces pool quantity and quality, alters stream shading, which affects 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.

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

Land use activities continue to have large impacts on salmonid habitat in the Central Valley watershed. Until about 150 years ago, the Sacramento River was bordered by up to 500,000 acres of riparian forest, with bands of vegetation extending outward for 4 or 5 miles (California Resources Agency 1989). Starting with the gold rush, these vast riparian forests were cleared for building materials, fuel, and to clear land for farms. 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.

Land use activities associated with road construction, urban development, logging, mining, agriculture, and recreation have significantly altered fish habitat quantity and quality through alteration of streambank and channel morphology, alteration of ambient stream water temperatures, degradation of water quality, elimination of spawning and rearing habitat, fragmentation of available habitats, elimination of downstream recruitment of gravel and LWD, removal of riparian vegetation and elimination of large trees, and increased streambank erosion (Meehan and Bjornn 1991). LWD influences stream morphology by affecting pool formation, channel pattern and position, and channel geometry. Organic input to the water course also provides nutrients necessary for primary productivity and as a food source for aquatic insects, which, in turn, are consumed by salmonids. 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).

Increased sedimentation resulting from agricultural and urban practices and decreased sediment transport capacity caused by altered flow regimes is one of the primary causes of salmonid habitat degradation in the Central Valley (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). Embedded substrates can reduce the reproductive success of salmonids and hinder the ability of over-wintering juveniles to take refuge from high flow events.

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 wetland marsh has been "reclaimed" for agricultural purposes, leaving only small remnant patches. 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, since the 1850's (Conomos *et al.* 1985, Nichols *et al.* 1986, Wright and Phillips 1988, Monroe *et al.* 1992, Goals Project 1999). Channelized, levied, and rip-rapped river reaches and sloughs in the river and delta typically have low habitat complexity, low abundance of food organisms, and offer little protection from either fish or avian predators. 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.

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 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 bedload 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-run season and the spring-run 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.

Shoreline habitats in the Sacramento River and Delta have been extensively altered by bank revetment projects. In 1960, the U.S. Congress (Congress) authorized the Sacramento River Bank Protection Program (SRBPP), under the auspices of the U.S. Army Corps of Engineers (Corps), to control flooding in the Sacramento River Basin. By 2001, the estimated total embankment riprapped within the SRBPP was approximately 199 miles, or 51 percent of the 388 miles of river bank. In a subsequent evaluation of levee integrity, Sacramento was determined to be the city most vulnerable to flooding due to the insufficient integrity or lack of protective levee embankments. In response, levee construction increased in the Central Valley under the auspices of the Corps and Department of Water Resources, with technical assistance from NMFS. More than 75 percent of the banks in the lowermost Sacramento River are now covered with riprap, and the loss of LWD may now exceed 90 percent (USFWS 2000).

Juvenile salmonids in the lower Sacramento River have been impacted by large-scale habitat simplification resulting from bank revetment projects. Riprapping affects salmonids by arresting the natural fluvial processes that create the habitats on which native fish, plants, and wildlife species are dependent. Juvenile salmonids rely on near-shore LWD and overhanging or flooded vegetation for shelter and protection from predators, high flows, and high water temperatures (Yoshiyama *et al.* 1998). Exposure to high water temperatures can impact fish incubation, emergence and growth, swimming performance, and increased vulnerability to predators and disease (USFWS 1999). Additionally, a loss of shaded riverine aquatic habitat decreases inputs of LWD and other organic materials, which are crucial to a properly functioning stream ecosystem. The effect of cutting off allochthonous energy inputs is decreased river productivity at all trophic levels.

Urban stormwater and agricultural runoff may also affect Central Valley salmon and steelhead populations. Pesticides, oil, grease, heavy metals, polycyclic aromatic hydrocarbons (PAHs), and other organics and nutrients (CRWQCB 1998) found in runoff can destroy aquatic life necessary for salmonid survival (NMFS 1996a and 1996b). 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 and 1996b). 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.

Pesticide contamination increased substantially in the mid-1970s when application of rice pesticides increased (70 FR 17386; April 6, 2005). Estimated toxic concentrations for the Sacramento River during 1970 to 1988 may have deleteriously affected striped bass larvae (Bailey et al. 1994). White sturgeon also may accumulate polychlorinated biphenols (PCBs) and selenium (White *et al.* 1989). For example, the non-native overbite clam which was introduced in 1988 and has become the most common food of white sturgeon, is known to bioaccumulate selenium, a toxic metal (CDFG 2002a; Linville *et al.* 2002). The significance of threat to North American green sturgeon is unclear, although green sturgeon are believed to spend relatively more time in the marine environment than white sturgeon and, therefore, may have less exposure. The Biological Review Team for North American green sturgeon reviewed this issue and concluded that contaminants also pose some risk for North American green sturgeon; however, the actual impacts have not been quantified or estimated.

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.

7. Water Quality

The water quality of the Delta has been negatively impacted over the last 150 years. Juvenile salmonids are exposed to increased water temperatures in the Delta during the late spring-run and summer due to the loss of riparian shading, and by thermal inputs from municipal, industrial, and agricultural discharges. Decreased DO levels and increased turbidity and contaminant loads have also degraded the quality of the aquatic habitat for the rearing and migration of salmonids. Survival of green sturgeon eggs and larvae requires specific water quality parameters like temperature, DO, and turbidity. These parameters likely constrain the current area available as larval nursery and juvenile foraging area and have likely contributed to increased mortality of juvenile Chinook salmon and steelhead as they move through the Delta.

Increased water quantity and quality have a positive influence on spawning green sturgeon, and since flow in spawning segments of the Sacramento River is controlled by Shasta Dam, the predictability of flows is high, and project operations can directly influence the successful production of larvae and juveniles. Green sturgeon require sufficient instream flows for passage of reproductive adults and effective fertilization. Temperature, DO, and suitable in-river habitats also influence larval survival. The installation of the Shasta Dam temperature control device in 1997 is thought to have improved the conditions for green sturgeon in the upper Sacramento River, although Shasta Dam has a limited storage capacity and cold water reserves could be depleted in long droughts. Water temperatures at RBDD have not been higher than 62ºF since 1995 and are within the optimum range (59 to 66ºF) for growth and survival of green sturgeon egg and larvae (Mayfield and Cech 2004). Conversely, CDFG (2002a) has indicated that water temperatures may be inadequate for spawning and egg incubation in the Feather River as the result of releases of warmed water from Thermalito Afterbay. It is likely that water temperatures greater than 63ºF may deleteriously affect sturgeon egg and larval development, especially for late-spawning fish in drier water years (70 FR 17386; April 6, 2005).

Some common pollutants include effluent from wastewater treatment plants and chemical discharges such as dioxin from San Francisco bay petroleum refineries (McEwan and Jackson 1996). In addition, agricultural drain water, another possible source of contaminants, can contribute up to 30 percent of the total inflow into the Sacramento River during the low-flow period of a dry year (NMFS 2009a). 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).

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. Increased loads of selenium entering the system through agricultural practices in the western side of the San Joaquin Valley are a cause of concern for green sturgeon, which have been identified by University of California at Davis (UC Davis) researchers as being highly sensitive to selenium levels. For example, the non-native overbite clam, introduced in 1988, has become the most common food of white sturgeon. The overbite clam is known to bioaccumulate selenium, a toxic metal (CDFG 2002a; Linville *et al.* 2002). The significance of this threat to green sturgeon is unclear.

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 and 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 [EPA] 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 depends on their trophic level and the amount of contaminated forage base they consume.

8. Hatcheries

Six hatcheries currently produce Chinook salmon in the Central Valley, and four of these also produce steelhead. Annual production targets include over 32-million fall-run Chinook salmon, 2-million spring-run Chinook salmon, 1-million late fall-run Chinook salmon, 0.25-million winter-run Chinook salmon, and 2-million steelhead. Anadromous salmonid hatcheries were established to mitigate for salmonid production lost above dams, to enhance natural spawning populations, and to contribute to fish abundance for harvest. Juvenile salmonids originating in Central Valley hatcheries are released in-stream or are trucked and released into San Pablo Bay; they migrate to and rear to maturity in the Pacific Ocean, and return to freshwater habitats to spawn. Central Valley salmonid hatcheries contribute substantially to local and state economies and culture.

Salmonid hatcheries can have negative effects on ESA-listed salmonids. Hatchery fish can introduce or amplify fish pathogens in the natural environment and lower natural disease tolerance through hybridized fish progeny. 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 are primarily 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 (U.S. Department of the Interior 1999). Genetic impacts are greatest for hatchery stocks originating from outside of the basin, which are adapted to environmental conditions atypical of the Central Valley. For example, Nimbus Hatchery on the American River rears Eel River steelhead stock and releases these fish in the Sacramento River basin. Adult steelhead from the Nimbus Hatchery that do not return to the hatchery but instead spawn naturally in the Central Valley would be expected to pass along traits associated with improving fitness in coastal streams, which may differ dramatically from conditions in the Central Valley. One of the recommendations in the Joint Hatchery Review Report (CDFG and NMFS 2001) was to identify and designate new local sources of steelhead brood stock to replace the current Eel River origin brood stock.

Hatchery practices have contributed to the hybridization of some subpopulations of Central Valley spring-run and fall-run Chinook salmon (CDFG 1998). As early as the 1960s, Slater (1963) observed that spring-run and fall-run Chinook salmon were competing for spawning sites in the Sacramento River below Keswick Dam, and speculated that the two runs may have hybridized. Spring-run Chinook salmon from the FRFH 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 at the same time as fall-run Chinook salmon. 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.

Central Valley hatcheries also pose risks to naturally produced salmonids through competition for limited resources. Hatchery fish compete with natural fish in their fluvial, lacustrine, estuarine, and ocean habitats, and can exceed 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 the inability to physically separate spring-run and fall-run Chinook salmon adults (Fukushima *et al.* 1998, CDFW/CDWR 2012). This concurrent spawning has led to hybridization between the two sympatric stocks in the Feather River (DWR 2001, CDFW/CDWR 2012). 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 during other times of the year.

Increasing numbers of hatchery produced salmonids can also affect the survival and distribution of naturally produced salmonids as they compete for limited resources in the marine environment. A combined 350 million hatchery and wild smolts out-migrating from the Columbia River Basin in 1992 were believed to have outnumbered the historical abundance (HSRG 2004). California's contribution to ocean migration includes approximately 55 million salmon and 3.3 million steelhead hatchery-reared juveniles (CDFG and NMFS 2001), and unquantified, but significantly less, naturally produced fish. The marine ecosystem has shifting

food production capabilities which influence the survivability and distribution of salmon and steelhead. The oceanic system undergoes continuous short- and long-term change, often under the influence of random factors originating outside of itself (HSRG 2004). Limited marine carrying capacity has implications for naturally produced fish experiencing competition with increasing numbers of hatchery production (HSRG 2004). Bigler *et al.* (1996) identified a negative association between fish size and abundance of salmon in the North Pacific; decreases in fish size were associated with an increase in salmon abundance. The authors interpreted this relationship as an effect of density-dependent factors, such as increased ocean survivorship and expansion of fish enhancement hatchery programs, although selective harvesting of larger fish also likely contributed. Increasing salmonid abundance in the marine environment may also result in reduced fecundity, egg size, age at maturity, and survival (Bigler *et al.* 1996). This was demonstrated by an increase in average body weight of pink salmon (*O. gorbuscha*) and average size of chum salmon (*O. keta*) stocks from 1944-46 through 1958, years of high ocean productivity and less fish abundance in coastal waters in the Pacific Northwest (Godfrey 1959a, 1959b in Bigler *et al.* 1996).

Environmental influences determine food productivity of the marine ecosystem and carrying capacity of the ocean (Bradford 1995). Ocean events cannot be predicted with a high degree of certainty at this time, but research is focusing on the ocean ecosystem monitoring programs to facilitate flexible management strategies. Until good predictive models are developed, there will be years when hatchery production may be in excess of the marine carrying capacity, placing depressed natural fish at a disadvantage by directly inhibiting their opportunity to recover (Northwest Power and Conservation Council [NPCC] 2003).

The steady production of Chinook salmon and steelhead in Central Valley hatcheries, concomitant with decreased levels of natural production, has led to a reversal of the relative numbers of hatchery and natural salmonid stocks in the Central Valley. For example, in the 1950's California Central Valley steelhead were comprised of 88 percent naturally-produced fish (McEwan 2001), however, that proportion has recently been estimated at 23 to 37 percent naturally-produced fish (Nobriga and Cadrett 2003). The relatively high level of hatchery production in the Central Valley can result in high harvest-to-escapements ratios for natural stocks, where hatchery and natural fish are not all marked and fishing regulations are set according to the combined abundance of hatchery and natural stocks. This can lead to over-exploitation and reduction in the abundance of wild populations that are indistinguishable and exist in the same system as hatchery populations.

Depending on goals of hatcheries and how they are managed, benefits can outweigh the risks on salmonid populations (HSRG 2009). Winter-run Chinook salmon produced at the Livingston Stone NFH are considered part of the winter-run ESU and are being propagated using best management practices for the purpose of contributing to the recovery of the ESU. 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 (HSRG 2009), as was the case with the winter-run Chinook salmon population during the 1990s. However, abundance is only one component of a viable salmonid population and recovery of salmonid populations is reliant on self- sustaining

natural spawning stocks. Therefore, while hatcheries may, under certain circumstances, provide some benefits to natural populations, they alone cannot produce population recovery without satisfying the other essential components of Viable Salmonid Populations (70 FR 37204; June 28, 2005).

9. Ocean Commercial and Sport Harvest

Extensive ocean recreational and commercial troll fisheries for Central Valley Chinook salmon exist along the Northern and Central California coast, and within inland waters of the Central Valley. Central Valley salmon stocks comprise an estimated 85 to 95 percent of total ocean harvest south of Point Arena to Point Sur and contribute significantly to the ocean fishery off Cape Falcon in northern Oregon and a lesser portion of harvest north of Point Arena (Boydstun 2000). Commercial and recreational salmon fisheries in California target primarily Central Valley fall-run Chinook salmon, which are produced in excess of thirty million annually at several Central Valley hatcheries. The Pacific Fisheries Management Council (PMFC), established by the Magnuson-Stevens Fishery Conservation and Management Act of 1976, is responsible for developing fishery management plans for salmon off the coast of Washington, Oregon, and California, and is guided by conservation objectives that include an escapement of 122,000 to 180,000 (hatchery and natural) adults. Within these numerical harvest guidelines, commercial and recreational fisheries are further managed to minimize incidental catch of listed Sacramento River winter-run Chinook salmon, Central Valley Spring-run Chinook salmon, and Klamath River fall-run Chinook salmon.

Preseason estimates of abundance are used to estimate the harvestable surplus of Central Valley fall-run Chinook salmon, and form the basis of harvest regulations in both the Pacific Ocean and Sacramento River. Since 2009, the abundance of Central Valley fall-run Chinook salmon has been estimated using the Sacramento Index, which produces a preseason estimated abundance of Sacramento River fall-run Chinook salmon, based on the escapement of jacks the previous year. Since the Sacramento Index estimator has been used only during recent years, it does not provide a long-term time series from which to gain a perspective of impacts resulting from fishery harvest. Prior to 2009, ocean harvest of Central Valley Chinook salmon was estimated using an abundance index called the Central Valley Index (CVI). The CVI is the sum of ocean fishery Chinook salmon harvested in the area south of Point Arena (where 85 percent of Central Valley Chinook salmon are caught), plus the Central Valley adult Chinook salmon escapement. Coded wire tag (CWT) returns indicate that Sacramento River salmon congregate off the California coast between Point Arena and Morro Bay, but also contribute significantly off of Cape Falcon in northern Oregon.

Since 1970, the CVI for winter-run Chinook salmon has ranged between 0.50 and 0.80. In 1990, when ocean harvest of winter-run was first evaluated by NMFS and the PFMC, the CVI 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 winter-run Chinook salmon. In addition, the final rule designating winter-run Chinook salmon critical habitat (June 16, 1993, 58 FR 33212) stated that commercial and recreational fishing do not appear to be significant factors in 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). NMFS (1996b, 1997) concluded that incidental ocean harvest

of 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 biological opinions, measures were developed and implemented by the PFMC, NMFS, and CDFG to reduce ocean harvest by approximately 50 percent. In 2001, the CVI harvest index dropped to 0.27, most likely due to the reduction in harvest and the higher abundance of salmonids originating from the Central Valley (Good *et al*. 2005). The 2010 biological opinion determined that the fisheries jeopardized the species (NMFS 2010). To avoid jeopardy, the action agency (NMFS Sustainable Fisheries Division) continues to implement the reasonable and prudent alternative, which: (1) specifies that the previous consultation standards for winter-run Chinook salmon regarding minimum size limits and seasonal windows south of Point Arena for both the commercial and recreational fisheries will continue to remain in effect at all times regardless of abundance estimates or impact rate limit; and (2) establishes an abundance-based management framework where, during periods of relatively low abundance, the fisheries are restricted in order to lower the impact rate on winter-run Chinook salmon.

Chinook salmon produced at the CNFH contribute substantially to commercial and recreational salmon fisheries. The following summary of ocean harvest of brood years 1992 to 2002 fall and late fall-run Chinook salmon from the CNFH is summarized from a draft report produced by the RBFWO (Null 2008). During brood years 1996 through 2001, fall-run Chinook salmon originating at the CNFH contributed an average of 67,931 fish annually to the ocean salmon fishery. This equates to an average ocean harvest (contribution) rate for CNFH fall-run Chinook salmon of 0.57 percent of the number released. The contribution rates observed for brood years 1996 through 2001 were heavily weighted upwards by one very productive brood year (1999). Nearly 84 percent of the brood year 1996 to 2001 CNFH fall-run Chinook salmon harvested in the ocean were age-3. Harvest of fall-run Chinook salmon from CNFH occurs along the entire West Coast; however, the majority of landings occur along the coast of California. An average of 71.2 percent of the total Coleman fall-run Chinook salmon harvested from 2000 to 2003 were brought to dock at California ports. In most years, the majority of fall-run Chinook salmon were landed between Horse Mountain and Point Arena; however, over half of the CNFH fall-run Chinook salmon harvested in 2000 were landed in ports south of Pigeon Point. The ocean fishery contribution for late fall-run Chinook salmon from brood years 1992 through 2002 averaged 0.55 percent of the number released, with approximately 4,475 fish harvested annually in ocean commercial and sport fisheries. Greater than half (51.59 percent) of the late fall-run Chinook salmon were harvested at age 2. Late fall-run Chinook salmon are generally harvested further south than fall-run Chinook salmon, and nearer to the mouth of the San Francisco Bay. An average of 86.49 percent of the CNFH late fall-run Chinook salmon harvested from 1996 to 2004 were landed from boats docked at California ports and 77.36 percent were landed south of Point Arena.

Fisheries can alter fish behavior and change the age structure of a stock by selecting for particular segment of the run. By targeting the largest and oldest fish for many years, ocean fisheries have affected the age structure of spring-run Chinook salmon and reduced the numbers of 4- and 5-year-old fish escaping to spawn (CDFG 1998). Cramer and Demko (1997) indicated that harvest rates of 3-year-old fish ranged from 18 percent to 22 percent, 4-year-olds ranged from 57 percent to 84 percent, and 5-year-olds ranged from 97 percent to 100 percent. Winter-run Chinook salmon spawners have also been affected by ocean fisheries, as most spawners

return as 3-year olds but the percentage of older-aged individuals has increased when fishing pressure has been curtailed. As a result of very low returns of fall-run Chinook salmon to the Central Valley in 2007, there was a complete closure of the commercial and recreational ocean Chinook salmon fishery in 2008 and 2009 and very-limited commercial and recreational fishing seasons in 2010. As a result of not having been subjected to fishing pressure, there will likely be more 4- and 5-year old winter-run and spring-run Chinook salmon returning to spawn in 2011. The harvest of wild fish influences their incidence in the spawning population (NPCC 2003). Reducing the age structure of a stock reduces its resiliency to factors that may impact year class strength, causes increased variability of year class strength, and increases the chance of extinction.

10. Inland Sport Harvest

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). The Central Valley Chinook salmon fishery generally occurs from July through December. This period overlaps with a portion of the migration and/or holding periods of adult and juvenile winter-run and spring-run Chinook salmon and steelhead. Peak angler effort on the mainstem Sacramento River occurs in October, from Pittsburg to Sacramento. Angling opportunity for CNFH fish is greatest in the portion of the river extending from 500 ft upstream of RBDD to the Deschutes Road Bridge (Anderson). Within this stretch of river, the most intense angling effort generally concentrates at the "Barge Hole", a deep pool located at RM 271.5 at the mouth of Battle Creek.

Since 1987, the Fish and Game Commission has adopted increasingly stringent regulations to reduce incidental catch of winter-run Chinook salmon in the in-river sport fishery. 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 is intended to span the months that migrating adult winter-run Chinook salmon are ascending the Sacramento River to their spawning grounds; however, some winter-run Chinook salmon have shown up in creel surveys during recent years. These closures have reduced impacts on 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 spring-run Chinook salmon throughout the species' range. During the summer, adult spring-run Chinook salmon are easily targeted by anglers when they congregate and hold 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 spring-run Chinook salmon in Mill, Deer, Butte, and Big Chico creeks and the Yuba River have been added to the existing CDFG regulations. Additionally, the current regulations, including those developed for winter-

run Chinook salmon, provide some level of protection for spring-run Chinook salmon (CDFG 1998).

There is little information on steelhead harvest rates in California, and there is currently not a Fisheries Management Plan in place. 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 to 1992 through 1993 to 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 California 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). Based on angling studies using baited single or barbed hooks or artificial lures, direct hooking mortality rates could range from 1.6 to 14.9 percent or higher (Hooton 1987, 2001). Incidence of delayed mortality is affected by recapture frequency, hooking anatomical location, degree of blood loss, water temperature, and fish handling practices of anglers (Hooton 2001, Lindsay *et al.* 2004). CDFG estimates mortality ranging from 0.25-1.4 percent for the Central Valley fisheries (CDFG 2001). CDFG reinstated creel surveys in the Central Valley beginning in 2007 following a hiatus of several years due to lack of funding. Creel data from 2007 to 2012 (Mike Brown, CDFW, personal communication, 2014; Kevin Niemela, USFWS, personal communication, 2014) reported an annual average of 2,979 ad-clipped steelhead caught, of which an average of 21 percent were harvested, and an annual average of 22,957 non-ad-clipped steelhead (greater than 16 inches in length) or resident rainbow trout (less than 16 inches in length), with one percent harvested (these fish are likely mostly resident fish, and could represent the same fish getting caught multiple times).

11. <u>Disease</u>

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, *Ceratomyxosis shasta*, columnaris, furunculosis, infectious hematopoietic necrosis (IHN), redmouth and black spot disease, whirling disease, and erythrocytic inclusion body syndrome are known, among others, to affect Chinook salmon and steelhead (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 pathogens are more likely to cause infection within the hatchery environment as compared to the natural environment. Nevertheless, wild salmonids may contract diseases that are spread from infected hatchery fish through the water column (*i.e*., waterborne pathogens). Additionally, juvenile salmonids can be infected by vertical transmission from infected parents. 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.

12. Predation

Predation also may be a factor in the decline of winter-run and spring-run Chinook salmon, and to a lesser degree California 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 mainstem Sacramento River, high rates of predation are known to occur at the RBDD, ACID diversion dam, GCID 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 historic levels due to flow dynamics associated with the operation of this structure. Due to their small size, early emigrating winter-run Chinook salmon may have been very susceptible to predation in Lake Red Bluff when the RBDD gates remained closed in summer and early fall. In passing the dam, juveniles are subject to conditions which disorient them, making them highly susceptible to predation by fish or birds. Sacramento pikeminnow 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 Sacramento pikeminnow predation on juvenile salmonids during the summer months increased to 66 percent of the total weight of stomach contents in the predatory Sacramento 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).

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). More recent studies by the California Department of Water Resources (DWR 2008) have verified this level of predation also exists for steelhead smolts within Clifton Court Forebay, indicating that these predators were efficient at removing salmonids over a wide range of body sizes.

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. Striped bass and pikeminnow predation on salmon 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). North American green sturgeon also likely to experience predation by introduced species, including striped bass, but the actual impacts of predation have yet to be estimated (70 FR 17386; April 6, 2005). 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 salmonid include: badger (*Taxidea taxus*), bobcat (*Linx 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. Southern Residents, in particular, target Chinook salmon as their preferred prey (96 percent of prey consumed during spring, summer and fall, from long-term study of resident killer whale diet; Ford and Ellis 2006). 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.

13. <u>Ocean Productivity</u>

The time at which juvenile salmonids enter the marine environment marks a critical period in their life history. Studies have shown the greatest rates of growth and energy accumulation for Chinook salmon occur during the first 1 to 3 months after they enter the ocean (Francis and

Mantua 2003, MacFarlane *et al*. 2008). Emigration periods and ocean entry can vary substantially among, and even within, races in the Central Valley. For example, winter-run Chinook salmon typically rear in freshwater for 5-9 months and exhibit a peak emigration period in March and April. Emigration of spring-run Chinook salmon is more variable and can occur in December or January (soon after emergence as fry), or from October through March (after rearing for a year or more in freshwater). While acknowledging this variability in emigration patterns, the general statement can be made that Chinook salmon typically rear in freshwater environments for less than a year and enter the marine environment as subyearlings in late spring to early summer. In contrast to Chinook salmon, steelhead generally rear in freshwater environments longer (anywhere from 1 to 3 years) and their period of ocean entry can span many months (Moyle 2002). Juvenile steelhead presence at Chipps Island has been documented between at least October and July (NMFS 2009). Although steelhead life histories are more elastic than those of Chinook salmon, they typically enter the ocean in approximately the same time frame. This general timing pattern of ocean entry is commonly attributed to evolutionary adaptations that allow salmonids to take advantage of highly productive ocean conditions that typically occur off the California coast beginning in spring and extending into the fall (MacFarlane *et al*. 2008). Therefore, the conditions that juvenile salmonids encounter when they enter the ocean can play an important role in their early marine survival and eventual development into adults.

Survival of salmon in the marine environment correspond with periods of cold and warm ocean conditions, with cold regimes being generally favorable for salmon survival and warm ones unfavorable (Behrenfeld *et al.* 2006, Wells *et al.* 2006). Peterson *et al.* (2006) provide evidence that growth and survival rates of salmon in the California Current off the Pacific Northwest can be linked to fluctuations in ocean conditions. An evaluation of conditions in the California current since the late 1970s reveals a generally warm, unproductive regime that persisted until the late 1990s. This regime has been followed by a period of high variability that began with colder, more productive conditions lasting from 1999 to 2002. In general, salmon populations increased substantially during this period. However, this brief cold cycle was immediately succeeded by a 4-year period of predominantly warm ocean conditions beginning in late 2002, which appeared to have negatively impacted salmon populations in the California Current (Peterson *et al*. 2006). Evidence suggests these regime shifts follow a more or less linear pattern beginning with the amount and timing of nutrients provided by upwelling and passing "up" the food chain from plankton to forage fish and eventually, salmon. There are also indications that these same regime shifts affect the migration patterns of larger animals that prey on salmon (*e.g*., Pacific hake, sea birds) resulting in a "top-down" effect as well (Peterson *et al*. 2006).

Peterson *et al*. (2006) evaluated three sets of ecosystem indicators to identify ecological properties associated with warm and cold ocean conditions and determine how those conditions can affect salmon survival. The three sets of ecosystem indicators include: (1) large-scale oceanic and atmospheric conditions [specifically, the Pacific Decadal Oscillation (PDO) and the Multivariate ENSO Index]; (2) local observations of physical and biological ocean conditions off northern Oregon (*e.g*., upwelling, water temperature, plankton species compositions, *etc*.); and (3) biological sampling of juvenile salmon, plankton, forage fish, and Pacific hake (which prey on salmon). When used collectively, this information can provide a general assessment of ocean conditions in the northern California Current that pertain to multi-year warm or cold phases. It

can also be used to develop a qualitative evaluation for a particular year of the effect these ocean conditions have on juvenile salmon when they enter the marine environment and the potential impact to returning adults in subsequent years.

The generally warmer ocean conditions in the California Current that began to prevail in late 2002 have resulted in coastal ocean temperatures remaining 1 to 2°C above normal through 2005. A review of the previously mentioned indicators for 2005 revealed that almost all ecosystem indices were characteristic of poor ocean conditions and reduced salmon survival. For instance, in addition to the high sea surface temperatures, the spring transition, which marks the beginning of the upwelling season and typically occurs between March and June, was very late, postponing upwelling until mid-July. In addition, the plankton species present during that time were the smaller organisms with lower lipid contents associated with warmer water, as opposed to the larger, lipid-rich organisms believed to be essential for salmon growth and survival throughout the winter. The number of juvenile salmon collected during trawl surveys was also lower than any other year previously sampled (going back to 1998, Peterson *et al*. 2006). Furthermore, although conditions in 2006 appeared to have improved somewhat over those observed in 2005 (*e.g*., sea surface temperature was cooler, the spring transition occurred earlier, and coastal upwelling was more pronounced), not all parameters were necessarily "good." In fact, many of the indicators were either "intermediate" (*e.g*., PDO, juvenile Chinook salmon presence in trawl surveys) or "poor" (*e.g*., copepod biodiversity, Peterson *et al.* 2006).

Updated information provided by Peterson *et al*. (2006) on the NWFSC Climate Change and Ocean Productivity website shows the transition to colder ocean conditions, which began in 2007, has persisted throughout 2008. All ocean indicators point toward a highly favorable marine environment for those juvenile salmon that entered the ocean in 2008. After remaining neutral through much of 2007, PDO values became negative (indicating a cold California Current) in late 2007 and remained negative through at least August, 2008, with sea surface temperatures also remaining cold. Coastal upwelling was initiated early and will likely be regarded as average overall. Furthermore, the larger, energy-rich, cold water plankton species have been present in large numbers in 2007 and 2008. Therefore, ocean conditions in the broader California Current appear to have been favorable for salmon survival in 2007 and to a greater extent in 2008, which boded well for Chinook salmon populations returning in 2009 and 2010. These ecosystem indicators can be used to provide an understanding of ocean conditions, and their relative impact on marine survival of juvenile salmon, throughout the broader, northern portion of the California Current. However, they may not provide an accurate assessment of the conditions observed on a more local scale off the California coast.

Wells *et al*. (2008) developed a multivariate environmental index that can be used to assess ocean productivity on a finer scale for the central California region. This index (also referred to as the Wells Ocean Productivity Index) has also tracked the Northern Oscillation Index, which can be used to understand ocean conditions in the North Pacific Ocean in general. The divergence of these two indices in 2005 and 2006 provided evidence that ocean conditions were worse off the California coast than they were in the broader North Pacific region. The Wells *et al.* (2008) index incorporates 13 oceanographic variables and indices and has correlated well with the productivity of zooplankton, juvenile shortbelly rockfish, and common murre production along the California coast (MacFarlane *et al*. 2008). In addition to its use as an

indicator of ocean productivity in general, the index may also relate to salmon dynamics due to their heavy reliance on krill and rockfish as prey items during early and later life stages. For instance, not only did the extremely low index values in 2005 and 2006 correlate well with the extremely low productivity of salmon off the central California coast in those years, but the index also appears to have correlated well with maturation and mortality rates of adult salmon from 1990-2006 in that region (Wells and Mohr 2008).

Sufficient data are currently not available to determine the Wells *et al*. (2008) index values for 2007 and 2008; however, sufficient information does exist to provide an indication of the likely ocean conditions for those two years, which can then be compared to 2005 and 2006. A review of the available information suggests ocean conditions in 2007 and 2008 have improved substantially over those observed in 2005 and 2006. For instance, the spring transition, which marks the beginning of the upwelling season and typically occurs between March and June, was earlier in 2007 and 2008 compared to 2005 and 2006. An early spring transition is often indicative of greater productivity throughout the spring and summer seasons (Wells and Mohr 2008, Peterson *et al*. 2006). Coastal upwelling, the process by which cool, nutrient rich waters are brought to the surface (perhaps the most important parameter with respect to plankton productivity), was also above average in 2007 and 2008. Moreover, coastal sea surface temperature and sea level height (representative of the strength of the California current and southern transport) values were also characteristic of improved ocean productivity (Wells and Mohr 2008). Thus, contrary to the poor ocean conditions observed in the spring of 2005 and 2006, the Wells *et al*. (2008) index parameters available at this time indicate spring ocean conditions have been generally favorable for salmon survival off California in 2007 and 2008.

In contrast to the relatively "good" ocean conditions that occurred in the spring, the Wells *et al*. (2008) index values for the summer of 2007 and 2008 were generally poor, and similar to those observed in 2005 and 2006. Summer sea surface temperature followed a similar pattern in both 2007 and 2008, starting out cool in June, and then rising to well above average in July before dropping back down to average in August (Wells and Mohr 2008). The strong upwelling values observed in the spring-run of 2007 and 2008 were not maintained throughout the summer, and instead dropped to either at or below those observed in 2005 and 2006. Finally, sea level height and spring curl values (a mathematical representation of the vertical component of wind shear which represents the rotation of the vector field), which are negatively correlated with ocean productivity, were both poor (Wells and Mohr 2008). Therefore, during the spring of 2007 and 2008, ocean conditions off California were indicative of a productive marine environment favorable for ocean salmon survival (and much improved over 2005 and 2006). However, those conditions did not persist throughout the year, as Wells *et al*. (2008) index values observed in the summer of 2007 and 2008 were similar to those experienced in the summer of 2005 and 2006, 2 years marked by extremely low productivity of salmon off the central California coast.

The correlation between various environmental indices that track ocean conditions and salmon productivity in the Pacific Ocean, both on a broad and local scale, provides an indication of the role they play in salmon survival in the ocean. Evidence exists that suggests early marine survival for juvenile salmon is a critical phase in their survival and development into adults. Lindley *et al.* (2009) identified anomalously poor ocean conditions as the primary cause for the unusually poor survival of the 2004 and 2005 broods of Sacramento River fall-run Chinook

salmon. Each of these consecutive broods from the Central Valley entered the ocean during periods of weak upwelling, warm sea surface temperatures, and low prey densities resulting in poor conditions for feeding and growth. Moreover, when discussing the potential extinctions of salmon populations, Francis and Mantua (2003) point out that climate patterns would not likely be the sole cause but could certainly increase the risk of extinction when combined with other factors, especially in ecosystems under stress from humans. Thus, the efforts to try and gain a greater understanding of the role ocean conditions play in salmon productivity will continue to provide valuable information that can be incorporated into the management of these species and should continue to be pursued.

14. Global Climate Change

Earth's climate has been warming since the advent of the industrial revolution in the mid-1700s (National Wildlife Federation [NWF] 2005). Nine of the 10 hottest years in our plant's recorded history have occurred in the last decade. In much of the United States, spring-run arrives about two weeks earlier than it did 50 years ago. Global warming has increased average daily temperatures by 1.3^{o} F since the last century, and an averaged warming increase of 5.4^{o} F (2.5 to 10.4^{o} F) is predicted by the end of the 21st century (Northwest Regional Council [NRC] 2001; Intergovernmental Panel on Climate Change [IPCC 2001]). Since the last century, the Arctic has experienced a temperature rise of 4 to 7 ^{o}F, resulting in reduced annual snowfall, melted mountain glaciers, shrinking of the tundra, melting of the permafrost and shrinking summer sea ice cover to its smallest extent in millennia (NOAA Climate). The ocean has warmed about 0.09^{o}F, averaged over the layer extending from the surface down to 10,000 ft, since the 1950s (NRC 2001). Over the past 100 years, global sea level has risen by an average of 1 to 2 mm per year, and this rate is expected to accelerate into the 22nd century (IPCC 2001).

In the marine environment, global warming may be affecting the ENSO, as there has been more frequent, persistent and intense episodes of El Nino since the mid-1970s compared with the previous 100 years (IPCC 2001). A noted decline in zooplankton (*e.g.*, copepods and krill) production has occurred off southern California, a result of increased warming of 1.4^{o}C in sea surface temperature that depressed nutrient upwelling from below the thermocline. Sea temperatures affect movements of fish predators and the bioenergetics of their prey.

Increasing temperatures are a consequence of growing levels of greenhouse gases, which trap some of the energy going out from the earth and redirect it back to the earth's surface. Water vapor accounts for over 90 percent of the natural greenhouse effect, but small increases in the other greenhouse gases can warm global temperature via the amount of heat trapped in the atmosphere. CO_2 produced from the burning of fossil fuels is the primary source of increased atmospheric CO_2 in recent times. CO_2 levels have fluctuated between 180 ppm and 280 ppm over thousands of years, but have steadily risen in the last 150 years to its current level of 370 ppm (NWF 2005). Methane (CH_4), nitrous oxide (N_2O), ozone (O_3), carbon monoxide (CO), chlorofluorocarbons (CFCs), and other greenhouse gases (*e.g.*, hydrofluorocarbons (HFCs), aerosols, and carbon pollution) also correspond to increasing global temperatures (NRC 2001; IPCC 2002). Natural systems which ameliorate the impacts of global warming (*e.g.*, forests, wetlands, oceans) cannot balance the amount of greenhouse gases currently being emitted and are also being impacted or reduced.

Climate change is postulated to have had a negative impact on salmonids throughout the Pacific Northwest due to large reductions in available freshwater habitat (Battin *et al.* 2007). Widespread declines in springtime snow-water equivalents (SWE) have occurred in much of the North American West since the 1920s, especially since mid-century (Knowles and Cayan 2004, Mote 2006). This decrease in SWE can be largely attributed to a general warming trend in the western United States since the early 1900s (Mote *et al.* 2005, Regonda *et al.* 2005, Mote 2006), even though there have been modest upward precipitation trends in the western United States since the early 1900s (Hamlet *et al.* 2005). The largest decreases in SWE are taking place at low to mid elevations (Mote 2006, Van Kirk and Naman 2008) because the warming trend overwhelms the effects of increased precipitation (Hamlet *et al.* 2005, Mote *et al.* 2005, Mote 2006). These climactic changes have resulted in earlier onsets of springtime snowmelt and streamflow across western North America (Hamlet and Lettenmaier 1999, Regonda *et al.* 2005, Stewart *et al.* 2005), as well as lower flows in the summer (Hamlet and Lettenmaier 1999, Stewart *et al.* 2005).

The projected runoff-timing trends over the course of the 21st century are most pronounced in the Pacific Northwest, Sierra Nevada, and Rocky Mountain regions, where the eventual temporal centroid of streamflow (*i.e.* peak streamflow) change amounts to 20 to 40 days in many streams (Stewart *et al.* 2005). Although climate models diverge with respect to future trends in precipitation, there is widespread agreement that the trend toward lower SWE and earlier snowmelt will continue (Zhu *et al*. 2005, Vicuna *et al*. 2007). Thus, availability of water resources under future climate scenarios is expected to be most limited during the late summer (Gleick and Chalecki 1999, Miles *et al*. 2000). A one month advance in timing centroid of streamflow would also increase the length of the summer drought that characterizes much of western North America, with important consequences for water supply, ecosystem, and wildfire management (Stewart *et al.* 2005). These changes in peak streamflow timing and snowpack will negatively impact salmonid populations due to habitat loss associated with lower water flows, higher stream temperatures, and increased human demand for water resources. Conservative predictions of decreased water flows include an 18 to 38 percent loss of current salmonid freshwater habitat across the U.S. by 2090 (O'Neal 2002). Stream flows fed by snow melt, such as those in the Sierra-Nevada Range, are expected to be reduced while precipitation patterns change, also possibly resulting in increased scouring of streambeds and impacting fish passage, egg incubation, and juvenile rearing.

To understand and predict localized effects of climate change on individual river systems and salmon we must consider climactic patterns within the context of local effects of individual river systems, including: logging, water utilization, harvesting, hatchery interactions, and development (Bradford and Irvine 2000, Mayer 2008, Van Kirk and Naman 2008). Climate affects the physical, biological, and biogeochemical characteristics of the oceans and coasts at different time and space scales, modifying their ecological structure and functions. For example, predicting and understanding effects of global warming at the scale of a stream reach is confounded by solar radiation, relative humidity, wind speed, water depth, groundwater inflow, riparian shading, artificial heat inputs, and thermal conductivity of sediments (Tschaplinski 2000). Understanding effects of global warming at the watershed scale are also greatly influenced by anthropogenic activities. Total water withdrawals in California, Idaho, Oregon and Washington increased 82 percent between 1950 and 2000, with irrigation accounting for

nearly half of this increase (MacKichan 1951, Hutson *et al.* 2004), while during the same period climate change was taking place.

Coldwater fish may be directly affected by global warming in their freshwater habitat by: (1) higher water temperatures, (2) lower oxygen levels in the water, (3) slower growth rates, (4) increased susceptibility to predation and disease, and, (5) decreasing availability. Higher stream temperatures may also indirectly impact fishes by disrupting their prey base, *e.g.*, mayfly (*Ephemeroptera*), caddisfly (*Trichoptera*), and stonefly (*Plecoptera*) nymphs (NWF 2005). Stream flows fed by snowmelt are expected to be reduced while precipitation patterns change; excessive spring-run flooding events could increase scouring of streambed, further impacting fish by affecting passage and egg incubation.

Large-scale impacts of global warming include increases in sea level and sea-surface temperature, decreases in sea-ice cover, and changes in salinity, alkalinity, wave climate, and ocean circulation (IPCC 2001). Carbon uptake through circulation and mixing effects on nutrient availability and primary productivity may affect the efficiency of ocean uptake and storage capacity for greenhouse gases; and potential instability in the climate system caused by freshwater influx to the oceans and resultant weakening of the thermohaline circulation. Predicted temperatures under a double CO_2 climate are large enough to shift the position of the thermal limits into the Bering Sea by the middle of the next century, and could potentially severely restrict the area of the marine environment that would support fish growth (Welch *et al.* 1998).

15. Non-Native Invasive Species

As currently seen in the San Francisco estuary, non-native invasive species (NIS) can alter the natural food webs that existed prior to their introduction. Perhaps the most significant example in the Sacramento-San Joaquin Delta is illustrated by the introduction of 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 (*Eichornia crassipes*) and *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.

16. Additional Water Quality

Low DO levels are frequently observed in the portion of the Stockton deep water ship channel (DWSC) extending from Channel Point, downstream to Turner and Columbia Cuts. Over a 5-year period, starting in August 2000, DO levels at Rough and Ready Island (Dock 20 of the West Complex) have violated the DO criteria of 5 milligrams per liter (mg/l) for 297 days during the September through May migratory period for salmonids. Dissolved oxygen depressions occur during all migratory months, with significant events occurring from November through March when listed California Central Valley steelhead adults and smolts would be utilizing this portion of the San Joaquin River as a migratory corridor.

17. Summary

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 caused 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 tail-water 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. Fish hatcheries were created to mitigate for impacts resulting from Central Valley water management projects. The production of hatchery fish in mitigation hatcheries has been successful at providing fishing opportunities while causing unquantified impacts to natural salmonid populations from increased competition, genetic impacts, exposure to diseases, increased harvest, etc.

Land-use activities such as road and levee 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.

M. Factors Affecting the Current Status of the Southern Resident Killer Whale DPS

The major threats identified in the listing of the Southern Resident killer whale DPS were prey availability, pollution and contaminants, and effects from vessels and sound. Other factors

contributing to the long-term viability of the Southern DPS of Resident killer whale include: demographics, small population size, and vulnerability to oil spills.

1. Prey Availability and Quality

Healthy killer whale populations depend on adequate quantity and quality of food resources. Southern Residents consume a variety of fish species (22 species) and one species of squid (Scheffer and Slipp 1948; Ford *et al*. 1998, 2000; Ford and Ellis 2006; Saulitis *et al*. 2000), but salmon are identified as their preferred prey (96 percent of prey consumed during spring, summer and fall, from long-term study of resident killer whale diet; Ford and Ellis 2006). Southern and Northern Residents show a strong preference for Chinook salmon (72 percent of identified salmonids) during late spring-run to fall (Krahn *et al.* 2007, Ford and Ellis 2006, Krahn *et al.* 2002), however, chum salmon (23 percent) are also taken in significant amounts, especially in autumn. Other salmonids eaten include coho salmon (2 percent), pink salmon (3 percent), steelhead (less than 1 percent), and sockeye salmon (*O. nerka* less than 1 percent). Non-salmonid prey fishes include Pacific herring, sablefish (*Anoplopoma fimbria*), Pacific halibut (*Hippoglossus stenolepis*), quillback rockfish (*S. maliger*) and yelloweye rockfish (*S. ruberrimus*).

Chinook salmon are the preferred salmonid prey of Southern and Northern Residents. Despite the much lower abundance of Chinook salmon in the study area in comparison to other salmonids (primarily sockeye salmon), Chinook salmon were preferentially consumed. A preference for Chinook salmon probably results because of the species' large size, high fat and energy content (Stansby 1976, Winship and Trites 2003) and year-round occurrence in the area. The preference for Chinook salmon may also relate to size-selectivity, as killer whales selectively capture and consume older (*i.e*., larger) than average Chinook salmon (Ford and Ellis 2006). Genetic analysis of fecal and prey samples from the research indicates that Southern Residents consume Fraser River-origin Chinook salmon, as well as salmon from Puget Sound, Washington and Oregon coasts, the Columbia River, and Central Valley California (Hanson *et al.* 2007, NWFSC unpubl. data). The vast majority of salmon produced in the Central Valley are of hatchery origin.

Size of individual salmon could affect the foraging efficiency by Southern Residents. As discussed above, available data suggests that Southern Residents prefer larger prey. In general, the literature indicates a historical decrease in salmon age, size, or size at a given age. Hypotheses advanced to explain declining body size are life history changes related to the origin of fishes (*i.e.*, hatchery or natural), density-dependent growth, and selection of larger, older fish by fisheries. Fish size is also influenced by environmental conditions.

NMFS estimated that the Southern Resident population could need approximately 3.74 billion kilocalories annually from Chinook salmon across their coastal range (NMFS 2008a). This estimate incorporated the 2008 age and sex structure of the Southern Resident population, and assumed a high diet composition of Chinook salmon, as indicated in research. The size and energy content of Chinook salmon vary by age, stock, and season, among other factors. Based on a size range of Chinook salmon (FL 465 to 777 mm) that Southern Residents are likely to select (NMFS 2008a), we evaluated a range in kilocalories per Chinook salmon (2,121 to 10,531 kilocalories) based on a regression model of fork length to kilocalories (O'Neill *et al*. 2006).

Based on these estimates, Southern Residents may need from approximately 356,000 to 1.76 million Chinook salmon annually across their coastal range.

It is uncertain to what extent long-term or more recent declines in salmon abundance contributed to the decline of the Southern Resident DPS, or whether current salmon levels are adequate to support the survival and recovery of the Southern Residents. When prey is scarce, whales must spend more time foraging than when it is plentiful. Increased energy expenditure and prey limitations could lead to lower reproductive rates and higher mortality rates. Food scarcity could cause whales to draw on fat stores, mobilizing contaminants stored in their fat and affecting reproduction and immune function (discussed further below). Ford *et al*. (2005) correlated coast wide reduction in Chinook salmon abundance (Alaska, British Columbia, and Washington) with decreased survival of resident killer whales (Northern and Southern Residents), but changes in killer whale abundance have not been definitively linked to local areas or changes in specific salmon stock groups. Ward *et al*. (2009) correlated Chinook salmon abundance trends with changes in fecundity of Southern Residents, and reported the probability of calving differed by 50 percent between years of low and high Chinook salmon abundance.

Human influences have had profound impacts on the abundance of many prey species in the northeastern Pacific during the past 150 years, including salmon. The health and abundance of wild salmon stocks have been negatively affected by altered or degraded freshwater and estuarine habitat (*i.e*., hydro-power systems, urbanization, forestry and agriculture), harmful artificial propagation practices, and over-fishing (see Status sections for Chinook salmon, above). While wild salmon stocks have declined in many areas, hatchery production has been generally strong. Southern Residents likely consume both natural and hatchery salmon (Barre 2008). Hatchery production contributes a significant component of the salmon returning to watersheds within the range of Southern Residents (Pacific Salmon Commission Joint Chinook salmon Technical Committee 2008), and production of hatchery salmon has off-set some of the historical declines in the abundance of wild salmon within the range of Southern Residents. The best available information does not indicate that Southern Residents would be affected differently by consuming natural or hatchery salmon [*i.e*., no general pattern of differences in size, run-timing, or ocean distribution (*e.g*., Nickum *et al*. 2004, Weitkamp and Neely 2002)], however, the NMFS Recovery Plan for Southern Resident Killer Whales (NMFS 2008a) states a need for research on the extent of feeding on hatchery salmon, because "the characteristics (*e.g.*, energy content and contaminant loads) of hatchery salmon may differ somewhat from those of wild salmon. This information may also help evaluate whether future changes in hatchery management and production levels will impact the whales." Although hatchery production of Chinook salmon likely comprise a considerable portion of the diet of Northern and Southern Residents, hatcheries also pose risks to wild salmon populations, and healthy wild salmon populations are important to the long-term maintenance of prey populations available to Southern Residents.

Salmon abundance is also substantially affected by climate variability in freshwater and marine environments, particularly by conditions during early life-history stages of salmon (review in NMFS 2008c). Sources of variability include inter-annual climatic variations (*e.g*., El Niño and La Niña), longer-term cycles in ocean conditions (*e.g*., PDO, Mantua *et al*. 1997), and ongoing global climate change. For example, climate variability can affect ocean productivity in the

marine environment and water storage (*e.g.*, snow pack) and in-stream flow in the freshwater environment. Early life-stage growth and survival of salmon can be negatively affected when climate variability results in conditions that hinder ocean productivity (*e.g.*, Scheuerell and Williams 2005) and/or water storage (*e.g.*, Independent Scientific Advisory Board 2007) projects in freshwater systems. The availability of adult salmon as prey of Southern Residents may be reduced in years following unfavorable conditions to the early life-stage growth and survival of salmon.

The quality of salmon as food source of resident killer whale is affected by contaminants. Many types of chemicals are toxic when present in high concentrations, including organochlorines, PAHs, and heavy metals. Emerging contaminants such as brominated flame retardants (BFRs) and perfluorinated compounds are increasingly being linked to harmful biological impacts as well. Persistent contaminants, such as organochlorines, are ultimately transported to the oceans, where they enter the marine food chain. Contaminants enter fresh and marine waters and sediments from numerous sources, but are typically concentrated near populated areas of high human activity and industrialization. Chinook salmon contain higher levels of some contaminants (*i.e.*, PCBs) than other salmon species (O'Neill *et al*. 2005). Only limited information is available for contaminant levels of Chinook salmon along the west coast (*i.e.*, higher PCB and PBDE levels may distinguish Puget Sound origin stocks, whereas higher DDT-signature may distinguish California origin stocks; Krahn *et al*. 2007). Although the ban of several contaminants, such as DDT, by Canada and the United States in the 1970s resulted in an initial decline in environmental contamination, Southern Residents may be slow to respond to these reductions because of their body size and the long duration of exposure over the course of their life spans, which is up to 80-90 years for females and 60 to 70 years for males (Hickie *et al*. 2007).

Recent studies have documented high concentrations of PCBs, DDTs, and polybrominated diphenylethers (PBDE) in killer whales (Ross *et al*. 2000, Ylitalo *et al*. 2001, Reijnders and Aguilar 2002, Krahn *et al*. 2004). Organochlorines are also highly fat soluble, and accumulate in the fatty tissues of animals (O'Shea 1999, Reijnders and Aguilar 2002). Bioaccumulation through trophic transfer allows relatively high concentrations of these compounds to build up in top-level marine predators, such as marine mammals (O'Shea 1999). High levels of persistent organic pollutants (POPs) such as PCBs and DDT are documented in Southern Residents (Ross *et al*. 2000, Ylitalo *et al*. 2001). As top predators, when killer whales consume contaminated prey they accumulate the contaminants in their blubber. Killer whales are candidates for accumulating high concentrations of organochlorines because of their high position in the food web and long life expectancy (Ylitalo *et al*. 2001, Grant and Ross 2002). Their exposure to these compounds occurs exclusively through their diet (Hickie *et al*. 2007). When prey is scarce, killer whales metabolize their blubber and the contaminants are mobilized (Krahn *et al*. 2002). Nursing females transmit large quantities of contaminants to their offspring. The mobilized contaminants can reduce the killer whales' resistance to disease and can affect reproduction.

2. <u>Sound and Vessel Effects</u>

Vessels have the potential to affect whales through the physical presence and activity of the vessel, increased underwater sound levels generated by boat engines, or a combination of these factors. Vessel strikes are rare, but do occur and can result in injury or mortality (Gaydos and

Raverty 2007). In addition to vessels, underwater sound can be generated by a variety of other human activities, such as dredging, drilling, construction, seismic testing, and sonar (Richardson *et al*. 1995, Gordon and Moscrop 1996, National Research Council 2003). Impacts from these sources can range from serious injury and mortality to changes in behavior.

Killer whale mortalities from vessel strikes have been reported in both Northern and Southern Resident killer whale populations. Although rare, collisions between vessels and killer whales could result in serious injury or death. Other impacts from vessels are less obvious, but may negatively affect the health of killer whales. The presence of vessels may alter killer whale behavior, including faster swimming, less predictable travel paths, shorter or longer dive times, moving into open water, and altering normal behavioral patterns at the surface (Kruse 1991, Williams *et al.* 2002a, Bain *et al*. 2006, Lusseau *et al.* 2009, Williams *et al*. 2009, Noren In Review). Chemicals such as unburned fuel and exhaust may be inhaled or ingested, which could contribute to toxic loads (Bain *et al*. 2006). Noise from vessel traffic may mask echolocation signals (Bain and Dahlheim 1994, Holt 2008), which reduces foraging efficiency or interferes with communication. The sound from vessels may also contribute to stress (Romano *et al*. 2003) or affect distribution of animals (Bejder *et al*. 2006). Southern Residents are the primary driver for a multi-million dollar whale watching industry in the Pacific Northwest. Commercial whale watching vessels from both the U.S. and Canada view Southern Residents when they are in inland waters in summer months. Mid-frequency sonar generated by military vessels also has the potential to disturb killer whales. To date, there are no directed studies concerning the impacts of military mid-frequency sonar on killer whales, but observations of unusual whale behavior during an event that occurred in the Strait of Juan de Fuca and Haro Strait in 2003 illustrate that mid-frequency sonar can cause behavioral disturbance (NMFS 2004).

Killer whales rely on their highly developed acoustic sensory system for navigating, locating prey, and communicating with other individuals. Increased levels of anthropogenic sound from vessels and other sources have the potential to mask echolocation and other signals used by the species, as well as to temporarily or permanently damage hearing sensitivity. Exposure to sound may therefore be detrimental to survival by impairing foraging and other behavior, resulting in a negative energy balance (Bain and Dahlheim 1994; Gordon and Moscrop 1996; Erbe 2002; Williams *et al*. 2002a, 2002b, 2006; Holt 2008). In other cetaceans, hormonal changes indicative of stress have been recorded in response to intense sound exposure (Romano *et al*. 2003). Chronic stress is known to induce harmful physiological conditions including lowered immune function, in terrestrial mammals and likely does so in cetaceans (Gordon and Moscrop 1996).

3. <u>Oil Spills</u>

Exposure to petroleum hydrocarbons released into the marine environment from oil spills and other discharge sources represents another potentially serious health threat to killer whales in the northeastern Pacific. Oil spills are also potentially destructive to prey populations and therefore may adversely affect killer whales by reducing food availability. Marine mammals are generally able to metabolize and excrete limited amounts of hydrocarbons, but acute or chronic exposure poses greater toxicological risks (Grant and Ross 2002). In marine mammals, acute exposure can cause changes in behavior and reduced activity, inflammation of the mucous membranes, lung congestion, pneumonia, liver disorders, and neurological damage (Geraci and St. Aubin 1990). Vapors inhaled at the water's surface and hydrocarbons ingested during feeding are the

likely pathways of exposure. Matkin (1994) reported that killer whales did not attempt to avoid oil-sheened waters following the Exxon Valdez oil spill in Alaska. Retrospective evaluation shows it is highly likely that oil exposure contributed to deaths of resident and transient pods of killer whales that frequented the area of the massive Exxon Valdez oil spill in Prince William Sound, Alaska, in 1989 (Matkin *et al*. 2008). The cohesive social structure of the Southern Residents puts them at risk for a catastrophic oil spill that could affect the entire DPS when they are all in the same place at the same time.

N. Current Viability of Listed Species

To predict the effects of a proposed action on an imperiled species it is necessary to understand the likelihood of the species in question becoming viable, and whether the proposed action can be expected to reduce this likelihood. The abundance of spawners is just one of several criteria that must be met for a population to be considered viable. McElhany *et al*. (2000) acknowledged that a viable salmonid population at the ESU scale is not merely a quantitative number that needs to be attained. Rather, for an ESU to persist, populations within the ESU must be able to spread risk and maximize future potential for adaptation. ESU viability depends on the number of populations and subunits within the ESU, their individual status, their spatial arrangement with respect to each other and sources of catastrophic disturbance, and diversity of the populations and their habitats (Lindley *et al*. 2007). Populations comprise diversity groups, which are intended to capture important components of habitat, life history or genetic diversity that contribute to the viability of the ESU (Hilborn et al. 2003 *op. cit*. Lindley *et al.* 2007, Bottom *et al*. 2005 *op. cit*. Lindley *et al*. 2007). Lindley *et al*. (2007) suggest that at least two viable populations within each diversity group are required to ensure the viability of the diversity group, and hence, the ESU/DPS. The draft Central Valley Recovery Plan (NMFS 2009b) has identified additional criteria for reaching viability at the ESU/DPS level.

1. Sacramento River Winter-run Chinook salmon ESU

To determine the likelihood of the Sacramento River winter-run Chinook salmon ESU becoming viable, we used the historical population structure of winter-run Chinook salmon presented in Lindley *et al*. (2004) and the concept of VSP for evaluating populations developed by McElhany *et al.* (2000). Lindley *et al.* (2004) identified four historical populations within the Sacramento River winter-run Chinook salmon ESU, all independent populations, defined as those sufficiently large to be historically viable in isolation and whose demographics and extinction risk were minimally influenced by immigrants from adjacent populations (McElhany *et al*. 2000). All four independent populations, however, are extinct in their historical spawning ranges. Three (Little Sacramento River; Pit-Fall rivers; and McCloud River) are blocked by the impassable Keswick and Shasta dams (Lindley *et al*. 2004), and Sacramento River winter-run Chinook salmon no longer return to Battle Creek on a regular basis (Lindley *et al*. 2007).

Lindley *et al*. (2007) applied the VSP concept to the Sacramento River winter-run Chinook salmon ESU and provided various quantitative criteria to evaluate the risk of extinction (Table 5). A population must meet all the low-risk thresholds to be considered viable. The following provides the evaluation of the likelihood of Sacramento River winter-run Chinook salmon ESU becoming viable based on the VSP parameters of population size, population growth rate, spatial structure, and diversity. These specific parameters are important to consider because they are

predictors of extinction risk, and the parameters reflect general biological and ecological processes that are critical to the growth and survival of salmon (McElhany *et al.* 2000).

a. *Population Size*

Knowledge of population size provides an indication of the type of extinction risk that a population faces. For instance, smaller populations are at a greater risk of extinction than large populations because the processes that affect populations operate differently in small populations than in large populations (McElhany *et al.* 2000). One risk of low population sizes is depensation. Depensation occurs when populations are reduced to very low densities and per capita growth rates decrease as a result of a variety of mechanisms [*e.g.,* failure to find mates and therefore reduced probability of fertilization, failure to saturate predator populations (Liermann and Hilborn 2001)]. The winter-run Chinook salmon population was following an increasing trend of adult escapement from the mid-1990s until 2006. In 2007, the winter-run population declined precipitously. Low adult escapement was repeated in 2008, 2009, 2010, and at its lowest since 1994 in 2011. Likewise, the 5-year moving average cohort replacement rate was relatively stable since the late 1990s, with each cohort approximately doubling in size. However, the cohort replacement rate of 6.08 in 2003 buffered the effect of the significant decline in the cohort replacement rate of 0.32 in 2007. This is evident in the 5-year moving average cohort replacement rate ending in 2008, when the 6.08 cohort replacement rate in 2003 is not factored in. Lindley *et al*. (2007) indicated that current abundance of winter-run Chinook salmon satisfies the moderate-risk criteria for population extinction. However, they also acknowledged that the previous precipitous decline to a few hundred spawners per year in the early 1990s would have qualified it as high risk at that time, and the 1976-77 drought would have qualified as a high-risk catastrophe. In consideration of the almost 7-fold decrease in population in 2007, coupled with the dry water year type in 2007, followed by the critically dry water year type in 2008 (which could be qualified as a high-risk catastrophe) and low abundance in 2008 through 2011, NMFS concludes that winter-run are currently at a high risk of extinction based on population size.

b. *Population Growth Rate*

The productivity of a population (*i.e.,* production over the entire life cycle) can reflect conditions (*e.g.,* environmental conditions) that influence the dynamics of a population and determine abundance. In turn, the productivity of a population allows an understanding of the performance of a population across the landscape and habitats in which it exists and its response to those habitats (McElhany *et al.* 2000). In general, declining productivity equates to declining population abundance. McElhany *et al.* (2000) suggested a population's natural productivity should be sufficient to maintain its abundance above the viable level (a stable or increasing population growth rate). This guideline seems reasonable in the absence of numeric abundance targets.

Winter-run Chinook salmon have declined substantially from historic levels. The one remaining population spawning in the mainstem Sacramento River constitutes the entire ESU. Although the population growth rate (indicated by the cohort replacement rate) increased through 2006, it drastically decreased from 2007 through 2011, despite the near complete closure of the ocean fishery, indicating that the population is not replacing itself, and is at a high risk of extinction in the foreseeable future.

Table 5. Criteria for assessing the level of risk of extinction for populations of Pacific salmonids (reproduced from Lindley *et al.* 2007).

	Risk of Extinction		
Criterion	High	Moderate	Low
Extinction Risk from PVA	> 20 percent within 20 years -or any ONE of-	>5 percent within 100 years -or any ONE of-	<5 percent within 100 years -or ALL of-
Population size[a]	$N_e \leq 50$ -or- $N \leq 250$	$50 < N_e \leq 500$ -or- $250 < N \leq 2500$	$N_e \geq 500$ -or- $N \geq 2500$
Population decline	Precipitous decline[b]	Chronic decline or depression[c]	No decline apparent or probable
Catastrophe rate and effect[d]	Order of magnitude decline within one generation	Smaller but significant decline[e]	not apparent
Hatchery influence[f]	High	Moderate	Low

[a]Census size N can be used if direct estimates of effective size N_e are not available, assuming ne/N=0.2

[b]Decline within last two generations to annual run size $\leq$ 500 spawners, or run size > 500 but declining at $\geq$ 10 percent per year. Historically small but stable population not included.

[c]Run size has declined to $\leq$ 500, but not stable

[d]Catastrophes occurring within the last 10 years.

[e]Decline < 90 percent but biologically significant.

[f]See Figure 1 for assessing hatchery impacts

c. *Spatial Structure*

In general, there is less information available on how spatial processes relate to salmonid viability than there is for the other VSP parameters (McElhany *et al.* 2000). Understanding the spatial structure of a population is important because spatial structure can affect evolutionary processes and, therefore, alter the ability of a population to adapt to spatial or temporal changes in the species' environment (McElhany *et al*. 2000). The spatial structure of winter-run Chinook salmon resembles that of a panmictic population, where there are no subpopulations, and every

mature male is equally likely to mate with every mature female. The four historical independent populations of winter-run have been reduced to one population, resulting in a significant reduction in their spatial diversity. An ESU comprised of one population is not viable because it is unlikely to be able to adapt to significant environmental changes. A single catastrophe (*e.g.*, volcanic eruption of Mount Lassen, prolonged drought which depletes the cold water pool at Lake Shasta, or some related failure to manage cold water storage, spill of toxic materials, or a disease outbreak) could extirpate the entire winter-run Chinook salmon ESU if its effects persisted for three or more cohorts. In addition, the one remaining population is artificially maintained in the Sacramento River by a regulated, finite cold-water pool behind Shasta Dam. The majority of winter-run Chinook salmon spawn as 3-year-olds, so a single catastrophe with effects that persist for at least 3 years would affect all of the winter-run cohorts. Therefore, NMFS concludes that winter-run Chinook salmon are at a high risk of extinction based on spatial structure. The draft Central Valley Recovery Plan (NMFS 2009b) has determined that reintroducing populations back into historically occupied areas like Battle Creek and the McCloud River would significantly benefit the spatial structure of the ESU.

d. *Diversity*

Diversity, both genetic and behavioral, is critical to success in a changing environment. Salmonids express variation in a suite of traits, such as anadromy, morphology, fecundity, run timing, spawn timing, juvenile behavior, age at smolting, age at maturity, egg size, developmental rate, ocean distribution patterns, male and female spawning behavior, and physiology and molecular genetic characteristics. The more diverse these traits (or the more these traits are not restricted), the more adaptable a population is, and the more likely that individuals, and therefore the species, would survive and reproduce in the face of environmental variation (McElhany *et al.* 2000). However, when this diversity is reduced due to loss of entire life history strategies or to loss of habitat used by fish exhibiting variation in life history traits, the species is in all probability less able to survive and reproduce given environmental variation.

The primary factor affecting the diversity of winter-run Chinook salmon is the limited area of suitable spawning habitats downstream of Keswick Dam. This specific and narrow range of available spawning habitat limits the flexibility and variation in spawning locations for winter-run Chinook salmon to tolerate environmental variation. For example, a catastrophe on the mainstem Sacramento River could affect the entire population, and therefore, ESU. However, with the majority of spawners being 3 years old, winter-run Chinook salmon do reserve some genetic and behavioral variation in adjacent year classes to buffer against catastrophic occurrences in the freshwater environment; in any given year, two cohorts exist in the marine environment, and therefore, the entire ESU is not simultaneously exposed to the same freshwater stressors.

The Livingston Stone NFH is a conservation hatchery operated to maximize genetic diversity and minimize domestication of the offspring produced in the hatchery. However, the winter-run Chinook salmon propagation program still faces some of the same concerns as other hatcheries in reducing the diversity of the naturally-spawning population. Therefore, Lindley *et al*. (2007) characterizes hatchery influence as a looming concern with regard to diversity. Even with a small contribution of hatchery fish to the natural spawning population, hatchery contributions could compromise the long term viability and extinction risk of winter-run.

NMFS concludes that the current diversity in this ESU is much reduced compared to historic levels, and that winter-run Chinook salmon are at a high risk of extinction based on the diversity VSP parameter.

e. *Summary of the Current Viability of the Sacramento River Winter-run Chinook salmon ESU*

An age-structured density-independent model of spawning escapement by Botsford and Brittnacker (1998 *op. cit.* Good *et al*. 2005) assessing the viability of winter-run Chinook salmon found the species was certain to fall below the quasi-extinction threshold of three consecutive spawning runs with fewer than 50 females (Good *et al*. 2005). Lindley and Mohr (2003) assessed the viability of the population using a Bayesian model based on spawning escapement that allowed for density dependence and a change in population growth rate in response to conservation measures. This analysis found a biologically significant expected quasi-extinction probability of 28 percent. Of primary concern is that only one population exists, and it depends on cold-water releases from Shasta Dam, which could be vulnerable to a prolonged drought (Good *et al*. 2005).

Recently, Lindley *et al.* (2007) determined that the winter-run Chinook salmon population, which is confined to spawning 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, data used for Lindley *et al*. (2007) did not include the significant decline in adult escapement numbers in 2007 to 2011, and thus, does not reflect the current status of the population size or the recent population decline.

Lindley *et al.* (2007) also states that the Sacramento River winter-run Chinook salmon ESU 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 reestablished in native spawning areas of 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). Based on the above descriptions of the population viability parameters, NMFS believes that the Sacramento River winter-run Chinook salmon ESU is currently not viable.

2. <u>Central Valley Spring-run Chinook salmon ESU</u>

The Butte, Deer, and Mill creek populations of spring-run Chinook salmon are in the Northern Sierra Nevada diversity group. Lindley *et al*. (2007) indicated that spring-run Chinook salmon populations in Butte and Deer Creeks had a low risk of extinction, 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 is at moderate extinction risk according to the PVA model, but appears to satisfy the other viability criteria for low-risk status. However, the Central Valley spring-run Chinook salmon ESU fails to meet the "representation and redundancy rule," since the Northern Sierra Nevada is the only diversity group in the ESU that contains demonstrably viable populations out of at least three diversity groups that

historically contained them. Independent populations of spring-run Chinook salmon only occur within the Northern Sierra Nevada diversity group. The Northwestern California diversity group contains a few ephemeral populations of spring-run Chinook salmon that are likely dependent on the Northern Sierra Nevada populations for their continued existence. The spring-run Chinook salmon populations that historically occurred in the Basalt and Porous Lava diversity group and Southern Sierra Nevada diversity group have been extirpated. Over the long term, the three 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 the Deer, Mill, and Butte creek watersheds due to their close proximity to each other. One large catastrophic event could eliminate all three populations.

In order to determine the current likelihood of the Central Valley spring-run Chinook salmon ESU becoming viable, we used the historical population structure of spring-run Chinook salmon presented in Lindley *et al*. (2007) and the concept of VSP for evaluating populations described by McElhany *et al.* (2000). While McElhany *et al.* (2000) introduced and described the concept of VSP, Lindley *et al*. (2007) applied the concept to the Central Valley spring-run Chinook salmon ESU. Lindley *et al*. (2004) identified 26 historical populations within the spring-run Chinook salmon ESU; 19 were independent populations, and 7 were dependent populations. Of the independent populations of spring-run Chinook salmon that occurred historically, only the Deer, Mill, and Butte creek populations remain. Extant dependent populations occur in Battle, Antelope, Big Chico, Clear, Beegum, and Thomes creeks, as well as in the Yuba River, the Feather River below Oroville Dam, and in the mainstem Sacramento River below Keswick Dam.

Following is an evaluation of the likelihood of the threatened Central Valley spring-run Chinook salmon ESU becoming viable based on the VSP parameters of population size, population growth rate, spatial structure, and diversity.

a. *Population Size*

Spring-run Chinook salmon declined drastically in the mid- to late 1980s before stabilizing at very low levels in the early to mid-1990s. Since the late 1990s, there does not appear to be a trend in basin-wide abundance, having fluctuated from approximately 25,000 fish in 1999 to slightly more than 10,000 fish in 2008. Abundance is generally dominated by the Butte Creek population. Other independent and dependent populations are smaller. A recent decline has been observed, with the 5-year moving average of the tributary populations reaching a low of 3,961 (the lowest since 1997). The cohort replacement rate behaved similarly, falling below 1.0 in the 4 previous years, in parallel with the reduced escapement numbers, with the lowest cohort replacement rate of 0.45 in 2011. The 5-year moving average cohort replacement rate, however, had remained above 1.0 since 1993 until 2008.

b. *Population Growth Rate*

Cohort replacement rates (CRR) are indications of whether a cohort is replacing itself in the next generation. As mentioned in the previous subsection, the cohort replacement rate since the late 1990s has fluctuated substantially on a year-to-year basis. A trend of decreasing CRRs since the

mid- to late-1990s indicates a trend of decreasing abundance. The 5-year moving average of population estimate indicated an increasing population trend from the mid-1990s until 2005 at which point the population has decreased in six consecutive years.

c. *Spatial Structure*

Lindley *et al*. (2007) indicated that of the 19 independent populations of Central Valley spring-run Chinook salmon that occurred historically, only three (Butte, Mill, and Deer creeks) remain, and their current distribution makes the spring-run Chinook salmon ESU vulnerable to catastrophic disturbance. Butte, Mill, and Deer creeks all occur in the same biogeographic region (diversity group), whereas historically, independent spring-run Chinook salmon populations were distributed throughout the Central Valley among at least three diversity groups (*i.e*., basalt and porous lava, northern Sierra Nevada, and southern Sierra Nevada). In addition, dependent spring-run Chinook salmon populations historically persisted in the Northwestern California diversity group (Lindley *et al*. 2004). Currently, there are dependent populations of spring-run Chinook salmon in the Big Chico, Antelope, Clear, Thomes, Battle, and Beegum creeks, and in the Sacramento, Feather, and Yuba rivers. As noted earlier, extant populations in the Feather River and mainstem Sacramento River do not likely reflect pure spring-run Chinook salmon lineage due to hybridization with fall-run Chinook salmon (Lindley *et al*. 2007).

d. *Diversity*

Diversity, both genetic and behavioral, provides a species the opportunity to adapt to environmental changes. As a species' abundance decreases, and spatial structure of the ESU is reduced, a species has less flexibility to track changes in the environment. Spring-run Chinook salmon have been entirely extirpated from the basalt and porous lava region and the southern Sierra Nevada region. The only viable and independent populations (*i.e*., Mill, Deer, and Butte creeks) of spring-run Chinook salmon are limited to the northern Sierra Nevada region, and a few dependent populations are found in the Northwestern California region. Additionally, a small population in Battle Creek has been reestablished, persisting over the last 15 years. A single catastrophe, for example, the eruption of Mount Lassen, a large wildland fire at the headwaters of Mill, Deer, and Butte creeks, or a drought, poses a significant threat to the extinction risk of the ESU that would have been ameliorated if the ESU's spatial structure and diversity were greater. Spring-run Chinook salmon, as with winter-run Chinook salmon, reserve some resilience by maintaining genetic variation within adjacent year classes. In any given year, at least two cohorts are in the marine environment concomitantly, and therefore, not exposed to the same environmental stressors as their freshwater cohorts.

Although spring-run Chinook salmon produced at the FRFH are part of the ESU (June 28, 2005, 70 FR 37160), hatchery practices have compromised the genetic diversity of naturally-spawned spring-run Chinook salmon in the Feather River due to a history of hybridization with fall-run Chinook salmon. More than 523,000 FRFH spring-run Chinook salmon fry were planted at the base of Whiskeytown Dam during the 3-year period 1991 to 1993 (NMFS 2009a). The fact that these hatchery fish behave more like fall-run (spawn later than spring-run Chinook salmon in Deer, Mill, and Butte creeks), likely increases introgression of the spring- and fall- runs, and reduces diversity.

e. *Summary of the Current Viability of the Central Valley Spring-run Chinook salmon ESU*

The initial factors that led to the decline of Central Valley spring-run Chinook salmon were related to the loss of upstream habitat caused by mining activities and impassible dams. Since this initial loss of habitat, other factors have contributed to the decline of Central Valley spring-run Chinook salmon and affected the ESU's ability to recover. These include a combination of physical, biological, and management factors such as climatic variation, water management, hybridization, predation, and harvest (CDFG 1998). Protective measures likely have led to recent increases in abundance of spring-run Chinook salmon in Butte Creek and Deer creeks, where spring-run Chinook salmon populations are at low risk of extinction according to population viability analysis (PVA) and other viability criteria. Mill Creek is at moderate extinction risk according to the PVA, but appear to satisfy the other viability criteria for low-risk status (Lindley *et al*. 2007). As a whole, the Central Valley spring-run Chinook salmon ESU remains substantially below levels observed from the 1960s through 1990. Spring-run Chinook salmon fail the representation and redundancy rule for ESU viability, as the current distribution of independent populations has been severely restricted to only the Northern Sierra Nevada diversity group. The current population structure of the Northern Sierra Nevada diversity group is dominated by Butte Creek spring-run Chinook salmon, which currently comprise the majority of returning fish. Threats to the Central Valley spring-run Chinook salmon ESU continue to persist, and the ESU continues to display broad fluctuations in abundance. Therefore, the Central Valley spring-run Chinook salmon ESU is at moderate risk of extinction in 100 years.

3. <u>Current Viability of the California Central Valley steelhead DPS</u>

The VSP concept (McElhany *et al*. 2000) was used to determine the likelihood of the DPS of California Central Valley steelhead becoming viable. McElhany *et al.* (2000) introduced and described the concept of VSP, and Lindley *et al*. (2007) applied the concept to the California Central Valley steelhead DPS. We used the historical population structure of California Central Valley steelhead presented in Lindley *et al*. (2006, 2007) and the concept of VSP for evaluating populations described by McElhany *et al.* (2000). Following is an evaluation of the likelihood of the threatened California Central Valley steelhead DPS becoming viable based on the VSP parameters of population size, population growth rate, spatial structure, and diversity.

a. *Population Size*

Estimated natural California Central Valley steelhead escapement in the upper Sacramento River has declined substantially from 1967 through 1993. There is still a nearly complete lack of steelhead monitoring in the Central Valley (Good *et al*. 2005), and therefore, data are lacking regarding a definitive population size for California Central Valley steelhead. Efforts are underway to improve this deficiency, and a long term adult escapement monitoring plan is being considered (NMFS 2011c). However, the little data that exist indicate that the California Central Valley steelhead population is substantially reduced compared to historic levels and continues to decline (Good *et al*. 2005). Hatchery production and returns are dominant over wild 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 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.

b. *Population Growth Rate*

California Central Valley steelhead has shown a pattern of a negative growth rate since the late 1960s (Good *et al*. 2005) provided no indication that this trend has changed since the last California Central Valley steelhead population census in 1993. 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.

c. *Spatial Structure*

Lindley *et al*. (2006) identified 81 historical and independent populations within the California Central Valley steelhead DPS. These populations form 8 diversity groups, based on the similarity of the habitats they occupied for spawning and rearing. About 80 percent of the habitat that was historically available to California Central Valley steelhead is now behind impassable dams, and 38 percent of the populations have lost all of their habitats. Although much of the habitat has been blocked by impassable dams or degraded, small populations of California Central Valley steelhead are still found throughout habitat available in the Sacramento River and many of the tributaries, and some of the tributaries to the San Joaquin River (Good *et al.* 2005, NMFS 2011c, Zimmerman *et al.* 2009). The efforts to provide passage of salmonids over impassable dams, as recommended in the draft Central Valley Recovery Plan would increase the spatial diversity of Central Valley Steelhead.

d. *Diversity*

Diversity, both genetic and behavioral, provides a species the opportunity to survive environmental changes. California Central Valley steelhead exhibit the most diverse life history strategies of the listed Central Valley anadromous salmonid species. In addition to being iteroparous, they reside in freshwater for 1 to 3 years before emigrating to the ocean (Moyle 2002). However, as the species' abundance decreases, and spatial structure of the DPS is reduced, it has less flexibility to adapt to changes in the environment. California Central Valley steelhead abundance and growth rate continue to decline, largely the result of a significant reduction in the diversity of habitats available (Lindley *et al*. 2006). The resilience of California Central Valley steelhead is also compromised by spawning with hatchery-origin fish. Multiple generations of hatchery propagation has undoubtedly resulted in the perpetuation of domesticated traits and decreasing adaptedness to the natural environment, thereby placing the populations at high risk of extinction (Lindley *et al*. 2007).

e. *Summary of the Current Viability of the California Central Valley steelhead DPS*

Good *et al.* (2005) indicated that prior population census estimates completed in the 1990s found the California Central Valley steelhead spawning population above RBDD had a fairly strong negative population growth rate and small population size. Good *et al.* (2005) indicated the decline was continuing, as evidenced by new information (Chipps Island trawl data). California Central Valley steelhead populations generally show a continuing decline and overall low abundances. Hatchery-origin steelhead continue to comprise the majority of returns to the Central Valley. Hatchery steelhead production within this DPS also raises concerns about the potential ecological interactions between introduced stocks and native stocks. The future of

California Central Valley steelhead is uncertain due to limited data concerning their status. Lindley *et al.* (2007) concluded that there is sufficient evidence to suggest that the DPS is at moderate to high risk of extinction.

4. Current Viability of the Southern DPS of North American Green Sturgeon

The Southern DPS of North American green sturgeon has not been analyzed to characterize the status and viability as has been done in recent efforts for Central Valley salmonid populations (Lindley *et al*. 2006, Good *et al.* 2005). Since the general VSP parameters used for assessing salmonids are applicable to any population, NMFS will use the same parameters to assess 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.

a. *Population Size*

The current population status of the Southern DPS of green sturgeon is unknown (Beamesderfer *et al.* 2007, Adams *et al.* 2007). It is believed, based on captures of green sturgeon during surveys for the sympatric white sturgeon in the San Francisco Bay estuary that the population is relatively small (USFWS 1995), ranging from several hundred to a few thousand adults. However, these estimates are very uncertain, and limited by the inherent biases of the sampling methods. The sole population of the Southern DPS of green sturgeon spawns within the Sacramento River basin and is believed to spawn primarily in the mainstem of the Sacramento River between Keswick Dam (RM 302) and Hamilton City (RM 200). Israel (2006) indicated that between 2002 and 2005, a range of 18 to 42 adult green sturgeon were estimated to have bred above RBDD, based on genetic analysis of captured larvae in the Sacramento River.

b. *Population Growth Rate*

Recruitment data for the Southern DPS of green sturgeon are essentially nonexistent. Incidental catches of larval green sturgeon in the mainstem of the upper Sacramento River and juvenile fish at the CVP and SWP pumping facilities in the South Delta suggest that green sturgeon are successful at spawning, but that annual year class strength may be highly variable, as adults may only spawn every 3-5 years (Beamesderfer *et al*. 2007, Adams *et al*. 2007). Recent declines in the number of larvae captured in the RSTs near the RBDD may indicate a reduction in spawning success in the past several years, with resulting depressions in the year class strengths for those years. Green sturgeon are iteroparous and long-lived, so that spawning failure in any 1 year may be rectified in a succeeding spawning year. This would give the potential for a succession of multiple, strong year classes, interspersed with weaker year classes.

c. *Spatial Structure*

Until 2011, Southern DPS green sturgeon spawning had only been confirmed in one principle spawning area in the Sacramento River. In 2011, Van Eenennaam (2011) confirmed green sturgeon spawning occurred in the Feather River. In 2011, there were documented observations of green sturgeon exhibiting spawning behavior in the Yuba River (Bergman 2011). Remaining spawning sites are, for the most part, outside of the historical spawning area for the DPS. The recent habitat evaluations conducted in the upper Sacramento River for salmonid recovery

suggest that significant spawning habitat was made inaccessible or altered by dams (Lindley *et al.* 2004, 2006; Adams *et al.* 2007). The historical spawning habitat may have extended up into the three major branches of the upper Sacramento upstream of the current location of Shasta Dam; the Little Sacramento River, the Pitt River, and the McCloud River. Additional spawning habitat is believed to have once existed upstream of the current location of Oroville Dam on the Feather River. Other watersheds, including the San Joaquin River basin may also have supported opportunistic green sturgeon spawning in the past (Adams *et al.* 2007, Beamesderfer *et al.* 2007)

Green sturgeon are found throughout the Sacramento–San Joaquin Delta and the San Francisco Bay estuary. Coastal migrants, which include both adult and subadult life stages, are found from approximately Central California to southeastern Alaska with aggregations of Southern DPS green sturgeon occurring in several estuaries along the West Coast from California northwards to Washington during the late summer and early fall. An aggregation of green sturgeon has also recently been identified off of the northwestern tip of Vancouver Island. Although both northern and southern populations mix in the ocean and coastal estuaries, it is believed that each DPS maintains a high fidelity to their natal watershed and little straying occurs between the two DPSs.

The reduction of the Southern DPS of green sturgeon spawning habitat into one reach on the Sacramento River between Keswick Dam and Hamilton City increases the vulnerability of this spawning population to catastrophic events. One spill of toxic materials into this reach of river, similar to the Cantara Loop spill of herbicides on the upper Sacramento River, could remove a significant proportion of the adult spawning broodstock from the population, as well as reduce the recruitment of the exposed year class of juvenile fish. Likewise, the necessary water temperatures required for normal egg development in the spawning reach is reliant on the cold-water releases for winter-run Chinook salmon. Extended drought conditions could imperil the spawning success for green sturgeon. This was particularly the case for those that were restricted to the river reaches below RBDD, which should no longer occur as of 2012 since the gates will no longer be lowered.

d. *Diversity*

Diversity, both genetic and behavioral, provides a species the opportunity to track and adapt to environmental changes. As a species' abundance decreases, spatial structure of the ESU or DPS is reduced concomitant with a reduction of genetic diversity. The reduction of the Southern DPS of green sturgeon population to one extant population reduces the potential variation of life history expression and genetic diversity within this population. Similar to winter-run Chinook salmon, the Southern DPS of green sturgeon face greater risks to long-term persistence of the population due to the reduction of variability in their current condition.

e. *Summary of the Viability of the Southern DPS of North American Green Sturgeon DPS*

The Southern DPS of green sturgeon is at substantial risk of future population declines (Adams *et al*. 2007). The potential threats faced by the green sturgeon include enhanced vulnerability due to the reduction of spawning habitat into one concentrated area on the Sacramento River, lack of good empirical population data, vulnerability of long-term cold water supply for egg incubation and larval survival, loss of juvenile green sturgeon due to entrainment at the project

fish collection facilities in the South Delta and agricultural diversions within the Sacramento River and Delta systems, alterations of food resources due to changes in the Sacramento River and Delta habitats, and exposure to various sources of contaminants throughout the basin to juvenile, sub-adult, and adult life stages. Available information on green sturgeon indicates that the mainstem Sacramento River may be the last viable spawning habitat (Good *et al.* 2005) for the green sturgeon Southern DPS.

The new pumping plant and fish screens constructed at RBDD will improve upstream migration of green sturgeon and contribute to greater spawning success and possibly population abundance, however no restoration strategies exist for expanding the current range of the species. Lindley *et al.* (2007) pointed out that a salmon ESU or steelhead DPS represented by a single population at moderate risk is at a high risk of extinction over the long term; this is also true for green sturgeon (Anderson *et al*. 2009). For these reasons, the extinction risk of the green sturgeon Southern DPS is high.

5. Current Viability and Extinction Risk of the Southern Resident Killer Whale DPS

A population viability analyses (PVA) for Southern Residents was conducted by the BRT (Krahn *et al*. 2004). Demographic information from the 1970s to fairly recently (1974-2003, 1990-2003, and 1994-2003) were considered to estimate extinction and quasi-extinction risk. "Quasi-extinction" was defined as the stage at which 10 or fewer males or females remained, or a threshold from which the population was not expected to recover. The model evaluated a range in Southern Resident survival rates, based on variability in mean survival rates documented from past time intervals (highest, intermediate, and lowest survival). The model used a single fecundity rate for all simulations. The study considered seven values of carrying capacity for the population ranging from 100 to 400 whales, three levels of catastrophic event (*e.g*., oil spills and disease outbreaks) frequency ranging from none to twice per century, and three levels of catastrophic event magnitude in which 0, 10, or 20 percent of the animals died per event. Analyses indicated that the Southern Residents have a range of extinction risk from 0.1 to 18.7 percent in 100 years and 1.9 to 94.2 percent in 300 years, and a range of quasi-extinction risk from 1 to 66.5 percent in 100 years and 3.6 to 98.3 percent in 300 years (Table 6). The population is generally at greater risk of extinction over a longer time horizon (300 years) than over a short time horizon (100 years). There is a greater extinction risk associated with increased probability and magnitude of catastrophic events.

Table 6. Range of extinction and quasi-extinction risk for Southern Resident killer whales in 100 and 300 years, assuming a range in survival rates (depicted by time period), a constant rate of fecundity, between 100 and 400 whales, and a range of catastrophic probabilities and magnitudes (Krahn et al. 2004).

Time Period	Extinction Risk (%)		Quasi-Extinction Risk (%)	
	100 years	300 years	100 years	300 years
Highest survival	0.1-2.8	1.9-42.4	1-14.6	3.6-67.7
Intermediate survival	0.2-5.2	14.4-65.6	6.1-29.8	21.4-85.3
Lowest survival	5.6-18.7	68.2-94.2	39.4-66.5	76.1-98.3

IV. EFFECTS OF THE ACTION

Pursuant to section 7(a)(2) of the ESA, Federal agencies are directed to insure 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. To evaluate whether an action is likely to result in jeopardy to a listed species or result in the destruction or adverse modification of designated critical habitat, this biological opinion considers the combination of the status of the species and critical habitat, the environmental baseline, the effects of the action, and the cumulative effects of non-Federal actions that are reasonably certain to occur within the action area. Regulations that implement section 7 of the ESA provide that the "effects of the action" refers to the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). An action that is not likely to jeopardize the continued existence of the listed species is one that is not reasonably expected to appreciably reduce the likelihood of both the survival and recovery of the species in the wild by reducing its numbers, reproduction, or distribution (50 CFR 402.02). 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 rely upon the statutory provisions of the ESA and determine the effects of the action on the conservation value of critical habitat designated for listed species. This biological opinion assesses the effects of the artificial propagation of Central Valley fall and late fall-run Chinook salmon and California Central Valley steelhead at the CNFH, and the effects of collection of late fall-run Chinook salmon at Livingston Stone NFH, on the listed Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, California Central Valley steelhead DPS, Southern DPS of North American green sturgeon, and their designated critical habitats, and on the Southern Resident killer whale DPS.

In its biological assessment, the USFWS described the term of the proposed action as continuing until the year 2021. By 2021, the USFWS assumes that winter-run Chinook salmon will be actively reintroduced into Battle Creek as part of the Battle Creek Salmon and Steelhead Restoration Project. Active reintroduction of winter-run Chinook salmon into Battle Creek is not part of the proposed action described in the biological assessment and analyzed in this biological opinion. This biological opinion analyzes the effects of fish propagation programs at the CNFH and collection of natural-origin late fall-run Chinook salmon at Livingston Stone NFH as those programs and actions are described in the biological assessment and the *Description of the Proposed Action* section of this biological opinion. Therefore, NMFS is not limiting its analysis of the effects of the action in this biological opinion to a specific term (*i.e.*, until the year 2021). The effects of the proposed action are included in the analysis in this biological opinion to the extent they can be meaningfully evaluated. With regard to active reintroduction of winter-run Chinook salmon into Battle Creek, a Fisheries Management Plan is currently being written by the California Department of Fish and Wildlife (Mike Berry, CDFW, personal communication, June 2013), which will include a winter-run Chinook salmon reintroduction plan. Since essential information regarding the scope and timing of this reintroduction have not been developed yet, NMFS does not have sufficient information at this time to determine the effects of the proposed action described in this biological opinion on a population of winter-run Chinook salmon that may be reintroduced in Battle Creek in the future. When sufficient information regarding reintroduction of winter-run Chinook salmon to Battle Creek has been developed, it will likely

result in the need to reinitiate consultation for the proposed action described in this biological opinion (see 50 CFR 402.16(b)).

Artificial propagation programs may affect listed salmon and steelhead and their habitats through the operations of the hatchery facility and through the effects of hatchery fish on various life history stages of listed salmon and steelhead in the natural environment. Hatchery actions may adversely affect listed salmon and steelhead through direct mortality (*e.g.*, broodstock collection, spawning and propagation, disease transmission, or predation) or sub-lethal effects (*e.g.*, impeding migration), and indirectly through genetic, demographic, and ecological interactions of natural salmon and steelhead with hatchery-produced salmon and steelhead in the natural environment. Dependent upon program management, hatchery actions may impede, enhance, or have no effect on population viability or the potential for recovery of listed natural salmon and steelhead.

A. Approach to the Assessment

NMFS generally approaches "jeopardy" and critical habitat analyses in a series of steps. First, we evaluate the available evidence to identify the direct and indirect physical, chemical, and biotic effects of proposed actions 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 we have identified the effects of an action, we evaluate the available evidence to identify a species' probable response (including behavioral responses) to those effects to determine if those effects could reasonably be expected to degrade the Viable Salmonid Population parameters of listed species, including abundance, productivity, diversity, or spatial structure. We then use available evidence to determine if proposed activities would be likely to diminish the quantity, quality, or diversity of critical habitats. Lastly, we determine if the effects of the proposed actions, if there are any, to VSP parameters or critical habitats could reasonably be expected to appreciably reduce a species' likelihood of surviving and recovering in the wild or result in destruction or adverse modification to critical habitat.

B. Information Available for the Assessment

To conduct this assessment, NMFS examined an extensive amount of evidence 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 ESU and DPS status reviews, the scientific literature, life history descriptions, Federal Register notices, *etc*. This assessment also used information from the biological assessment developed for the proposed action, and available monitoring data from other Central Valley fish studies.

C. Assumptions Underlying This Assessment

Impacts of the proposed action on the Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, and California Central Valley steelhead DPS, Southern DPS North American green sturgeon, and Southern Resident killer whale DPS and their respective designated critical habitats that may be affected by the proposed action must be

analyzed on the basis of limited data. Where data are limited, NMFS made a series of reasoned assumptions to overcome limits in our understanding, and NMFS has made reasoned deductions regarding the level of impact based on the general effects of hatchery propagation on natural populations in the natural environment and the extent to which best hatchery management practices have been adopted by USFWS in its management of the CNFH propagation programs.

D. Effects of CNFH Complex Facilities and their Operation on Listed Species

1. Failure of broodstock collection and holding facilities

The risk of failure of broodstock collection and holding facilities is of concern not only when listed fish are propagated at the facilities, but whenever listed species could be present at the hatchery facilities. For example, factors such as flow reductions, flooding, and overcrowding may result in the catastrophic loss of listed adult fishes being collected during broodstock collection at the CNFH, and may result in loss of listed CNFH-origin steelhead eggs and juveniles that are being raised until release. Hatchery facility failure can directly affect the abundance and spatial structure of ESA-listed salmon and steelhead. The following BMPs, which are incorporated into CNFH facilities and operations, are considered important in reducing the risks of catastrophic loss resulting from failure of the broodstock collection and holding facilities and occur at the CNFH Complex:

- Minimizing the time adult listed fishes are held in captivity;
- Minimizing hatchery facility failure and responding expediently to facility failures, through, for example, on-site residence by hatchery personnel;
- Using alarms for water supplies to notify personnel of water emergencies;
- Installing back-up generators to respond to power loss; and
- Training all hatchery personnel in standard and emergency fish propagation and fish health maintenance methods.

a. *CNFH*

Battle Creek is the source of water for all fish culture activities at CNFH. CNFH diverts water from the tailrace of the Coleman Powerhouse or directly from Battle Creek for multiple purposes related to fish propagation, including broodstock collection and holding, spawning, egg incubation, and rearing of juvenile fishes (USFWS 2010). The flow of water into CNFH may be interrupted or reduced by power outages or other operational emergencies such as: failure of the Coleman Powerhouse or penstocks, failure of the intake at the Inskip Powerhouse, or failure of any part of the water conveyance system between the Inskip Powerhouse and the Coleman Powerhouse forebay. However, the possibility of a significant interruption of water flow to the hatchery is considered low due to redundancies built-in to the water delivery system. Also, the CNFH has an alarm system to alert hatchery staff to respond to power outages and sudden water cutoffs. CNFH also incorporates on-station housing, which increases the likelihood for a quick response to water emergencies (USFWS 2010).

Unplanned or emergency actions resulting in the reduction or suspension of water deliveries to the hatchery holding ponds would be expected to cause the level of DO to decrease and water temperature to increase. Salmonid fishes, including listed California Central Valley steelhead,

are sensitive to these constituents of water quality and could experience metabolic stress (*e.g.*, due to oxygen deprivation) and possibly mortality as a result. These conditions would be most likely to occur during an outage of longer than 30 minutes or when adult collection ponds are overcrowded. Such a situation would require temporary mitigation (*e.g.*, aeration equipment and supplementary power supply) at rearing units. Failure of the backup system could result in total fish mortality in the hatchery, including listed hatchery-origin and natural-origin California Central Valley steelhead. Killer whales could be impacted as a result of broodstock collection and holding facilities failure, as a significant failure could reduce prey availability.

Listed natural-origin California Central Valley steelhead are encountered in the adult collection ponds at the CNFH during the entire period of broodstock collection, extending from October 1 through February. Listed hatchery-origin adipose fin clipped steelhead are collected for use as hatchery broodstock. As of broodyear 2009, natural-origin steelhead are not being integrated into the hatchery broodstock. Incidentally collected natural-origin steelhead are identified and released upstream of the hatchery barrier weir at the initial sorting. Natural-origin steelhead in the hatchery's holding ponds will experience some delay in migration, and could be exposed to the adverse effects of overcrowding or dewatering. Since 2002, incidental collection of known (non-adipose fin-clipped) natural-origin steelhead at the CNFH has ranged from 164 to 428 annually. All of the fishes simultaneously present in the hatchery collection pond could be potentially susceptible to a single overcrowding or dewatering event. In addition, collection of CNFH-origin steelhead into the hatchery, since spawning reports have been available beginning in 1988, have ranged from 467 to 4,429 annually, and these adult CNFH-origin steelhead and their progeny are similarly susceptible to such events. Since 2001, there have been no reported cases of injury or mortality of steelhead at the CNFH resulting from hatchery facility failure.

b. *Livingston Stone NFH*

Listed California Central Valley steelhead and winter-run Chinook salmon are incidentally captured in the Keswick Dam fish trap while trapping for natural-origin late fall-run Chinook salmon broodstock, which extends from December through February. Steelhead and winter-run Chinook salmon collected at the Keswick Dam fish trap are transported in a fish distribution truck to Livingston Stone NFH, sorted, placed in another fish distribution truck and returned to the Sacramento River at Redding, California. Although there is some chance of mechanical failure of the distribution truck, which could lead to take of listed species, this type of failure has never occurred and is considered a discountable risk (Kevin Niemela, USFWS, personal communication, 2013a).

c. *Summary of effects of failure of broodstock collection and holding facilities*

Some take of listed spring-run and winter-run Chinook salmon and steelhead may occur in the event of failure of broodstock collection and holding facilities, however, potential effects to the VSP parameters of abundance, productivity, diversity, and spatial structure are adequately mitigated to reduce the risk to levels that will not adversely affect population viability. Anticipated take of spring-run Chinook salmon is limited to hatchery-origin adults from the FRFH. The hatchery's water supply employs numerous checks and redundancies and alarms that reduce the likelihood of catastrophic fish losses resulting from dewatering and overcrowding in

the adult collection pond. Failure of broodstock collection and holding facilities do not pose risk to green sturgeon. Failure of broodstock collection and holding facilities may affect killer whales, as a significant failure could reduce prey availability; however, this risk is considered discountable, as it is extremely unlikely to occur. There have been no incidences of catastrophic loss of fall-run Chinook salmon broodstock collection or holding facilities since 1991 (Scott Hamelberg, USFWS, personal communication, 2013). As discussed above, the hatchery's water supply employs numerous checks and redundancies and alarms that reduce the likelihood of catastrophic fish losses resulting from dewatering and overcrowding in the adult collection pond. Green sturgeon would not be affected by a failure at Coleman or Livingston Stone NFH as they are not collected or held at either facility.

2. Fish Entrainment

a. *CNFH*

Three intake structures and associated conveyance facilities (upstream of the barrier weir and hatchery) are used to divert and convey water directly from Battle Creek and the tailrace of PG&E Coleman Powerhouse. The hatchery's primary intake (Intake 1) is located in the tailrace of the PG&E Coleman powerhouse. Intake 1 is located in an area inaccessible to anadromous salmonids and, therefore, take of salmonids is not expected to occur at that location. A recent modification to the hatchery's water rights permit allows the entire hatchery water allocation to be diverted at Intake 1. The hatchery's alternative intakes (Intake 2 and Intake 3) are available as standby, in the event that water is not available at the primary intake. Water diversions at Intake 3 are screened to meet criteria of NMFS (NMFS 1997). These screening criteria for water withdrawal devices set forth conservative standards that help reduce the risk of harming naturally produced salmonids and other aquatic fauna. Intake 2 is not screened and may entrain naturally produced juvenile salmonids when it is operated.

Intake 2 on Battle Creek is used to divert water to the hatchery when sufficient water is not available at Intakes 1 and 3; this situation occurs only during periodic maintenance or emergency situations. The normal operating condition of the PG&E Coleman powerhouse involves discharge of flow from the Coleman Powerhouse forebay, through the penstocks and turbine, and into the tailrace where the hatchery's Intake 1 is located. Occasionally, water is blocked from the Coleman powerhouse to perform maintenance or repairs of the PG&E canals and turbine. Planned maintenance activities are typically scheduled to correspond with decreased water needs at CNFH and at times when there is a reduced likelihood of encountering natural-origin salmonids emigrating from Battle Creek. The timing of unplanned events in the PG&E system, such as turbine trip or canal failure, is haphazard and cannot be predicted.

Any take of juvenile salmonids at the CNFH Intake 2 occurs as lethal entrainment. Entrainment of juvenile salmonids in the hatchery Intake 2 may affect the abundance and diversity of ESA-listed Central Valley spring-run Chinook salmon and steelhead. The number of juvenile salmonids entrained at Intake 2 has been estimated by USFWS based on: (1) the proportion of Battle Creek flow diverted into the hatchery; (2) the magnitude and timing of diversions at Intake 2; and, (3) the magnitude and timing of salmonid emigrations in Battle Creek past Intake 2. Estimates of future entrainment of listed juvenile salmonids from Intakes 2 are shown in Table 7 (USFWS 2011); however, these estimates could differ largely from actual take levels due to

changes in the aforementioned factors. Take of winter-run Chinook salmon is not anticipated because a persistent population of winter-run Chinook salmon does not currently exist in Battle Creek. Take of green sturgeon is not anticipated because they are not known to occur in Battle Creek.

Table 7. Estimated take of ESA-listed salmonids resulting from CNFH water diversions from Battle Creek. Numerical take estimates do not include non-lethal take, *i.e.*, fishes salvaged from the hatchery's water supply system.

Type of Take	Species		
	Winter-run Chinook salmon	Spring-run Chinook salmon	Steelhead
Unintentional Lethal Take[a]	0	243	6
percent of Estimated Outmigrants	0	0.25	0.11

[a] Juvenile take through Intake 2 will occur as entrainment.

The aforementioned estimates of take resulting from water diversions through Intake 2 do not account for salvage of fishes from the hatchery's water supply system. USFWS has developed a method to salvage fishes using a fyke net with live box in the CNFH canal. USFWS has demonstrated some success in salvaging juvenile fishes entrained into the hatchery canal. A single efficiency trial conducted in February 2006 from the head of the hatchery canal to the fyke net live box produced an efficiency of 88 percent (Whitton *et al*., 2007). However, improvements to methods and trap modifications implemented since that time have likely improved the efficiency of the fyke net salvage technique, further reducing lethal take of listed salmonids. Fishes salvaged from the hatchery canal could still be exposed to significant sublethal effects, including disruption of migration rates, feeding opportunities, and sheltering behavior leading to impaired health and ability to avoid predators or compete for resources. Fish also can be injured in fyke nets or dip nets; damage may occur to internal organs from being squeezed, scales and mucus can be damaged due to handling, and damage to jaws and fins may occur. All of these effects can lead to a decreased likelihood of survival.

b. *Summary of Effects of Juvenile Entrainment*

Under the typical operational scenario all of the water used for fish production at the CNFH is supplied through Intakes 1 and 3. Intake 1 is located in an area inaccessible to anadromous salmonids and Intake 3 is screened to standards of NMFS, therefore, neither impingement nor entrainment is anticipated at either intake. Occasionally, the hatchery diverts water through Intake 2, which is unscreened and may entrain juvenile fish including ESA-listed spring-run Chinook salmon and steelhead. USFWS has developed estimates of lethal take associated with forecasted operations of unscreened intakes. Actual amount of lethal take may be reduced from estimated values due to the salvage of listed fishes from the hatchery canal. The estimated levels of take at the CNFH intakes will reduce the abundance of ESA-listed spring-run Chinook salmon and steelhead in Battle Creek but will not affect the other parameters of VSPs. USFWS anticipates an annual lethal take of 243 juvenile spring-run Chinook salmon and 6 juvenile steelhead from water diversion through Intake 2. Lethal take levels may be reduced to non-lethal

take depending on level of salvage efforts and success. Take of green sturgeon is not anticipated because they are not known to occur in Battle Creek.

3. Hatchery Water Withdrawals

a. *CNFH*

Typical flow patterns of Battle Creek indicate sufficient quantity and quality of water to meet both the water requirements at the CNFH and to maintain recommended minimum flows and water quality in Battle Creek (USFWS 2011). However, some atypical situations, such as equipment failures (*e.g.,* associated with hydropower diversions or facilities) and environmental conditions (primarily lack of snowpack on Mount Lassen and prolonged drought), could alter normal flow patterns causing water diversions at the CNFH to reduce flow in a 1.6 mile stretch of Battle Creek to a level where salmonids are negatively affected. The potential for impacting salmonids and their habitats is likely greatest during late-summer and fall months (*e.g.,* August through November) when hatchery water requirements comprise the greatest proportion of Battle Creek flow. Although hatchery water demands are higher in December and January, flows in Battle Creek during those months are higher as well, which would reduce the relative effects of hatchery water withdrawals.

Between 1961 and 1999, average daily flows in Battle Creek were less than total water requirements (CNFH plus minimum recommended instream flows in Battle Creek) for 3.0 percent of the days (547 days out of 17,943 days on record; USGS historic flow records). Most of the days where Battle Creek flow did not meet total water requirements in the 1.6 mile reach affected by hatchery diversions occurred in December (216 days), January (114 days), October (102 days) and September (50 days). On approximately 0.9 percent of the days Battle Creek flows resulted in a reduction to less than 95 percent of weighted usable area. Weighted Usable Area (WUA), is defined as the wetted area of a stream weighted by its suitability for use by species and life-stage. Days with mean flows that were less than that necessary to maintain 95 percent WUA occurred in December (94 days), October (28 days), January (33 days) and February (12 days). Times when flows were less than 95 percent WUA were largely consistent with years of drought (*e.g*., late-1970s, late-1980s, and early-1990s).

Potential effects of decreased instream flows in Battle Creek include the disruption of migration, spawning, rearing, and emigration of listed Central Valley spring-run Chinook salmon and steelhead, which could affect the abundance, productivity, diversity, and spatial structure of the ESUs. Impeding the upstream migration of adults or emigration of juveniles could cause them to increase energy expenditures if they are delayed, crowded together, or forced to remain in suboptimal habitats (*e.g.,* with elevated water temperatures) that they otherwise would not occupy. This may reduce energy reserves and decrease survivability, or reduce the reproductive output of adults due to, for example, increased stress and susceptibility to disease or reduced number or size of eggs produced (Brett 1995). Reduced abundance or quality of rearing habitat may reduce juvenile feeding and growth rates due to increased competition for food resources. Water withdrawals may also affect other stream-dwelling organisms that serve as a food resource for listed fishes by reducing habitat or causing entrainment, impingement, and physical injury. The degree to which these effects are realized would depend on the timing, severity, and duration of substandard flows relative to the life history requirements of listed fishes.

b. *Summary of effects of hatchery water withdrawals*

The 1.6 miles immediately upstream of the hatchery is subjected to the effects of hatchery water withdrawals. This section of stream functions as a migration corridor for ESA-listed salmonids, and does not provide suitable habitat for prolonged residence or spawning. Stream flows typical of Battle Creek are sufficient to maintain year-round connectivity and functionality of the portion of stream affected by hatchery water withdrawals. Water withdrawals from Battle Creek may result in take in the form of migration delays or reduced rearing habitat to ESA-listed spring-run Chinook salmon and steelhead, possibly affecting their productivity. No adverse effects to green sturgeon from hatchery water withdrawals are anticipated because they are not known to occur in Battle Creek.

4. Discharge of Hatchery Effluent

a. *CNFH*

The CNFH discharges an average of 40.8 million gallons of water per day into Battle Creek. On average, approximately eight percent of the discharge water is first diverted through a pollution abatement pond. The abatement pond is used primarily to reduce the discharge of solid materials (*e.g*., fecal material, unconsumed food, algae, and silt) associated with raceway cleanings. Water discharged from the CNFH, despite limited treatment, is expected to include small amounts of particulates, as well as chemicals such as antibiotics, and formaldehyde (used as a fungicide for fish eggs).

Discharges of hatchery effluent can affect several parameters of the receiving water, including temperature, turbidity, pH, suspended solids, ammonia, organic nitrogen, total phosphorus, and chemical oxygen demand in the receiving stream's mixing zone (Kendra 1991). Discharge of hatchery effluent could potentially result in detrimental effects to the VSP parameters of abundance, productivity, diversity, and spatial structure. Impacts to water quality, such as elevated water temperatures or suspended sediment levels or decreased DO levels, could cause non-lethal detrimental effects such as physiological stress to fish, or induce habitat avoidance behaviors to the extent that migration is impeded. Suspended sediment may affect salmonids by decreasing reproductive success, reducing feeding success and growth, causing avoidance of rearing habitats, and disrupting migration cues (reviewed by Bash *et al.* 2001). If these impacts are sustained, the increased energy output could reduce energy stores required for reproduction by adults, or cause juveniles to experience reduced growth rates. The level of impact depends on the quality and amount of discharge relative to the flow volume of the receiving stream. The most severe adverse impacts probably occur at the immediate point of discharge, because effluent dilutes rapidly.

The CNFH, and all hatcheries with annual production greater than 20,000 pounds, are required by the Clean Water Act to obtain a National Pollutant Discharge Elimination System (NPDES) permit to discharge hatchery effluent to surface waters. These permits are intended to protect aquatic life and public health, and to ensure that every facility treats its wastewater to achieve site-specific discharge limits. The impacts from the water releases are also required to be monitored and reported. Failure to comply with NPDES requirements, or violations of

established water quality criteria, is subject to enforcement actions (EPA 1994). In addition to the NPDES permit, the CNFH must meet water discharge requirements set forth by the CRWQCB. These requirements incorporate SWRCB water discharge standards to reduce hatchery wastewater constituents to concentrations which are below the level at which the beneficial uses of surface and/or ground water are adversely affected, including those affecting the quality of aquatic communities and populations of vertebrate, invertebrate and plant species in Battle Creek and the Sacramento River. The CNFH water system is monitored daily by hatchery staff. Hatchery effluent is sampled monthly to ensure compliance with the discharge and receiving water limitations of its SWRCB and NPDES permit. Monitoring data indicate that this effluent limitation of the SWRCB and NPDES permits have been consistently achieved at the CNFH (USFWS 2001b).

Hatchery discharge also has the potential to transport disease pathogens and aquatic nuisance organisms out of the hatchery. Water discharged from hatcheries may contain pathogens including: Infectious Hematopoitic Necrosis Virus (IHNV), Bacterial Kidney Disease (BKD; *Renibacterium salmoninarum*), *Yersinia ruckeri, Flexibacter columnaris, Ceratomyxa shasta, Ichthyophthirius multifilis,* and *Nanophyetus salmincola).* Numerous other bacterial, parasitic, and fungal organisms have also been identified as being present in hatchery populations. The high density of fish reared in typical large-scale production hatcheries creates an environment susceptible to rapid transmission of pathogens. Similarly, it is possible that water discharged from the hatchery could contain non-native invasive organisms, including invertebrates (*e.g.,* New Zealand mud snail (*Potamopyrgus antipodarum*), Zebra mussel (*Dreissena polymorpha*), quagga mussel (*Dreissena bugensis*) and plants (*e.g., Hydrilla verticillata*, Eurasian watermillfoil (*Myriophyllum spicatum*), *etc*). Discharge regulations set forth by the EPA and SWRCB do not set discharge limits nor do they require monitoring for the transmission of disease or non-native invasive organisms.

The CNFH has developed and implemented treatments, practices, and protocols to decrease risks associated with spreading disease and invasive species both into and out of the hatchery. A water treatment facility consisting of filtration and ozonation began operating at full capacity in 2000. Since the inception of the CNFH ozone water treatment plant, the pathogens that pose the greatest risk to natural-origin salmonid populations (*i.e.* IHNV and BKD) have not been a health problem in juveniles reared at the CNFH (Scott Hamelberg, personal communication, 2012). Health problems observed in juvenile salmonids since 2000 have been limited to external parasites present throughout the Central Valley, such as *Ichthyobodo* sp., *Flavobacterium columnare*, and *Yersinia ruckeri*, or non-infectious issues (feed, water quality, coagulated yolk, and gill irritation due to debris). To decrease risks of spreading non-native invasive species, the CNFH has developed and implemented Hazard Analysis and Critical Control Point (HACCP) plans and Invasive Species Risk Assessment and Planning (ISRAP) plans. These plans identify invasive organisms that could potentially be transmitted from the hatchery and assess the potential for their transmittance through the conduct of hatchery activities. Critical control points have been identified and control measures implemented to reduce the risks of spreading invasive organisms into and out of the hatchery.

b. *Summary of effects of discharge of hatchery effluent*

Protocols and policies in place at the CNFH Complex reduce the risk of spreading pathogens and invasive organisms in effluent of the CNFH. Since monitoring data has indicated that effluent permit limitations have been consistently achieved, and pathogens of hatchery reared juveniles are now considered insignificant, after the installation of the ozone water treatment plant in 2000, NMFS believes water discharged from the CNFH Complex is not likely to adversely affect VSP parameters of ESA-listed winter-run or spring-run Chinook salmon or steelhead. Adverse effects to green sturgeon from discharge of hatchery effluent are insignificant for the reasons described above and because they are not known to occur in Battle Creek.

5. Broodstock Congregation and Collection

The Coleman barrier weir fish ladders are the principal components of broodstock collection facilities at the CNFH. The Coleman barrier weir is located approximately 5.5 miles upstream from the confluence of Battle Creek with the Sacramento River. The weir is permanent, and extends across the full width of Battle Creek. The barrier weir obstructs passage of adult salmonids to upper Battle Creek (upstream of the hatchery) and diverts them to a fish ladder leading to the hatchery's adult holding ponds or a separate fish ladder which allows circumnavigation of the barrier weir. The upstream fish ladder is currently closed during the month of August to preclude fall-run Chinook salmon from gaining access to spring-run Chinook salmon spawning areas. Blocking fish passage during August is conducted through a verbal agreement between NMFS, USFWS and CDFG to prevent fall-run Chinook salmon from accessing the upper watershed where they may impact ESA-listed spring-run Chinook salmon (M. Tucker, NMFS, personal communication, 2004). The CNFH requires that the upstream fish ladder be closed from September 1 through February to congregate and collect broodstock. The fish ladder leading to the adult collection and holding ponds is opened in late-September or early October. Collected fish are counted and either retained in the hatchery (targeted broodstock) or released to spawn naturally upstream of the barrier weir (non-target fishes, including natural-origin steelhead, spring-run Chinook salmon, and natural-origin late fall-run Chinook salmon).

The CNFH barrier weir can directly affect listed salmonids by:

- Delaying upstream migration;
- Causing fishes to reject the weir or fishway structure, thus inducing spawning downstream of the weir (displaced spawning, or leading to pre-spawning mortality);
- Contributing to fallback of fish that have passed above the weir;
- Injuring, killing, or stressing fishes when they attempt to jump the barrier (Hevlin and Rainey 1993, Spence et al. 1996) or during the time they are diverted into the hatchery;
- Changing the spatial distribution of juvenile salmon and steelhead seeking preferred habitats; and
- Disorienting fish as they pass downstream over the weir, resulting in increased susceptibility to predation.

Potential effects of the CNFH barrier weir and associated activities to ESA-listed salmonids include the following, which may affect the VSP parameters of ESA-listed salmonids including abundance, productivity, diversity, and spatial structure:

- Causing physical harm to the fishes during their capture and retention in the fish holding area at the weir, or in the fish ladders;
- Causing stress or harm to fish during captivity;
- Delaying migration/spawning
- Physically harming fish during handling; and
- Increasing fish susceptibility to predation and displacement downstream following their release.

The proper design and operation of weirs, traps, and fish ladders can reduce many of their potential negative impacts (Hevlin and Rainey 1993). The CNFH barrier weir and associated fish ladders were constructed in 1950, rebuilt in 1991, and modified, most recently, in 2008. The current configuration of the barrier weir is intended to provide the capability of blocking fish migration upstream in Battle Creek at flows up to 800 cfs. The fish ladders at the CNFH barrier weir are intended to provide fish attraction and passage capabilities equivalent to those of ladders planned for the PG&E dams upstream of the hatchery.

a. *CNFH*

Effects of broodstock collection activities to listed California Central Valley steelhead and spring-run Chinook salmon are discussed below. Winter-run Chinook salmon do not regularly inhabit Battle Creek at this time, and are not currently anticipated to be affected by broodstock collection activities at the CNFH. Broodstock collection activities will not affect green sturgeon or killer whale.

Steelhead migrate into Battle Creek from October through mid-June, and are blocked by the CNFH barrier weir during much of their migration. During this time, the fish ladder leading into the adult collection and holding ponds is opened periodically. Opening of the fish ladder leading to the adult collection ponds is highly variable. For example, the fish ladder leading into the hatchery could be opened continuously or for only a few hours over the course of a week depending on the number of fish entering the hatchery relative to the number of fish available as broodstock in Battle Creek and broodstock collection and spawning targets at the hatchery.

Steelhead impeded by the barrier weir at the CNFH may attempt passage over the weir, remain in lower Battle Creek to spawn naturally, enter the CNFH collection ponds, or redistribute downstream to the Sacramento River. Hatchery-origin adipose-fin clipped steelhead entering the hatchery are retained for use as broodstock. Since the CNFH-origin steelhead are also part of the listed DPS, the effects of this propagation program on the DPS are part of the analysis. Since 1988, numbers of hatchery-origin steelhead collected during hatchery operations have varied from 467(1989) to 4,429 (1992). Unintentional mortality occurrence also varies, with the highest mortality reaching 696 fish. Migration is delayed for natural-origin steelhead entering the hatchery, but they are usually sorted within one to seven days then released upstream. Sorting, bypassing, and transporting adult steelhead may involve capturing, sedating with CO_2, and handling of fish. Fish are maintained in the water to the extent possible through the use of mechanical weirs and crowders and a hydraulic lift into the sedation tank. Because steelhead are intermingled with Chinook salmon as they enter and are processed through the hatchery they may be subject to injury as they interact with these larger-bodied fish. For this reason, natural-

origin steelhead are removed first from the sedation tank and sampled for biological data and released upstream of the barrier weir. These activities involve the use of nets and direct handling of the fish.

Stress and injury to steelhead resulting from the congregation and collection of hatchery broodstock is reduced by preventing overcrowding in the hatchery's adult collection ponds, quickly sorting Chinook salmon, and using sedatives to reduce stress, injury, and handling time. From 2002 through 2012, the number of natural-origin steelhead collected annually at the CNFH ranged from 164 to 428. Mortality of natural-origin steelhead in the adult collection ponds over this same time period ranged from zero to 8 fish annually (USFWS 2011; Kevin Niemela, USFWS, personal communication, 2013b).

High concentrations of fishes below the barrier weir, in the hatchery ponds, and during handling in the hatchery may cause elevated stress levels, injury, or mortality in steelhead. Energy reserves may be reduced in stressed fishes, ultimately impacting reproductive output of adults (Brett 1995) through a variety of mechanisms (*e.g.*, reduced likelihood of survival to spawning through increased stress or likelihood of disease, reduced number or size of eggs produced). Captivity may also cause stress-induced behaviors, such as increased aggressiveness or jumping, which can result in contact with the concrete walls of the ponds, metal fencing, or interactions with other fishes. The crowded conditions in the hatchery's collection ponds may also allow for increased transmission of disease, especially to injured fishes.

Effects of broodstock congregation and collection at the CNFH are expected to be negligible for spring-run Chinook salmon in Battle Creek because the timing of broodstock collections does not overlap the timing of natural spring-run Chinook salmon migration. Natural-origin spring-run Chinook salmon migrate upstream in Battle Creek beginning in March, followed by a prolonged period of holding near preferred spawning areas in the upper watershed as they reach sexual maturity. The barrier weir's upstream fish ladder is opened on March 1 and remains open until August 1, after the migration of spring-run Chinook salmon into Battle Creek. The upstream ladder is closed on August 1 to isolate spring-run Chinook salmon, which spawn upstream of the barrier weir, from fall-run Chinook salmon, which are confined downstream of the barrier weir. Closing the upstream fish ladder in August reduces the likelihood that fall-run Chinook salmon will negatively impact spring-run Chinook salmon through hybridization or competition, including superimposition of redds. Natural-origin spring-run Chinook salmon could be blocked by the CNFH barrier weir after the fish ladder is closed in August, however, this migration strategy has not been verified by genetic analysis and is thought to be an atypical migration strategy of spring-run Chinook salmon.

Hatchery-origin spring-run Chinook salmon from the FRFH have been observed to enter the CNFH while collecting fall-run Chinook salmon broodstock. From 2001 to 2010, an average of four CWT spring-run Chinook salmon originating at the FRFH have been observed to enter the hatchery annually during the spawning of fall-run Chinook salmon. The maximum number observed during a season was 11, which occurred during 2010. FRFH-origin spring-run Chinook salmon entering the hatchery during the fall-run Chinook salmon spawning season would be either spawned or excessed. Upstream migration in the late-summer and fall is atypical

of Central Valley spring-run Chinook salmon, and may be the result of hybridization with fall-run Chinook salmon in the Feather River, at the FRFH or at the CNFH.

Spring-run Chinook salmon attempting to migrate upstream in Battle Creek when the upstream ladder is open may become stressed or injured if they jump at the hatchery's barrier weir, or forced to reside downstream of the barrier weir if they do not locate the entrance to the fish ladder. Adult and juvenile spring-run Chinook salmon moving downstream over the CNFH barrier weir may become disoriented. Disoriented fish may become more susceptible to predation as juveniles and as adults as they drop into the bubble curtain below the weir. The potential for harmful impacts to spring-run Chinook salmon at the CNFH has been reduced through the design of efficient and effective fish ladders and by employing precautionary operational strategies. The size and design of the fish ladders at the CNFH barrier weir provides sufficient attraction flows to reduce the amount of time required for salmonids to quickly locate the ladder entrance and pass upstream (Null *et al.* 2011), thereby reducing the potential for injury and stress.

b. *Livingston Stone NFH*

California Central Valley steelhead may be incidentally collected while trapping late fall-run broodstock at the fish trap at Keswick Dam. Late fall-run broodstock collections at the Keswick Dam fish trap extend from December through March 1. Steelhead co-exist in the upper Sacramento River with late fall-run and winter-run Chinook salmon, and may be incidentally collected in the Keswick Dam fish trap along with the target stocks. From 2004 to 2010, an average of 15 natural-origin steelhead, and a maximum of one CNFH-origin steelhead were inadvertently collected at the Keswick Dam fish trap from January through March 1, when late fall-run Chinook salmon broodstock are collected. The maximum number of natural-steelhead collected during this period was 36, which occurred in 2004, and a total of three CNFH-origin steelhead were collected during this period. Take of these ESA-listed steelhead may occur through capture, handling, transport, tissue sampling, and unintentional lethal take. These fish are subjected to holding in possibly crowded conditions in the fish trap and during transport to the Livingston Stone NFH where they are sorted from target broodstock. Steelhead collected at the Keswick Dam fish trap are also exposed to sedation with CO_2, handling with hands and nets, and additional transport to the release site at the Sacramento River. Capture, captivity, delay, handling, and transport of these fish causes them stress and possible injury or mortality.

Adult migrations of winter-run and late fall-run Chinook salmon are overlapping and winter-run Chinook salmon may be incidentally collected while trapping late fall-run broodstock at the fish trap at Keswick Dam. Late fall-run broodstock collections at the Keswick Dam fish trap extends from December through February. Late fall-run Chinook salmon are distinguished from non-target fishes using phenotypic characteristics, including coloration, muscle tone, and amount of fungus. Fishes identified by phenotype as being other than late fall-run Chinook salmon are likely winter-run Chinook salmon since the migration of spring-run Chinook salmon typically begins in March. Using this assumption, USFWS indicated an average of 97 winter-run Chinook salmon were inadvertently collected between 2004 and 2010 during the period when late fall-run Chinook salmon broodstock are currently collected. The largest number occurred during 2009, when 175 were collected. Take of ESA-listed winter-run Chinook salmon encountered during the collection of late fall-run broodstock may occur through capture, handling, transport, tissue

sampling, and unintentional lethal take. Collected fishes are subjected to holding in possibly crowded conditions in the fish trap and during transport to the Livingston Stone NFH, where they are sorted from target broodstock. Winter-run Chinook salmon collected at the Keswick Dam fish trap are also exposed to sedation with CO_2, handling with hands and nets, and additional transport to the release site at the Sacramento River. Capture, captivity, delay, handling, and transport of these fish causes them stress and possible injury or mortality. Fish identified as winter-run Chinook salmon are minimally handled, and measures are taken to decrease the potential for negative impacts. These fish are quickly taken back to the Sacramento River and released.

c. *Summary of effects of broodstock congregation and collection*

Some take of listed spring-run and winter-run Chinook salmon and steelhead will occur through artificial spawning, handling, stress, delayed passage, injury, or mortality, affecting the VSP parameters of abundance and productivity. Some efforts to minimize these impacts include proper facility design and conscientious fish handling practices. Further, hatchery-origin late fall-run Chinook salmon and hatchery-origin steelhead are excluded from passing upstream of the hatchery's barrier weir during March and April, and fall-run Chinook salmon are prevented from accessing spring-run Chinook salmon spawning areas upstream of the hatchery during August. These exclusions of hatchery fish upstream of the barrier weir are for the benefit of restoring natural-origin salmonids as part of the Battle Creek Salmon and Steelhead Restoration Project. Effects to green sturgeon are discountable, as they are not known to occur in Battle Creek, they have never been captured in the Keswick Trap, and they are not known to travel that far up the Sacramento River.

6. Genetic Effects

Anadromous salmonids typically show a high level of fidelity to their natal streams. The ability to "home" with great accuracy and maintain high fidelity to natal streams encourages the development of locally adapted gene complexes, favoring the survival of fishes within specific wild, local habitats. The genetic risks that artificial propagation poses to natural salmonid populations can be separated into two broad groupings: changes in the genetic variability (diversity) among and within populations (Hard *et al.* 1992; Cuenco *et al.* 1993; NRC 1996; Waples 1996). Each of these factors can affect locally adapted gene complexes and have deleterious effects on fitness or survivorship, thereby affecting the VSP parameters of productivity and diversity to ESA-listed salmon and steelhead. Proposed project activities will not have genetic effects on green sturgeon and killer whale.

a. *Loss of Diversity among Populations*

Genetic differences among salmon populations arise as a natural consequence of their homing tendency, which creates some level of demographic isolation among populations. This demographic isolation produces conditions where evolutionary forces, such as natural selection and random genetic drift, create differences in allele frequencies among populations. Many of these differences are believed to be adaptive – meaning that populations have been shaped by natural selection to have a particularly good fit to their local environment (Taylor 1991; McElhany *et al.* 2000).

Hatchery activities can threaten the natural genetic diversity among salmon populations in several different ways. For example, many hatcheries have historically bred and released salmon that were not native to the drainage into which they were released. If these introduced hatchery fish breed with native salmon the unique genetic attributes of the local populations can be degraded or lost. Because wild fish are tuned genetically to their native streams, the introduction of non-native traits is generally expected to result in reductions of fitness and productivity. Research based primarily on findings in the Kalama River, Washington, for summer-run steelhead has suggested that interbreeding between non-indigenous Skamania hatchery stock steelhead (a highly domesticated, hatchery stock) and native naturally produced fish may have negatively affected the genetic diversity and long-term reproductive success of naturally produced steelhead (Leider *et al.* 1990; Hulett *et al.* 1996). Non-indigenous hatchery and native naturally produced steelhead crosses may be less effective at producing adult off-spring in the natural environment compared to naturally produced fish (Chilcote *et al.* 1986; Blouin 2004). Hatchery programs in the Central Valley have contributed to the loss of genetic diversity among salmon populations through the routine transfer of eggs and fish from different hatchery populations. Such practices are not included in the proposed action at the CNFH.

Genetic diversity can also be lost by hatchery practices that lead to excessive straying of hatchery fish, or by collecting mixtures of genetically discrete populations for use as hatchery broodstock. Excessive gene flow into a natural population from naturally spawning hatchery fish can reduce the fitness of individual populations through a process called outbreeding depression. Outbreeding depression arises because natural salmonid populations adapt to the local environment and this adaptation is reflected in the frequency of specific alleles that improve survival in that environment. Outbreeding depression can occur when eggs and fish are transferred among populations and/or when out of basin hatchery populations are released to spawn with the local population. When gene flow occurs, alleles that may have developed in a different environment are introduced and these new alleles may not benefit the survival of the receiving population leading to outbreeding depression. Another source of outbreeding depression is the loss of combinations of alleles called coadapted complexes. Gene flow from hatchery to natural salmonids can introduce new alleles that can replace alleles in the coadaptive complexes, leading to a reduction in performance (Busack and Currens 1995). There is evidence for local adaptation of salmonid populations (see Taylor 1991, and McElhany *et al.* 2000 for reviews), but the only empirical data on outbreeding depression in fish involves distantly related populations (Busack and Currens 1995).

Campton (1995) examined the risks of genetic introgression to naturally produced fish and suggested the need to distinguish the biological effects of hatcheries and hatchery fish from the indirect and biologically independent effects of fisheries management actions. In his review of the scientific literature for steelhead, Campton (1995) suggested that many of the genetic effects detected to date appear to be caused by practices such as stock transfers and mixed stock fisheries and not by biological factors intrinsic to hatchery fish. Phelps *et al.* (1994) and Narum *et al*. (2006) found that native steelhead genotypes persisted in areas where hatchery production has been extensive. However, loss of among population genetic diversity as a result of these types of hatchery practices has been documented for western trout, where unique populations have been lost through hybridization with introduced rainbow trout (Behnke 1992). Phelps *et al.*

(1994) found evidence for introgression of non-native hatchery steelhead into a number of natural populations within the southwest Washington region.

The loss of genetic variability among populations can be minimized by employing the following BMPs, where applicable, which occur at the CNFH Complex as follows:

- Propagating and releasing only fish from the local indigenous population or spawning aggregate;
- Avoiding or adequately reducing, gene-flow from a hatchery program into a natural population - this occurs for the steelhead and late fall-run Chinook salmon programs;
- Ceasing the practice of fish and egg transfers;
- Releasing fish at or near the hatchery to ensure that they retain a high site fidelity;
- Using returning spawners rather than a transferred donor population as broodstock for restoration programs to foster local adaptation;
- Maintaining natural populations that represent sufficient proportions of the existing total abundance and diversity of an ESU/DPS without hatchery intervention - this does not occur in the Central Valley currently; and
- Visually marking hatchery-produced salmonids to allow for monitoring and evaluation of straying and contribution to natural production (Kapuscinski and Miller 1993; Flagg and Nash 1999) - this occurs at 100 percent for all propagation, except for fall-run Chinook salmon which are marked at 25 percent.

A NMFS-sponsored workshop in 1995 focused on the biological consequences of hatchery fish straying into natural salmonid populations (Grant 1997). The workshop addressed how much gene flow can occur and still remain compatible with the long-term conservation of local adaptations and genetic diversity among populations. Based on selection effects in other animals, a gene flow rate of greater than five percent from a non-local population would quickly lead to replacement of neutral and locally-adapted genes (Grant 1997). NMFS notes that gene flow is expected to be much less than the population census rate because not all hatchery fish that stray will spawn successfully. Thus, NMFS supports the standard that hatchery stray rates should be managed such that less than five percent of the naturally spawning population consists of non-local hatchery broodstock.

These criteria have been incorporated by the Interior Columbia Technical Recovery Team (ICTRT) and Willamette/Lower Columbia Technical Recovery Team (WLCTRT) in their approaches of assessing risk associated with exogenous spawners for the recovery of listed species (ICTRT 2005; WLCTRT 2006). The ICTRT (2005) define exogenous spawners as all hatchery-origin and all natural-origin fish that are present due to unnatural, anthropogenically induced conditions (Figure 10). The WLCTRT developed similar metrics to describe risks from hatchery stocks derived from locally adapted broodstock, including one measuring the potential loss of fitness over time (Figure 3b and 3c in WLCTRT 2006) that is based on the Proportionate Natural Influence (PNI). Proportionate Natural Influence is defined as the relationship between the percent of hatchery-origin fish spawning naturally and the percent of natural-origin fish in the hatchery broodstock (see HSRG *et al.* 2004, 2009a). Another metric for diversity looked at the influence of non-local origin fish strays, originating from both within the ESU and out-of-ESU, on diversity, but considered these strays only if there was evidence of interbreeding (WLCTRT

2006). The WLCTRT combined these and other metrics to develop a score for the diversity criteria that is used to assess the overall viability of a population.

The methods for weighing the different metrics within the criteria and developing a final combined score have not been finalized. It should also be noted that the failure in one of the metrics (*e.g.*, loss of fitness over time) does not prevent the population from meeting the diversity criteria. The optimal proportion of hatchery fish spawning naturally depends on the type of program (*i.e.*, isolated or integrated) and the status of the natural spawning population. For isolated hatchery programs, the management goal is to limit the proportion of natural spawners comprised of hatchery-origin fish (pHOS) to not exceed five percent (HSRG 2005). For integrated, pHOS should be determined by the status of the natural-origin population and its importance to recovery (HSRG 2009).

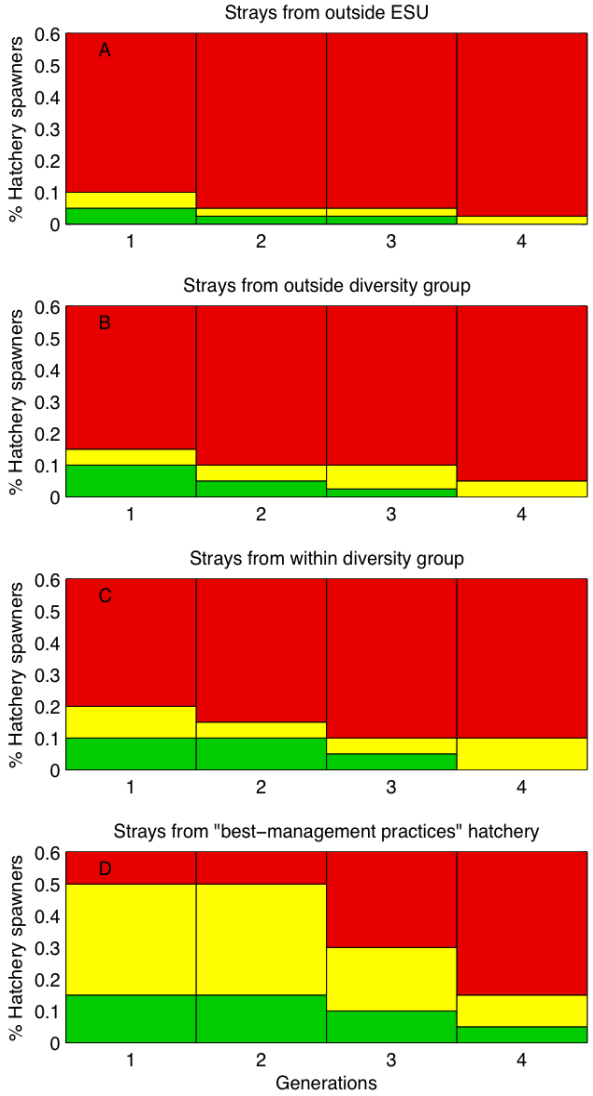

Figure 9. Extinction risk levels corresponding to different amount, duration, and source of hatchery strays. Green bars indicate the range of low risk, yellow bars moderate risk, and red areas indicate high risk. Which chart to use depends on the relationship between the source and recipient populations. A: Hatchery strays are from a different ESU than the wild population. B: Hatchery strays are from the same ESU but from a different diversity group

within the ESU. C: Hatchery strays are from the same ESU and diversity group, but the hatchery does not employ "best management practices." D: Hatchery strays are from the same ESU and diversity group, and the hatchery employs "best management practices." Redrawn from Interior Columbia Basin Technical Recovery Team (2005) and taken from Lindley *et al* 2007.

b. *Loss of Diversity Within Populations*

Loss of within population genetic diversity (variability) is defined as the reduction in quantity, variety, and combinations of alleles in a population (Busack and Currens 1995). Quantity is defined as the proportion of an allele in the population and variety is the number of different kinds of alleles in the population.

Genetic diversity within a population can change from random genetic drift, inbreeding, and domestication selection. Random genetic drift occurs because the progeny of one generation represents a sample of the quantity and variety of alleles in the parent population. Since the next generation is not an exact copy of the parent generation, rare alleles can be lost, especially in small populations where a rare allele is less likely to be represented in the next generation (Busack and Currens 1995).

The process of genetic drift is governed by the *effective population size* rather than the observed number of breeders. The effective size of a population is defined as the size of an idealized population that would produce the same level of inbreeding or genetic drift seen in an observed population of interest (see Hartl and Clark 1989). Attributes of such an idealized population typically include discrete generations, equal sex ratios, random mating and specific assumptions about the variance of family size. Real populations almost always violate one or more of these idealized attributes, and the effective size of a population is therefore almost always smaller than the observed census size. Small effective population size in hatchery programs can be caused by the following factors, which do not occur at the CNFH Complex:

- Using a small number of adults for hatchery broodstock;
- Using an unequal sex ratio for the hatchery broodstock;
- Pooling the gametes of many adults during spawning which would allow one male to potentially dominate fertilization;
- Changing the age structure of the spawning population from what would have occurred naturally; and
- Allowing progeny of some matings to have greater survival than allowed others (Gharrett and Shirley 1985; Simon *et al.* 1986; Withler 1988 cited in Busack and Currens 1995; Waples 1991; Campton 1995).

Some hatchery stocks have been found to have less genetic diversity and higher rates of genetic drift than some naturally produced populations, presumably as a result of a small effective number of breeders in the hatcheries (Waples *et al.* 1990). Potential, negative impacts of artificial propagation on within population diversity may be indicated by changes in morphology (*e.g.*, Bugert *et al.* 1992) or behavior of salmonids (*e.g.* Berejikian 1995). Busack and Currens (1995) observed that it would be difficult to totally control random loss of within population genetic diversity in hatchery populations, but by controlling the broodstock number, sex ratios, and age structure, loss could be reduced. Theoretical work has demonstrated that hatcheries can

reduce the effective size of a natural population in cases where a large number of hatchery strays are produced by a relatively small number of hatchery breeders (Ryman *et al.* 1995). This risk can be reduced by maintaining large effective population size for fish produced in the hatchery and by controlling pHOS or the proportion of natural spawners comprised of hatchery-origin fish.

The breeding of related individuals (inbreeding) can lead to changes in the genetic diversity within a population. Inbreeding depression occurs primarily because nearly all individuals harbor large numbers of deleterious alleles whose effects are masked because they also carry a non-deleterious 'wild type' allele for the same gene. Inbreeding leads to a higher frequency of individuals homozygous for deleterious alleles, and thus a reduction in the mean fitness of the population (Waldman and McKinnon 1993).

Currently, there is little empirical data on inbreeding depression or substantial loss of genetic variability in any natural or hatchery population of Pacific salmon or steelhead, although there are considerable data on the effects of inbreeding in rainbow trout (Hard and Hershberger 1995, quoted in Myers *et al.* 1998). Studying inbreeding depression is particularly difficult in anadromous Pacific salmon because of their relatively long generation times, and the logistical complexities of rearing and keeping track of large numbers of families. Many of these changes associated with inbreeding depression would be expected to occur over many generations; so long term monitoring is likely to be necessary to observe all but the most obvious changes. Monitoring the rate of loss of molecular variation in hatchery and naturally produced populations is an alternative method for studying the impacts of hatcheries on genetic variability (e.g., Waples *et al.* 1993), but does not provide information on inbreeding depression or other fitness.

Loss of diversity within populations can also be affected by domestication selection. Domestication means changes in quantity, variety, and combination of alleles between a hatchery population and its source population that are the result of selection in the hatchery environment (Busack and Currens 1995). Domestication is also defined as the selection for traits that favor survival in a hatchery environment and that reduce survival in natural environments (NMFS 1999a). Domestication can result from propagation in an environment that imposes different selection pressures than what would be encountered in the wild. The concern is that domestication effects will decrease the performance of hatchery fish and their descendants in the wild. Busack and Currens (1995) identified three types of domestication selection: (1) intentional or artificial selection; (2) biased sampling during some stage of culture; and (3) unintentional or relaxed selection.

> (1) Intentional or artificial selection is the attempt to change the population to meet management needs, such as growth rate. Genes in wild salmon and steelhead are selected for fitness in the wild and are thereby "tuned" genetically to their native streams. Hatchery fish selected to perform well in a hatchery environment tend to exhibit reduced fitness when released into the wild. Natural populations can be impacted when hatchery adults spawn with natural-origin fish and the performance of the natural population is reduced (a form of outbreeding depression; Busack and Currens 1995).

(2) Selection in the hatchery can result during any stage of hatchery operation. Hatchery operations can favor or disfavor the survival of fish if they respond differently to activities such as feeding, ponding, sorting, and disease treatments. Spawning of broodstock with particular traits is a common mechanism of selection in hatcheries.

(3) Genetic changes due to unintentional or relaxed selection occur because salmon in hatcheries usually have (by design) much higher survival rates than they would have in the wild. Hatchery fish are reared in a sheltered environment that increases their survival relative to similar life stages in the natural environment. This survival advantage allows deleterious genotypes that would have been lost in the natural environment to potentially contribute to the next generation.

Alteration of the innate predator avoidance is another potential mechanism causing reduced fitness through domestication. Berejikian (1995) reported that wild-origin steelhead fry survived predation by prickly sculpins (*Cottus asper*) better than size-matched off-spring of locally-derived hatchery steelhead that were reared under similar conditions. However, Joyce *et al.* (1998) reported that an Alaskan spring-run Chinook salmon stock under domestication for four generations did not significantly differ from offspring of naturally produced spawners in their ability to avoid predation. The domesticated and naturally produced Chinook salmon groups also showed similar growth and survival rates in freshwater performance trials.

Domestication effects from artificial propagation and the level of genetic differences between hatchery and natural fish can be reduced by employing the following BMPs, as appropriate, which occur at the CNFH Complex as follows:

- Randomly selecting adults for broodstock from throughout the natural population migration to provide an unbiased sample of the natural population with respect to run timing, size, age, sex ratio, and other traits identified as important for long term fitness;
- Ensuring that returning adults used as broodstock by a hatchery continually incorporate natural-origin fish over the duration of the program to reduce the likelihood for divergence of the hatchery population from the natural population - this does not occur with the steelhead program currently;
- For supplementation programs, limiting the program duration to a maximum of three salmon generations (approximately 12 years) to reduce the likelihood of divergence between hatchery broodstocks and target natural stocks and to reduce the risk of domestication of the composite hatchery/natural stock, however, the hatchery propagation programs at the CNFH are not supplementation programs;
- Employing appropriate spawning protocols to avoid problems with inbreeding, genetic drift and selective breeding in the hatchery (e.g., Simon *et al.* 1986; Allendorf and Ryman 1987; Gall 1993). Methods include collection of broodstock proportionally across the breadth of the natural return, randomizing matings with respect to size and phenotypic traits, application of at least 1:1 male to female mating schemes (Kapuscinski and Miller 1993), and avoidance of intentional selection for any life history or morphological trait;
- Using spawning protocols that equalize as much as possible the contributions of all parents to the next breeding generation;

- Using only natural fish for broodstock in the hatchery each year to reduce the level of domestication – *e.g.*, the winter-run Chinook salmon program where practical;
- Size of the hatchery stock should be appropriately scaled to the natural system, so as not to dominate the natural population - due to production goals and mitigation requirements this does not occur for most programs;
- Setting minimum broodstock collection objectives to spawn the number of adults needed to minimize the loss of some alleles and the fixation of others (Kapuscinski and Miller 1993);
- Setting minimum escapements for natural spawners and maximum broodstock collection levels to allow for at least 50 percent of escaping fish to spawn naturally each year, to help maintain the genetic diversity of the donor natural population - although natural spawning of hatchery returns occurs, minimum escapements have not been set for late-fall-run, or fall-run Chinook salmon, or steelhead;
- Using hatchery methods that mimic the natural environment to the extent feasible (e.g. use of substrate during incubation, exposure to ambient river water temperature regimes and structure in the rearing ponds) - some methods have been implemented; and
- Limiting the duration of rearing in the hatchery by releasing at early life-stages to reduce the level of intervention into the natural salmonid life cycle, thereby reducing the mechanisms causing domestication - this occurs where appropriate.

NMFS believes that the measures identified for reducing the potential adverse genetic impacts of hatchery produced fish on naturally produced fish should be applied to protect listed species. The actual measures selected will depend on a number of factors including but not limited to:

- The objectives of the program (i.e. recovery, reintroduction or harvest augmentation);
- The source of the broodstock, its history, and level of domestication;
- The spawning protocols of the hatchery program;
- The status of the natural population targeted by the hatchery program;
- The ability of fish managers to remove or control the number of hatchery adults in the natural spawning population;
- The proposed rearing practices for the hatchery program; and
- The total number of hatchery fish released into the subbasin.

More detailed discussions on the measures to implement these strategies can be found in Reisenbichler (1997), Reisenbichler and McIntyre (1986), Nelson and Soule (1987), Goodman (1990), Hindar *et al.* (1991), and Waples (1991) among others.

The propagation programs at the CNFH can have genetic impacts on ESA-listed Central Valley salmonids. The fall-run Chinook salmon propagation program could impact listed Central Valley spring-run Chinook salmon through hybridization of spring-run Chinook salmon, or through superimposition of spring-run Chinook salmon redds. Steelhead propagation at the CNFH could affect listed California Central Valley steelhead when hatchery steelhead comingle with natural-origin steelhead in natural spawning areas, potentially reducing the fitness of the population due to the effects of domestication or outbreeding depression. The late fall-run Chinook salmon propagation program is not likely to impart detrimental genetic effects to listed salmonids.

c. *CNFH fall-run Chinook salmon*

Spawning areas of Central Valley spring-run and fall-run Chinook salmon were historically segregated, both spatially and, to a large extent, temporally. Spring-run Chinook salmon adults migrated to the uppermost reaches of the watershed during the spring, when water levels were high. Spring-run Chinook salmon would hold over during the summer in cool, deep pools prior to spawning. In contrast, fall-run Chinook salmon adults migrated in the late summer and fall when water levels are lower; consequently, the spawning areas of fall-run Chinook salmon tend to be lower elevation streams and rivers. The current distribution of spring-run and fall-run Chinook salmon spawning may overlap in areas where spring-run Chinook salmon are blocked from reaching their historic spawning areas by dams or altered flow patterns.

CNFH-origin fall-run Chinook salmon that spawn naturally in the Central Valley could impact spring-run Chinook salmon through genetic introgression and redd superimposition. The CNFH releases approximately 90 percent of its fall-run Chinook salmon and all of its late fall-run Chinook salmon into Battle Creek. On-site releases of smolts reduce the likelihood that fish will stray to other watersheds and decrease the likelihood of genetic impacts to spring-run Chinook salmon in other watersheds (USFWS 2011). However, more than one million fall-run Chinook salmon are trucked from the CNFH and released into the San Pablo Bay each year. Straying of these fish likely occurs at a high rate. Previous USFWS studies have shown stray rates exceeding 75 percent for fall-run Chinook salmon smolts released into the west Delta at Benicia (USFWS 2001b). Fall-run Chinook salmon released into the Delta stray throughout the Central Valley, including into streams used by spawning spring-run Chinook salmon. Genetic introgression and redd superimposition of CNFH-origin fall-run Chinook salmon and spring-run Chinook salmon is most likely to occur in areas where spring-run have been blocked from their historic spawning areas, such as the Sacramento River, Feather River, and Clear Creek, which were blocked by Keswick Dam, Oroville Dam, and Whiskeytown Dam, respectively. Independent Spring-run Chinook salmon populations in Mill, Deer, and Butte creeks still maintain the capability for temporal and spatial segregation of fall and spring-run Chinook salmon spawning. In those areas, the capabilities exist for spatial segregation of fall and spring-run Chinook salmon spawners, thereby reducing the likelihood of detrimental genetic impacts. Weirs are used to avoid hybridization between fall-run and spring-run Chinook salmon in Clear and Battle creeks.

It is also possible that operations of the CNFH could cause hybridization between spring-run and fall-run Chinook salmon in Battle Creek and the CNFH. The CNFH barrier weir fish ladder structure is generally operated to congregate and collect broodstock for fall-run and late fall-run Chinook salmon and steelhead from approximately September 1 to March 1. Additionally, upstream passage is blocked at the barrier weir during August. Blockage of salmonids at the CNFH barrier weir during August is conducted at the request of the fishery management agencies to prohibit fall-run Chinook salmon from impacting listed spring-run Chinook salmon in upper Battle Creek. A multi-agency decision was reached in 2004 to close the upstream fish ladder on August 1 to reduce the likelihood that fall-run Chinook salmon would impact natural origin spring-run Chinook salmon through direct hybridization or redd superimposition upstream of the hatchery in Battle Creek.

d. *CNFH late fall-run Chinook salmon*

Production of late fall-run Chinook salmon at the CNFH is not likely to adversely affect the genetic diversity and fitness of listed salmonids in the Central Valley. Detrimental genetic impacts are unlikely because the spawn timing of late fall-run Chinook salmon does not overlap with those of ESA-listed Chinook salmon. Until 2008, the CNFH provided up to 1/3 of its annual production of late fall-run Chinook salmon for experimental releases into the Delta. Stray rates of these release groups were estimated to approach 85 percent (USFWS 2001b). Although differences in spawn timing ameliorated risk to ESA listed salmon, the multi-agency studies that required these off-site releases have been completed and no additional studies requiring off-site releases of late fall-run Chinook salmon are currently being proposed.

e. *CNFH steelhead*

Hatchery steelhead are all marked with an adipose fin clip prior to release into the upper Sacramento River. Because hatchery steelhead are all marked by clipping their adipose fin they are easily identifiable upon return to the hatchery as adults. Steelhead with a clipped adipose fin that return to the hatchery are retained to prevent them from spawning naturally. Because the release location is in close proximity to the hatchery, CNFH-origin steelhead are believed to return as adults primarily to Battle Creek and are not known to comprise a high proportion of broodstock to any natural spawning population (USFWS 2011). Hatchery-origin steelhead returning to Battle Creek and collected in the hatchery adult holding ponds or in the fish barrier weir ladder trap from October through around April are removed from the natural environment and are precluded from spawning in the natural environment upstream of the hatchery, further reducing the potential for detrimental genetic, domestication, and reduced fitness impacts to natural-origin steelhead in Battle Creek. However, an unknown number of hatchery-origin steelhead are able to migrate past the CNFH barrier weir, particularly when stream flow in Battle Creek exceeds 800 cfs, as well as during the barrier weir ladder open period when trapping ceases and video monitoring only begins (around end of April through July). Hatchery-origin steelhead that migrate past the barrier weir may spawn with natural-origin steelhead potentially reducing contribution from that natural origin adult. Hatchery-origin steelhead from the CNFH have been shown to have lower reproductive success relative to natural-origin steelhead in Battle Creek; however, the mechanism for this difference (*e.g.*, behavioral or genetic) requires additional investigation (Robert Null, USFWS, personal communication, 2012). Additionally, hatchery-origin steelhead that stray to other areas with listed steelhead populations, such as Mill, Deer, Clear, Antelope, and Cow creeks, as well as the Sacramento River, may spawn with natural populations.

f. *Summary of genetic effects*

NMFS believes that the impact of genetic introgression between Coleman Hatchery-origin fall and late fall-run Chinook salmon and steelhead to ESA-listed winter-run and spring-run Chinook salmon and steelhead varies. The impact of genetic introgression between hatchery-origin fall-run Chinook and ESA-listed spring-run Chinook has the potential to be quite high, especially due to trucking and releasing a portion of the fall-run Chinook salmon from the CNFH to the San Pablo Bay which has shown to significantly increase the likelihood of straying. The remaining interactions are expected to have a low impact on genetic introgression.

NMFS considers the CNFH barrier weir to be an important management tool offering the capability of selective fish passage to upper Battle Creek. When operated so as to curb the passage of hatchery-origin fishes to prevent the intermingling of fall-run and spring-run Chinook salmon in upper Battle Creek by closing the fish ladder during August, NMFS believes that the CNFH barrier weir functions as a conservation measure benefitting listed spring-run Chinook salmon.

7. Disease

Fish pathogens can be transported from the CNFH to Battle Creek in hatchery effluent, exposing natural fish to pathogens. Pathogens may also be transmitted between juvenile and adult hatchery and natural fish both in the hatchery and throughout the range of the species where they coexist in the wild. Juvenile hatchery-origin fish have an increased likelihood of carrying fish pathogens because of relatively high rearing densities in the hatchery environment. Higher rearing densities cause increased stress and can lead to greater manifestation of disease and subsequent spread of pathogens. Disease outbreaks may be triggered by stressful hatchery rearing conditions, or by a stressful change in the environment after hatchery-fish are released (Saunders 1991). Consequently, it is possible that hatchery effluent and the release of hatchery fish may lead to the spread of pathogens, possibly affecting the VSP parameters of abundance, productivity, diversity, and spatial structure for listed species in the Central Valley. The likelihood of this occurrence is increased when hatchery and natural fish intermingle, become stressed, and congregate in close proximity, such as when adult salmonids congregate below the barrier weir in Battle Creek.

Because pathogens responsible for fish diseases are generally present in both hatchery and natural populations, there is some uncertainty associated with determining the source of disease epidemics, if they were to occur (Williams and Amend 1976; Hastein and Lindstad 1991). Some studies suggest that the incidence of some pathogens may be higher in naturally spawning populations than in proximate hatchery populations (Elliott and Pascho 1994). For example, Congleton *et al* (1995) and Elliott *et al* (1997) found the incidence of high enzyme-linked immunosorbent assay titers for Renibacterium salmoninarum, the causative agent of Bacterial Kidney Disease (BKD), generally appears to be more prevalent among wild smolts of spring/summer Chinook salmon than hatchery smolts. However, detecting and verifying pathways of pathogen transmittance is complicated by uncertain interactions between pathogen and host, making cause-and-effect relationships difficult to determine. Although pathogens may cause a high rate of post-release mortality among hatchery fish there is little evidence that hatchery-origin fish routinely infect naturally produced salmon and steelhead (Enhancement Planning Team 1986; Steward and Bjornn 1990).

Many of the disease concerns related to hatchery fish are based on old management styles that emphasized the production of as many fish as possible, regardless of the implications that increased rearing densities have on fish health. Since that time, however, the desire to increase survival of hatchery fish has led to better husbandry practices, including decreases in fish numbers to reduce crowding and stress that affects the resistance of salmonids to disease (Salonius and Iwama 1993; Schreck et al. 1993). Along with decreased densities and improved animal husbandry, advances in fish health care and adherence to federal and interagency fish

health policies have considerably decreased the possibility of pathogen transmission from hatchery fish to natural-origin fish.

Compliance with the regional fish health policies minimizes the risk for fish disease transfer. State and federal fisheries agencies have established fish pathology labs to monitor and manage fish health in state, federal and tribal hatcheries. The success of hatchery programs, as measured by the production of quality smolts that survive and contribute to achieving program goals, depend on good fish health management. Working toward this objective, fisheries managers have established a number of fish health policies to address concerns of potential disease transmission from hatchery salmonids to naturally produced fish. These policies established guidelines to ensure that fish health is monitored, sanitation practices are applied, and that hatchery fish are reared and released in healthy condition (PNFHPC 1989; IHOT 1995; WDFW 1996; WDFW and WWTIT 1998; USFWS 1995; USFWS 2004). Standard fish health monitoring under these policies include monthly and pre-release checks of propagated salmonid populations by a fish health specialist, with intensified efforts to monitor presence of specific pathogens that are known to occur in the populations. Specific reactive and proactive strategies for disease control and prevention are also included in the fish health policies. Fish mortality at the hatchery due to unknown cause(s) will trigger sampling for histopathological exam. Incidences of viral pathogens in salmonid broodstocks are determined by sampling fish at the time of spawning. Compliance with NPDES permit provisions at hatcheries also acts to minimize the likelihood for disease epizootics and water quality impacts that may lead to increased naturally produced fish susceptibility to disease outbreaks.

The fall and late fall-run Chinook salmon and steelhead propagation programs at the CNFH are monitored by the California-Nevada Fish Health Center. Fish culture practices and rearing conditions at both hatcheries are designed to reduce stress and disease in the fishes being propagated. Monthly and pre-release checks are conducted by the staff of the fish health center, with intensified efforts to monitor presence of specific pathogens that are known to occur in the populations. Recommendations are provided to hatchery staff for disease control and prevention.

Strategies to reduce the risk of transmitting pathogens are implemented at the CNFH Complex. The ozone water treatment plant at the CNFH, fully operational since 2000, has reduced the incidence of disease at the CNFH and the risk of transmitting pathogens into the natural environment. Since 2000, the pathogens that pose the greatest risks to natural-origin salmonid populations (*i.e.* IHNV and BKD) have not been a health problem in juveniles reared at the CNFH. Recent health problems in juvenile salmonids have primarily been limited to external parasites (*Ichthyobodo* sp.), *Flavobacterium columnare*, *Yersinia ruckeri*, or non-infectious issues (feed, water quality, coagulated yolk, and gill irritation due to debris).

a. *Summary of effects of disease*

NMFS believes that existing practices and protocols for fish propagation and fish health management at the CNFH Complex are sufficient to reduce the risks of pathogen transmission to listed fish species in the Central Valley, including winter-run and spring-run Chinook salmon, and steelhead. Potential effects to the VSP parameters of abundance, productivity, diversity, and spatial structure are adequately mitigated to reduce the risk to levels that will not adversely affect listed populations in Battle Creek or the listed ESUs/DPSs. Risks of fish specific pathogen

transmission from the proposed action are not known to affect mammals such as killer whale. Salmonids do not transmit obligate sturgeon pathogens; the potential for this risk is considered discountable (Kevin Niemela, USFWS, personal communication, 2013c).

8. Competition and Density-Dependent Effects

Competition occurs when the demand for a resource by two or more organisms exceeds the available supply. If the resource in question (e.g., food or space) is present in such abundance that it is not limiting, or if resources are used at different times, then competition is not occurring, even if both species are using the same resource. Specific mechanisms for hatchery fish to negatively affect natural salmonids through competitive interactions include competition for food and spawning sites, which may affect the VSP parameters of abundance, productivity, diversity, and spatial structure of listed species. Adverse effects of competition may result from direct interactions, whereby a hatchery-origin fish directly interferes with the accessibility to limited resources by naturally produced fish, or through indirect means, whereby the use of a limited resource by hatchery fish reduces the amount available for naturally produced fish (SIWG 1984). Competition between hatchery- and natural-origin salmonids can occur at both the adult and juvenile life stages and in both freshwater and marine environments, which are discussed below. Competitive interactions between hatchery-origin salmonids and green sturgeon and killer whale are not likely to occur.

a. *Adult fishes*

Salmonids have evolved a variety of strategies to partition resources between species, such as species-specific preferences for food resources, spawning substrate, and water temperature and velocity. Habitat partitioning strategies allow multiple species and life stages to coexist in limited habitats. The addition of hatchery-origin fish can overload habitat partitioning mechanisms and impact the productivity of naturally produced stocks. Competition for anadromous salmonids is often assumed to be greatest in freshwater spawning and rearing habitats; however, little information is available concerning resource limitations in the estuary or ocean. Returning or straying hatchery fish may compete for spawning gravel, displace naturally produced spawners from preferred spawning areas, outcompete natural origin spawners during mate selection, or adversely affect listed salmonid survival through redd superimposition. Superimposition of redds by similarly timed or later spawners disturbs or removes previously deposited eggs from the gravel and has been identified as a significant source of salmon mortality in some areas (Bakkala 1970). Competition between hatchery and natural adult salmonids during the mate selection process can increase the potential for outbreeding depression and decrease productivity due to reduction of fitness associated with domestication.

The risks of competitive interactions between adult hatchery and natural fishes in freshwater habitats can be reduced by rearing juvenile fish for an extended duration (*e.g.*, eyed egg to smolt) in their "home" or natal stream, to reduce straying (USFWS 2011). Homing fidelity is also improved through the use of locally adapted broodstocks. When hatchery fishes are released away from their natal stream, acclimation may be used to improve the imprint to their stocking location; however, even prolonged acclimation cannot be expected to reduce straying to the level of direct releases into the natal stream (Kenaston *et al.* 2001). The risks of competitive

interactions in natural spawning areas can also be reduced by removing hatchery-origin fishes from natural spawning areas.

USFWS attempts to reduce straying of fish produced at the CNFH by releasing most fall and late fall-run Chinook salmon at the site of the hatchery on Battle Creek. However, the recent 2008 change in hatchery practices to transport approximately 10 percent of the fall-run Chinook salmon juveniles to the San Pablo Bay for release is anticipated to result in substantial straying for that portion of the hatchery production. This Bay-Delta release practice is directly opposed to best management practices designed to reduce straying of hatchery-origin fishes and is of concern to NMFS in regards to the high rates of straying anticipated to result from this action. Published reports and previous studies have shown that CNFH fall-run Chinook salmon released into the Delta stray across the Central Valley and at rates exceeding 75 percent. Hatchery-origin fall-run Chinook salmon are expected to stray at a high rate and could stray to the spring-run Chinook salmon spawning areas, such as the upper Sacramento River, the Feather River, and the soon-to-be established population in the San Joaquin River, where they may hybridize with spring-run Chinook salmon or superimpose upon spring-run Chinook salmon redds. A temporary weir that is installed to segregate spring-run and fall-run Chinook salmon in Clear Creek would likely decrease, if not preclude spawning area interactions in that tributary and temporal and spatial segregation would likely reduce impacts from straying fall-run Chinook salmon in other tributaries of the Sacramento River where spring-run Chinook salmon spawning occurs. However, hybridization and redd superimposition of straying early-spawning hatchery-origin fall and late-spawning spring-run Chinook salmon is likely to occur in the mainstem Sacramento River, and the extent of this is not currently known. In addition, this potentially occurs in Clear Creek if the temporary weir fails as a result of storm events or vandalism, which has occurred in some years (Sarah Giovannetti, USFWS, personal communication 2012).

Late fall-run Chinook salmon spawn concurrently with listed California Central Valley steelhead; however, the likelihood of significant effects of redd superimposition is low. CNFH uses local broodstock and releases juveniles into Battle Creek. These practices promote imprinting and homing to the hatchery. Hatchery-origin late fall-run Chinook salmon are confined downstream of the hatchery's barrier weir in Battle Creek, an area where natural steelhead are not known to spawn. The CNFH releases natural-origin late fall-run Chinook salmon upstream of the hatchery barrier weir, so it is possible that these fish could spawn on top of established redds of natural-origin steelhead. The likelihood of redd superimposition by late fall-run Chinook salmon upon listed California Central Valley steelhead is reduced because the species select different habitats for spawning. California Central Valley steelhead typically do not spawn in the same parts of the stream channel as late fall-run Chinook salmon (Matt Brown, USFWS, personal communication 2012). Steelhead spawning areas are generally located closer to shore and where gravel size is smaller as opposed to Chinook salmon, which select deeper spawning areas with faster flow and larger substrate.

Competitive interactions between adult hatchery-origin steelhead and listed species are reduced by releasing steelhead smolts into the upper Sacramento River at Bend Bridge, which is sufficiently near to the hatchery to encourage a high degree of fidelity to Battle Creek (USFWS 2011). Brood stock collection practices at the CNFH help to further reduce competitive interactions between hatchery-origin steelhead and listed stocks. All hatchery-origin steelhead

collected at the hatchery are either spawned or stripped of their gametes and then placed into a pond located on the hatchery premises, where they are "reconditioned" prior to release below the barrier weir in Battle Creek. By maintaining collected hatchery-origin steelhead captive throughout the duration of the steelhead spawning season, the potential for competitive interactions with listed species is substantially reduced.

However, an unknown number of hatchery-origin steelhead are able to migrate past the CNFH barrier weir, particularly when stream flow in Battle Creek exceeds 800 cfs. Hatchery-origin steelhead that migrate past the barrier weir may compete for spawning habitat with natural-origin steelhead. Hatchery-origin steelhead have been shown to have lower reproductive success than natural-origin steelhead either due to behavioral or genetic differences (Robert Null, USFWS, RBFWO, personal communication, 2012). Additionally, hatchery-origin steelhead that stray to other areas with natural populations of listed steelhead, such as Mill, Deer, Clear, Antelope, and Cow creeks, as well as the Sacramento River; potentially result in outbreeding depression or reduction in productivity.

b. *Juvenile fishes*

Hatchery smolts may compete with naturally produced fish for food and space at the site of release and during their downstream migration (SIWG 1984). Naturally produced fish may be competitively displaced by hatchery fish, especially when hatchery fish are more numerous, of equal or greater size, and (if hatchery fish are released prior to smolting or as non-migrants) the hatchery fish have taken up residency before naturally produced fry emerge from redds. Hatchery programs directed at fry and non-migrant fingerling releases are of particular concern because they produce fish that compete with naturally produced salmonids for longer durations. Competition is increased when hatchery fish are planted within, or disperse into, areas where naturally produced fish are present. Release of hatchery fish prior to the onset of smoltification is believed to have greater potential for competitive impacts because of the extended period of concurrent residence in the freshwater environment. A negative change in growth and condition of naturally produced fish could occur following the release of hatchery salmonids due to a change in diet or feeding habits. Competitive impacts likely diminish as hatchery-produced fish disperse and decrease in abundance, but resource competition may continue to occur as commingled hatchery and natural origin juveniles emigrate seaward.

Interactions with juvenile hatchery-origin salmonids may cause behavioral changes in listed natural salmonids that are detrimental to their productivity and survival. Hatchery fish can alter behavioral patterns and habitat use by naturally produced salmon, making them more susceptible to predators (Hillman and Mullan 1989; Steward and Bjornn 1990). Hatchery-origin fish may also alter salmonid migratory responses or movement patterns, causing increased predation or reduced foraging success (Steward and Bjornn 1990; Hillman and Mullan 1989). The potential for negative impacts on the behavior and survival of naturally produced fish as a result of hatchery releases depends on the degree of spatial and temporal overlap in occurrence of hatchery and naturally produced fish, the relative size of hatchery- and naturally-produced fish, as well as the abundance of hatchery fish encountered (Steward and Bjornn 1990).

Very large releases of hatchery smolts may displace naturally produced juvenile salmonids from rearing areas, leading to abandonment of advantageous feeding stations or premature out-

migration (Pearsons *et al.* 1994). Pearsons *et al.* (1994) reported small-scale displacement of juvenile naturally produced rainbow trout following the release of hatchery steelhead into an upper Yakima River tributary. Observed displacements and agonistic interactions resulted from the larger size of hatchery steelhead, which behaviorally dominated most contests. The authors noted, however, that releases of hatchery steelhead did not appear to have significantly affected the abundance of naturally produced rainbow trout.

Weber and Fausch (2005) observed that releases of fall-run Chinook salmon from the CNFH may not have displaced wild juvenile Chinook salmon in the Sacramento River. Weber and Fausch (2005) measured the densities and size distributions of hatchery and natural fall-run Chinook salmon in two rearing areas along the margins of the upper Sacramento River before, during, and after two large releases from the CNFH. Hatchery releases did not increase fish densities above the baseline level, except after one release at one site, which returned to the baseline level within 3 days. Although hatchery fish were generally much larger than wild fish, the mean size of fish observed along the river margins did not increase appreciably after hatchery releases. These data suggest that hatchery smolts emigrated quickly from the upper Sacramento River, and the strategy of releasing hatchery smolts after most wild fish have emigrated is relatively effective in reducing potential interactions in freshwater rearing areas of the stream margin in the upper river. Weber and Fausch (2005) also tested competition between wild and hatchery ocean-type Chinook salmon and found high densities of hatchery salmon reduced growth, but not survival, of wild salmon during one year, when reduced water velocity probably limited invertebrate drift. The impact from and extent of competition and potential for carrying capacity exceedance from hatchery fall-run Chinook salmon releases is not fully understood.

Habitat partitioning in rearing areas and the emigration corridor reduces intra- and interspecific competition. Bell (1984) and Dawley *et al.* (1986) comment on differential habitat selection, with steelhead choosing river areas in the thalweg and nearer to the surface, subyearling Chinook salmon being more likely to follow the shorelines, and yearling Chinook salmon seeking greater depths. Additional partitioning of habitats occurs between earlier and later life stages of cohabitating species.

The risk of adverse competitive interactions between juvenile hatchery and natural salmonids can be reduced by employing the following BMPs, where appropriate, which occur at the CNFH Complex:

- Releasing hatchery smolts that are physiologically ready to migrate. Hatchery fish released as smolts emigrate seaward soon after liberation, reducing the potential for competition with juvenile naturally produced fish in freshwater (Steward and Bjornn 1990);
- Rearing hatchery fish to a sufficient size so that smoltification occurs within nearly the entire population (Bugert *et al.* 1991); and
- Releasing hatchery smolts after the major seaward emigration period for naturally produced salmonid populations to minimize the risk of interaction that may lead to competition.

Release strategies for juveniles from CNFH are designed/expected to reduce competition and density dependent effects in freshwater. For example, releases of fall-run Chinook salmon smolts from CNFH occur in the late-spring, after most natural-origin fall-run Chinook salmon juveniles salmonids have emigrated from the upper Sacramento River. Late fall-run Chinook salmon and steelhead are released from CNFH as yearling smolts to encourage rapid emigration. Additionally, releases of late fall-run Chinook salmon are timed to coincide with high flow and turbid water events, which promotes rapid emigration from Battle Creek and the upper Sacramento River and reduces competitive interactions between hatchery-origin and natural-origin salmonids.

Fall-run Chinook salmon smolts from CNFH exhibit prompt downstream movement upon release into Battle Creek, emigrating from the upper Sacramento River in large pulses, with few fish exhibiting delayed emigration. Emigration past the RBDD typically begins about 1.5 days after release and, by the fourth day after release, the vast majority of fish have passed RBDD (USFWS 2010). Emigration downstream of Red Bluff occurs at an equally rapid pace. Juvenile monitoring conducted during 1998 and 1999 showed that the majority of fall-run Chinook salmon smolts released from CNFH emigrate past Knights Landing (RM 90) from one to three weeks post-release, with no marked hatchery-origin fall-run Chinook salmon being captured after May (Snider and Titus 2000). This emigration monitoring data shows a sustained rate of travel of at least nine miles per day through Battle Creek and the Sacramento River, 181.5 miles downstream to Knights Landing.

Hatchery-origin late fall-run Chinook salmon released from CNFH also exhibit rapid emigration from the upper Sacramento River. Monitoring conducted during 1993 showed that the majority of hatchery-origin late fall-run Chinook salmon smolts emigrated past GCID (RM 205) within two days, and past Sherwood Harbor (RM 55) within seven days following their release into Battle Creek (USFWS unpublished data, CDFG unpublished data). Monitoring efforts conducted at the RBDD during 1995 and 1996 show similar trends of rapid downstream movement, with approximately 50 percent of hatchery-origin late fall-run Chinook salmon being sampled from two to six days following release into Battle Creek. These data demonstrate a rate of travel equal to more than 30 miles per day through the Sacramento River (USFWS, RBFWO, unpublished data).

Hatchery-origin steelhead are released into the Sacramento River at Bend Bridge as yearling smolts during January, at a time when river flows are typically high. River conditions and the physiological status of steelhead encourage rapid emigration from the upper Sacramento River. Rapid emigrations of hatchery-origin steelhead smolts from the CNFH are believed to reduce competition with natural-origin salmonids. Two groups of steelhead smolts released in January 1993 were recaptured at GCID five and 22 days post-release (Bigelow *et al.* 1995a). Differing rates of emigration observed in that investigation were associated with prevailing flow conditions. Steelhead released from CNFH on January 8, 1996, were sampled emigrating past the RBDD primarily on January 16 (8-days post-release), translating to an emigration rate of approximately four miles per day. Similar emigration patterns of hatchery-origin steelhead from CNFH have been documented through rotary screw trap monitoring at RBDD for brood year 1996 through 1998 (USFWS, RBFWO unpublished data).

c. *Competition in the Ocean*

Most research on competitive interactions of salmonids occurs in freshwater environments; however, hatchery-origin smolts, sub-adults, and adults may also compete with naturally produced fish in estuarine and marine areas. The risk of adverse competitive interactions in marine waters is difficult to assess because of a paucity of data, including a lack of basic information on fish distribution, size, food availability, and carrying capacity (SIWG 1984). Food is the most likely limiting resource for naturally produced fish that could be affected through competition within marine waters. The early marine life stage, when naturally produced fish are concentrated in a relatively small area is a time of particular susceptibility (SIWG 1984). This does not discount limitations in more seaward areas as a result of competition by hatchery-origin fish, as data are available to show that survival and growth in marine environments are density dependent, and thus possibly a reflection of food availability (SIWG 1984).

Determining the effects of competitive interactions between hatchery production on listed salmon and steelhead in the ocean would be speculative, since hatchery fish intermingle at the point of ocean entry with wild and hatchery anadromous salmonids from many other regions. The Supplemental Comprehensive Analysis of the Federal Columbia River Power System (FCRPS) biological opinion (NMFS 2008d), and the FCRPS adaptive management plan (NMFS 2009c) both concluded that available knowledge and research abilities are insufficient to discern any important role or contribution of hatchery fish in density-dependent interactions affecting salmon and steelhead growth and survival in the mainstem Columbia River, the Columbia River estuary, and the Pacific Ocean.

d. *Summary of Impacts of Competition*

The USFWS CNFH employs several practices and protocols designed to reduce competitive interactions with naturally produced fishes, including: releasing fishes at the smolt stage and when environmental conditions favor rapid outmigration, releasing fish in areas that promote a strong imprint to the hatchery to decrease the likelihood of straying, and retaining hatchery-origin steelhead adults at the hatchery. Competitive interactions may be further reduced through the natural segregation of fishes in the natural environment, including mechanisms such as habitat partitioning and spawning site selection. Although releasing a portion of the fall-run Chinook salmon produced at CNFH in the Bay-Delta likely reduces competition between juveniles in the freshwater environment, it is expected to increase straying and therefore increase competitive interactions between adults in natural spawning areas as well as affect the genetic integrity of native spring-run Chinook salmon populations.

9. <u>Predation</u>

Risks of direct predation (direct consumption) or indirect predation (increase in predation due to enhanced attraction) can result from releases of hatchery salmonid in freshwater and estuarine areas. Direct predation by hatchery-origin fish can occur at both juvenile and adult life-stages. Newly released hatchery Chinook salmon and steelhead smolts have the potential to prey on naturally produced salmonid fry and fingerlings that are encountered in freshwater during downstream migration. Recently released and residualized hatchery steelhead could predate upon green sturgeon larvae in the Sacramento River. Hatchery-origin smolts, sub-adults, and

adults may also prey directly on naturally produced fish of susceptible sizes and life stages in estuarine and marine areas where they commingle. In general, naturally produced salmonid and green sturgeon will be most vulnerable to predation when predator abundance is high, in altered habitats, where migration distances are long, and when environmental conditions favor high visibility. Hatchery fish may be inefficient predators soon after release, reducing the potential for predation impacts (Sosiak et al. 1979; Bachman 1984; Olla et al. 1998).

Direct predation on listed salmon and steelhead may be greatest when hatchery fish are large relative to naturally produced fish, such as when hatchery smolts encounter newly emerged green sturgeon larvae or salmonid fry or fingerlings (SIWG 1984). Predation by hatchery fish on natural-origin smolts or sub-adults is less likely to occur than predation on fry. Vulnerability to predation is believed to be greatest for newly emerged fry and decreases as fish grow, improve swimming capabilities, develop predator avoidance behaviors, and move into shallow, protected shoreline areas (USFWS 1994). Some reports suggest that hatchery fish can prey on fish that are ½ their length (HSRG 2004; Pearsons and Fritts 1999), but other studies have concluded that salmonid predators prefer fish ⅓ or less their length (Horner 1978; Hillman and Mullan 1989; Beauchamp 1990; Cannamela 1992; CBFWA 1996). A recent study in 2009 (USFWS 2011) observed that salmonids are more likely to consume macroinvertebrates (one late fall-run Chinook salmon out of 378 salmon and steelhead was found to have stomach contents containing fish).

Predation by hatchery fishes continues into estuarine and marine environments. Chinook salmon, after entering the marine environment are capable of preying on fish equal to one-half their body length and consume, on average, fish prey that are less than one-fifth of their length (Brodeur 1991). During early marine life, predation on naturally produced Chinook salmon, coho, and steelhead will likely be highest in situations where large, yearling-sized hatchery fish encounter sub-yearling fish (SIWG 1984). Juanes (1994), in a survey of studies examining prey size selection of piscivorous fishes, showed a consistent pattern of selection for small-sized prey. Hood Canal, Nisqually Reach, and north Puget Sound data show little or no evidence of predation on juvenile salmonids by juvenile and immature Chinook salmon (Simenstad and Kinney 1978). In a recent literature review of Chinook salmon food habits and feeding ecology in Pacific Northwest marine waters, Buckley (1999) concluded that cannibalism and intra-generic predation by Chinook salmon are rare events. Likely reasons for apparent low predation rates on salmon juveniles, including Chinook salmon, by larger Chinook salmon and other marine predators suggested by Cardwell and Fresh (1979) include:

- The rapid growth in fry, resulting in the increased ability to elude predators and becoming accessible to a smaller proportion of predators due to size alone;
- The rapid dispersal of fry, making them present in lower densities relative to other fish and invertebrate prey; and
- The learning of predator avoidance behaviors.

Large concentrations of juvenile fishes, such as would be encountered during the release of fish from a hatchery, may attract predators (birds, fish, otters and seals) and consequently contribute indirectly to predation of naturally produced fish (Steward and Bjornn 1990). The presence of large numbers of hatchery fish may also alter the behavioral patterns of naturally produced

salmonids, potentially influencing their vulnerability and susceptibility to predation (Hillman and Mullan 1989; USFWS 1994). Hatchery fish released into natural production or migration areas may therefore pose an elevated risk of indirect predation to commingled ESA-listed fishes. Alternatively, a mass of hatchery fish migrating through an area may overwhelm established predator populations, providing a beneficial, protective effect to co-occurring listed naturally produced fish.

Hatchery impacts from predation can be reduced by the following practices, as appropriate, which occur at the CNFH Complex as follows:

- Releasing actively migrating smolts through volitional release practices - no volitional releases occur at the CNFH Complex, but controlled releases are implemented;
- Insuring that a high proportion of the population is smolted prior to release. This can be facilitated by reducing the variability in the size of hatchery fish being released. Smolts tend to migrate seaward rapidly when fully smolted, limiting the duration of interaction between hatchery and naturally produced fish present within, and downstream of, release areas;
- Delaying hatchery fish releases until the major seaward emigration period for naturally produced salmonid populations has been completed can minimize the risk of interaction that may lead to predation;
- Releasing hatchery smolts in lower river areas, downstream of areas used for stream-rearing young-of-the-year naturally produced salmon fry, reducing the likelihood for interaction between the hatchery and naturally produced fish - this does not occur as it is counter to the measure to reduce stray rate; and
- Operating hatchery programs and releases to minimize the potential for residualism (see discussion below).

Occurrences of direct predation by hatchery-origin fall-run Chinook salmon on ESA-listed salmonids are expected to be very low in the freshwater system. The average size of fall-run Chinook salmon smolts at the time of release in April is 76 mm (range: 40-109 mm, std. = 7; USFWS 2010). With the exception of newly-emerged late fall-run Chinook salmon and steelhead, all natural-origin salmonids potentially co-occurring in the river system with hatchery-origin fall-run Chinook salmon are larger, and are therefore incapable of being consumed by hatchery-origin fall-run Chinook salmon (USFWS 2010). Natural-origin young-of-the-year late fall-run Chinook salmon and steelhead are emerging during April when hatchery-origin fall-run Chinook salmon are released. However, predation by hatchery-origin fall-run Chinook salmon is considered unlikely because juvenile fall-run Chinook salmon are believed to be largely non-piscivorous when they are liberated from the hatchery. Fall-run Chinook salmon from the CNFH are unlikely to exhibit piscivory during their emigration through the Sacramento River due to their small body size, gape limitation, and non-piscivorous feeding patterns. For these reasons, effects of predatory interactions involving fall-run Chinook salmon smolts upon natural-origin salmonids are thought to be low in the freshwater environment.

Hatchery-origin late fall-run Chinook salmon juveniles could potentially capture and consume spring-run and winter-run Chinook salmon and steelhead juveniles during their emigration. The average size of hatchery-origin late fall-run Chinook salmon smolts at the time of release in

January is 135 mm (range: 65-202 mm, std. = 19.9; USFWS 2010). Based on the body size of hatchery-origin late fall-run Chinook salmon, size ranges of natural-origin salmonid stocks, and predator-prey size constraints *(i.e.*, prey less than half of predator length), hatchery-origin late fall-run Chinook salmon could potentially consume natural-origin fall, spring, and winter-run Chinook salmon and steelhead juveniles following their release.

Although hatchery-origin late fall-run Chinook salmon juveniles could potentially capture and consume spring-run and winter-run Chinook salmon and steelhead juveniles, impacts from predation by late fall-run Chinook salmon are likely greatest on juvenile fall-run Chinook salmon. During January, when late fall-run Chinook salmon are released from CNFH, fall-run Chinook salmon are beginning to emerge from the gravel. Hatchery-origin late fall-run Chinook salmon are therefore more likely to prey on the abundant and less-agile newly emerged fall-run Chinook salmon fry rather than winter-run and spring-run Chinook salmon, which are less abundant, larger, and more capable of escaping predation. With an average rate of emigration of over 30 miles per day through Battle Creek and the Sacramento River, hatchery-origin late fall-run Chinook salmon smolts would likely travel a substantial distance down the Sacramento River system prior to becoming efficient predators on larger, more evasive organisms.

Environmental conditions typical at the time when late fall-run Chinook salmon are released from the hatchery also discourage extensive predation by hatchery-origin late fall-run Chinook salmon. USFWS releases late fall-run Chinook salmon from the CNFH during storms and high-flow events, which are characterized by cool water temperature, high flows, and elevated turbidity levels in Battle Creek and the Sacramento River; conditions that are favorable for rapid downstream emigration (Godin 1981) and unfavorable for foraging (Gregory and Levings 1998). Water temperature in Battle Creek and the Sacramento River are commonly below 10°C during January, reducing the metabolic requirements of predators and consequently reducing consumption by hatchery-origin late fall-run Chinook salmon. Sacramento River flows during January are highly variable and erratic depending on precipitation events. Increases of flow in the Sacramento River are usually accompanied by elevated turbidity. Emigration of naturally produced salmonids is commonly associated with floods and increased water turbidity, which reduce underwater light transmission (Godin 1981) and reduce predation. The strong tendency of salmonid juveniles to emigrate during periods of high flow and turbidity has been considered an adaptation to avoid predation.

Relative to Chinook salmon, hatchery-origin steelhead likely pose a much greater risk of predation on ESA-listed Central Valley salmonids. Risks of predation are higher for steelhead for the following reasons: (1) hatchery-origin steelhead are more likely to be piscivorous at the time they are released from the hatchery; (2) hatchery-origin steelhead are larger when they are released, and more-likely capable of capturing and consuming co-occurring naturally produced fishes; and (3) steelhead are more likely to residualize and predate for a longer duration in the freshwater environment.

Residualism by itself does not pose a threat to listed salmon and steelhead; however, if a substantial portion of the hatchery-produced juvenile salmonids residualize the risks of direct predation and competition (Steward and Bjornn 1990) are likely to be exacerbated.

Residualization by hatchery steelhead in spawning and nursery areas is a particular concern due to the potential of predating upon and competing with listed salmon and steelhead juveniles. It is possible that residualized hatchery steelhead may also predate upon larval green sturgeon, although information is lacking in this area. Larval green sturgeon of approximately 20-50 mm total length are present in the upper Sacramento River from April through July (Bill Poytress, personal communication, USFWS, 2008) and, based on the size of larval green sturgeon relative to that of hatchery-origin steelhead, they could be susceptible to predation by residualized steelhead. However, data from RBDD rotary screw traps indicate low residualization during the green sturgeon larval emergence period (Bill Poytress, personal communication, USFWS, 2013), and current best available scientific data has not indicated any documented occurrence of predation by hatchery steelhead on larval green sturgeon; therefore the impact is considered to be insignificant.

The rate of residualism for hatchery-origin steelhead has been found to vary greatly, but is thought to typically average between five percent and 10 percent of the number of fish released (USFWS 1994). Impacts of steelhead residualism on listed fish can be reduced by releasing hatchery steelhead smolts that are of the proper size and physiologically prepared to migrate. Timing hatchery releases to occur during conditions that encourage outmigration, such as high flow and turbid water, is also believed to discourage residualization.

USFWS characterizes the risks of steelhead predation (USFWS 2010) as “low to moderate” for the ESUs/DPSs of listed salmonids and green sturgeon and “none” for Battle Creek for the following reasons: (1) steelhead are released at Bend Bridge, so predation by juvenile steelhead in Battle Creek is very unlikely; (2) steelhead are opportunistic feeders, and more likely to consume abundant and less-agile fall-run Chinook salmon as opposed to spring-run and winter-run Chinook salmon; and (3) river conditions at the time of release (*e.g.,* cold temperature, high flows and turbid water) typically disfavor predation.

USFWS has conducted monitoring in the Sacramento River to assess rates of piscivory by hatchery-origin late fall-run Chinook salmon and steelhead during their emigration through the Sacramento River. Following the release of CNFH late fall-run Chinook salmon and steelhead in the winter-run of 2008-2009, USFWS collected 162 late fall-run Chinook salmon and 96 steelhead using rotary-screw traps located at RBDD, GCID, and at Knights Landing, located 34-miles, 71-miles, and 187-miles downstream of the release site, respectively. Captured fish ranged in size from 73-247 mm FL for Chinook salmon and 113-263 mm FL for steelhead. Stomach contents were evacuated in the field and transported to a laboratory where they were identified. Only one fish, a late fall-run Chinook salmon (150 mm FL), was found to contain a fish in its stomach; the prey species is unknown. The stomach of other fishes contained the following: fish food pellets (consumed prior to release), small gastropods, vegetation, and insects (Robert Null; USFWS, personal communication, 2012). The fish that was consumed was measured at approximately 27 mm fork length. These data support the hypothesis that emigrating hatchery-origin late fall-run Chinook salmon may be piscivorous; however, impacts of predation are likely to be low during their emigration through the Sacramento River. Further, this study did not document predation by emigrating hatchery-origin steelhead. However, this study assessed only predation by emigrating steelhead and the proportion of steelhead that residualized or delayed migration prior to emigrating was not determined.

Risks of indirect predation to listed natural-origin salmonids could either increase or decrease during the emigration of hatchery-origin fall and late fall-run Chinook salmon. The attraction of predators caused by the presence of large numbers of hatchery fish could negatively affect survival of listed spring-run and winter-run Chinook salmon and steelhead and could also alter behavioral patterns of predators, potentially influencing their vulnerability and susceptibility to predation. In the Sacramento-San Joaquin Delta and San Francisco Estuary, predation, particularly by introduced fish predators such as striped bass and largemouth bass, is considered to be substantial (see section *III. Environmental Baseline*). Predation is considered to be a significant source of mortality especially in the south Delta, where reverse flows caused by the CVP and SWP pumping plants, the South Delta Temporary Barriers facilities, and elevated water temperatures and pollutants may serve both to create habitat likely to support predatory fish populations and impair or disorient out-migrating juvenile salmonids. Diversion of hatchery fish from the Sacramento River drainage through the Delta Cross Channel into the south Delta, and diversion of fish from the San Joaquin drainage through Old River could increase predation on natural origin salmonids by artificially supporting a larger abundance of predators. However, it is also possible that a mass of emigrating hatchery fish could also overwhelm potential predators and provide a beneficial, protective effect to co-occurring listed naturally produced fish.

a. *Predation by killer whale*

Implementation of the proposed action would be expected to increase the abundance of salmonids, a primary food resource for Southern Resident killer whale. Persuasive scientific information shows that Southern Residents in inland waters of the state of Washington and British Columbia prefer Chinook salmon as a food resource. It is also likely that Chinook salmon are a preferred food source throughout coastal waters of their range, which extend into Central California. The range of Southern Residents overlap largely with those of Central Valley Chinook salmon and steelhead, which are available to Southern Residents across their coastal range and in greater magnitude south of Cape Falcon. Some of the numerous sightings of Southern Residents in California waters have coincided with large runs of salmon, and direct observation of predation on Chinook salmon has been made in Monterey Bay. Additionally, there is genetic and chemical evidence that Chinook salmon from the Central Valley are consumed by Southern Residents (*i.e.*, genetic identity confirmed from prey remains, and DDT-signature in the whales).

Hatchery production of fall- and late fall-run Chinook salmon are likely a major source of forage for the Southern Residents and these stocks increase the likelihood for Southern Residents to sustain their current ocean abundance. Without hatchery production, in absence of the historic spawning habitat for Chinook salmon, Southern Residents would need to expend additional energy to locate and capture available prey. Increased energy expenditure caused by an insufficient forage base may result in poor nutrition, which could lead to reproductive or immune effects or, if severe enough, death. Such a scenario would be expected to decrease the resiliency of Southern Resident killer whale to stochastic events, and further reduce their viability.

b. *Summary of effects of Predation*

Hatchery practices are implemented by the CNFH to reduce impacts of predation on listed winter-run and spring-run Chinook salmon, Central Valley steelhead, and green sturgeon. This includes ensuring that a high proportion of the population is smolted prior to release and releasing late fall-run Chinook salmon and steelhead when flows are high and the water is turbid. Results of recent studies indicate the impacts of predation on listed salmonids and green sturgeon are at an insignificant level. These studies included predation by residualized hatchery steelhead, which have a higher likelihood of impacting juvenile fish. Since studies have indicated rates of hatchery steelhead residualization vary, regular monitoring may be required to ensure impacts remain at an insignificant level. Hatchery-origin fall- and late fall-run Chinook salmon from California's Central Valley are likely a major source of forage for the Southern Resident killer whale; thus, the proposed project is likely to contribute to their conservation by enhancing the availability of food resources.

10. Fisheries

Fisheries managed for, or directed at, the harvest of hatchery-origin fish have been identified as one of the primary factors leading to the decline of many naturally produced salmonid stocks (Flagg *et al.* 1995; Myers *et al.* 1998). Depending on the characteristics of a fishery regime, the commercial and recreational pursuit of hatchery fish can lead to the harvest of naturally produced fish in excess of levels compatible with their survival and recovery (NRC 1996). Listed salmon and steelhead may be intercepted in mixed stock fisheries targeting predominately returning hatchery fish or healthy natural stocks (Mundy 1997). Chinook salmon commercial and sport fisheries in California are managed for the aggregate return of hatchery and naturally produced fish, which can lead to higher than desired harvest of naturally produced stocks. Incidental harvest of listed fish stocks in freshwater, estuarine, and marine environments can potentially affect the VSP parameters of abundance, productivity, diversity, and spatial structure.

Rutter (1997) observed that the effects on listed stocks from harvesting hatchery-produced fish can be reduced by certain management actions, however, none of these are currently implemented at the CNFH Complex except for the first bullet:

- Externally marking hatchery fish so that they can be differentiated from unmarked, natural fish - this occurs for all programs; fall-run Chinook salmon are marked at a constant fractional marking rate of 25 percent.
- Conducting fisheries that can selectively harvest only hatchery-produced fish with naturally produced fish being released [outside the jurisdiction of the action agency: USFWS];
- Managing fisheries for the combined harvest rate (exploitation rate) from all fisheries to ensure cumulative impacts are not higher than expected (Mundy 1997) [outside the jurisdiction of the action agency: USFWS];
- Ensuring that harvest rates of listed stocks are not increased because of a large return of hatchery fish, fisheries can be managed based on the abundance and status of naturally produced fish [outside the jurisdiction of the action agency: USFWS];
- Releasing hatchery fish from terminal areas so that returning adults can be harvested with little or no interception of naturally produced fish. Fisheries can occur near acclimation

sites or in other areas where released hatchery fish have a tendency to concentrate, which reduces the catch of naturally produced fish; and

- Reducing or eliminating the number of fish released from hatcheries if fisheries targeting hatchery fish cannot be managed to be compatible with the survival and recovery of listed fish.

Harvest management on the Pacific coast has undergone substantial reform. Modern fisheries management is targeted on harvesting surplus stocks, which are predominantly of hatchery-origin, and is constrained by the incidental take of ESA-listed stocks. Principles of weak stock management are now the prevailing management paradigm. In California, incidental harvest of weak stocks is managed by fishery regulations that impose limits on the time and area of harvest. Since the mid-1980s, ocean troll and recreational fisheries have been closed or constrained to protect weak stocks.

The fall- and late fall-run Chinook salmon and steelhead hatchery programs considered in this biological opinion produce fish to mitigate for harvest opportunities lost as a result of impacts from the Shasta Dam. During the pursuit of harvestable stocks in the ocean and the Sacramento River system, listed salmon and steelhead will be taken incidentally, however, the Action Agency subject to this biological opinion does not have jurisdiction for fishery decisions and any "take" resulting from these fisheries is analyzed and authorized under separate biological opinions (NMFS 2010, NMFS 2000b). The incidental take of listed salmon and steelhead in the U.S. Exclusive Economic Zone (EEZ) off the coasts of Washington, Oregon, and California are managed under the Federal Pacific Coast Salmon Fishery Management Plan (FMP). All species of hatchery and natural salmon that are contacted by the ocean salmon fishery fall under the jurisdiction of the FMP, including both target and non-target (*i.e.,* incidentally caught) stocks. Detailed management regulations are developed annually, designed to respond to new information and the current status of each salmon stock. The Pacific Fishery Management Council (PFMC) develops and provides recommendations to the Secretary of Commerce, through NMFS, for review and approval. The Secretary may approve the PFMC's recommendations for implementation as federal regulation if consistent with applicable law, including the ESA.

a. *Summary of Effects of Fisheries*

NMFS analyzes the effects of commercial and recreational fisheries in the U.S. EEZ off the coasts of Washington, Oregon, and California through a separate consultation under section 7(a)(2) of the ESA, in which NMFS serves as both the action and consulting agency (NMFS 2000b, 2010).

11. <u>Masking</u>

Returning adult hatchery fish can confound the ability to determine the annual abundance of naturally produced fish. Accurately differentiating and enumerating hatchery and natural fishes is complicated in areas where they commingle and when all or a significant portion of hatchery fish are not marked or tagged. This can lead to an over-estimation of the actual abundance and productivity of the natural population, resulting in the inability to assess the health and production potential of critical habitat for that population. This latter factor exists because the

hatchery fish are not subject to the same spawning and early life history productivity limits experienced by the natural population in the natural freshwater environment. The abundance and productivity of the naturally produced fish and the health of the habitat that sustains them, is therefore "masked" by the continued infusion of hatchery-produced fish. Therefore, whereas masking does not directly threaten the VSP parameters of listed salmon and steelhead, masking can obscure information important to effectively monitor and manage listed fishes and their critical habitats.

Masking of natural fish status by hatchery fish was one basis for the recommended listing of the Puget Sound Chinook salmon ESU as "threatened" under the ESA (Myers *et al.* 1998). Annual spawning ground censuses of fall-run Chinook salmon populations had historically aggregated naturally spawning hatchery and naturally produced fish. When an identifying mark was applied to a proportion of the hatchery fish, efforts were made to subtract out hatchery fish from escapement estimates through expanded mark recovery estimates. In many instances, however, the release of unmarked hatchery fall-run Chinook salmon groups, predominately of a single stock, led to the situation where salmon spawning escapement abundances were artificially sustained, and the actual annual abundances of the indigenous naturally produced fall-run Chinook salmon populations in some watersheds were over-estimated or unknown. The situation in the Puget Sound has been corrected and now all hatchery-origin Chinook salmon are marked.

Attempts to identify and remedy anthropogenic factors adversely affecting fish habitat may be impeded through masking of natural fish status. For example, instability and degradation of spawning gravel in critical spawning areas may not be recognized as a limiting factor to natural production if annual spawning ground censuses are subsidized by returning adults from annual hatchery releases. If the vast majority of the adult fish observed were of direct hatchery origin, the poor natural productivity status of the spawning areas may not be evident.

Resolution of the masking issue can be achieved by the following practices, which occur at the CNFH Complex as follows:

- Providing an effective means to easily differentiate hatchery fish from natural-origin fish on the spawning grounds. A readily visible external mark applied to all or a sufficient portion of hatchery fish prior to release, combined with an effective spawning ground census program designed to derive separate estimates of hatchery and natural fish, is one avenue available. Mass marking of hatchery fish using an internal mark (*e.g.*, otolith banding or genetic "marks") may also be used to differentiate hatchery from natural-origin fish on the spawning grounds, if a statistically valid adult sampling design to collect and analyze mark recovery data is also implemented;
- Releasing fish near the hatchery to reduce straying to natural spawning areas, or, imprinting hatchery fish to return to lower river or tributary areas not used by natural spawning fish;
- Removing hatchery fish through selective fisheries or at weirs and dams; and
- Reducing or limiting the number of hatchery fish released, leading to decreased adult hatchery fish returns, may also reduce masking effects - due to production goals and mitigation requirements this does not occur at the CNFH Complex.

Current marking and tagging programs for salmon and steelhead produced at the CNFH Complex reduce the likelihood of masking of natural population spawning abundance for most species. Late fall-run Chinook salmon and steelhead produced at the CNFH have been marked at a 100 percent rate since 1992 and 1997, respectively, and, therefore, there is no masking effect that results from these programs (as long as monitoring programs are able to observe and differentiate fish). Since 2006, fall-run Chinook salmon from the CNFH and all other Central Valley hatcheries have been marked with an adipose-fin clip and a coded-wire tag (CWT) at a consistent rate of 25 percent; this is called the "constant fractional mark" program. Various federal, state, and other agencies annually conduct spawning ground surveys to recover marked Chinook salmon that have an adipose fin-clip indicating a CWT. The recovery of CWTs from natural spawning areas allows for an estimation of the number of hatchery fall-run Chinook salmon spawning naturally.

a. *Summary of Effects of Masking*

The current practice of releasing juveniles near the hatchery and marking and tagging programs for salmon and steelhead produced at the CNFH Complex reduce the likelihood of masking of natural population spawning abundance for most species. CNFH releases late fall-run and fall-run juveniles adjacent to the hatchery, which reduces straying to natural spawning areas, and increases imprinting to return to the hatchery. CNFH also has the ability to selectively retain hatchery fish in Battle Creek at the barrier weir. Late fall-run Chinook salmon and steelhead produced at the CNFH have been marked at a 100 percent rate since 1992 and 1997, respectively, and, therefore, there is no masking effect that results from these programs (as long as monitoring programs are able to observe and differentiate fish). Since 2006, fall-run Chinook salmon from the CNFH have been marked with an adipose-fin clip and a coded-wire tag (CWT) at a consistent rate of 25 percent. The recovery of CWTs from natural spawning areas allows for an estimation of the number of hatchery fall-run Chinook salmon spawning naturally.

12. Nutrient Cycling

The flow of energy and biomass from productive marine environments to terrestrial environments supports a high level of productivity in the ecotone where the two ecosystems meet (Polis and Hurd 1996). Anadromous salmonids are a major vector for transporting marine nutrients from marine to freshwater and terrestrial ecosystems in the Central Valley, extending the link between marine and terrestrial production hundreds of miles inland. Nutrients and biomass extracted from milt, eggs, and decomposing carcasses of spawning salmon stimulate growth and restore the nutrients of aquatic ecosystems. Nutrients originating from salmon carcasses are also important to riparian plant growth. Direct consumption of carcasses and secondary consumption of plants and small animals that are supported by carcasses is an important source of nutrition for terrestrial wildlife (Cederholm *et al.* 1999).

Current populations of naturally spawning anadromous salmonids in the Central Valley are severely depressed from historic levels. The delivery of organic nitrogen and phosphorus to streams where anadromous salmonids spawn and rear is, therefore, also likely less than what occurred prior to the decline in abundance of Central Valley salmonid populations.

Artificial propagation programs in the Central Valley add substantial amounts of fish biomass to the freshwater ecosystem. The potential to utilize the marine-derived nutrients that are imported to freshwater ecosystems in the carcasses of hatchery returns may be of value for stimulating ecosystem recovery. Experiments have shown that carcasses of hatchery-produced salmon can be an important source of nutrients for juvenile salmon rearing in streams (Bilby *et al.* 1998). Hatchery carcasses may also replace some of the nutrient deficit in riparian plant and terrestrial wildlife communities where naturally produced spawners are lacking. The contribution of artificial propagation programs has the potential to exceed the contribution of naturally produced fish in replenishing the nutrient capital of aquatic ecosystems in the short term, but should not be regarded as a long term solution to replacing the nutrient subsidy provided by naturally produced salmon.

The possibility of introducing organic pollutants into aquatic food webs through contaminated fish carcasses has been recently brought to the attention of fish habitat restoration planners (Missildine 2005). The tissues of anadromous salmonids returning to the Sacramento River and tributaries carry a signature of bioaccumulation from the chemical environments to which they were exposed. Trace organic contamination derived through bioaccumulation of toxins derived through ocean food sources is a general concern of the San Francisco Bay Regional Water Quality Control Board, which has issued a health advisory for people consuming fish from San Francisco Bay, and developed a comprehensive contaminant monitoring program aimed at monitoring contaminants in sport fish in the Bay (Greenfield *et al.* 2004).

A program to utilize carcasses of hatchery adult salmon collected at the CNFH Complex for nutrient enhancement in natural spawning and rearing areas is not currently being implemented. Hatchery fish that do not return to the hatchery provide marine derived nutrient enhancement to local basins and may provide a positive impact on the natural populations. This is especially relevant in and downstream of the hatchery on Battle Creek, where substantial returns of hatchery-origin fall-run Chinook salmon add appreciably to the supply of marine derived nutrients.

a. *Summary of Effects of Marine Derived Nutrients*

Fish production programs at the CNFH Complex contribute to the influx of marine derived nutrients downstream of the hatchery on Battle Creek. Carcasses of hatchery returns may be of value for stimulating ecosystem recovery by stimulating growth of aquatic and riparian plants, and may directly benefit listed salmonids and green sturgeon by providing a food source.

13. <u>Monitoring and Evaluation</u>

Monitoring and evaluation programs are necessary to determine the performance of artificial propagation programs. The Artificial Production Review (NPPC 1999) of fish hatcheries in the Columbia River listed four specific questions for evaluating hatchery mitigation programs:

1. Has the hatchery achieved its objectives?
2. Has the hatchery incurred costs to natural production?
3. Are there genetic impacts associated with the hatchery production?
4. Is the benefit greater than the cost?

Historically, hatchery performance was determined solely on the hatchery's ability to release a specified number of fish (NPPC 1999), commonly referred as a "production target". Evaluation of hatcheries by their ability to achieve production targets was subsequently expanded to include hatchery contribution to fisheries (e.g. Wallis 1964; Wahle and Vreeland 1978; Vreeland 1989). Past program-wide reviews of artificial propagation programs in the Northwest have indicated that monitoring and evaluation has not been adequate to determine if the hatchery objectives are being met (ISG 1996; NRC 1996; NFHRP 1994). The lack of adequate monitoring and evaluation has resulted in the loss of information that could have been used to adaptively manage the hatchery programs (NRC 1996) and to optimize the benefits of hatchery fishes.

Monitoring and evaluation programs for artificial production are not only necessary for adaptive management purposes but are necessary to track compliance with terms and conditions, and to ensure that artificial propagation activities do not limit the recovery of populations listed under the ESA. Monitoring and evaluation of artificial propagation activities are necessary to determine if management actions are adequate to reduce hatchery impacts to natural-origin salmonids, and to determine if the hatchery is meeting its performance goals. Monitoring and evaluation activities should occur both within the hatchery facilities as well as in the natural production areas. Monitoring and evaluation within the hatchery can include measurements to evaluate hatchery production (*i.e.*, survival, nutrition, size at age, condition, disease prevention, genetic makeup, total released, percent smolted, etc.). Monitoring and evaluation in natural production areas can include assessments of juvenile outmigration characteristics, competitive interactions, spawning stock origin, genetic research and monitoring, and reproductive success.

Activities conducted during the course of hatchery monitoring and evaluation can adversely affect listed fishes, potentially affecting their abundance, productivity, and diversity. Some monitoring and evaluation programs target or incidentally encounter naturally produced fishes during the course of their conduct. For example, monitoring fish assemblages in the natural environment may be necessary to determine any positive or negative effects the artificial production program is having on natural populations. A variety of sampling methods can be used to collect fishes, including weirs, electro-fishing, rotary screw traps, seines, hand nets, spawning ground surveys, snorkeling, radio tagging, and carcass recovery. Listed fishes collected intentionally or incidentally to sampling projects can be affected through migration delays, injury, direct mortality, or stress. Additionally, sample methods, like tagging methods, can adversely impact listed fish, both those targeted for data collection and those taken incidentally to the data collection.

Hatchery monitoring and evaluation programs should be designed and coordinated with other plans to maximize the data collection while reducing the potential for impacts to listed fish. NMFS has developed some general guidelines to reduce impacts when collecting listed adult and juvenile salmonids (NMFS 1999b; NMFS 2000a) which have been incorporated as terms and conditions into section 10 and section 7 permits for research and enhancement activities (e.g., NMFS 1999c).

The USFWS employs approximately ten full-time staff to conduct monitoring and research associated with the operation of the CNFH Complex. Funding provided by Reclamation directly

contributes in excess of $650,000 annually to the Hatchery Evaluation Program, which is located in the RBFWO and is considered an essential component of hatchery operations. Research and monitoring activities involve the handling and collection of biological data from listed salmon and steelhead collected at the CNFH, the Livingston Stone NFH and in natural habitats where hatchery and natural salmon and steelhead may commingle and interact. Information collected is used to resolve biological and ecological uncertainties and to provide information to adaptively manage the propagation programs at the CNFH Complex.

Natural-origin, listed California Central Valley steelhead are not currently used as broodstock at the CNFH but are incidentally collected at the hatchery during the course of collecting target broodstock of fall and late fall-run Chinook salmon and steelhead. Incidentally collected natural-origin steelhead are subjected to delays in migration, sedation with CO_2 and handling using hands and nets to collect various biological samples and data, including length and weight, fin tissue, and scales. Steelhead are provided time to recover in captivity prior to release upstream of the barrier weir in Battle Creek. There have been no observed direct mortalities associated with this monitoring activity.

Natural-origin, listed California Central Valley steelhead and winter-run Chinook salmon are incidentally collected at the Keswick Dam fish trap during the course of collecting target broodstock of natural-origin late fall-run Chinook salmon. Incidentally collected natural-origin steelhead and spring-run Chinook salmon are subjected to delays in migration and handling using hands and nets to collect various biological samples and data, including length and weight, fin tissue, and scales.

a. *Summary of Effects of Monitoring and Evaluation*

NMFS believes that hatchery monitoring and evaluation activities conducted in association with the CNFH Complex add substantial informational benefits to the adaptive management of the hatchery, promoting optimization of hatchery benefits while at the same time reducing the likelihood of negatively impacting listed stocks. Existing monitoring activities, as described in the CNFH biological assessment, are conducted in a manner that minimizes the risks to the VSP parameters of abundance, productivity, and diversity to levels that are not likely to adversely affect populations of listed fish in Battle Creek or the listed ESUs or DPSs.

14. Beneficial Effects of the CNFH Listed Steelhead Propagation Program on the California Central Valley steelhead DPS

Since the CNFH steelhead program is considered part of the listed DPS, effects of the program include beneficial effects on the listed DPS. The CNFH steelhead program releases 600,000 juveniles annually, which adds to the total juveniles produced for the DPS. Although numbers of returning hatchery-origin steelhead have become more reliably estimable since year 2002/2003, due to 100 percent marking, spawning reports have been available since 1988 (Kevin Niemela, USFWS, personal communication, 2014). The number of hatchery-origin steelhead returning to Battle Creek that have been collected during hatchery operations since 1988 has varied from 467 to 4,429, and those spawned for propagation purposes has varied, from 45 to 1,092. The variability of spawn numbers results mostly from the number of returning steelhead. Although the minimum steelhead spawning target is between 400 and 800 fish, the number of fish typically

spawned has been higher, generally between 800 and 1,100 fish, depending on fecundity, to produce eggs equal to approximately twice the number necessary to achieve the hatchery production target. This additional number of steelhead spawned compared to the number necessary to achieve the hatchery production target is for the purpose of ensuring genetic diversity in the hatchery production. Hatchery-origin steelhead that survive the artificial spawning process or the egg stripping process (those that are not spawned) are then reconditioned for up to several months, and those that survive are released back into Battle Creek. The numbers of reconditioned adults released have ranged from 500 to 3,000. Thus, the CNFH steelhead program increases the abundance of the threatened California Central Valley steelhead DPS.

E. Determinations Based on Effects Analysis

Using the best scientific and commercial data currently available, NMFS concurs with USFWS's determination that the proposed action is likely to adversely affect listed winter-run and spring-run Chinook salmon and steelhead. In addition, NMFS concurs with USFWS's determination that the proposed action may affect, but is not likely to adversely affect, listed killer whale and green sturgeon. The potential for adverse effects to listed killer whale and green sturgeon are either not anticipated, discountable or insignificant, based on the analysis above. For these reasons, NMFS will not include discussion of effects of the proposed action on listed killer whale and green sturgeon in the following sections.

F. Effects of CNFH Complex Facilities and their Operation on Critical Habitat

The effects of the proposed action on designated critical habitat for the endangered Sacramento River winter-run Chinook salmon ESU, the threatened Central Valley spring-run Chinook salmon ESU, and the threatened Central Valley steelhead DPS are expected to be minimal. NMFS concurs with the USFWS's determination that the proposed action may affect but is not likely to adversely affect Southern DPS of green sturgeon critical habitat. Potential effects to PCEs of green sturgeon critical habitat are either discountable or insignificant. For these reasons, NMFS will not include discussion of effects of the proposed action on green sturgeon critical habitat in the following sections.

Discharge of hatchery effluent could potentially degrade the quality of critical habitats of listed salmonids, however, adherences to existing discharge requirements of the SWRCB and NPDES provide assurance that wastewater discharge from the CNFH Complex will not significantly disrupt physical and biological features or life history requirements such as feeding, sheltering, reproduction, and migrating that are PCEs or Essential Features of listed salmonids. Discharge of hatchery effluent will have no effect to green sturgeon critical habitat.

The effects of competition to the PCEs or Essential Features of critical habitat may result in a temporary redistribution of some individual fish, primarily rearing juvenile salmonids; however, due to their temporary nature, the adverse effects that are anticipated to result from the proposed project are not of the type, duration, or magnitude that would be expected to adversely modify critical habitat to the extent that it could lead to an appreciable reduction in the function and condition of the affected critical habitat. NMFS expects that all of the adverse effects to critical

habitat from this project will be temporary, infrequent, and localized to the extent that individual fish will not be adversely affected beyond temporary displacement, and the overall conservation value of the critical habitat to these listed species will not be diminished. Competitive interactions between hatchery-origin salmonids and green sturgeon are not likely to occur.

Rearing habitat condition is strongly affected by the presence of predators of juvenile salmonids. Although risks of direct predation (direct consumption) or indirect predation (increase in predation due to enhanced attraction) can result from releases of hatchery salmonid in freshwater and estuarine areas, CNFH times releases of smolts to reduce some of the potential impacts. In addition, recent studies indicate predation of released hatchery fish on listed salmonids and green sturgeon are at an insignificant level.

Additionally, the proposed action is expected to diminish stream flow in a 1.6 mile stretch of Battle Creek affecting critical habitat for Central Valley spring-run Chinook salmon and California Central Valley steelhead. While the stream flow in this 1.6 mile stretch of Battle Creek will be reduced, based on historic data, minimum recommended flow requirements in Battle Creek will be exceeded more than 97 percent of the time. The section of Battle Creek affected by CNFH water diversions serves as a freshwater migration corridor for spring-run Chinook salmon and steelhead. Water diversions to the CNFH may cause depletions of flow, which will reduce the size of the migration corridor in Battle Creek but are not expected to block or delay passage of juvenile or adult salmonids. Therefore, NMFS believes that the effects of CNFH water diversions would result in a low level of impact to designated critical habitat for the Central Valley spring-run Chinook salmon ESU and the California Central Valley steelhead DPS, and would not appreciably reduce the value of their respective critical habitat for the conservation of the species.

V. CUMULATIVE EFFECTS

Cumulative effects include the effects of future State, tribal, local, or private actions that are reasonably certain to occur in the action area considered in this biological opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

A. Water Diversions

Water diversions for irrigated agriculture, municipal and industrial use, hydropower generation, 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, their tributaries including Battle Creek, and the Delta, and many of them 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 listed anadromous species. 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).

B. Agricultural Practices

Agricultural practices may negatively affect riparian and wetland habitats through upland modifications that lead to increased siltation or reductions in water flow in stream channels flowing into the action area, including the Sacramento River and Delta. 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 nitrogen, ammonia, and other nutrients into the watershed, which then flow into receiving waters. Stormwater and irrigation discharges related to both agricultural and urban activities contain numerous pesticides and herbicides that may negatively affect salmonid reproductive success and survival rates (Dubrovsky *et al.* 1998, 2000; Daughton 2003).

The primary agricultural practices in the Battle Creek Watershed consist of low density livestock grazing and timber harvests. These practices have not produced appreciable adverse impacts to salmonids nor have they severely degraded salmonid habitat in Battle Creek (Reclamation 2003). There are no current plans to modify the type or intensity of agricultural practices in the watershed. As discussed in the next section, conservation easements and agreements are being pursued along the riparian corridors of the Battle Creek Watershed, providing further assurance that future agricultural practices will not be likely to adversely affect salmonids or salmonid habitat.

C. Conservation Agreements and Easements

Several conservation agreements and easements have been developed and implemented throughout the riparian corridors and uplands of the Battle Creek and Sacramento River Watershed. Implementation of these agreements is expected to maintain the current quality of riparian and aquatic habitat in Battle Creek and the Sacramento River, and could potentially improve the condition of these habitats for salmonids.

D. Aquaculture and Fish Hatcheries

More than 32-million fall-run Chinook salmon, 2-million spring-run Chinook salmon, 1-million late fall-run Chinook salmon, 0.25-million winter-run Chinook salmon, and 2-million steelhead are released annually from six hatcheries producing anadromous salmonids in the Central Valley. All of these facilities are currently operated to mitigate for natural habits that have already been permanently lost as a result of dam construction. The loss of this available habitat results in dramatic reductions in natural population abundance which is mitigated for through the operation of hatcheries. Salmonid hatcheries can, however, have additional negative effects on ESA-listed salmonid populations. The high level of hatchery production in the Central Valley can result in high harvest-to-escapements ratios for natural stocks. California salmon fishing regulations are set according to the combined abundance of hatchery and natural stocks, which can lead to over-exploitation and reduction in the abundance of wild populations that are indistinguishable and exist in the same system as hatchery populations. Releasing large numbers of hatchery fish can also pose a threat to wild Chinook salmon and steelhead stocks through the spread of disease, 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. Impacts of hatchery fish can occur in both freshwater and the marine ecosystems. Limited marine carrying capacity has implications for naturally produced fish

experiencing competition with hatchery production (HSRG 2004). Increased salmonid competition in the marine environment may also decrease growth and size at maturity, and reduce fecundity, egg size, age at maturity, and survival (Bigler *et al.* 1996). Ocean events cannot be predicted with a high degree of certainty at this time. Until good predictive models are developed, there will be years when hatchery production may be in excess of the marine carrying capacity, placing depressed natural fish at a disadvantage by directly inhibiting their opportunity to recover (Northwest Power and Conservation Council [NPCC] 2003).

More localized impacts of hatcheries may also affect salmonid populations in Battle Creek. Mount Lassen Trout Farms, Inc. consists of nine private trout-rearing facilities located within the Battle Creek Watershed. This private aquaculture operation rears domesticated strains of fishes, including rainbow and brown trout, for stocking in private ponds and lakes throughout California. Although the facilities are located above the anadromous habitats of Battle Creek, some facilities are located near the hydroelectric project canals. These facilities have been certified as disease free for many years and the potential for fish or disease to escape from these facilities into Battle Creek is considered very small.

Darrah Springs Fish Hatchery is located on Baldwin Creek, a tributary to the mainstem Battle Creek. Darrah Springs Hatchery raises catchable trout for recreational fisheries and it is a key hatchery of CDFG's inland fisheries program. It is possible that fish or disease could escape the hatchery into anadromous portions of Battle Creek. However, no such impacts have been previously documented and are not expected to occur in the future.

E. 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 (California Commercial, Industrial, and Residential Real Estate USFWSs Directory 2002). A population increase of this magnitude will result in increased urbanization and housing developments, which can impact habitat by altering watershed characteristics, including 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. The city of Manteca (2007) anticipated 21 percent annual growth through 2010 reaching a population of approximately 70,000 people. The City of Lathrop (2007) expected 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 water bodies, will not require Federal permits, and thus will not undergo review through the 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 re-suspending 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 moving through the system. Increased recreational boating in the Delta will create increased contamination from the operation of gasoline and diesel powered engines.

F. 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 CO_2 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). 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 primary constituent elements (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 cause 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 overtake native fish species and impact predator-prey relationships (Peterson and Kitchell 2001, Stachowicz *et al.* 2002).

Global warming is predicted to increase temperature in California's Central Valley between 2°C and 7°C by 2100 (Dettinger *et al.* 2004, Hayhoe *et al.* 2004, Van Rheenen *et al.* 2004), with a drier hydrology predominated by precipitation rather than snowfall. The cold snowmelt that furnishes the late spring-run and early summer runoff will be replaced by warmer precipitation runoff. Altered river runoff patterns will transform the tributaries that feed the Central Valley. 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. Summer temperatures and flow levels in some areas of the Central Valley will become unsuitable for salmonid survival. 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 California Central Valley steelhead) that must hold below the dam over the summer and fall periods.

G. Activities within the Nearshore Pacific Ocean

Future tribal, state and local government actions will likely be in the form of legislation, administrative rules, or policy initiatives and fishing permits. These actions may include changes in ocean policy and increases and decreases in the types of activities that currently occur, including changes in the types of fishing activities, resource extraction, or designation of marine protected areas, any of which could impact listed species or their habitat. Government actions are subject to political, legislative and fiscal uncertainties. Private activities are primarily associated with commercial and sport fisheries, construction, and marine pollution. These potential factors are ongoing and expected to continue in the future, and the level of their impact is uncertain. For these reasons, it is not possible to predict beyond what is included in the subsections pertaining to cumulative effects, above, whether future non-Federal actions will lead to an increase in effects to the survival and recovery of listed species. These realities, added to the geographic scope, which encompasses several government entities exercising various authorities, and the changing economies of the region, make analysis of cumulative effects speculative.

VI. INTEGRATION AND SYNTHESIS

The *Integration and Synthesis* section is the final step of NMFS' assessment of risks posed to species and critical habitat as a result of implementation of the proposed action. In this section, we integrate effects, and then add these effects to the baseline (Section III) and cumulative effects (Section V) to assess whether it is reasonable to expect that the proposed action is likely to: (1) reduce appreciably the likelihood of both survival and recovery of the species in the wild; or (2) result in the destruction or adverse modification of designated critical habitat (as determined by whether the value of critical habitat to the conservation of the species is reduced). These assessments are made in full consideration of the status of the species and critical habitat (Section III).

In the *Environmental Baseline and Status of the Species and Critical Habitat* section (Section III), NMFS summarized the current likelihood of extinction of each of the listed species. We described the factors that have led to the current listing of each species under the ESA across their ranges. These factors include past human activities and climate trends and ocean conditions that have been identified as influential to the survival and recovery of the listed species.

In addition, the *Cumulative Effects* section (section V) describes how many unscreened diversions are found throughout the Central Valley, as well as grazing activities, stormwater and irrigation discharges. Conservation easements and agreements along the riparian corridors may provide assurance that future practices will not be likely to adversely affect salmonids or salmonid habitat. Hatcheries will continue to mitigate for permanently lost habitat, as well as potentially threaten wild Chinook salmon and steelhead stocks. Urbanization may reduce habitat quality. Global climate change will likely increase ocean temperatures, and cause sea levels to rise, affecting salmonid critical habitat. Water temperatures and flow levels will likely become unsuitable for salmonid survival in some areas of the Central Valley. Future tribal, state and

local government actions are ongoing and expected to continue in the future, and the level of their impact is uncertain.

When our assessments indicate that a species or population has a moderate or high likelihood of extinction, we understand that future adverse environmental changes could have significant consequences on the ability of the species to survive and recover. Also, it is important to note that an assessment of a species having a moderate or high likelihood of extinction does not mean that the species has little or no potential to survive and recover, but that the species faces moderate to high risks from internal and external processes that can drive a species to extinction. The *Integration and Synthesis* will consider all of these factors to determine the proposed action's influence on the likelihood of both the survival and recovery of the species, and on the conservation value of designated critical habitat.

The basis of the "destruction or adverse modification" analysis is to evaluate whether the proposed action results in negative changes in the function and role of the critical habitat in the conservation of the species. As a result, NMFS bases the critical habitat analysis on the affected areas and functions of critical habitat essential to the conservation of the species, and not on how individuals of the species will respond to changes in habitat quantity and quality.

USFWS has implemented numerous measures to reduce the potential for adverse impacts. A rigorous program of research and monitoring activities collects information to better define the level of impacts and identify where additional corrective actions are most needed to reduce impacts. In the *Effects of the Action* section (IV), NMFS evaluated the impacts of the fall and late fall-run Chinook salmon and steelhead propagation programs at the CNFH on individual listed fish, as well as at the ESU/DPS level, for each of the 10 general risks: Hatchery Facilities (which includes hatchery failure, fish entrainment, hatchery water withdrawals, and discharge of hatchery effluent), Broodstock Congregation and Collection, Genetics, Disease, Competition/Density Dependence Effects (including ocean competition), Predation, Fisheries, Masking, Nutrient Cycling, and Monitoring and Evaluation. In this section, we examine the effects of the proposed action on the populations of listed species involved, and consider how those population-level effects, taken together with the effects of other activities likely to occur in the action area, might impact listed salmon and steelhead at the ESU or DPS level. ESU/DPS-level impacts of hatchery program components were characterized as: No impact (activity will not affect fish risk factor), Low Impact (activity may result in small changes for risk factor, but would remain within expected year-to-year variability of the affected species and would not affect population viability), Moderate Impact (action is likely to produce a moderate change in risk factor similar in magnitude to changes witnessed during atypical conditions such as drought, and should conditions or impacts persist, population viability may be affected), and High Impact (likely to cause large immediate changes in risk factor such as a catastrophic natural event). In addition, in some cases, there may be a beneficial effect from the hatchery programs. This section will also examine the effects of the proposed action on designated critical habitat at the ESU or DPS level.

A. Sacramento River Winter-run Chinook salmon ESU

1. <u>Status of Sacramento River Winter-run Chinook salmon ESU</u>

Historically, independent winter-run Chinook salmon populations existed in the Pit, McCloud, and Little Sacramento rivers. Information also suggests winter-run Chinook salmon existed at least occasionally in Battle Creek. Winter-run Chinook salmon have been eliminated from one-hundred percent of their historic spawning areas, with the majority of habitat loss occurring as a result of the construction and operation of Shasta and Keswick Dams. The one remaining population of winter-run Chinook salmon is confined to non-native spawning habitats in the main stem of the Sacramento River downstream of Keswick Dam. Winter-run Chinook salmon do not currently inhabit Battle Creek as a self-sustaining population, probably because hydropower operations make conditions for eggs and fry unsuitable (NMFS 1997); however, habitat restoration activities ongoing and planned for that watershed endeavor to create conditions favorable for winter-run Chinook salmon.

Winter-run Chinook salmon population estimates were as high 100,000 fish in the 1960s, but declined to under 200 fish in the 1990s (Good *et al.* 2005). In recent years, the carcass survey population estimates of winter-run Chinook salmon included a high of 17,334 in 2006, followed by a precipitous decline to about 1,500 fish in 2010, and an even further decline in 2011 with only 827 fish (Grandtab 2013).

We used the cohort replacement rate, and also a 5-year running average of the cohort replacement rate, as a measure of population growth rate for Sacramento River winter-run Chinook salmon. When the cohort replacement rate is 1.0, the population is stable and replacing itself. Table 2 provides cohort replacement rates since 1986. As shown, the cohort replacement rates from 1995 through 2006 were stable or increasing, indicating a trend of positive population growth. However, the cohort replacement rate for the recent four spawning runs was less than one, indicative of decreasing abundance.

In the most recent status assessment of winter-run Chinook salmon, Lindley *et al.* (2007) determined that the population is at a moderate extinction risk according to population viability analysis, and at a low risk according to other criteria (*i.e.*, population size, population decline, the risk of wide ranging catastrophe, hatchery influence). Data used for Lindley *et al*. (2007) did not include the significant decline in escapement numbers since 2007, which are reflected in the population size and population decline.

Lindley *et al.* (2007) also states that the winter-run ESU fails the "representation and redundancy rule" because it has only one population and that population spawns outside of the ecoregion in which it evolved. An ESU represented by only one spawning population at moderate risk of extinction is at a high risk of extinction (Lindley *et al*. 2007). A single catastrophe could extirpate the entire Sacramento River winter-run Chinook salmon ESU if its effects persisted for four or more years. The entire stretch of the Sacramento River used by winter-run Chinook salmon is within the zone of influence of Mount Lassen, an active volcano, which last erupted in 1915. Some other possible catastrophes include a prolonged drought that depletes the cold water storage of Shasta Reservoir or some related failure to manage cold water storage, a spill of toxic materials with effects that persist for four years, or a disease outbreak (Lindley *et al*. 2007).

NMFS concludes that the winter-run Chinook salmon ESU remains at a high risk of extinction. Key factors upon which this conclusion is based include: (1) the ESU is composed of only one

population, which has been blocked from its entire historic spawning habitat; and (2) the ESU has a risk associated with catastrophes, especially considering the remaining population's proximity to Mount Lassen and its dependency on the cold water management of Shasta Reservoir.

2. Baseline and Cumulative Effects on Winter-run Chinook salmon

This section summarizes the environmental baseline and cumulative effects upon which we will add the effects of the proposed action in order to help assess the response and risk to the species. The general baseline stress regime for Chinook salmon in the freshwater, estuarine, and marine environment is depicted in figure 11.

Commercial and recreational fisheries that target fall and late fall-run Chinook salmon will result in incidental take of winter-run Chinook salmon; however, the impacts associated with commercial and recreational fisheries are not part of the proposed action covered in this biological opinion. The Sacramento River winter-run Chinook salmon ESU may be affected by fisheries. The effects of this take are analyzed in a separate ESA consultation (NMFS 2010). Fisheries and harvest managers reevaluate exploitation rates and harvest strategies on an annual basis.

Climate change is a key aspect of stress for ESA-listed salmonids in the Central Valley. Lindley *et al*. (2007) summarized several studies (Hayhoe *et al*. 2004, Dettinger *et al*. 2005, VanRheenen *et al*. 2004, Knowles and Cayan 2002) of how climate change is expected to alter the Central Valley, and based on these studies, described the possible effects to anadromous salmonids. Climate models for the Central Valley are broadly consistent in that temperatures in the future will warm significantly, total precipitation may decline, the variation in precipitation may substantially increase (*i.e.*, more frequent flood flows and critically dry years), and snowfall will decline significantly (Lindley *et al*. 2007). Not surprisingly, temperature increases are expected to further limit the amount of suitable habitat available to anadromous salmonids. The potential for more frequent flood flows might be expected to reduce the abundance of populations, as egg scour becomes a more common occurrence. The increase in the occurrence of critically dry years also would be expected to reduce abundance as, in the Central Valley, low flows during juvenile rearing and outmigration are associated with poor survival (Kjelson and Brandes 1989, Baker and Morhardt 2001, Newman and Rice 2002). In addition to habitat effects, climate change may also impact Central Valley salmonids through community effects. For example, warmer water temperatures would likely increase the metabolism of predators, reducing the survival of juvenile salmonids (Vigg and Burley 1991). Peterson and Kitchell (2001) showed that on the Columbia River, pikeminnow predation on juvenile salmon during the warmest year was 96 percent higher than during the coldest. In summary, climate change is expected to exacerbate existing stressors and pose new threats to Central Valley salmonids by reducing the quantity and quality of inland habitat (Lindley *et al*. 2007).

3. Summary of Proposed Action Effects on the Winter-run Chinook salmon ESU

Proposed action-related effects to winter-run Chinook salmon are summarized in Table 8. Detailed descriptions regarding the exposure, response, and risk to winter-run Chinook salmon from these stressors was presented earlier in this document.

Table 8. Hatchery risks to winter-run Chinook salmon; affected Viable Salmon Population parameters, including Abundance, Diversity, Productivity, and Spatial Structure; indication of whether take is expected; and level of impact to the Evolutionarily Significant Unit.

Risk	VSP Parameter	Take	Level of Impact
Hatchery Facilities	Abundance	Yes	Low
Broodstock Collection	Abundance	Yes	Low
Genetics	Abundance & Productivity	Yes	Low
Disease	Abundance & Productivity	Yes	Low
Competition & Density Dependent Effects	Productivity	Yes	Low
Predation	Abundance	Yes	Low
Masking	Abundance	No	None
Nutrient Cycling	Abundance & Productivity	No	Beneficial
Monitoring & Evaluation	Abundance	Yes	Beneficial

As shown in Table 8, proposed action-related stressors could reduce the abundance, productivity, and diversity of winter-run Chinook salmon; however the level of impacts resulting from the project are generally low. Proposed activities at the CNFH are not likely to affect spatial structure of winter-run Chinook salmon because the hatchery is located outside of the area currently used by juvenile and adult winter-run Chinook salmon. Winter-run Chinook salmon do not currently inhabit Battle Creek as a viable population. Hatchery practices have been implemented to reduce interactions between fall and late fall-run Chinook salmon and steelhead on winter-run Chinook salmon.

Broodstock collection activities conducted at the CNFH are largely isolated from winter-run Chinook salmon and are therefore not expected to adversely affect the Sacramento River winter-run Chinook salmon ESU, at this time (until winter-run Chinook salmon are re-introduced into Battle Creek). Winter-run Chinook salmon may be incidentally collected while trapping for natural-origin late fall-run Chinook salmon at the Keswick Dam fish trap. Take may occur as handling, stress, delayed migration, injury, or mortality. Although annual abundance levels are currently low, estimated take is low, therefore this activity is expected to have a low level of impact to the winter Chinook salmon ESU.

The potential for genetic introgression or redd superimposition resulting from stray hatchery-origin fall and late fall-run Chinook salmon will not limit the viability and potential for recovery of the Sacramento River winter-run Chinook salmon ESU because there is a temporal separation in spawning times. Winter-run Chinook salmon are largely segregated, both temporally and spatially, from CNFH-origin fall and late fall-run Chinook salmon and steelhead in the freshwater environment. Monitoring and evaluation activities conducted by USFWS and CDFG confirm that over the last 14 years, no hatchery-origin fall or late fall-run Chinook salmon produced at the CNFH have been observed in winter-run Chinook salmon spawning areas during the time when winter-run Chinook salmon spawn (USFWS 2005; USFWS 2009).

It is unlikely that the CNFH Complex propagation programs will detrimentally affect the viability of the winter-run Chinook salmon ESU through the transmission of disease for the

following reasons: (1) the diseases observed in the hatchery are already present in the natural populations; (2) there is limited freshwater interaction between fall and late fall-run Chinook salmon and steelhead with winter-run Chinook salmon because spawning areas are largely segregated temporally and spatially; and (3) disease management tools and protocols used at the CNFH limit the potential for the hatchery programs to contribute to adverse effects due to disease transfer or amplification.

Effects of competition and density dependent factors to listed winter-run Chinook salmon are expected to be low. Competitive impacts are reduced by releasing fish at the smolt stage and timing hatchery releases when the vast majority of natural-origin winter-run Chinook salmon have emigrated from the upper river system. The location of the releases, downstream of primary winter-run Chinook salmon spawning areas, also helps to reduce the potential for competitive impacts. Monitoring activities in the Sacramento River have demonstrated that released fall and late fall-run Chinook salmon exhibit rapid emigration, thus minimizing the potential to interact with listed winter-run Chinook salmon (USFWS 2010). There are potential competitive interactions between hatchery- and natural-origin salmonids, particularly in the early marine life stage when the abundance of food could result in negative effects to Sacramento River winter-run Chinook salmon; however, little information is available regarding the carrying capacity of estuarine environments, which are known to be highly variable. Potential effects to winter-run Chinook salmon would likely be mitigated to some degree because winter-run Chinook salmon enter the marine environment earlier than hatchery-origin fall-run Chinook salmon, the major production program at the CNFH. Competition at the adult life stage is not believed to be a factor limiting viability and recovery of winter-run Chinook salmon.

Predation by salmon and steelhead released from the artificial propagation programs at CNFH on listed winter-run Chinook salmon is not expected to impact the viability or recovery potential for the winter-run Chinook salmon ESU. The timing and locations of juvenile releases largely isolate hatchery-origin smolts from natural-origin winter-run Chinook salmon juveniles and reduce the likelihood of predation in the upper river system. Predation by hatchery fish on winter-run Chinook salmon is further reduced because hatchery fish are released at the smolt stage and exhibit rapid emigration from the river system. Monitoring of emigration patterns show that fall and late fall-run Chinook salmon smolts from CNFH travel downstream rapidly, moving out of the upper Sacramento River in large pulses, with few fish exhibiting delayed emigration. Additionally, winter-run Chinook salmon are not likely to be susceptible to high levels of predation due to their size at the time when hatchery releases occur.

Masking of Sacramento River winter-run Chinook salmon by hatchery-origin late fall-run Chinook salmon is not likely to significantly impact population viability or the potential for recovery. One hundred percent of the late fall-run Chinook salmon are adipose-fin clipped and coded-wire tagged, providing the ability to sufficiently reduce the potential of masking. However, because fall-run Chinook salmon are currently marked at a rate of 25 percent, this significantly reduces the ability to differentiate them from winter-run Chinook salmon if not separated spatially or temporally. Because of the temporal separation, the potential for masking is considered low.

Utilization of hatchery adult carcasses for nutrient enhancement is not currently being implemented at the CNFH. However hatchery fish that do not return to the hatchery provide marine derived nutrient enhancement to local basins and may provide a positive impact on the local populations, especially lower Battle Creek.

Hatchery monitoring and evaluation activities associated with the CNFH will impose a low level of impact to winter-run Chinook salmon. Winter-run Chinook salmon will be incidentally collected during the process of collecting late fall-run Chinook salmon broodstock at the Keswick Dam fish trap. Chinook salmon determined to be winter-run based on phenotypic characteristics will be measured to length and floy tagged prior to release in the Sacramento River at Redding. Take will occur through trapping, handling, sampling, and transport possibly resulting in stress, delayed migration, injury, or mortality. Effects of this activity to the winter-run Chinook salmon ESU are expected to be minor, and may provide some benefits.

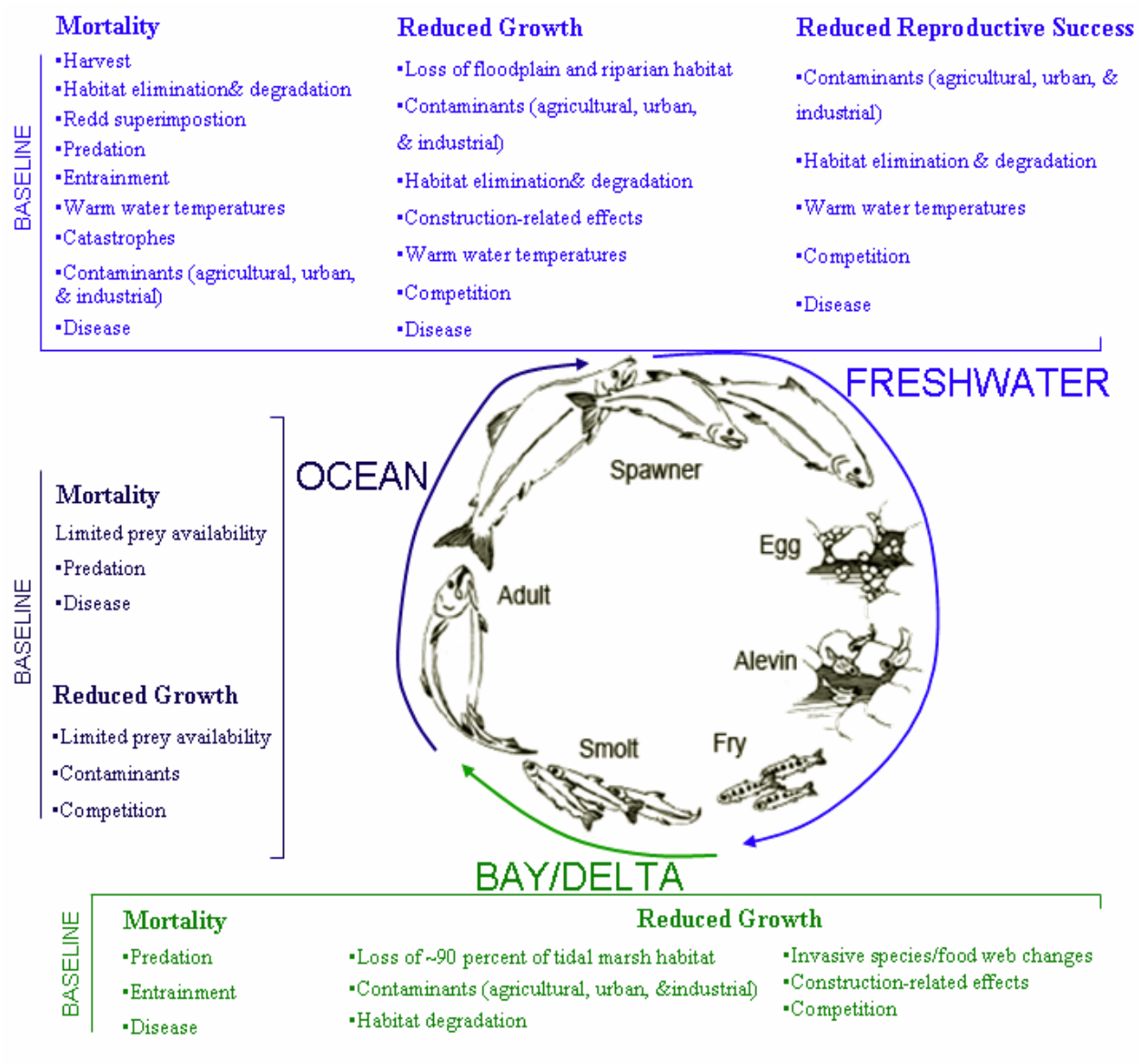

Figure 10. Chinook salmon stressors excluding the CNFH related effects (*i.e.*, the figure represents the general baseline stress regime). Chinook salmon are in freshwater during their adult immigration and holding, spawning, egg incubation, alevin, fry, and fingerling life stages. They are in the Bay/Delta as smolts and in the ocean as sub-adults and adults. Although not depicted in the figure, climate change is a baseline stressor expected to exacerbate conditions for anadromous salmonids throughout their life cycle, particularly with respect to water temperature in all environments, inland hydrology, and ocean productivity (*e.g.*, upwelling).

4. Assess Risk to the Winter-run Chinook salmon ESU

Population viability is determined by four parameters: spatial structure, diversity, abundance, and productivity (growth rate). Both population spatial structure and diversity (behavioral and genetic) provide the foundation for populations to achieve abundance levels at or near potential

carrying capacity and to achieve stable or increasing growth rates. Spatial structure on a watershed scale is determined by the availability, diversity, and utilization of properly functioning conditions (habitats) and the connections between such habitats (McElhany *et al*. 2000). Properly functioning condition defines the inland habitat conditions necessary for the long-term survival of Pacific salmon populations (McElhany *et al*. 2000).

Impacts of hatchery facilities (which includes hatchery failure, fish entrainment, hatchery water withdrawals, and discharge of hatchery effluent), broodstock collection, genetic introgression, disease, competition/density dependence effects (including ocean competition), predation, masking, nutrient cycling, and monitoring would result in a low level of effects to the Sacramento River winter-run Chinook salmon ESU. Because all impacts on listed winter-run Chinook salmon cannot be completely eliminated, there will always be the potential for hatchery programs to negatively affect natural-origin fish. The impacts of the proposed artificial propagation programs on listed winter-run Chinook salmon are summarized in Table 8. These potential effects on natural-origin winter-run Chinook salmon have been addressed through the conservation measures of the proposed action, and at this time, these impacts are not expected to rise to a high level of adverse effect on the ESU. In addition, these effects are being adaptively monitored to determine if further action is needed. Based on the analysis above, NMFS has considered recovery planning documentation, and the potential effects of the proposed action on winter-run Chinook salmon populations, combined with other ongoing activities within the Action Area, and determined that the proposed action is not expected to appreciably reduce the likelihood of survival and recovery of the Sacramento River winter-run Chinook salmon ESU in the wild by reducing the reproduction, numbers, or distribution of the ESU (reproduction, numbers, and distribution of the ESU relate to the VSP parameters of spatial structure, diversity, abundance, and productivity).

5. Status of Sacramento River Winter-run Chinook salmon Critical Habitat

As described in section III, winter-run Chinook salmon critical habitat is composed of seven physical and biological features that are essential for the conservation of winter-run Chinook salmon. However, all of those physical and biological features can be characterized as suitable and necessary habitat features that provide for successful spawning, rearing, and migration. Therefore, we will be evaluating the effect of the proposed action in terms of its effect on spawning and rearing habitat and migratory corridors.

Currently, many of the physical and biological features that are essential for the conservation of winter-run Chinook salmon are impaired, and provide limited conservation value. For example, unscreened diversions throughout the mainstem Sacramento River, and the delta cross channel when the gates are open during winter-run Chinook salmon outmigration, do not provide a safe migratory corridor to San Francisco Bay and the Pacific Ocean.

In addition, the annual change in the temperature control point has annually degraded the conservation value of spawning habitat by reducing the amount of spawning habitat based on preferred spawning water temperature (56°F). The current condition of riparian habitat for winter-run Chinook salmon rearing is degraded by the channelized, leveed, and riprapped river reaches and sloughs that are common in the Sacramento River system. However, some complex, productive habitats with floodplains (*e.g.*, 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) remain in the system.

Based on impediments to salmonid migration, unscreened diversions, DCC (gates open during the winter-run Chinook salmon outmigration period), and the degraded condition of spawning habitat and riparian habitat, the current condition of winter-run Chinook salmon critical habitat is degraded, and does not provide the conservation value necessary for the recovery of the species.

6. Project Effects on Sacramento River Winter-run Chinook salmon Critical Habitat

Critical habitat for winter-run Chinook salmon is comprised of physical and biological features that are essential for the conservation of winter-run Chinook salmon, including freshwater spawning sites, rearing sites, and migration corridors to support one or more life stages of winter-run Chinook salmon. More specifically, the access to and availability of spawning gravel; adequate flow and water temperatures for spawning, egg incubation, fry development, and outmigration; water quality; sufficient riparian habitat for rearing; and an unobstructed emigration corridor, are not expected to be degraded by this proposed action, therefore, the conservation value of critical habitat for the Sacramento River winter-run Chinook salmon ESU in the Sacramento River and Delta will not be degraded by the proposed action.

B. Central Valley Spring-run Chinook salmon ESU

In this section, we describe how the proposed action is expected to affect the likelihood of survival and recovery of the Central Valley spring-run Chinook salmon ESU. We first summarize the status of the entire Central Valley spring-run Chinook salmon ESU. Next, we assess the baseline stress regime and cumulative effects in the action area. We then summarize how the proposed action will affect two specific components of the ESU: (1) the Battle Creek spring-run Chinook salmon population; and (2) the rest of the Central Valley spring-run Chinook salmon ESU including spring-run Chinook salmon in Butte, Deer, Mill, Antelope, Beegum, Thomes, Clear, and Big Chico creeks, as well as the Feather, Yuba, and Sacramento rivers. We then assess the risk associated with the proposed action on the Battle Creek spring-run Chinook salmon population and the Central Valley spring-run Chinook salmon ESU as a whole considering its status, the baseline stress regime, and cumulative effects.

If an adverse population-level response on any of the populations within the ESU is expected from implementation of the proposed action, then the extinction risk would be expected to increase. Conversely, if the population-level effect is positive or beneficial then the extinction risk to the ESU would decrease as a response to the proposed action. This conclusion is based on the recommendation from the Central Valley technical recovery team (TRT) that every extant population is necessary for the recovery of the species (Lindley *et al.* 2007). NMFS interprets this recommendation to indicate that an increase in the extinction risk of one or more of the populations increases the extinction risk of the species.

1. Status of Central Valley Spring-run Chinook salmon ESU

Lindley *et al*. (2007) stated that perhaps 15 of the 19 historical populations of spring-run Chinook salmon are extinct, with their entire historical spawning habitats behind various

impassable dams. Those authors only considered Butte, Deer, and Mill Creeks as watersheds with persistent populations of Chinook salmon confirmed to be spring-run Chinook salmon, although they recognized that Chinook salmon exhibiting spring-run characteristics persist within the FRFH population spawning in the Feather River below Oroville Dam and in the Yuba River below Englebright Dam. The populations in Butte, Deer, and Mill creeks and in the Feather and Yuba rivers fall within the Northern Sierra Nevada diversity group. Butte and Deer creek spring-run Chinook salmon populations had recently been considered at a low risk of extinction, and the Mill Creek population at a moderate or low risk (Lindley *et al*. 2007), but in the last four years returning spring-run Chinook salmon have declined in these creeks. Other small populations of spring-run Chinook salmon continue to persist in this diversity group in Antelope and Big Chico creeks, albeit at an annual population size in the tens or hundreds of fish, with no returning mature adults in some years.

In addition, small populations of spring-run Chinook salmon occur in the Basalt and Porous Lava diversity group in the main stem of the Sacramento River and in Battle Creek. Although, similar to the Antelope and Big Chico creek populations, these populations are made up of only tens or hundreds of fish and may be dependent on strays from other populations, although the extent of this dependency is not known. Monitoring of the Sacramento River mainstem 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 mainstem very difficult to determine, and there is speculation as to whether a true spring-run Chinook salmon population still exists downstream of Keswick Dam. Although the physical habitat conditions downstream of Keswick Dam are capable of supporting spring-run Chinook salmon, some years have had high water temperatures resulting in substantial levels of egg mortality. Less than 15 redds per year were observed in the Sacramento River from 1989 to 1993, during September aerial redd counts (USFWS 2003). Redd surveys conducted in September between 2001 and 2013 have observed an average of 36 salmon redds from Keswick Dam downstream to the RBDD, ranging from three to 105 redds (CDFG, unpublished data, 2013). 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). Lindley *et al.* (2007) concluded that these populations are entirely composed of strays as spring-run Chinook salmon had been extirpated from the entire diversity group. Battle Creek spring-run Chinook salmon are at an abundance level that makes the population vulnerable to extirpation from demographic stochasticity - random effects of variation in individual survival or fecundity with little or no environmental pressure (Shaffer 1981, Allendorf *et al*. 1997, McElhany *et al*. 2000). As such, the population would fall into the high risk of extinction category based on abundance, as described in Lindley *et al*. (2007).

Ephemeral populations of Central Valley spring-run Chinook salmon are found in the Northwestern California Diversity Group in Beegum and Clear Creeks, and salmon have been

observed in Thomes Creek during the spring, although monitoring in that creek has not been conducted consistently due to poor access and difficult terrain. Returning adult spring-run Chinook salmon population sizes in Beegum and Clear creeks have generally ranged from tens up to a few hundred fish. Habitat restoration in Clear Creek has improved conditions for spring-run Chinook salmon and the population has been responding positively to these improvements. The draft Central Valley Salmon and Steelhead Recovery Plan considers Clear Creek to be a core 1 population that will be capable of reaching viable status (NMFS 2009b).

Historically, the majority of spring-run Chinook salmon in the Central Valley were produced in the Southern Sierra Nevada Diversity Group, which contains the San Joaquin River and its tributaries. All spring-run Chinook salmon populations in this diversity group have been extirpated (Lindley *et al*. 2007). Current San Joaquin River Restoration Program plans are underway to restore spring-run Chinook salmon production in the San Joaquin River downstream of Friant Dam (U.S. District Court 2006).

With demonstrably viable populations in only one of four diversity groups that historically contained them, spring-run Chinook salmon fail the representation and redundancy rule for ESU viability (Lindley *et al*. 2007). The current distribution of viable populations makes spring-run Chinook salmon vulnerable to catastrophic disturbance. All three extant independent populations are in basins whose headwaters occur within the debris and pyroclastic flow radii of Mount Lassen, an active volcano that the USGS views as highly dangerous (Hoblitt *et al*. 1987). The current ESU structure is, not surprisingly, also vulnerable to drought. Even wildfires, which are of much smaller scale than droughts or large volcanic eruptions, pose a significant threat to the ESU in its current configuration. A fire with a maximum diameter of 30 km, big enough to burn the headwaters of Mill, Deer and Butte creeks simultaneously, has roughly a 10 percent chance of occurring somewhere in the Central Valley each year (Lindley *et al*. 2007).

2. <u>Baseline Stress Regime and Cumulative Effects on the Central Valley Spring-run Chinook salmon ESU Excluding the CNFH Effects</u>

This section summarizes the environmental baseline upon which we will add the effects of the proposed action in order to help assess the response and risk to the species. Habitat elimination and degradation has been a primary factor causing the threatened status of spring-run Chinook salmon in the Central Valley. Physical habitat modifications (*e.g.*, dam construction and river straightening and associated riprap applications) and other anthropogenic and natural effects in freshwater, estuarine, and marine environments have greatly diminished the viability of the ESU, and continue to do so. These baseline stressors are similar to those that affect winter-run Chinook salmon and include harvest, predation, water management, agricultural, urbanization, and contaminants. The general baseline stress regime for Battle Creek spring-run Chinook salmon is similar to the status described in the Status of Central Valley Spring-run Chinook salmon ESU section above.

The Central Valley spring-run Chinook salmon ESU may be affected by fisheries. The effects of this take are analyzed in separate ESA consultations (NMFS 2000b). Fisheries and harvest managers reevaluate exploitation rates and harvest strategies on an annual basis to ensure that fisheries for fall- and late fall-run Chinook salmon provide for the survival and recovery of the listed ESUs.

As described for Sacramento River winter-run Chinook salmon above, climate change is a key aspect of stress for ESA-listed salmonids in the Central Valley.

3. Summary of Proposed Action Effects on the Central Valley Spring-run Chinook salmon ESU

The effects of the proposed action on spring-run Chinook salmon are summarized for both the ESU and the Battle Creek population in Table 9. Detailed descriptions regarding the exposure, response, and risk of spring-run Chinook salmon to these stressors are presented earlier in this document. The CNFH is located on Battle Creek, and the magnitude and type of effects from hatchery facilities and operations on the Battle Creek spring-run Chinook salmon population may be significant, while effects on the ESU as a whole remain insignificant.

Table 9. Hatchery risks to spring-run Chinook salmon; affected Viable Salmon Population parameters including Abundance, Diversity, Productivity, and Spatial Structure; indication of whether take is expected; and level of impact to the Evolutionarily Significant Unit.

Risk	VSP Parameter	Take	Level of Impact
Hatchery Facilities	Abundance	Yes	Low
Broodstock Collection	Abundance & Productivity	Yes	Low
Genetics	Abundance, Diversity, & Productivity	Yes	Low
Disease	Abundance & Productivity	Yes	Low
Competition & Density-Dependent Effects	Productivity	Yes	Low
Predation	Abundance	Yes	Low
Masking	Abundance	No	Low
Nutrient Cycling	Abundance & Productivity	No	Beneficial
Monitoring & Evaluation	Abundance	Yes	Beneficial

Hatchery operations at the CNFH will affect the Battle Creek population of spring-run Chinook salmon at both the juvenile and adult life stages, but these effects appear to result in a low level of impact to the population and measures are being implemented in the proposed project activities to reduce the risk to this population. Water diversions from Battle Creek may result in entrainment of spring-run Chinook salmon juveniles when the hatchery's primary water intakes are inoperable. During normal operations, water withdrawal systems at the CNFH are conducted using intake structures that are in areas considered free of anadromous fish (Intake #1) or meet NMFS fish screening criteria (Intake #3) and no take of Battle Creek spring-run Chinook salmon is anticipated. Take may occur when an unscreened backup Intake 2 is used. USFWS will avoid using the backup intake structure to the extent practicable, and will employ salvage operations to reduce lethal take of listed salmonids when practical and necessary. Entrainment impacts to Battle Creek spring-run Chinook salmon are expected to be low, although if an emergency usage of Intake 2 occurs during outmigration, impacts to juveniles could raise.

Water use at the CNFH will result in decreased flow in 1.6 miles of Battle Creek directly upstream of the hatchery. During drought years hatchery water withdrawals may constrict the migration corridor or impair water quality, adversely impacting listed Central Valley spring-run Chinook salmon by impeding the migration of adults and reducing the quantity or quality of

juvenile rearing habitat. The degree of impact to listed salmonids will depend on the extent and duration of substandard flows. USFWS believes that the impact of the CNFH water diversions on the Battle Creek spring-run Chinook salmon population will be low for the following reasons: (1) flow reductions will occur in a section of Battle Creek used as a "migration corridor", containing no spawning or rearing habitats for spring-run Chinook salmon; (2) flows would rarely fall below recommended WUA levels, and such events would not occur during the spring-run Chinook salmon migration, therefore, migrating spring-run Chinook salmon are not likely to be impacted by such events; and (3) stream flow will maintain connectivity throughout the Battle Creek migration corridor, at levels sufficient to support juvenile and adult migrations of spring-run Chinook salmon.

The viability of the natural-origin spring-run Chinook salmon ESU is not likely to be impacted by broodstock collection activities at the CNFH Complex, including operation of the CNFH Barrier Weir ladder into the hatchery and the fish trap at the Keswick Dam. Spring-run Chinook salmon are not likely to be collected during broodstock collection activities at the CNFH because the migration timing of natural-origin spring-run Chinook salmon in Battle Creek does not coincide with the period of broodstock congregation and collection in that tributary. In addition, Spring-run Chinook salmon are not likely to be incidentally collected during late fall-run Chinook salmon collection at the Keswick Dam fish trap, due to no overlap in run timing between the two runs. In addition to impacts from CNFH Complex activities, spring-run Chinook salmon may experience adverse effects during Restoration Project Monitoring at the CNFH Barrier Weir upstream fish ladder. The Barrier Weir is a permanent structure, and extends across the full width of Battle Creek. The primary purpose of the fish barrier weir is to route hatchery fish through the hatchery ladder into the hatchery facility, but it also serves to inhibit the upstream immigration of adult salmonids into Battle Creek upstream of the barrier weir. Manipulation of gates and flows within the fish ladder system allows the routing of fish into the hatchery adult collection facility and holding ponds during periods of broodstock collection. The ladder system also can allow fish to bypass the hatchery and proceed into upper Battle Creek through the upstream fish ladder. The Barrier Weir is currently used to block hatchery fish from accessing Battle Creek upstream of the hatchery, and to allow wild fish access during portions of the year (as per the Restoration Project). Impacts to listed species during monitoring of the ladder allowing wild fish upstream have been analyzed separately through section 10(a)(1)(A) of the ESA in the past, and are currently being analyzed for a new ESA section 10(a)(1)(A) permit in 2013/2014.

Stray hatchery-origin adipose fin clipped spring-run Chinook salmon from the FRFH occasionally enter the CNFH while collecting fall-run Chinook salmon broodstock. Upstream migration in the late-summer and fall is atypical of Central Valley spring-run Chinook salmon, and likely is the result of hybridization with fall-run Chinook salmon in the Feather River or FRFH. An average of four FRFH spring-run Chinook salmon strays have been observed at the CNFH annually since 2001. The maximum number observed during a season was 11, which occurred during 2010. FRFH-origin spring-run Chinook salmon, which are 100 percent adipose-fin clipped, entering the CNFH during the collection of fall-run Chinook salmon broodstock cannot be identified based on phenotype or physical marks, and they are likely to be either spawned or excessed at the hatchery. After being spawned or excessed, CWTs are removed and later read to identify run, hatchery of origin, and age of fish.

Juvenile spring-run Chinook salmon may become disoriented as they migrate downstream past the CNFH barrier weir, possibly increasing their susceptibility to predation, however, successful downstream juvenile passage was taken into consideration during the 2008 structure modification. Spring-run Chinook salmon are mostly segregated, both temporally and spatially, from fall and late fall-run Chinook salmon produced at the CNFH. Therefore, there is little interaction between CNFH juvenile salmonids and spring-run Chinook salmon juveniles.

Genetic effects and redd superimposition resulting from natural spawning hatchery-origin late fall-run Chinook salmon and steelhead are not likely to occur, or to reduce the viability and potential for recovery of spring-run Chinook salmon, due to the temporal separation from spring-run Chinook salmon spawning timing. Temporal and spatial separation of spawning limits the likelihood of genetic impacts of fall-run Chinook salmon historically, but because many systems in the Central Valley have dams on them, spring-run Chinook salmon and fall-run Chinook salmon have some overlap both temporally and spatially; additionally, off-site releases of fall-run Chinook salmon produced at the CNFH increases rates of straying and increases the likelihood of genetic impacts to spring-run Chinook salmon. This impact is greatest in areas where spring-run Chinook salmon are blocked by dams from natal spawning areas, such as in the mainstem Sacramento River and in Clear Creek. Detrimental genetic affects to spring-run Chinook salmon in Battle Creek are discouraged through the general practice of preventing fall-run Chinook salmon from passing upstream of the CNFH barrier weir; however, they may pass upstream during high flow events, or if migrating early when the ladder is still open.
The potential for genetic introgression or redd superimposition resulting from stray hatchery-origin fall-run Chinook salmon will not limit the viability and potential for recovery of the Sacramento River winter-run Chinook salmon ESU because there is a temporal separation in spawning times. Winter-run Chinook salmon are largely segregated, both temporally and spatially, from CNFH-origin fall and late fall-run Chinook salmon and steelhead in the freshwater environment.

The potential for transmitting disease from the artificial propagation programs at the CNFH to listed spring-run Chinook salmon is low. Diseases that could be expected at the CNFH are already present in the natural populations, and thus hatchery fish are not expected to introduce new diseases in to the wild. The potential for the hatchery programs to contribute to adverse effects due to disease transfer or amplification are substantially reduced by use of the ozone water treatment plant and disease management protocols used at the CNFH.

Competition and density dependent effects on listed spring-run Chinook salmon from the artificial propagation program juvenile releases are thought to be low due to the timing and location of the releases, which occur downstream of spring-run Chinook salmon spawning and early-rearing areas, and except for hatchery late-fall Chinook salmon, occur after juvenile spring-run Chinook salmon have outmigrated. Hatchery-origin fishes are released at the smolt stage to encourage rapid emigration, thereby reducing the potential for interactions with listed spring-run Chinook salmon in the freshwater environment, but this needs to be looked at further. Potential interactions between hatchery- and natural-origin salmonids could occur during the early marine life stage, when the abundance of food may be limiting; however, little information is available regarding the carrying capacity of estuarine environments, which are known to be highly

variable. Potential effects to spring-run Chinook salmon would likely be mitigated to some degree because spring-run Chinook salmon enter the marine environment earlier than hatchery-origin fall-run Chinook salmon, the major production program at the CNFH.

Competition at the adult life stage is not believed to be a factor limiting viability and recovery of spring-run Chinook salmon; however, competitive interactions at the adult life stage are increased by releasing fall-run Chinook salmon at off-site locations, which increases rates of straying. Fall-run Chinook salmon that stray to the upper Sacramento River or Clear Creek could compete with spring-run Chinook salmon for spawning habitat during the later portion of spring-run Chinook salmon spawn timing. Redd superimposition could also occur subsequent to spring-run Chinook salmon spawning. Competition in Battle Creek is reduced through the operation of the CNFH barrier weir to discourage fall-run Chinook salmon from passing upstream of the CNFH barrier weir.

Predation by salmon and steelhead released from the proposed artificial propagation programs on listed spring-run Chinook salmon is thought to have a low level of effects on the viability or recovery potential for the spring-run Chinook salmon ESU, but these potential impacts have not been well documented. The timing and locations of juvenile releases largely isolate hatchery-origin smolts from natural-origin spring-run Chinook salmon juveniles and reduce the likelihood of predation in the upper river system. The likelihood of predation by hatchery fish on spring-run Chinook salmon is further reduced because hatchery fish are released at the smolt stage and exhibit rapid emigration from the river system. Monitoring of emigration patterns show that fall and late fall-run Chinook salmon smolts from CNFH travel downstream rapidly, moving out of the upper Sacramento River in large pulses, with few fish exhibiting delayed emigration. Additionally, spring-run Chinook salmon are not likely to be susceptible to high levels of predation due to their size at the time when hatchery releases occur.

Masking of Central Valley spring-run Chinook salmon by hatchery-origin late fall-run Chinook salmon is not likely to significantly impact population viability or the potential for recovery. One hundred percent of the late fall-run Chinook salmon are adipose-fin clipped and coded-wire tagged, providing the ability to sufficiently reduce the potential of masking. However, because fall-run Chinook salmon are currently marked at a rate of 25 percent, this significantly reduces the ability to differentiate them from spring-run Chinook salmon in areas where spring-run Chinook salmon do not have access to habitat that has the ability to separate the two runs spatially.

The carcasses of adult hatchery-origin salmonids collected at the CNFH are currently not being used for nutrient enhancement. However, hatchery fish that do not enter the hatchery provide marine derived nutrient enhancement to local basins and may provide a positive impact on the local populations, especially in and downstream of lower Battle Creek. Habitat in and near Battle Creek above the CNFH barrier weir will not benefit from marine derived nutrients resulting from returning hatchery-origin fall and late fall-run Chinook salmon because management actions preclude them from these areas. Supplementation of hatchery-origin carcasses could assist restoration actions in Battle Creek until populations reach self-sustaining levels.

Hatchery monitoring and evaluation activities associated with the CNFH will impose a low level of impact to spring-run Chinook salmon. Spring-run Chinook salmon that are collected in the hatchery during the spawning of late fall-run Chinook salmon may be anaesthetized, sampled for tissues and measured for length prior to release upstream of the barrier weir in Battle Creek. Additionally, spring-run Chinook salmon could be incidentally collected during the process of collecting late fall-run Chinook salmon broodstock at the Keswick Dam fish trap. Chinook salmon determined to be spring-run based on phenotypic characteristics, will be measured for fork length and floy tagged prior to release in the Sacramento River at Redding. Take will occur through trapping, handling, sampling, and transport possibly resulting in stress, delayed migration, injury, or mortality. Effects of these activities to spring-run Chinook salmon in Battle Creek and the Central Valley spring-run Chinook salmon ESU are expected to be low, and may provide some benefits.

4. Assess Risk to the Central Valley Spring-run Chinook salmon ESU

Population viability is determined by four parameters: spatial structure, diversity, abundance, and productivity (growth rate). Both population spatial structure and diversity (behavioral and genetic) provide the foundation for populations to achieve abundance levels at or near potential carrying capacity and to achieve stable or increasing growth rates. Spatial structure on a watershed scale is determined by the availability, diversity, and utilization of properly functioning conditions (habitats) and the connections between such habitats (McElhany *et al*. 2000). Properly functioning condition defines the inland habitat conditions necessary for the long-term survival of Pacific salmon populations (McElhany *et al*. 2000). The Central Valley spring-run Chinook salmon ESU is currently at risk in large part because: (1) the ESU is composed of only one diversity group containing independent populations; (2) habitat elimination and modification throughout the Central Valley have drastically altered the ESU's spatial structure and diversity; and (3) the ESU has a risk associated with catastrophes, especially considering the remaining independent population's proximity to Mount Lassen and the probability of a large scale wild fire occurring in those watersheds (Lindley *et al*. 2007).

Overall, in the analysis for this biological opinion, NMFS has determined that proposed fish propagation programs at the CNFH are not a primary factor limiting the viability of Spring-run Chinook salmon in Battle Creek or the ESU of Central Valley spring-run Chinook salmon. Impacts of hatchery facilities (which includes hatchery failure, fish entrainment, hatchery water withdrawals, and discharge of hatchery effluent), broodstock collection, genetic introgression, disease, competition/density dependence effects (including ocean competition), predation, masking, nutrient cycling, and monitoring appear to result in a low level of effects to the spring Chinook in Battle Creek and the ESU of Central Valley Spring Chinook Salmon.

Because all impacts on listed spring-run Chinook salmon cannot be completely eliminated, there will always be the potential for hatchery programs to negatively impact natural-origin fish. Table 9 lists the potential impacts of the proposed artificial propagation programs on listed spring-run Chinook salmon. Based on the analysis above, NMFS has considered recovery planning documentation, and the potential effects of the proposed action on spring-run Chinook salmon populations, combined with other ongoing activities within the Action Area, and determined that the proposed action is not expected to appreciably reduce the likelihood of survival and recovery of the Central Valley spring-run Chinook salmon ESU in the wild by

reducing the reproduction, numbers, or distribution of the ESU (reproduction, numbers, and distribution of the ESU relate to the VSP parameters of spatial structure, diversity, abundance, and productivity).

5. Status of Central Valley Spring-run Chinook salmon Critical Habitat

Critical habitat for spring-run Chinook salmon is composed of primary constituent elements that are essential for the conservation of the species including, but not limited to, spawning habitat, rearing habitat, migratory corridors, and estuarine areas. Most of the historic spawning and rearing habitat for spring-run Chinook salmon is above impassable dams as is the case for the Sacramento, Feather, Yuba, American, Mokelumne, Stanislaus, Tuolumne, Merced, and San Joaquin rivers. Current spring-run Chinook salmon spawning habitat largely occurs in areas that historically functioned as either rearing habitat or migratory corridors, or spawning habitat for fall-run Chinook salmon. In areas where the spawning distributions of fall and spring-run Chinook salmon overlap, the quality of spawning habitat used by spring-run Chinook salmon is diminished when fall-run Chinook salmon, which spawn later than but still during spring-run Chinook salmon spawning, arrive at the spawning grounds and physically disturb spring-run Chinook salmon redds during their redd construction. This competition for spawning habitat between spring-run and fall-run Chinook salmon, which is the result of dam construction, occurs on several Central Valley rivers.

Battle Creek is located in the basalt and porous lava diversity group and provides suitable habitat for Central Valley spring-run Chinook salmon, largely due to the many cold springs which feed the creek. The Battle Creek watershed also receives a considerable amount of snowmelt during the spring-run and early summer. However, Battle Creek habitat is affected by several PG&E owned and operated diversion facilities on the North and South Forks. These facilities allow PG&E to control the majority of the flows in the anadromous fish reaches of the Battle Creek watershed. Because these facilities limit the availability of suitable habitats for anadromous salmonid within the watershed, a cooperative partnership among Federal, State, and local entities was formed to develop and implement the Battle Creek Salmon and Steelhead Restoration Project. Specific restoration components being implemented include improved instream flow releases, selected decommissioning of dams at key locations in the watershed, dedication of water diversion rights for instream purposes at decommissioned sites, construction of tailrace connectors, and installation of fish screens and fish ladders (http://www.usbr.gov/mp/battlecreek/pdf/main/MOU.pdf).

At the scale of the ESU of Central Valley spring-run Chinook salmon, substantial habitat degradation and alteration also has affected the rearing, migratory, and estuarine areas used by spring-run Chinook salmon. Some general examples of how spring-run Chinook salmon critical habitat has been degraded include the direct loss of floodplain and riparian habitat, the loss of natural river function and floodplain connectivity through levee construction, and effects to water quality associated with agricultural, urban, and industrial land use. One specific example of degradation to estuarine habitats used by spring-run Chinook salmon is that human activities in the San Francisco Bay-Delta Estuary have caused the loss or conversion of more than 500,000 acres of tidal wetlands and thousands of acres of shoreline and stream habitat (http://sfep.abag.ca.gov/pdfs/fact_sheets/SF_Bay_Delta_Estuary.pdf). Perhaps the most striking indication that the status of estuarine habitats used by spring-run Chinook salmon has been

degraded is the collapse of the pelagic community in the Delta that has been observed in recent years (Sommer *et al*. 2007). It is not immediately clear how the changes in the Delta ecosystem affect spring-run Chinook salmon, but it is certain that substantial changes to spring-run Chinook salmon estuarine habitat are occurring. It should be noted that the area in which the pelagic organism collapse is occurring does overlap with spring-run Chinook salmon critical habitat in the Delta, but the area of collapse also occurs in areas of the Delta that are not designated as spring-run Chinook salmon critical habitat.

The current condition of critical habitat for the ESU of Central Valley spring-run Chinook salmon is highly degraded, and does not provide the conservation value necessary for the survival and recovery of the species.

6. Project Effects on Central Valley Spring-run Chinook salmon Critical Habitat

The proposed action is expected to diminish stream flow in a 1.6 mile stretch of Battle Creek affecting critical habitat for Central Valley spring-run Chinook salmon. While the stream flow in this 1.6 mile stretch of Battle Creek will be reduced, based on historic data, minimum recommended flow requirements in Battle Creek will be exceeded more than 97 percent of the time. The section of Battle Creek affected by CNFH water diversions serves as a freshwater migration corridor for spring-run Chinook salmon. Water diversions to the CNFH may cause depletions of flow, which will reduce the size of the migration corridor in Battle Creek but are not expected to block or delay passage of juvenile or adult salmonids. NMFS concludes that the effects of the proposed action would result in a low level of impact to designated critical habitat for the Central Valley spring-run Chinook salmon ESU and would not appreciably reduce the value of the critical habitat for the conservation of the species.

C. California Central Valley steelhead DPS

1. Status of the California Central Valley steelhead DPS

California Central Valley steelhead were listed as threatened on March 19, 1998 (63 FR 3347). Their classification was retained following a status review on January 5, 2006, (71 FR 834) and again on August 15, 2011 (76 FR 50447). This DPS includes all naturally-spawned steelhead populations (and their progeny) in the Sacramento and San Joaquin Rivers and their tributaries (inclusive of and downstream of the Merced River), excluding steelhead from San Francisco and San Pablo Bays and their tributaries, and including hatchery produced steelhead at CNFH and FRNFH. Historically, steelhead were well distributed throughout the Sacramento and San Joaquin Rivers (Busby *et al*. 1996). Steelhead were found from the upper Sacramento and Pit River systems (now inaccessible due to Shasta and Keswick Dams), south to the Kings and possibly the Kern River systems (now inaccessible due to extensive alteration from water diversion projects), and in both east- and west-side Sacramento River tributaries (Yoshiyama *et al*. 1996). The present distribution has been greatly reduced (McEwan and Jackson 1996), with nearly all historic spawning habitat blocked behind impassable dams in many major tributaries, including in the Northwestern California (Clear Creek), the Basalt and Porous Lava (Sacramento, Pitt, and McCloud rivers), the northern Sierra Nevada (Feather, Yuba, American, and Mokelumne rivers), and the southern Sierra Nevada (Stanislaus, Tuolumne, Merced, Calaveras, and San Joaquin rivers) diversity groups (Lindley *et al*. 2007).

Historic abundance of California Central Valley steelhead is difficult to estimate given limited data, but may have approached one to two million adults annually (McEwan 2001). By the early 1960s, California Central Valley steelhead abundance had declined to about 40,000 adults (McEwan 2001). Over the past 30 years, the naturally spawned steelhead populations in the upper Sacramento River have declined substantially. Hallock *et al.* (1961) estimated an average of 20,540 adult steelhead in the Sacramento River, upstream of the Feather River, through the 1960s. 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 the RBDD ended in 1993 due to changes in dam operations.

The only consistent data available on steelhead numbers in the San Joaquin River basin come from CDFG mid-water trawling samples collected on the lower San Joaquin River at Mossdale. These data indicate a decline in steelhead numbers in the early 1990s, which have remained low through 2002 (CDFG 2003). In 2004, a total of 12 steelhead smolts were collected at Mossdale (CDFG unpublished data).

Existing wild steelhead stocks in the Central Valley are mostly confined to the upper Sacramento River and its tributaries, including Antelope, Battle, Deer, and Mill creeks and the Yuba River. Small populations may also exist in Big Chico and Butte creeks. A few wild steelhead are produced in the American and Feather Rivers (McEwan and Jackson 1996). Steelhead redd surveys in Clear Creek observed the highest count in 2009, possibly due to restoration activities (S. Giovannetti and Brown 2009). Until recently, 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, Calaveras, and other streams previously thought to be void of steelhead (McEwan 2001). It is possible that naturally spawning populations exist in many other streams; however, these populations are undetected due to lack of monitoring programs (IEPSPWT 1999).

Steelhead returns to the Battle Creek watershed constitute a significant portion of the California Central Valley steelhead DPS, and most of the Battle Creek return originates at the CNFH. Differentiating abundance between hatchery- and natural-origin steelhead in Battle Creek has been reliably estimable since 2002, when the first full cohort of 100 percent marked hatchery fish returned to the CNFH. Prior to that year, hatchery and natural steelhead in Battle Creek were not differentiable, and all steelhead were managed as a single, homogeneous stock. Abundance estimates of natural origin steelhead in Battle Creek from 2001 to 2009 ranged from 222 to 545 (mean of 387, std.=101). The abundance of hatchery produced steelhead returning to CNFH from 2003 to 2009 ranged from 1,004 to 3,193 (avg. = 1,993, std.=763). These estimates of steelhead abundance include all variants of life history types of the species *Oncorhynchus mykiss*, including ocean-going fish commonly referred as “steelhead” and nonanadromous types commonly referred as “rainbow trout”. During recent years there has been a marked paucity of larger-sized natural-origin *Oncorhynchus mykiss* observed in Battle Creek (K. Niemela, USFWS, personal communication, 2010). This decline of larger-sized *O. mykiss* may indicate selection against an anadromous life history type.

2. Baseline Stress Regime and Cumulative Effects on the California Central Valley steelhead DPS Excluding the CNFH Effects

This section summarizes the environmental baseline upon which we will add the effects of the proposed action in order to help assess the response and risk to the species. Extensive habitat elimination and degradation has been a primary factor causing the threatened status of California Central Valley steelhead. Physical habitat modifications (*e.g.*, dam construction and river straightening and associated riprap applications) and many other anthropogenic effects on habitat have greatly diminished the viability of the DPS. The general baseline stress regime for steelhead in the freshwater, estuarine, and marine environment is similar to that of winter-run and spring-run Chinook salmon (Figure 11), with an exception that there is no targeted ocean fishery for steelhead. Detailed descriptions of baseline stressors to California Central Valley steelhead are provided in section III.

The steelhead DPS may be affected by inland fisheries. Fisheries and harvest managers reevaluate exploitation rates and harvest strategies on an annual basis. Since the recreational fishery is regulated to protect natural-origin steelhead, managers don't consider the impacts significant, although this has not been analyzed through ESA section 7 consultation. However, because the sizes of California Central Valley steelhead populations are largely unknown, it is difficult to make conclusions about the impact of the fishery (Good et al. 2005).

As described for Sacramento River winter-run Chinook salmon above, climate change is a key aspect of stress for ESA-listed salmonids in the Central Valley.

3. Summary of Proposed Action Effects on the California Central Valley steelhead DPS

Effects of the proposed action on California Central Valley steelhead are summarized in Table 10 for both the California Central Valley steelhead DPS and the Battle Creek population. Detailed descriptions regarding the exposure, response, and risk of steelhead to these stressors are presented earlier in this document. The fall and late fall-run Chinook salmon and steelhead propagation programs at the CNFH are located on Battle Creek, and the type and magnitude of effects from these programs on the Battle Creek steelhead population may be different from these effects on the DPS as a whole. We summarize the project effects on the Battle Creek steelhead population and the DPS of California Central Valley steelhead below.

Steelhead may be affected by broodstock collection activities at the CNFH, including operation of the CNFH barrier weir and fish ladders and the fish trap at the Keswick Dam. Hatchery-origin steelhead are collected for broodstock October 1 through the end of February. Natural-origin steelhead entering the CNFH during this broodstock collection period at the CNFH will be released upstream of the barrier weir at the time of first sorting. Steelhead encountered during the collection of natural-origin late fall-run Chinook salmon at the Keswick Dam fish trap will be sorted and released into the Sacramento River at Redding. Take will occur through spawning, trapping, handling, sampling, and transport possibly resulting in stress, delayed migration, injury, or mortality. Effects of these activities to steelhead in Battle Creek and the California Central Valley steelhead DPS are expected to be low, and in some aspects, like propagation increasing the abundance of juveniles produced within the DPS, beneficial.

Table 10. Hatchery risks to steelhead; affected Viable Salmon Population parameters including Abundance, Diversity, Productivity, and Spatial Structure; indication of whether take is expected; and level of impact to the Distinct Population Segment.

Risk	VSP Parameter	Take	Level of Impact
Hatchery Facilities	Abundance	Yes	Low
Broodstock Collection	Abundance & Productivity	Yes	Low
Genetics	Abundance, Diversity, & Productivity	Yes	Low
Disease	Abundance & Productivity	Yes	Low
Competition & Density-Dependent Effects	Productivity	Yes	Low
Predation	Abundance	Yes	Low
Masking	Abundance	No	None
Nutrient Cycling	Abundance & Productivity	No	Beneficial
Monitoring & Evaluation	Abundance	Yes	Beneficial
Spawning & Propagation	Abundance	Yes	Beneficial

Effects of genetic introgression and redd superimposition resulting from natural spawning hatchery-origin fall and late fall-run Chinook salmon and steelhead are expected to be low and not likely to limit the viability and recovery of steelhead in Battle Creek or other areas of the California Central Valley steelhead DPS. Releases of salmon and steelhead smolts from the CNFH occur at times and locations believed to impart a high degree of imprint on the hatchery, thereby reducing the likelihood of straying as adults (USFWS 2011). Adult hatchery-origin salmon and steelhead are not currently released upstream of the barrier weir into Battle Creek, limiting the potential for genetic effects or redd superimposition in that tributary. The potential for transmitting disease from the artificial propagation programs at the CNFH to listed steelhead is low. Diseases that could be expected at the CNFH are already present in the natural populations, and thus hatchery fish are not expected to introduce new diseases in to the wild. The potential for the hatchery programs to contribute to adverse effects due to disease transfer or amplification are substantially reduced by use of the ozone water treatment plant and disease management protocols used at the CNFH.

NMFS believes that competition and density dependent effects from the artificial propagation programs at CNFH will not affect the viability or likelihood of recovery of steelhead in Battle Creek or for the DPS of California Central Valley steelhead. Hatchery-origin fishes are released at the smolt stage to encourage rapid emigration, thereby reducing the potential for interactions with listed spring-run Chinook salmon in the freshwater environment. Extensive predation by hatchery-origin fall-run Chinook salmon is considered unlikely because juvenile fall-run Chinook salmon are believed to be largely non-piscivorous at the size and life stage when they are liberated from the hatchery. Additionally, most steelhead redds would be located above the area where hatchery-origin fall-run Chinook salmon are released. Predation by hatchery-origin late fall-run Chinook salmon is expected to have a low level of impact because steelhead are of a size that makes them unlikely to be susceptible to predation by late fall-run Chinook salmon. Extensive predation in the upper Sacramento River and the migration corridor is also unlikely because late fall-run Chinook salmon exhibit rapid emigration from the upper river. Predation on natural-origin steelhead in Battle Creek by hatchery-origin steelhead is unlikely because

hatchery-origin steelhead are released outside of the Battle Creek watershed. Competitive interactions between hatchery- and natural-origin salmonids may occur during the early marine life stage, when the abundance of food may be limiting; however, little information is available regarding the carrying capacity of estuarine environments, which are known to be highly variable. Potential effects to steelhead would likely be mitigated to some degree because steelhead enter the marine environment earlier and at a larger size than hatchery-origin fall-run Chinook salmon, the major production program at the CNFH.

Masking of California Central Valley steelhead by production of hatchery-origin steelhead is not likely because all of the steelhead released into the Central Valley are marked by clipping their adipose fins. Complete marking of hatchery-origin steelhead at the CNFH and on a basin-wide scale provides the ability to eliminate the potential of masking by enabling the discrimination of origin at scale of the DPS, populations, and individual fish.

Utilization of hatchery adult carcasses for nutrient enhancement is not currently being implemented at the CNFH. However hatchery fish that do not enter to the hatchery can provide marine derived nutrient enhancement to local basins and may provide a positive impact on proximate steelhead populations.

Hatchery monitoring and evaluation activities associated with the CNFH may impose a low level of impact to steelhead. Natural-origin steelhead that are collected in the hatchery may be anaesthetized, sampled for tissues and scales and measured for length prior to release upstream of the barrier weir in Battle Creek. Additionally, steelhead could be incidentally captured during the process of collecting late fall-run Chinook salmon broodstock at the Keswick Dam fish trap. Steelhead captured at the Keswick fish trap may be measured to length prior to release in the Sacramento River at Redding. Take will occur through trapping, handling, sampling, and transport possibly resulting in delayed migration, handling, stress, injury, or mortality. These activities are expected to have a low level of impact to steelhead in Battle Creek and the California Central Valley steelhead DPS.

Although take of ESA-listed CNFH-origin California Central Valley steelhead will occur as a result of the steelhead propagation program, there are also benefits of the program. Beneficial impacts include CNFH production of 600,000 steelhead juveniles annually, which adds to the total juveniles produced and adults returned for the DPS. Adult hatchery-origin steelhead have returned to Battle Creek in numbers ranging from 467 to 4,429.

4. <u>Assess Risk to the California Central Valley steelhead DPS</u>

Population viability is determined by four parameters: spatial structure, diversity, abundance, and productivity (growth rate). Both population spatial structure and diversity provide the foundation for populations to achieve abundance levels at or near potential carrying capacity and to achieve stable or increasing growth rates. Spatial structure on a watershed scale is determined by the availability, diversity, and utilization of properly functioning conditions (habitats) and the connections between such habitats (McElhany *et al*. 2000). Properly functioning conditions define the inland habitat conditions necessary for the long-term survival of Pacific salmon populations (McElhany *et al*. 2000). The California Central Valley steelhead DPS is currently at risk in large part because: (1) habitat elimination and modification have drastically altered the

spatial structure and diversity of the California Central Valley steelhead DPS; and (2) the DPS has a risk associated with catastrophes, especially considering the remaining independent population's proximity to Mount Lassen and the probability of a large scale wild fire occurring in those watersheds (Lindley *et al*. 2007).

Impacts of hatchery facilities, genetic introgression, disease, competition, predation, masking, broodstock collection, spawning and propagation, monitoring, and nutrient cycling would result in a low level of effects, and may also provide some beneficial effects, to steelhead in Battle Creek and the DPS of California Central Valley steelhead.

Table 10 summarizes impacts of the proposed artificial propagation programs on listed California Central Valley steelhead. Based on the analysis above, NMFS has considered recovery planning documentation, and the potential effects of the proposed action on California Central Valley steelhead populations, combined with other ongoing activities within the Action Area, and determined that the proposed action is not expected to appreciably reduce the likelihood of survival and recovery of the California Central Valley steelhead DPS in the wild by reducing the reproduction, numbers, or distribution of the DPS (reproduction, numbers, and distribution relate to the VSP parameters of spatial structure, diversity, abundance, and productivity).

5. Status of California Central Valley steelhead Critical Habitat

It is estimated that 80 percent of the historic spawning and rearing habitat for California Central Valley steelhead is above impassable dams as is the case for the Sacramento, Feather, Yuba, American, Mokelumne, Stanislaus, Tuolumne, Merced, and San Joaquin rivers. All critical habitat for California Central Valley steelhead occurs below impassable barriers. As such, steelhead critical habitat largely occurs in areas that historically functioned as either rearing or migratory habitats.

Critical habitat for California Central Valley steelhead is composed of PCEs that are essential for the conservation of the species including, but not limited to, spawning habitat, rearing habitat, migratory corridors, and estuarine areas. Stressors to California Central Valley steelhead PCEs are similar to the stressors described for spring-run Chinook salmon critical habitat and include water diversions and water management, dams and other structures, loss of floodplain connectivity, loss of natural riverine function, bank protection, dredging, sediment disposal, gravel mining, invasive aquatic organisms, and agricultural, urban, and industrial land use (McEwan 2001). In the Sacramento-San Joaquin Delta, while both spring-run Chinook salmon and California Central Valley steelhead critical habitat include the Sacramento Delta Hydrological Unit, California Central Valley steelhead critical habitat additionally includes the San Joaquin Delta Hydrological Unit. The Sacramento-San Joaquin Delta is an ecosystem that has had dramatic habitat changes in recent years related to water quality, toxic algae blooms (*e.g*., Microcystis), and invasive species (*e.g*., the aquatic macrophyte *Egeria densa*). Based on the host of stressors to spawning, rearing, migratory, and estuarine habitats in the Central Valley, it is apparent that the current condition of California Central Valley steelhead critical habitat is degraded, and does not provide the conservation value necessary for the survival and recovery of the species.

Steelhead habitat in Battle Creek is generally considered to be suitable largely due to many cold springs which feed the creek and the fact that the watershed receives a considerable amount of snowmelt during the spring-run and early summer. However, Battle Creek habitats are affected by several PG&E owned and operated diversion facilities on the North and South Forks. These facilities allow PG&E to control the majority of the flows in the anadromous fish reaches of the Battle Creek watershed. Because these facilities limit the availability of suitable anadromous salmonid habitat within the watershed, a cooperative partnership among Federal, State, and local entities was formed to develop and implement the Battle Creek Salmon and Steelhead Restoration Project. Specific restoration components being implemented include improved instream flow releases, selected decommissioning of dams at key locations in the watershed, dedication of water diversion rights for instream purposes at decommissioned sites, construction of tailrace connectors, and installation of fish Screens and fish Ladders (http://www.usbr.gov/mp/battlecreek/pdf/main/MOU.pdf).

6. Project Effects on California Central Valley steelhead Critical Habitat

The proposed action is expected to diminish stream flow in a 1.6 mile stretch of Battle Creek affecting critical habitat for California Central Valley steelhead. While the stream flow in this 1.6 mile stretch of Battle Creek will be reduced, based on historic data, minimum recommended flow requirements in Battle Creek will be exceeded more than 97 percent of the time. The section of Battle Creek affected by CNFH water diversions serves as a freshwater migration corridor for steelhead. Water diversions to the CNFH may cause depletions of flow, which will reduce the size of the migration corridor in Battle Creek but are not expected to block or delay passage of juvenile or adult salmonids. NMFS concludes that the effects of proposed action would result in a minor impairment to designated critical habitat for the California Central Valley steelhead DPS and will not appreciably reduce the value of the critical habitat for the conservation of the species.

VII. CONCLUSION

After reviewing the best available scientific and commercial information, the current status of Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, California Central Valley steelhead DPS, the environmental baseline, the effects of the proposed project, and the cumulative effects, it is NMFS' biological opinion that the proposed action is not likely to jeopardize the continued existence of the Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, and California Central Valley steelhead DPS, nor will it result in the destruction or adverse modification of the designated critical habitat for the Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, or California Central Valley steelhead DPS.

VIII. 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 which

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 ESA section 7(b)(4) and section 7(o)(2), taking that is incidental to and not the purpose 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.

The measures described below are non-discretionary, and must be undertaken by USFWS so that they become binding conditions of any grant, contract or permit, as appropriate, for the exemption in ESA section 7(o)(2) to apply. USFWS has a continuing duty to regulate the activity covered by this incidental take statement. If USFWS: (1) fails to assume and implement the terms and conditions; or (2) fails to require the permittee, contractor, or grantee to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit, contract or grant document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, USFWS must report the progress of the action and its impact on the species to NMFS as specified in the incidental take statement (50 CFR §402.14(i)(3)).

A. Amount and Extent of Take

NMFS anticipates incidental take of Sacramento River winter-run Chinook salmon, California Central Valley steelhead, and Central Valley spring-run Chinook salmon from impacts related to artificial propagation of fall-, and late fall-run Chinook salmon, and steelhead; and associated activities at the CNFH Complex. Quantifiable estimates of take are limited to migrating adults, and migrating, rearing and smolting juveniles. Take resulting from hatchery water diversions from Battle Creek may occur as entrainment, impingement, or death of juvenile steelhead and spring-run Chinook salmon, and from handling during salvage efforts. Take resulting from broodstock congregation and collection in Battle Creek could result in migration delay, blockage, or unintentional lethal take for spring-run and winter-run Chinook salmon and steelhead. Collection of late fall-run Chinook salmon brood stock at the Keswick Dam fish trap could result in various combinations of capture, handle, transport, tissue sample, or unintentional mortality to California Central Valley steelhead and winter-run Chinook salmon. Projected levels of incidental take resulting from artificial propagation programs at the CNFH Complex are summarized in Table 11.

Except as provided in Table 11, potential impacts associated with hatchery effects do not permit a quantitative assessment of take because data were not available or were insufficient to quantify impacts. This inability to quantify impacts is due to the complex biology of salmon and steelhead and the multitude of other actions that simultaneously affect natural salmonid populations. In addition, these factors prevent us from developing specific habitat surrogates to describe the amount or extent of anticipated take for these potential impacts. When available data did not permit calculation of a quantitative estimate of take, impacts associated with hatchery facilities and operations were assessed qualitatively. In this situation, we have assessed impacts resulting from juvenile releases based substantially on a qualitative assessment of risks, drawing information from published literature and considering details related specifically to artificial propagation programs at CNFH. A summary of the qualitative estimates of take

resulting from artificial propagation programs at the CNFH is presented in Tables 8, 9, and 10. Even though we cannot specifically describe the amount or extent of incidental take, except as provided in Table 11, for certain potential impacts associated with hatchery effects, the proposed action, reasonable and prudent measures, and terms and conditions include measures to minimize the extent or impact of such incidental take. If the project is not implemented as described in the biological assessment prepared for this project, and it causes an effect to the listed species or critical habitat that was not considered in this biological opinion, reinitiation of consultation is triggered under the Reinitiation of Consultation section of this biological opinion and 50 CFR 402.16(c). If the project is not implemented in compliance with the terms and conditions of this incidental take statement, then the exemption in ESA section 7(o)(2) would not apply.

Table 11. Projected levels and types of annual incidental take of listed salmonids resulting from artificial propagation programs at CNFH and collection of late fall-run Chinook salmon at Livingston Stone NFH. Take of adults is indicated by "A" and juveniles by "J."

	ESA-listed Species		
	Winter-run Chinook salmon	Spring-run Chinook salmon	Steelhead
Battle Creek			
Death from entrainment or impingement at Intake 2 (J):	0	243	6
Capture, handle, tissue sample, mark-tag, delay, release (A):			
Non-lethal take	4	0	466
Unintentional lethal take	2	11 [a]	8
Sacramento River			
Capture, handle, transport, tissue sample, mark-tag, delay, release (A):			
Non-lethal take	173 [b]	0	35
Unintentional lethal take	2	0	1

a. Estimates of lethal take of spring-run Chinook salmon are based on recoveries of coded-wire tags from listed hatchery-origin spring-run Chinook salmon from the Feather River Fish Hatchery. Because there is not a take prohibition on adipose-fin-clipped spring-run Chinook salmon in the 4(d) rule, authorization is not needed, but the "take" is included here for tracking purposes.

b. Winter-run Chinook salmon collected during natural-origin late fall-run Chinook salmon broodstock collection are included in this table. Winter-run Chinook salmon collected during March through July are covered under USFWS's section 10 permit and are not included in this Table.

B. Take of ESA-listed CNFH-origin California Central Valley steelhead

Direct and incidental take of ESA-listed CNFH-origin California Central Valley steelhead occurs as a result of the propagation program, and is described in Table 12. CNFH-origin steelhead are 100 percent adipose-fin-clipped, and there is no take prohibition for adipose-fin-clipped steelhead in the 4(d) rule. Therefore, no authorization is needed for take of these fish; however, the collection, spawning, and release of these fish are still considered in the effects analysis of this biological opinion. For the purposes of tracking and determining reinitiation thresholds, we have quantified the amount and extent of take in the table below. The USFWS will provide NMFS with the information in Table 12 below, annually.

Table 12. Projected level of annual take of adult CNFH-origin California Central Valley steelhead collected, spawned, and released for the purposes of the CNFH steelhead propagation program, as well as juvenile CNFH-origin California Central Valley steelhead released.

Collected[a]	Spawned[a]	Unintentional Adult Mortality[a]	Adults Released after reconditioning[b]	Juveniles Released
4,429	1,092	696	500 to 3,000	600,000 (± 90,000)[c]

a. This number is variable; the number provided is the maximum.

b. This is a variable number depending on the number of adults returning to the hatchery and survival during the spawning and reconditioning processes.

c. Actual production levels may be up to 15% higher or lower than the production target because of variations in broodstock availability, fecundity levels of available females, and/or variable rates of on-station survival of eggs/juveniles.

C. 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 Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon or California Central Valley steelhead. In addition, NMFS determined that this level of anticipated take is not likely to result in the destruction or adverse modification of designated critical habitat for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon or Central Valley steelhead.

D. Reasonable and Prudent Measures

Pursuant to section 7(b)(4) of the ESA, NMFS concludes the following reasonable and prudent measures are necessary and appropriate to minimize impacts of incidental take of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and California Central Valley steelhead resulting from implementation of the action:

(1) The USFWS shall ensure that juvenile salmonid entrainment and impingement at Intake 2 diversion is avoided or minimized.
(2) The USFWS shall minimize impacts to naturally produced California Central Valley steelhead during the CNFH steelhead and late fall-run Chinook salmon collection period.
(3) The USFWS shall minimize impacts of CNFH releases on listed salmonids throughout their migratory range.

(4) The USFWS shall make necessary updates to existing propagation monitoring programs, to track take of anadromous fish associated with program implementation.

E. Terms and Conditions

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

(1) The USFWS shall ensure that juvenile salmonids entrainment and impingement at Intake 2 diversion is avoided or minimized.
   a. USFWS shall contact NMFS to determine the need for fish salvage in the event that use of Intake 2 is required, prior to usage if planned, or on the first work day of an unplanned outage;
   b. USFWS shall continue to work with PG&E, and USFWS Battle Creek Monitoring Program Managers, on determining the optimal schedule for planned usage of Intake 2 (annual maintenance of Coleman Canal);
   c. USFWS shall send a report to NMFS within a month following completion of any Intake 2 usages, including counts for listed species impacted;
   d. USFWS shall, by March, 2014, develop a plan, in coordination with NMFS, to evaluate the risk of entrainment at Intake 2 through year 2016. Between 2014 and 2016, fyke net efficiency trials shall also be conducted under varying conditions. A report of this evaluation and the efficiency trials shall be sent to NMFS within three months following the end of year 2016. In addition, the USFWS shall evaluate usage patterns of Intake 2 for two years post completion of the Battle Creek Restoration Project;
   e. Based on the evaluation report from 1(d), screening recommendations shall be determined jointly between USFWS and NMFS.

(2) The USFWS shall minimize impacts to naturally produced California Central Valley steelhead during the CNFH steelhead and late-fall-run Chinook salmon collection period.
   a. The USFWS shall investigate alternative ways to minimize handling of naturally produced steelhead such as evaluation of automatic sorting capability in the fish ladder or other alternatives as developed through the CNFH adaptive management plan process. USFWS shall report the results of this investigation to NMFS and implement feasible alternatives in coordination with NMFS.

(3) The USFWS shall minimize impacts of CNFH releases on listed salmonids throughout their migratory range.
   a. The USFWS shall, by January 1, 2015, in coordination with NMFS, develop a plan (approved by NMFS) to assess and better quantify impacts of large CNFH

releases; and by January 1, 2016, begin implementation of the plan. This plan shall include studies to better understand and evaluate some of the potential negative impacts on natural populations of releasing large numbers of CNFH fish, such as: including studies of competition and/or predation by hatchery juveniles; competition between hatchery and natural adult spawners; reduction in fitness or genetic separation between runs, due to hatchery and natural origin interbreeding; identify the number, location, and timing of naturally spawning hatchery fish; and rate and effects of residualization of hatchery-origin steelhead. USFWS shall submit annual reports of these studies and recommendations on adaptive management practices, based on study results, to NMFS for review and approval.

b. All releases of CNFH Chinook salmon production shall be in Battle Creek to reduce adult straying and maximize homing, with the exception of NMFS approved study groups.

c. USFWS shall request dedicated permanent funding from Reclamation for continuation of annual adipose fin clipping and coded-wire tagging of CNFH fall-run Chinook salmon at a rate of 25 percent.

(4) The USFWS shall make necessary updates to existing propagation monitoring programs, to track take of anadromous fish associated with program implementation.

a. The USFWS shall monitor annual take levels for the activities described in Table 11, and report these numbers to NMFS, annually.

Updates and reports required by these terms and conditions shall be submitted to:

Supervisor
California Central Valley Area Office
National Marine Fisheries Service
650 Capitol Mall, Suite 5-100
Sacramento CA 95814
FAX: (916) 930-3629
Phone: (916) 930-3600

IX. 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" is defined in the ESA as the use of all measures necessary to delist a species. These conservation recommendations include discretionary measures that USFWS and Reclamation can take to minimize or avoid adverse effects of a proposed action on a listed species or designated critical habitat or regarding the development of information. In addition to the terms and conditions of the Incidental Take Statement, NMFS provides the following conservation recommendations that will reduce or avoid adverse impacts on the listed species:

(1) The USFWS should include NMFS in discussions regarding future plans to mark or tag all hatchery stock at 100 percent as recommended in the HRSG Report (2012).

(2) The USFWS should request funding from Reclamation to begin funding the ocean harvest recovery and processing of the CWTs from CNFH, beginning the summer of 2014, consistent with responsibilities for the rearing, release and monitoring of hatchery fish reared for mitigation purposes. The responsibilities for CWT recovery and processing should be shared among the mitigation agencies in proportion to their annual contribution of tag recoveries in the Central Valley.

(3) The USFWS should discuss with Reclamation the need for holding pond improvement, or for construction of an additional holding pond, in order to minimize impacts to wild steelhead that are incidentally collected during late fall-run Chinook salmon and hatchery steelhead propagation periods.

(4) USFWS should continue to work cooperatively with the Greater Battle Creek Watershed Working Group, the CNFH Adaptive Management Plan Technical Advisory Committee, and NMFS's Recovery Plan Coordinator, particularly as natural populations increase and when winter-run Chinook salmon are reintroduced into Battle Creek, to investigate ways to further minimize adverse effects of the Project to listed species within Battle Creek and the Sacramento River Basin;

(5) The USFWS Red Bluff Hatchery Evaluation Program should continue to coordinate with USFWS Battle Creek monitoring program managers to continue to monitor levels of temporal/spatial overlap between hatchery release groups and natural-origin out-migrants;

X. REINITIATION OF CONSULTATION

This concludes formal consultation on the proposed action. Reinitiation of formal consultation is required if: (1) the amount or extent of taking specified in the incidental take statement 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 action, including the avoidance, minimization, and compensation measures listed in section II, is subsequently modified in a manner that causes an effect to the listed species that was not considered in the biological opinion; or (4) a new species is listed or critical habitat is designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, formal consultation shall be reinitiated immediately.

XI. LITERATURE CITED

Adams, P. B., C. B. Grimes, J. E. Hightower, S. T. Lindley, and M. L. Moser. 2002. Status review for North American green sturgeon, *Acipenser medirostris*. National Marine Fisheries Service. 58 pages.

Adams, P.B., C. Grimes, J.E. Hightower, S.T. Lindley, M.L. Moser, and M.J. Parsley. 2007. Population status of North American green sturgeon, Acipenser medirostris. Environmental Biology of Fishes 79:339-356.

Allen, P. J., B. Hodge, I. Werner, and J. J. Cech. 2006. Effects of ontogeny, season, and temperature on the swimming performance of juvenile green sturgeon (*Acipenser medirostris*). Canadian Journal of Fisheries and Aquatic Sciences 63:1360-1369.

Allen, P. J. and J. J. Cech Jr. 2007. Age/size effects on juvenile green sturgeon, *Acipenser medirostris*, oxygen consumption, growth, and osmoregulation in saline environments. Environmental Biology of Fishes 79:211-229.

Allendorf, F.W., D. Bayles, D.L. Bottom, K.P. Currens, C.A. Frissell, D. Hankin, J.A. Lichatowich, W. Nehlsen, P.C. Trotter, and T.H. Williams. 1997. Prioritizing Pacific salmon stocks for conservation. Conservation Biology 11:140–152.

Allendorf, F.W. and N. Ryman. 1987. Genetic management of hatchery stocks, p. 141-159. *In* N. Ryman and F. Utter (eds.), Population Genetics and Fishery Management. University of Washington Press; Seattle, Washington.

Anderson, J.J., M. Deas, P.B. Duffy, D.L. Erickson, R. Reisenbichler, K.A. Rose, and P.E. Smith. 2009. Independent Review of a Draft Version of the 2009 NMFS OCAP Biological Opinion. Science Review Panel report. Prepared for the CALFED Science Program. January 23. 31 pages plus 3 appendices.

Bailey, E.D. 1954. Time pattern of 1953-54 migration of salmon and steelhead into the upper Sacramento River. California Department of Fish and Game unpublished report. 4pp.

Bailey, H.C., C. Alexander, C. Digiorgio, M. Miller, S.I. Doroshov and D.E. Hinton. 1994. The effect of agriculture discharge on striped bass (morone saxatilis) in California's Sacramento-San Joaquin drainage. Ecotoxicology. 3 (123-142).

Bain, M.B., and N.J. Stevenson, editors. 1999. Aquatic habitat assessment: common methods. American Fisheries Society, Bethesda, Maryland.

Bain, D.E., and M.E. Dahlheim. 1994. Effects of masking noise on detection thresholds of killer whales. Pages 243-256 in T.R. Loughlin, editor. Marine mammals and the Exxon Valdez. Academic Press, San Diego, California.

Bain, D.E., J.C. Smith, R. William, and D. Lusseau. 2006. Effects of vessels on behavior of southern resident killer whales (*Orcinus spp*.). NMFS Contract Report No. AB133F03SE0950 and AB133F04CN0040. 61 pp.

Baird, R.W. 2000. The killer whale: foraging specializations and group hunting. Pages 127-153 in J. Mann, R.C. Connor, P.L. Tyack, and H. Whitehead, editors. Cetacean societies: field studies of dolphins and whales. University of Chicago Press, Chicago, Illinois.

Baker, P. F. and J. E. Morhardt. 2001. Survival of Chinook salmon smolts in the Sacramento/San Joaquin Delta and Pacific Ocean. Pages 163 – 182 in R.L. Brown, Editor. Contributions to the Biology of Central Valley Salmonids, Volume 2, Fish Bulletin 179. California Department of Fish and Game, Sacramento, California.

Bakkala, R.G. 1970. Synopsis of biological data on the chum salmon, *Oncorhynchus keta* (Walbaum) 1792. FAO Species Synopsis No. 41. Circular 315. U.S. Department of the Interior. Washington, D.C. 89p.

Barnhart, R.A. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest), steelhead. U.S. Fish and Wildlife USFWS, Biological Report 82 (11.60). 21 pages.

Barre, L. 2008. Stock identity of Chinook salmon taken by Southern Resident killer whales. Memorandum to the file from L. Barre, National Marine Fisheries Service, Seattle, Washington. June 24.

Barrett-Lennard, L.G. 2000. Population structure and mating patterns of killer whales as revealed by DNA analysis. PhD thesis, University of British Columbia, Vancouver BC.

Barrett-Lennard, L. G., and G. M. Ellis. 2001. Population structure and genetic variability in Northeastern Pacific killer whales: Towards an assessment of population viability. Canadian Scientific Advisory Secretariat, Department of Fisheries and Oceans Research Document 2001/065. Available at http://www.dfo-mpo.gc.ca/csas/Csas/publications/ResDocs-DocRech/2001/2001 065 e.htm.

Bash, J., Berman, C. and Bolton, S. 2001. Effects of Turbidity and Suspended Solids on Salmonids. Centre for Streamside Studies, University of Washington.

Battin, J., M. W. Wiley, M. H. Ruckelshaus, R. N. Palmer, E. Korb, K. K. Bartz, and H. Imaki. 2007. Projected impacts of climate change on salmon habitat restoration. Proceedings of the National Academy of Sciences of the United States of America 104: 6720-6725.

Beamesderfer, R., M. Simpson, G. Kopp, J. Inman, A. Fuller, and D. Demko. 2004. Historical and current information on green sturgeon occurrence in the Sacramento and San Joaquin rivers and tributaries. Prepared for State Water Contractors by S.P. Cramer and Associates, Inc., Gresham, Oregon. 46 pages.

Beamesderfer, R.C.P., M.L. Simpson, and G.J. Kopp. 2007. Use of life history information in a population model for Sacramento green sturgeon. Environmental Biology of Fishes. 79 (3-4): 315-337.

Behnke, R.J. 1992. Native trout of western North America. Am. Fish. Soc. Monog. 6, 275 p. American Fisheries Society, Bethesda, Maryland.

Behrenfeld, M. J., R. T. O'Malley, D. A. Siegel, C. R. McClain, J. L. Sarmiento, G. C. Feldman, A. J. Milligan, P. G. Falkowski, R. M. Letelier, and E. S. Boss. 2006. Climate-driven trends in contemporary ocean productivity. Nature 444: 752–755.

Bejder, L., A. Samuels, H. Whitehead, N. Cales, J. Mann, R. Connor, M. Heithaus, J. Watson-Capps, C. Flaherty, and M. Krutzen. 2006. Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. Conservation Biology.

Bell, M. C. 1991. Fisheries handbook of engineering requirements and biological criteria. Third edition. U.S. Army Corps of Engineers, Office of the Chief of Engineers, Fish Passage Development and Evaluation Program, North Pacific Division, Portland, Oregon.

Benson, R. L., S. Turo, and B. W. McCovey Jr. 2007. Migration and movement patterns of green sturgeon (*Acipenser medirostris*) in the Klamath and Trinity rivers, California, USA. Environmental Biology of Fishes 79:269-279.

Berejikian, B.A. 1995. The effects of hatchery and wild ancestry on the behavioral development of steelhead trout fry (Oncorhynchus mykiss). Ph. D. Dissertation, Univ. Washington, Seattle, Washington.

Bergman, P.S., J. Merz, and B. Rook. 2011. Green Sturgeon Observations at Daguerre Point Dam, Yuba River, CA. Memorandum to Elizabeth Campbell, AFRP, USFWS. Cramer Fish Sciences, June 7, 2011.

Berry, Mike. 2013. CDFW. Personal communication between NMFS and CDFW, regarding completion of a Fisheries Management Plan.

Bigg, M. 1982. An assessment of killer whale (*Orcinus orca*) stocks off Vancouver Island, British Columbia. Report of the International Whaling Commission 32:655-666.

Bigg, M.A., P.F. Olesiuk, G.M. Ellis, J.K.B. Ford, and K.C. Balcomb III. 1990. Social organization and genealogy of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Report of the International Whaling Commission, Special Issue 12:383-405.

Bigler, B.S., D.W. Wilch, and J.H. Helle. 1996. A review of size trends among North Pacific salmon (*Oncorhynchus spp.*). Canadian Journal of Fisheries and Aquatic Sciences. 53:455-465.

Bilby, R.E. 1984. Removal of woody debris may affect stream channel stability. Journal of Forestry 82:609-613.

Bilby, R.E., B.R. Fransen, P.A. Bission, and J.K. Walter. 1998. Response of juvenile coho salmon (Oncorhynchus kisutch) and steelhead (Oncorhynchus mykiss) to the addition of salmon carcasses to two streams in southwestern Washington, U.S.A. Can. J. Fish. Aquat. Sci. 55:1909-1918.

Black, N., R. Ternullo, A. Schulman-Janiger, A.M. Hammers, and P. Stap. 2001. Occurrence, behavior, and photo-identification of killer whales in Monterey Bay, California. In 14th Biennial Conference on the Biology of Marine Mammals, Vancouver, British Columbia. Society for Marine Mammalogy, San Francisco, California.

Blouin, M. 2004. Relative reproductive success of hatchery and wild steelhead in the Hood River. Final report on work conducted under BPA contract 9245, Project #1988-053-12 and ODFW interagency agreement No. 001-2007s. Corvallis, Oregon.

Botsford, L.W. and J.G. Brittnacher. 1998. Viability of Sacramento River Winter-Run Chinook salmon. Conservation Biology 12: 65-79.

Bottom, D.L., C.A. Simenstad, J. Burke, A.M. Baptista, D.A. Jay, K.K. Jones, E. Casillas, and M.H. Schiewe. 2005. Salmon at river's end: the role of the estuary in the decline and recovery of Columbia River salmon. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-NWFSC-68, 246 pages.

Boydstun, L.B. 2000. Ocean Salmon Fishery Management. *In*: R.L. Brown, editor. Contributions to the biology of Central Valley salmonids. Volume 2. California Department of Fish and Game Fish Bulletin 179: 183-196

Bradford, M.J. 1995. Comparative review of Pacific salmon survival rates. Canadian Journal of Fisheries and Aquatic Sciences. 52: 1327-1338.

Bradford, M. J. and J. R. Irvine. 2000. Land use, fishing, climate change, and the decline of Thompson River, British Columbia, Coho salmon. Can. J. Fish. Aquat. Sci. 57:13-16.

Brandes, P. L. and J. S. McLain. 2001. Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. *In*: R.L. Brown, editor. Contributions to the biology of Central Valley salmonids. Volume 2. California Department of Fish and Game Fish Bulletin 179:39-136.

Brett, J.R. 1995. Energetics. In: Groot C, Margolis L, Clarke WC (eds). Physiological ecology of Pacific Salmon. UBC Press, Vancouver, pp 3–68

Brown, Matt. 2012. USFWS. Personal Communication between USFWS and NMFS regarding potential effects of hatchery fish on naturally produced listed species.

Buckley, R.M. 1999. Incidence of cannibalism and intra-generic predation by Chinook salmon (*Oncorhynchus tshawytscha*) in Puget Sound, Washington. Technical Report # RAD 99-04. Fish Program, Resource Assessment Division. Washington Department of Fish and Wildlife, Olympia, Washington.

Bugert, R., K. Petersen, G. Mendel, L. Ross, D. Milks, J. Dedloff, and M. Alexandersdottir. 1992. Lower snake River compensation plan, Tucannon River spring chinook salmon hatchery evaluation plan, U.S. Fish and Wildlife Service, Boise, Idaho.

Busack, C.A. and K.P.Currens. 1995. Genetic Risks and Hazards in Hatchery Operations: Fundamental Concepts and Issues. American Fisheries Society Symposium 15: 71-80.

Busby, P. J., T. C. Wainwright, G. J. Bryant., L. Lierheimer, R. S. Waples, F. W. Waknitz, and I. V. Lagomarsino. 1996. Status review of west coast steelhead from Washington, Idaho, Oregon and California. U.S. Department of Commerce, National Oceanic and Atmospheric Administration Technical Memo NMFS-NWFSC-27. 261 pages.

California Commercial, Industrial and Residential Real Estate Services Directory. Available: http://www.ured.com/citysubweb.html. April 2002.

California Department of Fish and Game (CDFG). 1961. King Salmon Spawning Stocks of the California Central Valley, 1940-1959. *California Fish and Game Quarterly* 47(1):55-71.

California Department of Fish and Game. 1966. Pacific Gas and Electric Company's Battle Creek System Power Project, Minor Part License Number 1121.

California Department of Fish and Game (CDFG). 1992. Sturgeon in relation to water development in the Sacramento-San Joaquin Estuary. Entered by California Department of Fish and Game for the State Water Resources Control Board 1992 Water Rights Phase of the BayDelta Estuary Proceedings.

California Department of Fish and Game. 1993. Memorandum from Frank Fisher, CDFG Red Bluff to Deborah McKee, CDFG Inland Fisheries Division. February 3, 1993. 2 pp. + appendices.

California Department of Fish and Game California Steelhead Fishing Report-Restoration Card: A Report to the Legislature. July 2007.

California Department of Fish and Game. 1998. A status review of the spring-run run Chinook salmon in the Sacramento River drainage. Report to the Fish and Game Commission. Candidate species status report 98-1. June 1998. Sacramento, California. 394 pages.

California Department of Fish and Game. 2002. California Department of Fish and Game comments to NMFS regarding green sturgeon listing. 79 pages plus appendices.

California Department of Fish and Game. 2002a. Comments to NMFS regarding green sturgeon listing. 129 pages.

California Department of Fish and Game. 2003. Letter from Dean Marston, CDFG, to Madelyn Martinez, National Marine Fisheries Service, January 9.

California Department of Fish and Game. Unpublished data. 2013. Aerial salmon redd survey excel tables.

California Department of Fish and Game (CDFG). 2013. GrandTab spring-run and winter-run Chinook salmon population estimates.

California Department of Fish and Wildlife (CDFW). 2014. Personal communication between CDFW biologists and NMFS regarding abundance estimates on adult returns in Mill, Deer, and Butte creeks.

California Department of Fish and Game and National Marine Fisheries Service. 2001. Final Report on Anadromous Salmonid Fish Hatcheries in California. Joint Hatchery Review Committee. December 3. CDFG and NMFS Southwest Region. 36 pages plus 2 appendices.

California Department of Fish and Wildlife and California Department of Water Resources. 2012. Draft Hatchery and Genetic Management Plan for Feather River Fish Hatchery Spring-run Chinook Salmon. Email with attached draft sent from CDWR to NMFS on November 5, 2013.

California Department of Water Resources. 2002. Suisun Marsh Salinity Control Gates salmon passage evaluation report. Environmental USFWSs Office, Sacramento, California. 19 pages.

California Department of Water Resources. 2008. Quantification of pre-screen loss of juvenile steelhead within Clifton Court Forebay. Draft September 2008. xvii + 119 pages.

California Hatchery Scientific Review Group (California HSRG). 2012. California Hatchery Review Report. Prepared for the US Fish and Wildlife Service and Pacific States Marine Fisheries Commission. June 2012. 100 pgs.

California Regional Water Quality Control Board. 1998. Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins, fourth edition. Available: http://www.swrcb.ca.gov/~CRWQCB5/home.html

California Resources Agency. 1989. Upper Sacramento River fisheries and riparian management plan. Prepared by an Advisory Council established by SB1086, authored by State Senator Jim Nielson. 157 pages.

Calkins, R.D., W.F. Durand, and W.H. Rich. 1940. Report of the Board of Consultants on the fish problem of the upper Sacramento River. Stanford University, Stanford, CA, 34 pages.

Campton, D.E. 1995. Genetic effects of hatchery fish on wild populations of Pacific salmon and steelhead: What do we really know? Am. Fish. Soc. Symp. 15:337-353.

Cardwell, R.D. and K.L. Fresh. 1979. Predation upon juvenile salmon. Draft technical paper, September 13, 1979. Washington Department of Fish and Wildlife. Olympia, Washington. 19p.

Cederholm, C.J., M.D. Kunze, T. Murota, and A. Sibatani. 1999. Pacific salmon carcasses: essential contributions of nutrients and energy for aquatic and terrestrial ecosystems. Fisheries 24(10): 6-15.

Chilcote, M.W. 1998. Conservation status of steelhead in Oregon. Informational Report 98-3. Oregon Department of Fish and Wildlife, Portland, Oregon. 108p.

Chilcote, M.W., S.A. Leider, and J.J. Loch. 1986. Differential reproductive success of hatchery and wild summer-run steelhead under natural conditions. Transactions of the American Fisheries Society 115: 726-735.

City of Lathrop. 2007. City demographics accessed via the internet. Available online at: www.ci.lathrop.ca.us/cdd/demographics Clark, G. H. 1929. Sacramento-San Joaquin salmon (*Oncorhynchus tshawytscha*) fishery of California. California Fish and Game Bulletin 17:1-73.

City of Manteca. 2007. City demographics accessed via the internet. Available online at: www.ci.manteca.ca.us/cdd/demographics.

Clark GH. 1929. Sacramento-San Joaquin salmon (*Oncorhynchus tshawytscha*) fishery of California Division of Fish and Game. Fish Bulletin 17. p 1–73.

Cohen, A.N., and P.B. Moyle. 2004. Summary of data and analyses indicating that exotic species have impaired the beneficial uses of certain California waters: a report submitted to the State Water Resources Control Board on June 14, 2004. 25 pages.

Congleton, J.L. and 10 coauthors. 1995. Evaluation procedures for collection, bypass, and downstream passage of outmigrating salmonids. Draft annual report for 1995, MPE-96-10.

Conomos, T.J., R.E. Smith, and J.W. Gartner. 1985. Environmental settings of San Francisco Bay. Hydrobiologia 129: 1-12.

Cordone, A.J., and D.W. Kelley. 1961. The influences of inorganic sediment on the aquatic life of streams. California Fish and Game 47:89-228.

Cramer, S. P. and D. B. Demko. 1997. The Status of Late-Fall and Spring-run Chinook salmon in the Sacramento River Basin Regarding the Endangered Species Act. Special Report submitted to National Marine Fisheries Service on behalf of Association of California Water Agencies and California Urban Water Agencies. Sacramento CA.

Cuenco, M. L., T. W. H. Barkman, and P. R. Mundy. 1993. The use of supplementation to aid in natural stock restoration. In J. G. Cloud, and G. H. Thorgaard, eds. Genetic Conservation of Salmonid Fishes, pp. 269–294. Plenum Press, New York.

Daughton, C.G. 2003. Cradle-to-cradle stewardship of drugs for minimizing their environmental disposition while promoting human health. I. Rationale for and avenue toward a green pharmacy. Environmental Health Perspectives 111:757-774.

Decato, R.J. 1978. Evaluation of the Glenn-Colusa Irrigation District fish screen. California Department of Fish and Game, Anadromous Fisheries Branch Administrative Report No. 78-20.

Deng, X. 2000. Artificial reproduction and early life stages of the green sturgeon (*Acipenser medirostris*). Master's Thesis. University of California, Davis, California. 62 pp.

Deng, X., J. P. Van Eenennaam, and S. I. Doroshov. 2002. Comparison of early life stages and growth of green and white sturgeon. *In:* W. Van Winkle, P.J. Anders, D.H. Secor, and D.A. Dixon, editors, Biology, management, and protection of North American sturgeon, pages 237-248. American Fisheries Society, Symposium 28, Bethesda, Maryland.

Dettinger, M.D., D.R. Cayan, M.K. Meyer, and A.E. Jeton. 2004. Simulated hydrological responses to climate variations and changes in the Merced, Carson, and American River basins, Sierra Nevada, California, 1900-2099. Climatic Change 62:283-317.

Dettman, D.H., D.W. Kelley, and W.T. Mitchell. 1987. The influence of flow on Central Valley salmon. Prepared for the California Department of Water Resources. Revised July 1987. (Available from D.W. Kelley and Associates, 8955 Langs Hill Rd., P.O. Box 634, Newcastle, CA 95658).

Dolloff, C.A. 1993. Predation by river otters (*Lutra Canadensis*) on juvenile coho salmon (*Oncorhynchus kisutch*) and Dolly Varden (*Salvelinus malma*) in southeast Alaska. Canadian Journal of Fisheries and Aquatic Sciences 50: 312-315.

Dubrovsky, N.M., C.R. Kratzer, L.R. Brown, J.M. Gronberg, and K.R. Burow. 2000. Water quality in the San Joaquin-Tulare basins, California, 1992-95. U.S. Geological Survey Circular 1159.

Dubrovsky, N.M., D.L. Knifong, P.D. Dileanis, L.R. Brown, J.T. May, V. Connor, and C.N. Alpers. 1998. Water quality in the Sacramento River basin. U.S. Geological Survey Circular 1215.

Edwards, G.W., K.A.F. Urquhart, and T.L. Tillman. 1996. Adult salmon migration monitoring, Suisun Marsh Salinity Control Gates, September-November 1994. Technical Report 50. Interagency Ecological Program for the San Francisco Bay/Delta Estuary, 27 pages.

Elliott, D.G. and R. Pascho. 1994. Juvenile fish transportation: impact of bacterial kidney disease on survival of spring/summer Chinook salmon stocks. 1992. Annual report of the National Biological Survey to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Elliott D.G., R.J. Pascho, L.M. Jackson, G.M. Mathews, and J.R. Harmon. 1997. *Renibacterium salmoninarum* in spring-summer Chinook salmon smolts at dams on the Columbia and Snake River. Aquat. Animal Health 9: 114-126.

Emmett, R. L., S. A. Hinton, S. L. Stone, and M. E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in West Coast estuaries, Volume II: Species life history summaries. ELMR Report No. 8. NOAA/NOS Strategic Environmental Assessments Division, Rockville, Maryland. 329 pages.

Enhancement Planning Team. 1986. Salmon and steelhead enhancement plan for the Washington and Columbia River conservation area. Vol. 1. Preliminary review draft.

Environmental Protection Agency. 1994. Methods for Measuring the Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates. U.S. Environmental Protection Agency. EPA/600/R-94/024.

EPA (Environmental Protection Agency). 1999. National Pollutant Discharge Elimination System (NPDES) Permit Program. Available from *www.epa.gov/owm/gen2.htm*

Erbe, C. 2002. Underwater noise of whale-watching boats and potential effects on killer whales (*Orcinus orca*), based on an acoustic impact model. Marine Mammal Science 18: 394-418.

Erickson, D.L. and J.E. Hightower. 2007. Oceanic distribution and behavior of green sturgeon. American Fisheries Society Symposium 56:197-211.

Erickson, D. L., J. A. North, J. E. Hightower, J. Weber, L. Lauck. 2002. Movement and habitat use of green sturgeon *Acipenser medirostris* in the Rogue River, Oregon, USA. Journal of Applied Ichthyology 18:565-569.

Fairey, R., K. Taberski, S. Lamerdin, E. Johnson, R. P. Clark, J. W. Downing, J. Newman, and M. Petreas. 1997. Organochlorines and other environmental contaminants in muscle tissues of sportfish collected from San Francisco Bay. Marine Pollution Bulletin 34:1058-1071.

Feist, G. W., M. A. H. Webb, D. T. Gundersen, E. P. Foster, C. B. Schreck, A. G. Maule, and M. S. Fitzpatrick. 2005. Evidence of detrimental effects of environmental contaminants on growth and reproductive physiology of white sturgeon in impounded areas of the Columbia River. Environmental Health Perspectives 113:1675-1682.

Felleman, F.L., J.R. Heimlich-Boran, and R.W. Osborne. 1991. The feeding ecology of killer whales (*Orcinus orca*) in the Pacific Northwest. In K. Pryor and K.S. Norris (eds.) *Dolphin societies-discoveries and puzzles*. University of California Press, Berkeley. 113-147.

Fisher, F. W. 1994. Past and present status of Central Valley Chinook salmon. Conservation Biology 8(3): 870-873.

Flagg, T.A. and C.E. Nash (editors). 1999. A Conceptual Framework for Conservation Hatchery Strategies for Pacific Salmonids. U.S. Dept. of Commerce. NOAA Tech. Memo. NMFS-NWFSC-38, 54p. Section 7 Biological Opinion USFWS MCR-LCR Art. Prop. 230.

Flagg, T.A., F.W. Waknitz, D.J. Maynard, G.B. Milner, and C.V. Mahnken. 1995. The effect of hatcheries on native coho salmon populations in the lower Columbia River. *In*: Schramm, H.I. and Piper, R.G., eds. Uses and effects of cultured fishes in aquatic ecosystems. American Fisheries Society Symposium 15. Bethesda, Maryland.

Ford, J.K.B. 1989. Acoustic behaviour of resident killer whales (*Orcinus orca*) off Vancouver Island, British Columbia. Canadian Journal of Zoology. 67: 727-745.

Ford, J.K.B., and G.M. Ellis. 2005. Prey selection and food sharing by fish-eating 'resident' killer whales (*Orcinus orca*) in British Columbia. Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, 2005/041.

Ford, J. K. B. and G. M. Ellis. 2006. Selective foraging by fish-eating killer whales *Orcinus orca* in British Columbia. Marine Ecology Progress Series 316:185-199.

Ford, J. K. B., Ellis, G. M., and Olesiuk, P. F. 2005. Linking prey and population dynamics: did food limitation cause recent declines of "resident" killer whales (*Orcinus orca*) in British Columbia? Canadian Science Advisory Secretariat Research Document 2005/042.

Ford, J.K.B., G.M. Ellis and K.C. Balcomb. 2000. Killer whales: the natural history and genealogy of *Orcinus orca* in British Columbia and Washington State. 2nd ed. UBC Press, Vancouver, British Columbia.

Ford, J.K.B., G.M. Ellis, L.G. Barrett-Lennard, A.B. Morton, R.S. Palm, and K.C. Balcomb III. 1998. Dietary specialization in two sympatric populations of killer whales (*Orcinus orca*) in coastal British Columbia and adjacent waters. Canadian Journal of Zoology 76: 1456-1471.

Foster, E. P., M. S. Fitzpatrick, G. W. Feist, C. B. Schreck, and J. Yates. 2001a. Gonad organochlorine concentrations and plasma steroid levels in white sturgeon (*Acipenser transmontanus*) from the Columbia River, USA. Bulletin of Environmental Contamination and Toxicology 67:239-245.

Foster, E. P., M. S. Fitzpatrick, G. W. Feist, C. B. Schreck, J. Yates, J. M. Spitsbergen, and J. R. Heidel. 2001b. Plasma androgen correlation, EROD induction, reduced condition factor, and the occurrence of organochlorine pollutants in reproductively immature white sturgeon (*Acipenser transmontanus*) from the Columbia River, USA. Archives of Environmental Contamination and Toxicology 41:182-191.

Francis, R.C. and N.J. Mantua. 2003. Climatic influences on salmon populations in the Northeast Pacific. In *Assessing Extinction Risk for West Coast Salmon*, A.D. Mac Call and T.C. Wainwright (eds), NOAA Technical Memorandum NMFS-NWFSC-56. Northwest Fisheries Science Center: Seattle, WA.

Fry, D.H. 1961. King salmon spawning stocks of the California Central Valley, 1940-1959. California Fish and Game 47:55-71.

Gaines, P.D. and C.D. Martin. 2001. Abundance and seasonal, spatial and diel distribution patterns of juvenile salmonids passing the Red Bluff Diversion Dam, Sacramento River. Red Bluff Research Pumping Plant Report Series, Volume 14. U.S. Fish and Wildlife Service, Red Bluff, CA.

Gaines, P. D. and W. R. Poytress. 2004. Brood-year 2003 winter-run Chinook salmon juvenile production indices with comparisons to adult escapement. U.S. Fish and Wildlife USFWS report to California Bay-Delta Authority. San Francisco, California.

Gall, G.A.E. 1993. Genetic change in hatchery populations, p 81-92. *In*, J.G. Cloud and G.H. Thorogaard (eds.), Genetic Conservation of Salmonid Fishes. Plenum Press, New York.

Garcia, A. 1989. The impacts of squawfish predation on juvenile Chinook salmon at Red Bluff Diversion Dam and other locations in the Sacramento River. U.S. Fish and Wildlife USFWS Report No. AFF/FAO-89-05.

Garland, R. D., K. F. Tiffan, D. W. Rondorf, and L. O. Clark. 2002. Comparison of subyearling fall-run Chinook salmon's use of riprap revetments and unaltered habitats in Lake Wallula of the Columbia River. North American Journal of Fisheries Management 22:1283-1289.

Gaydos, J.K., and S. Raverty. 2007. Killer Whale Stranding Response, August 2007 Final Report. Report under UC Davis Agreement No. C 05-00581 V, August 2007.

Geraci, J.R. and D.J. St. Aubin, editors. 1990. Sea mammals and oil: confronting the risks. Academic Press, New York, New York.

Gharrett, A.J., Shirley, S.M., 1985. A genetic examination of spawning methodology in a salmon hatchery. Aquaculture 47, 245–256.

Gingras, M. 1997. Mark/recapture experiments at Clifton Court Forebay to estimate pre-screen loss of juvenile fishes: 1976-1993. Interagency Ecological Program Technical Report No. 55.

Giovannetti, Sarah. 2012. USFWS. Personal communication between NMFS and USFWS regarding fall-run and spring-run Chinook salmon hybridization/redd superimposition occurrence on Clear Creek.

Giovannetti, S. L., and M. R. Brown. 2009. Adult steelhead and late-fall Chinook salmon monitoring on Clear Creek, California. 2008 Annual report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Gleick, P. H. and E. L. Chalecki. 1999. The impacts of climatic changes for water resources of the Colorado and Sacramento-San Joaquin river basins. Journal of the American Water Resources Association 35: 1429-1441.

Goals Project. 1999. Baylands ecosystem habitat goals: A report of habitat recommendations prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. U.S. Environmental Protection Agency, San Francisco. San Francisco Bay Regional Water Quality Control Board, Oakland, California.

Godfrey, H. 1959*a*. Variations in annual average weights of British Columbia pink salmon 1944–1958. J. Fish. Res. Board Can. 16: 329–337.

Godfrey, H. 1959*b*. Variation in the annual average weight of chum salmon caught in British Columbia waters, 1946–1958. J. Fish. Res. Board Can. 16: 553–554.

Good, T.P., R.S. Waples, and P. Adams (editors). 2005. Updated status of federally listed ESU of West Coast salmon and steelhead. U.S. Department of Commerce, NOAA Technical Memo. NMFS-NWFSC-66, 598 pages.

Goodman, M.L. 1990. Preserving the genetic diversity of salmonid stocks: a call for federal regulation of hatchery programs. Environmental Law 20: 111-166. Section 7 Biological Opinion USFWS MCR-LCR Art. Prop. 231.

Gordon, J., and A. Moscrop. 1996. Underwater noise pollution and its significance for whales and dolphins. Pages 281-319 in M.P. Simmonds and J.D. Hutchinson, editors. The conservation of whales and dolphins: science and practice. John Wiley and Sons, Chichester, United Kingdom.

Goyer, R.A. 1996. Toxic effects of metals. *In* C.D. Klassen (editor), Casarett & Doull's toxicology: the basic science of poisons, fifth edition, pages 691-736. McGraw Hill. New York, New York.

Grant, S.W. (editor). 1997. Genetic effects of straying of non-native hatchery fish into natural populations: Proceedings of the workshop. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-30, 130p.

Grant, S.C.H. and P.S. Ross. 2002. Southern resident killer whales at risk: toxic chemicals in the British Columbia and Washington environment. Canadian Technical Report of Fisheries and Aquatic Sciences 2412: 1-111.

Greenfield, B., E. Wittner, N. David, S.B. Shonkoff, J. Davis. 2004. Monitoring Trace Organic Contamination in Central Valley Fish: Current Data and Future Steps. A Report Prepared For the Central Valley Regional Water Quality Control Board. Oakland, CA, San Francisco Estuary Institute.

Greenfield, B. K., J. A. Davis, R. Fairey, C. Roberts, D. Crane, and G. Ichikawa. 2005. Seasonal, interannual, and long-term variation in sport fish contamination, San Francisco Bay. Science of the Total Environment 336:25-43.

Hallock, R.J. 1989. Upper Sacramento River Steelhead, *Oncorhynchus mykiss*, 1952-1988. A report to the U.S. Fish and Wildlife USFWS.

Hallock, R.J. D.H. Fry, and D.A. LaFaunce. 1957. The use of wire fyke traps to estimate the runs of adult salmon and steelhead in the Sacramento River. California Fish and Game 43(4): 271-298.

Hallock, R.J., and F.W. Fisher. 1985. Status of winter-run Chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento River. Report to the California Department of Fish and Game, Anadromous Fisheries Branch, Sacramento, California.

Hallock, R. J., W. F. Van Woert, and L. Shapovalov. 1961. An evaluation of stocking hatchery-reared steelhead rainbow trout (*Salmo gairdnerii gairdnerii*) in the Sacramento River system. California Department of Fish and Game. Fish Bulletin No. 114. 74 pages.

Hamelberg, Scott. 2012. USFWS. Personal communication between USFWS J.S. Foott, PhD, California-Nevada Fish Health Center, Scott Hamelberg and NMFS, regarding pathogens from hatchery-origin salmonids.

Hamelberg, Scott. 2013. USFWS. Personal communication between NMFS and USFWS, regarding catastrophic loss of hatchery fish at Coleman National Fish Hatchery.

Hamlet, A. F. and D. P. Lettenmaier. 1999. Columbia River Streamflow Forecasting Based on ENSO and PDO Climate Signals. Journal of Water Resources Planning and Management 125(6): 333-341.

Hamlet, A. F., P. W. Mote, M. P. Clark, and D. P. Lettenmaier. 2005. Effects of temperature and precipitation variability on snowpack trends in the western United States. Journal of Climate 18: 4545-4561.

Hanson, M.B., R.W. Baird, C. Emmons, J. Hempelmann, G.S. Schorr, J. Sneva, and D.Van Doornik. 2007. Summer diet and prey stock identification of the fish-eating "southern resident" killer whales: Addressing a key recovery need using fish scales, fecal samples, and genetic techniques. Abstract from the 17th Biennial Conference on the Biology of Marine Mammals, Capetown, South Africa.

Hard, J. J., R. P. Jones Jr., R. S. Waples. 1992. Pacific Salmon and Artificial Propagation Under the Endangered Species Act. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-2.

Hard, J. J., W. K. Hershberger. 1995. Quantitative genetic consequences of captive broodstock programs for anadromous Pacific salmon (*Oncorhynchus* spp.). Pages 2-1 to 2-75 *in* An assessment of the status of captive broodstock technology for Pacific salmon. Final Report to Bonneville Power Admin., Proj. No. 93-56, Contract No. DE-AI79-93BP55064, June 1995.

Hartl, D.L. and A.G. Clark. 1989. Principles of Population Genetics, Second Edition. Sinauer Associates, Sutherland, Massachusetts.

Harvey, C. 1995. Adult steelhead counts in Mill and Deer Creeks, Tehama County, October 1993-June 1994. Inland Fisheries Administrative Report 95-3. Sacramento: California Department of Fish and Game.

Hastein, T. and T. Lindstad. 1991. Diseases in wild and cultured salmon: possible interaction. Aquaculture 98:277-288.

Hatchery Scientific Review Group (HSRG)-Lars Mobrand (chair), John Barr, Lee Blankenship, Don Campton, Trevor Evelyn, Tom Flagg, Conrad Mahnken, Robert Piper, Paul Seidel, Lisa Seeb and Bill Smoker. April 2004. *Hatchery Reform: Principles and Recommendations of the HSRG*. Long Live the Kings, 1305 Fourth Avenue, Suite 810, Seattle, WA 98101. (available from www.hatcheryreform.org).

HSRG (Hatchery Scientific Review Group). 2005. Hatchery reform in Washington State: principles and emerging issues. *Fisheries*, 30(6): 11–23.

HSRG (Hatchery Scientific Review Group). 2009. Columbia River hatchery reform system-wide report. http://hatcheryreform.us/hrp/uploads/C1EKAOMVHURK/01_HSRG%20Final%20Systemwide%20Report.pdf

HSRG. 2009a. Predicted Fitness Effects of Interbreeding between Hatchery and Natural Populations of Pacific Salmon and Steelhead. Columbia River hatchery reform system-wide report - Appendix A, White Paper Number 1.

HSRG (Hatchery Scientific Review Group). 2012. California Hatchery Review Report. Prepared for the US Fish and Wildlife Service and Pacific States Marine Fisheries Commission. June 2012. 100 pgs.

Hayhoe, K.D. Cayan, C.B. Field, P.C. Frumhoff, E.P. Maurer, N.L. Miller, S.C. Moser, S.H. Schneider, K.N. Cahill, E.E. Cleland, L. Dale, R. Drapek, R.M. Hanemann, L.S. Kalkstein, J. Lenihan, C.K. Lunch, R.P. Neilson, S.C. Sheridan, and J.H. Verville. 2004. Emissions pathways, climate change, and impacts on California. Proceedings of the National Academy of Sciences of the United States of America. 101(34)12422-12427.

Healey, M. C. 1991. Life history of Chinook salmon (*Oncorhynchus tshawytscha*). *In* C. Groot and L. Margolis, editors, Pacific Salmon Life Histories, pages 396-445 [check. Another reference said Pages 313-393]. University of British Columbia Press, Vancouver, British Columbia. 564 pages.

Heimlich-Boran, J.R. 1988. Behavioral ecology of killer whales (*Orcinus orca*) in the Pacific Northwest. Canadian Journal of Zoology 66: 565-578.

Hevlin, W. and S. Rainey. 1993. Considerations in the Use of Adult Fish Barriers and Traps in Tributaries to Achieve Management Objectives. In Fish Passage Policy and Technology, Symposium Proceedings, AFS Bioengineering Section. September, 1993. Portland, Oregon. pp 33-40.

Herren, J.R. and S.S. Kawasaki. 2001. Inventory of water diversions in four geographic areas in California's Central Valley. Pages 343-355. *In:* Contributions to the Biology of Central Valley Salmonids. R.L. Brown, editor. Volume. 2. California Fish and Game. Fish Bulletin 179.

Heublein, J.C. 2006. Migration of green sturgeon *Acipenser medirostris* in the Sacramento River. Master of Science Thesis. California State University, San Francisco. October 2006. 63 pages.

Heublein, J.C., J.T. Kelly, C.E. Crocker, A.P. Klimley, and S.T. Lindley. 2009. Migration of green sturgeon, *Acipenser medirostris*, in the Sacramento River. Environmental Biology of Fish 84: 245-258.

Hickie, B.E., P. S. Ross, R. W. Macdonald, and J.K.B. Ford. 2007. Killer whales (*Orcinus orca*) face protracted health risks associated with lifetime exposures to PCBs. Environmental Science and Technology 41: 6613-6619.

Hilborn R, T.P. Quinn, D.E. Schindler, and D.E. Rogers. 2003. Biocomplexity and fisheries sustainability. Proceedings of the National Academy of Sciences, USA 100: 6564–6568.

Hillman, T.W. and J.W. Mullan. 1989. Effect of hatchery releases on the abundance of wild juvenile salmonids. *In*, Summer and Winter Ecology of Juvenile Chinook Salmon and Steelhead Trout in the Wenatchee River, Washington. Report to Chelan County PUD by D.W. Chapman Consultants, Inc. Boise, Idaho.

Hindar, K., N. Ryman, and F. Utter. 1991. Genetic effects of cultured fish on natural fish populations. Canadian Journal of Fisheries and Aquatic Sciences 48:945-957.

Hoblitt, R.P, C.D. Miller, and W.E. Scott. 1987. Volcanic hazards with regard to siting nuclear-power plants in the Pacific Northwest. USGS Open-File Report 87-297. Vancouver, Washington. Available at: http://vulcan.wr.usgs.gov/Hazards/NRC_Report/framework.html.

Hoelzel, A.R., Dahlheim, M. and Stern, S.J. 1998. Low genetic variation among killer whales (*Orcinus orca*) in the eastern North Pacific and genetic differentiation between foraging specialists. Journal of Heredity 89, 121-128.

Holt, M.M. 2008. Sound exposure and Southern Resident killer whales (*Orcinus orca*): A review of current knowledge and data gaps. NOAA Technical Memorandum NMFS-NWFSC-89, U.S. Department of Commerce, Seattle, Washington.

Hooton, R. S. 1987. Catch and release as a management strategy for Steelhead in British Columbia. In R. Barnhart and T. Roelofs, editors, proceedings of: Catch and Release Fishing-A Decade of Experience. Humboldt State University, Arcata, California.

Hooton, R.S. 2001. Facts and issues associated with restricting terminal gear types in the management of sustainable steelhead sport fisheries in British Columbia. British Columbia. Ministry of Environment, Lands and Parks. Vancouver Island Region, Nanaimo, B.C.

Huang, B. and Z. Liu. 2000. Temperature Trend of the Last 40 Years in the Upper Pacific Ocean. Journal of Climate 4:3738–3750.Hulett, P.L., C.W. Wagemann, and S.A. Leider. 1996. Studies of hatchery and wild steelhead in the lower Columbia region. Progress report for fiscal year 1995. Fish Management Program Report RAD 96-01, Washington Department of Fish and Wildlife, Olympia. 22 pp.

Hutson, S. S., N. L. Barber, J. F. Kenny, K. S. Linsey, D. S. Kumia, and M. A. Maupin. 2004. Estimated Use of Water in the United States in 2000. U.S. Geological Survey Circular 1268. Available at: http://pubs.usgs.gov/circ/2004/circ1268.

Independent Scientific Advisory Board. 2007. Climate change impacts on Columbia River basin fish and wildlife. ISAB, Report 2007-2, Portland, Oregon.

Ingersoll, C.G. 1995. Sediment tests. *In* G.M. Rand (editor), Fundamentals of aquatic toxicology: effects, environmental fate, and risk assessment, second edition, pages 231-255. Taylor and Francis, Bristol, Pennsylvania.

IHOT (Integrated Hatchery Operations Team). 1995. Policy and procedures for Columbia Basin anadromous salmonid hatcheries. Annual report 1994 to the Bonneville Power Administration, Portland, Oregon. Project # 93-043.

Interagency Ecological Program Steelhead Project Work Team. 1999. Monitoring, assessment, and research on California Central Valley steelhead: status of knowledge, review existing programs, and assessment needs. In Comprehensive Monitoring, Assessment, and Research Program Plan, Tech. App. VII-11.

Intergovernmental Panel on Climate Change. 2001. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T.,Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, New York, USA. 881 pages.

Intergovernmental Panel on Climate Change (IPCC) (2002), Proceedings of the Workshop on Carbon Dioxide Capture and Storage, Regina, Canada, 18 – 21 November 2002, 178 pp., Energy Res. Cent. for the Netherlands, Amsterdam.

ICTRT. 2005. Interior Columbia Basin TRT: Viability Criteria for Application to Interior Columbia Basin ESUs. July 2005. Interior Columbia Technical Recovery Team. Northwest Fisheries Science Center. Seattle, Washington.

Israel, J. 2006. Determining spawning population estimates for green sturgeon with microsatellite DNA. Presentation at the 2006 CALFED Science Conference. Sacramento, California. October 23, 2006.

Jones & Stokes Associates, Inc. 2002. Foundation runs report for restoration action gaming trials. Prepared for Friant Water Users Authority and Natural Resource Defense Council.

Joyce, J., A.C. Wertheimer, and J.F. Thedinga. 1998. Effects of four generations of domestication on predator avoidance, growth in captivity and predation success in a stock of SE Alaska salmon. Page 112 *In,* Ecosystem considerations in fisheries management. American Fisheries Society symposium. Anchorage, Alaska.

Kapuscinski, A.R., and L.M. Miller. 1993. Genetic hatchery guidelines for the Yakima/Klickitat Fisheries Project. Co-Aqua, 2369 Bourne Avenue, St. Paul, Minnesota.

Keller, E.A., and F.J. Swanson. 1979. Effects of large organic material on channel form and fluvial processes. Earth Surface Processes 4:361-380.

Kelly, J.T., A.P. Klimley, and C.E. Crocker. 2007. Movements of green sturgeon, *Acipenser medirostris*, in the San Francisco Bay Estuary, CA. Environmental Biology of Fishes 79(3-4): 281-295.

Kenaston, K.R., R.B. Linsay, and R.K. Schroeder. 2001. Effect of Acclimation on the Homing and Survival of Hatchery Winter Steelhead. North American Journal of Fisheries Management 21:765-773.

Kendra, W. 1991. Quality of salmonid hatchery effluents during a summer low-flow season. Transactions of the American Fisheries Society 120: 43-51.

Kjelson, M.A. and P.L. Brandes, 1989, The use of smolt estimates to quantify the effects of habitat changes on salmonid stocks in the Sacramento-San Joaquin Rivers, California. Pages 100-115 *in* C.D. Levings, L.B. Holtby, and M.A. Henderson (editors), Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks. Canadian Special Publication of Fisheries and Aquatic Sciences 105.

Knowles N. and D. Cayan. 2002. Potential effects of global warming on the Sacramento/San Joaquin watershed and the San Francisco estuary. Geophysical Research Letters 29(18), 1891, doi:10.1029/2001GL014339.

Knowles, N. and D. R. Cayan. 2004. Elevational dependence of projected hydrologic changes in the San Francisco estuary and watershed. Climate Change 62: 319-336.

Krahn, M., M.J. Ford, W.F. Perrin, P.R. Wade, R.P. Angliss, M.B. Hanson, B.L. Taylor, G.M. Ylitalo, M.E. Dahlheim, J.E. Stein, and R.S. Waples. 2004. 2004 Status review of Southern Resident killer whales (*Orcinus orca*) under the Endangered Species Act. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-62. 73 p.

Krahn, M.M, M.B. Hanson, R.W. Baird, R.H. Boyer, D.G. Burrows, C.E. Emmons, J.K.B. Ford, L.L. Jones, D.P. Noren, P.S. Ross, G.S. Schorr, and T.K. Collier. 2007. Persistent organic pollutants and stable isotopes in biopsy samples (2004/2006) from Southern Resident killer whales. Marine Pollution Bulletin.

Krahn, M.M., P.R. Wade, S.T. Kalinowski, M.E. Dahlheim, B.L. Taylor, M.B. Hanson, G.M. Ylitalo, R.P. Angliss, J.E. Stein, and R.S. Waples. 2002. Status review of Southern Resident killer whales (*Orcinus orca*) under the Endangered Species Act. NMFS-NWFSC-54. 133 p.

Kruse, G.O. and D.L. Scarnecchia. 2002. Assessment of bioaccumulated metal and organochlorine compounds in relation to physiological bismarkers in Kootenai River white sturgeon. Journal of Applied Ichthyology 18:430-438.

Kruse, S. 1991. The interactions between killer whales and boats in Johnstone Strait, B.C. Pages 149-159 *in* K. Pryor and K.S. Norris, editors. Dolphin societies: discoveries and puzzles. University of California Press, Berkeley, California.

Kynard, B., E. Parker, and T. Parker. 2005. Behavior of early life intervals of Klamath River green sturgeon, *Acipenser medirostris*, with note on body color. Environmental Biology of Fishes 72:85-97.

Leider, S.A., P.L. Hulett, J.J. Loch, and M.W. Chilcote. 1990. Electrophoretic comparison of the reproductive success of naturally spawning transplanted and wild steelhead trout through the returning adult stage. Aquaculture 889: 239-252.

Liermann, M. and R. Hilborn. 2001. Depensation: evidence, models, and implications. Fish and Fisheries 2: 33-58.

Lindley, S.T. 2006. Large-scale migrations of green sturgeon. Presentation at Interagency Ecological Program 2006 Annual Workshop, Pacific Grove, California. March 3.

Lindley, S.T., C.B. Grimes, M.S. Mohr, W. Peterson, J. Stein, J.T. Anderson, L.W. Botsford, D. L. Bottom, C.A. Busack, T.K. Collier, J. Ferguson, J.C. Garza, A.M. Grover, D.G. Hankin, R.G. Kope, P.W. Lawson, A. Low, R.B. MacFarlane, K. Moore, M. Palmer-Zwahlen, F.B. Schwing, J. Smith, C. Tracy, R. Webb, B.K. Wells, and T.H. Williams. 2009. What caused the Sacramento River fall-run Chinook salmon stock collapse? Pre-publication report to the Pacific Fishery Management Council. March 18. 57 pages plus a 61-page appendix.

Lindley, S.T., and M.S. Mohr. 2003. Modeling the effect of striped bass (*Morone saxatillis*) on the population viability of Sacramento River winter-run Chinook salmon *(Oncorhynchus tshawytscha*). Fisheries Bulletin 101: 321-331.

Lindley, S.T., M.L. Moser, D.L. Erickson, M. Belchik, D.W. Welch, E.L. Rechisky, J.T. Kelley, J. Heublein and A.P. Klimley. 2008. Marine migration of North American green sturgeon. Transactions of the American Fisheries Society. 137:182-194.

Lindley, S.T., R. Schick, B.P. May, J.J. Anderson, S. Greene, C. Hanson, A. Low, D. McEwan, R.B. MacFarlane, C. Swanson, and J.G. Williams. 2004. Population structure of threatened and endangered Chinook salmon ESU in California's Central Valley basin. Public review draft NMFS Southwest Science Center. Santa Cruz, CA.

Lindley, S. T., R. Schick, A. Agrawal, M. Goslin, T. Pearson, E. Mora, J.J. Anderson, B. May, S. Greene, C. Hanson, A. Low, D. McEwan, R.B. MacFarlane, C. Swanson, and J. G. Williams. 2006. Historical population structure of California Central Valley steelhead and its alteration by dams. San Francisco Estuary and Watershed Science 4(1)(3):1-19. http://repositories.cdlib.org/jmie/sfews/vol4/iss1/art3

Lindley, S.T., R. Schick, E. Mora, P. B. Adams, J. J. Anderson, S. Greene, C. Hanson, B. P. May, D. R. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2007. Framework for assessing viability of threatened and endangered Chinook salmon and steelhead in the Sacramento-San Joaquin Basin. San Francisco Estuary and Watershed Science 5(1), Article 4: 26 pages. California Bay–Delta Authority Science Program and the John Muir Institute of the Environment.

Linville, R.G., S.N. Luoma, L. Cutter, and G.A. Cutter. 2002. Increased selenium threat as a result of invasion of the exotic bivalve *Potamocorbula amurensis* into the San Francisco Bay-Delta. Aquatic Toxicology 57: 51-64.

Lusseau, D., D.E. Bain, R. Williams, and J.C. Smith. 2009. Vessel traffic disrupts the foraging behavior of southern resident killer whales (*Orcinus orca*). Endangered Species Research 6: 211-221.

MacFarlane, R.B., S. Hayes, and B. Wells. 2008. Coho and Chinook salmon Decline in California during the Spawning Seasons of 2007/08. National Marine Fisheries Service. Southwest Region. Santa Cruz, California.

MacKichan, K. A. 1951. Estimated Use of Water in the United States—1950. U.S. Geological Survey Circular 115. Available at: http://pubs.usgs.gov/circ/1951/circ115.

Mantua, N.J., Hare, S.R., Zhang, Y., Wallace, J.M. and Francis, R.C. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bulletin of the American Meteorological Society 78: 1069–1079.

Martin, C. D., P. D. Gaines and R. R. Johnson. 2001. Estimating the abundance of Sacramento River juvenile winter-run Chinook salmon with comparisons to adult escapement. Red Bluff Research Pumping Plant Report Series, Volume 5. U.S. Fish and Wildlife USFWS, Red Bluff, California.

Maslin, P., M Lennox, and W. McKinney. 1997. Intermittent streams as rearing habitat for Sacramento River Chinook salmon (*Oncorhynchus tshawytscha*). California State University, Chico, Department of Biological Sciences. 89 pages.

Matkin, C. 1994. An observer's guide to the killer whales of Prince William Sound. Prince William Sound Books, Valdez, Alaska.

Matkin, C.O., E.L. Saulitis, G. M. Ellis, P. Olesiuk, S.D. Rice. 2008. Marine Ecology Progress Series Vol 356: 269-281.

Mayer, T. 2008. Analysis of trends and changes in Upper Klamath Lake hydroclimatology. United States Fish and Wildlife USFWS. Water Resources Branch. Portland, Oregon. 31 pp.

Mayfield, R.B. and J.J. Cech, Jr. 2004. Temperature Effects on green sturgeon bioenergetics. Transactions of the American Fisheries Society 133:961-970.

McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units. NOAA Tech. Memo. NMFS-NWFSC-42. U.S. Dept. of Commerce. National Oceanic and Atmospheric Administration. National Marine Fisheries Service. 156 pages.

McEwan, D. 2001. California Central Valley steelhead. *In* R .L. Brown (editor), Contributions to the Biology of Central Valley Salmonids, Volume 1, pages 1-44. California Department of Fish and Game, Fish Bulletin 179.

McEwan, D. and T. A. Jackson. 1996. Steelhead restoration and management plan for California. California Department of Fish and Game. Sacramento, California. 234 pages.

McGill, R.R. Jr. 1987. Land use changes in the Sacramento River riparian zone, Redding to Colusa. A third update: 1982-1987. Department of Water Resources, Northern District, 19 pages.

McReynolds, T. R., C. E. Garman, P. D. Ward, and M. C. Schommer. 2005. Butte and Big Chico Creeks spring-run Chinook salmon, *Oncorhynchus tshawytscha* life history investigation, 2003-2004. California Department of Fish and Game, Inland Fisheries Administrative Report No. 2005-1.

Meehan, W. R. and T. C. Bjornn. 1991. Salmonid distributions and life histories. *In* W. R. Meehan, editor, Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats, pages 47-82. American Fisheries Society Special Publication 19. American Fisheries Society. Bethesda, Maryland. 751 pages.

Michny, F., and M. Hampton. 1984. Sacramento River Chico Landing to Red Bluff project, 1984, Juvenile salmon study. U.S. Fish and Wildlife USFWS, Division of Ecological USFWSs. Sacramento, California.

Miles, E. L., A. K. Snover, A. F. Hamlet, B. Callahan, and D. Fluharty. 2000. Pacific Northwest regional assessment: the impacts of climate variability and climate change on the water resources of the Columbia River basin. Journal of the American Water Resources Association 36: 399-420.

Missildine, Brian. 2005. Salmon Carcass Deployment: A Potential Pathway for PCB Contamination. Fisheries: 30: 18-19. January 2005.

Monroe, M., J. Kelly, and N. Lisowski. 1992. State of the estuary, a report of the conditions and problems in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. June. 269 pages.

Morton, A.B. 1990. A quantitative comparison of the behaviour of resident and transient forms of the killer whale off the central British Columbia coast. Report of the International Whaling Commission (special issue 12), 245-248.

Moser, M.L. and S.T. Lindley. 2007. Use of Washington estuaries by subadult and adult green sturgeon. Environmental Biology of Fishes. 79:243-253.

Mote, P.W. 2006. Climate-driven variability and trends in mountain snowpack in western North America. Journal of Climate 19: 6209-6220.

Mote, P. W., A. F. Hamlet, M. P. Clark, and D. P. Lettenmaier. 2005. Declining snowpack in western North America. Bulletin of the American Meteorological Society. January 2005: 39-49.

Mount, J.F. 1995. California rivers and streams: The conflict between fluvial process and land use. University California Press, Berkeley, California.

Moyle, P.B., J.E. Williams, and E.D. Wikramanayake. 1989. Fish species of special concern of California. Wildlife and Fisheries Biology Department, University of California, Davis. Prepared for The Resources Agency, California Department of Fish and Game, Rancho Cordova.

Moyle, P.B., P.J. Foley, and R.M. Yoshiyama. 1992. Status of green sturgeon, *Acipenser medirostris*, in California. Final report sent to NMFS, Terminal Island, California by UC Davis Department of Wildlife and Fisheries Biology. 12 pages.

Moyle, P.B. 2002. Inland fish of California, 2nd edition. University of California Press, Berkeley, California.

Mundy, P.R. 1997. The role of harvest management in the future of Pacific salmon populations: shaping human behavior to enable the persistence of salmon. *In*, D.J. Stouder, P.A. Bisson, and R.J. Naiman (editors). Pacific salmon and their ecosystems: status and future options. Chapman and Hall.

Myers, J. M., R. G. Kope, G. J. Bryant, D. Teel, L .J. Lierheimer, T. C. Wainwright, W. S. Grant, F. W. Waknitz, K. Neely, S. T. Lindley, and R. S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. Technical Memorandum NMFS-NWFSC-35. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. 443 pages.

Nakamoto, R. J., T. T. Kisanuki, and G. H. Goldsmith. 1995. Age and growth of Klamath River green sturgeon (*Acipenser medirostris*). U.S. Fish and Wildlife USFWS. Project # 93-FP-13. 20 pages.

Narum, S.R., M.S. Powell, R. Everson, B. Sharp, and A.J. Talbot. 2006. Microsatellites Reveal Population Structure of Klickitat River Native Steelhead and Genetic Divergence from an Introduced Stock. North American Journal of Fisheries Management 26:147-155, 2006.

National Marine Fisheries Service. 1996a. Factors for decline: a supplement to the notice of determination for west coast steelhead under the Endangered Species Act. National Marine Fisheries Service, Protected Resource Division, Portland, OR and Long Beach, California.

National Marine Fisheries Service. 1996b. Making Endangered Species Act determinations of effect for individual or group actions at the watershed scale. Prepared by NMFS, Environmental and Technical USFWSs Branch, Habitat Conservation Branch, Portland, Oregon. 31 pages.

National Marine Fisheries Service. 1997. National Marine Fisheries Service Proposed Recovery Plan for the Sacramento River Winter-run Chinook salmon. NMFS, Southwest Region, Long Beach, California. 217 pages with goals and appendices.

National Marine Fisheries Service. 1998a. Factors Contributing to the Decline of Chinook salmon: An Addendum to the 1996 West Coast Steelhead Factors For Decline Report. Protected Resources Division, National Marine Fisheries Service. Portland, Oregon.

National Marine Fisheries Service. 1998b. Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-35. 443 pages.

NMFS. 1999a. Interim Standards for the use of Captive Propagation Technology in Recovery of Anadromous Salmonids Listed under the Endangered Species Act. NMFS. Sustainable Fisheries Division, Hatchery and Inland Fisheries Branch. Portland, Oregon. February 1999.

NMFS. 1999b. Backpack Electrofishing Guidelines. Protected Resources Division, Protected Resources Branch. Updated and available on the Internet at: http://www.nwr.noaa.gov/ESA-Salmon-Regulations-Permits/4d-Rules/upload/electro2000 (accessed May 31, 2006).

NMFS. 1999c. Endangered Species Act Section 7 Consultation. Biological Opinion. Issuance of ESA Section 10(a)(1)(A) Permits and Permit Modification for Scientific Section 7 Biological Opinion USFWS MCR-LCR Art. Prop. 240 Research/Monitoring Involving Chinook Salmon listed under the ESA for 1999 -2003. Protected Resources Division, Portland, Oregon.

NMFS. 2000. A Citizen's Guide to the 4(d) Rule for Threatened Salmon and Steelhead on the West Coast. National Marine Fisheries Service, Northwest and Southwest Regions, June 20, 2000.

NMFS. 2000a. Guidelines for Electrofishing Waters Containing Salmonids Listed Under the Endangered Species Act. June 2000. http://www.nwr.noaa.gov/ESA-Salmon-Regulations-Permits/4d-Rules/upload/electro2000.pdf (accessed May 31, 2006).

National Marine Fisheries Service. 2000b. Biological Opinion and Incidental Take Statement for the Effects of the Pacific Coast Salmon Plan on California Central Valley Spring-Run Chinook, and California Coastal Chinook Salmon. Northwest and Southwest Regional Sustainable Fisheries Divisions. April 28, 2000.

National Marine Fisheries Service. 2003. Draft Report of Updated Status of Listed ESUs of Salmon and Steelhead. NOAA Fisheries, Northwest Fisheries Science Center, Seattle, Washington. Available: http://www.nwfsc.noaa.gov/cbd/trt/brt/brtrpt.html.

National Marine Fisheries Service. 2004. Assessment of acoustic exposures on marine mammals in conjunction with USS Shoup active sonar transmissions in the eastern Strait of Juan de Fuca and Haro Strait, Washington. Office of Protected Resources, National Marine Fisheries Service, Silver Spring, Maryland.

National Marine Fisheries Service. 2005. Green sturgeon (*Acipenser medirostris*) status review update. Biological review team, Santa Cruz Laboratory, Southwest Fisheries Science Center, California. February. 31 pages.

National Marine Fisheries Service. 2008a. Recovery Plan for Southern Resident Killer Whales (*Orcinus orca*). National Marine Fisheries Service, Northwest Region, Seattle, Washington.

National Marine Fisheries Service. 2008b. Endangered Species Act – Section 7 Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation. Consultation on Treaty Indian and Non-Indian Fisheries in the Columbia River Basin Subject To the 2008-2017 US v. Oregon Management Agreement. NMFS, Northwest Region. May 5.

National Marine Fisheries Service. 2008c. Unpublished. Acoustic tagging program in Central Valley and San Francisco Bay. National Marine Fisheries Service, Santa Rosa Area Office, California. Data provided on October 29.

NMFS. 2008d. Supplemental Comprehensive Analysis of the Federal Columbia River Power System and Mainstem Effects of the Upper Snake and other Tributary Actions. May 5, 2008. NMFS Northwest Regional Office, Portland, Oregon.

National Marine Fisheries Service. 2009a. Biological opinion and Conference opinion on the Long-Term Operations of the Central Valley Project and State Water Project. National Marine Fisheries Service, Southwest Region. June 4, 2009

National Marine Fisheries Service (NMFS). 2009b. Public Draft Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead. Sacramento Protected Resources Division. October 2009.

NMFS. 2009. FCRPS Adaptive Management Implementation Plan. NMFS Northwest Regional Office, Portland, OR. September 15, 2009c.

National Marine Fisheries Service (NMFS). 2010. Biological Opinion for the Authorization of Ocean Salmon Fisheries Pursuant to the Pacific Coast Salmon Fishery Management Plan and Additional Protective Measures as it affects Sacramento River Winter Chinook Salmon. Southwest Region. April 30, 2010.

National Marine Fisheries Service. 2011a. Central Valley Recovery Domain. 5-Year Review: Summary and Evaluation of *Sacramento River Winter-run Chinook Salmon ESU.* National Marine Fisheries Service, Southwest Region. 38 pages.

National Marine Fisheries Service. 2011b. Central Valley Recovery Domain. 5-Year Review: Summary and Evaluation of *Central Valley Spring-run Chinook Salmon ESU.* National Marine Fisheries Service, Southwest Region. 34 pages.

National Marine Fisheries Service. 2011c. Central Valley Recovery Domain. 5-Year Review: Summary and Evaluation of *Central Valley Steelhead DPS.* National Marine Fisheries Service, Southwest Region. 34 pages.

National Research Council. 1996. *Upstream:* Salmon and Society in the Pacific Northwest. National Academy Press, Washington, D.C. 452 p.

National Research Council (NRC). 2001. Climate Change Science: An Analysis of Some Key Questions. National Academy Press, 42 pp.

National Research Council. 2003. Ocean noise and marine mammals. National Academy Press, Washington, D.C.

National Wildlife Federation (NWF). 2005. Fish out of water: a guide to global warming and Pacific Northwest rivers, Ed. By P. Glick. 40pp.

Needham, P.R., O.R. Smith and H.A. Hanson. 1941. Salmon salvage problems in relation to Shasta Dam, California, and notes on the biology of the Sacramento River salmon. Abstract, *Transactions of the American Fisheries Society*, 17th annual meeting.

Nelson, K. and M. Soule. 1987. Genetical conservation of exploited fishes, p. 345-368. *In* N. Ryman and F. Utter (eds.), Population Genetics and Fishery Management. University of Washington Press, Seattle, Washington.

Newman, K.B. and J. Rice. 2002. Modeling the survival of Chinook salmon smolts outmigrating through the lower Sacramento River system. Journal of the American Statistical Association 97(460):983-993.

Newton, J. M., and L.A. Stafford. 2011. Monitoring adult Chinook salmon, rainbow trout, and steelhead in Battle Creek, California, from March through November 2009. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Nichols, F.H., J.E. Cloern, S.N. Louma, and D.H. Peterson. 1986. The modification of an estuary. *Science* 231: 567-573.

Nickum, M.J., P.M. Mazik, J.G. Nickum, and D.D. MacKinlay, editors. 2004. Propagated fish in resource management. American Fisheries Society, Symposium 44, American Fisheries Society, Bethesda, Maryland.

Niemela, Kevin. 2010. USFWS. Personal Communication between USFWS and NMFS regarding status review of California Central Valley steelhead.

Niemela, Kevin. 2013a. USFWS. Personal communication between NMFS and USFWS, regarding risk of failure of distribution truck.

Niemela, Kevin. 2013b. USFWS. Personal communication between USFWS Kevin Niemela, and NMFS, providing unpublished data of mortality of natural-origin steelhead in the adult collection ponds at CNFH.

Niemela, Kevin. 2013c. USFWS. Personal communication between USFWS J.S. Foott, PhD, California-Nevada Fish Health Center, Kevin Niemela and NMFS, regarding pathogens from hatchery-origin salmonids to green sturgeon.

Niemela, Kevin. 2014. USFWS. Personal communication between USFWS and NMFS, providing the draft HGMP for the California Central Valley steelhead propagation program at CNFH.

Noakes, D. J. 1998. On the coherence of salmon abundance trends and environmental trends. North Pacific Anadromous Fishery Commission Bulletin, pages 454-463.

Nobriga, M. and P. Cadrett. 2003. Differences among hatchery and wild steelhead: evidence from Delta fish monitoring programs. Interagency Ecological Program for the San Francisco Estuary Newsletter 14:3:30-38.

Noren, D.P. (In review). Estimating daily energetic needs and prey consumption rates of Southern Resident killer whales. NOAA NMFS Northwest Fisheries Science Center. 16p.

Northwest Fisheries Science Center. Unpublished data. Prey samples from Southern Resident killer whale kills.

Northwest Power and Conservation Council (NPCC), 2003. Columbia River Basin Fish and Wildlife Program. Available at http://www.nwcouncil.org/library/2003/2003-20/default.htm.

NPPC. 1999. Artificial Production Review. Northwest Power Planning Council, Portland, Oregon. Council Document 99-15. 238p.

Null, Robert. 2012. USFWS. Personal communication between NMFS and USFWS, regarding unpublished data on stomach contents of hatchery Chinook salmon.

Null, Robert. 2012. USFWS. Personal communication between NMFS and USFWS, regarding reproductive success of hatchery steelhead.

Null, R.E. 2008. Ocean Harvest of Fall and Late fall-run Chinook salmon from the CNFH: Brood Years 1992-2002. U.S. Fish and Wildlife USFWS Report. U.S. Fish and Wildlife USFWS, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Null, R. E., J. Newton, C. Brownfield, S. Hamelberg, and K. Niemela. 2011. Monitoring and Evaluation of the Modified Fish Ladder and Barrier Weir at the CNFH. U.S. Fish and Wildlife USFWS Report. U.S. Fish and Wildlife USFWS, Red Bluff Fish and Wildlife Office, Red Bluff, California.

O'Neal, K.O. 2002. Effects of global warming on trout and salmon in U.S. streams. Defenders of Wildlife, 1101 Fourteenth St. NW, Suite 1400, Washington D.C.

O'Neill, S., G. Ylitalo, M. Krahn, J. West, J. Bolton, and D. Brown. 2005. Elevated levels of persistent organic pollutants in Puget Sound salmon: the importance of residency in Puget Sound. http://wdfw.wa.gov/science/articles/pcb/salmon_pollutants_slideshow_files/frame.htm

O'Neill, S.M., G.M. Ylitalo, J.E. West, J. Bolton, C.A. Sloan, and M.M. Krahn. 2006. Regional patterns of persistent organic pollutants in five Pacific salmon species (*Oncorhynchus spp.*) and their contributions to contaminant levels in northern and southern resident killer whales (*Orcinus orca*). *In*: 2006 Southern Resident Killer Whale Symposium.

O'Shea, T.J. 1999. Environmental contaminants and marine mammals. Pages 485-563 in J.E. Reynolds III and S.A. Rommel, editors. Biology of marine mammals. Smithsonian Institution Press, Washington, D.C.

Olesiuk, P.F., M.A. Bigg, and G.M. Ellis. 1990. Life history and population dynamics of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Rep. Int. Whal. Commn. (special issue) 12: 209-244.

Olesiuk, P.F., G.M. Ellis, and J.K. Ford. 2005. Life history and population dynamics of northern resident killer whales (*Orcinus orca*) in British Columbia. DFO Canadian Science Advisory Secretariat Research Document 2005/045.

Orsi, J. 1967. Predation study report, 1966-1967. California Department of Fish and Game.

Osborne, R.W. 1999. A historical ecology of Salish Sea "resident" killer whales (*Orcinus orca*): with implications for management. Ph.D. thesis, University of Victoria, Victoria, British Columbia.

PNFHPC (Pacific Northwest Fish Health Protection Committee). 1989. Model comprehensive fish health protection program. Olympia, Washington. 33p.

Pacific Salmon Commission Joint Chinook Technical Committee. 2008. Pacific Salmon Commission Joint Chinook Technical Committee Report: 2007 Annual Report of Catches and Escapements, Exploitation Rate Analysis and Model Calibration. Report TCCHINOOK (08)-1. February 14, 2008.

Pearsons, T.N., G.A. McMichael, S.W. Martin, E.L. Bartrand, M. Fischer, and S.A. Leider. 1994. Yakima River species interaction studies - annual report 1993. Bonneville Power Administration, Portland, Oregon. Project No. 89-105. 247p.

Peterson, J. H. and J. F. Kitchell. 2001. Climate regimes and water temperature changes in the Columbia River: Bioenergetic implications for predators of juvenile salmon. Canadian Journal of Fisheries and Aquatic Sciences. 58:1831-1841.

Peterson, W.T., R.C. Hooff, C.A. Morgan, K.L. Hunter, E. Casillas, and J.W. Ferguson. 2006. Ocean Conditions and Salmon Survival in the Northern California Current. White Paper. 52 pages.

Phelps, S.R., B.M. Baker, P.L. Hulett, and S.A. Leider. 1994. Genetic analyses of Washington steelhead: initial electrophoretic analysis of wild and hatchery steelhead and rainbow trout. Fisheries Management Program Report 94-9, Washington Department of Fish and Wildlife. Olympia, Washington.

Phillips, R.W. and H.J. Campbell. 1961. The embryonic survival of coho salmon and steelhead trout as influenced by some environmental conditions in gravel beds. Annual Report to Pacific Marine Fisheries Commission. 14:60-73.

Pickard, A., A. Grover, and F. Hall. 1982. An evaluation of predator composition at three locations on the Sacramento River. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary. Technical Report No. 2. 20 pages.

Polis, G.A. and S.D. Hurd. 1996. Linking Marine and Terrestrial Food Webs: Allochthonous Input from the Ocean Supports High Productivity in Small Island and Coastal Land Communities. American Naturalist 173(3):396-423.

Polis, G.A., W.B. Anderson and R.D. Holt. 1997. Toward an integration of landscape and food web ecology: the dynamics of spatially subsidized food webs. Annual Review of Ecology and Systemics 28: 289-316.

Poytress, W. 2008. U.S. Fish and Wildlife USFWS Fisheries Biologist, Red Bluff Fish and Wildlife Office, Red Bluff, California. Personal communication with Bruce Oppenheim, Fisheries Biologist, NMFS, on the status of juvenile green sturgeon passage. September 3.

Poytress, W.R., J.J. Gruber, D.A. Trachtenbarg, and J.P. Van Eenennaam. 2009. 2008 Upper Sacramento River Green Sturgeon Spawning Habitat and Larval Migration Surveys. Annual Report of U.S. Fish and Wildlife USFWS to U.S. Bureau of Reclamation, Red Bluff, California.

Poytress, William. 2013. USFWS. Personal communication between USFWS and NMFS regarding likelihood of residualized hatchery steelhead predating on larval green sturgeon.

Radtke, L. D. 1966. Distribution of smelt, juvenile sturgeon, and starry flounder in the Sacramento-San Joaquin Delta with observations on food of sturgeon, in Ecological studies of the Sacramento-San Joaquin Delta, Part II. (J. L. Turner and D. W. Kelley, comp.). California Department of Fish and Game Fish Bulletin 136:115-129.

Rand, G.M., P.G. Wells, and L.S. McCarty. 1995. Introduction to aquatic toxicology. *In* G.M. Rand (editor), Fundamentals of aquatic toxicology: effects, environmental fate, and risk assessment, second edition, pages 3-66. Taylor and Francis. Bristol, Pennsylvania.

Regonda, S.K., B. Rajagoplan, M. Clark, and J. Pitlick. 2005. Seasonal shifts in hydroclimataology over the western United States. Journal of Climate 18: 372-384.

Reijnders, P. J. H. and A. Aguilar. 2002. Pollution and marine mammals. Pages 948-957 *in* W. F. Perrin, B. Würsig, and J. G. M. Thewissen, editors. Encyclopedia of marine mammals. Academic Press, San Diego, California.

Reisenbichler, R.R. and J.D. McIntyre. 1986. Requirements for integrating natural and artificial production of anadromous salmonids in the Pacific Northwest, p. 365-374. *In*, R.H. Stoud (ed.), Fish Culture in Fisheries Management. American Fisheries Society, Bethesda, Maryland.

Reisenbichler, R.R. and S.P. Rubin. 1999. Genetic changes from artificial propagation of Pacific salmon affect the productivity and viability of supplemented populations. ICES Journal of Marine Science, 56:459-466.

Reisenbichler, R.R. 1997. Genetic Factors Contributing to Declines of Anadromous Salmonids in the Pacific Northwest, p. 223-244. *In*, D.J. Stouder, D.A. Bisson, and R.J. Naiman, (eds.), Pacific Salmon and Their Ecosystems. Status and Future Options. Chapman & Hall, New York. 685p.

Reynolds, F. L., T. J. Mills, R. Benthin, and A. Low. 1993. Restoring Central Valley streams: a plan for action. California Department of Fish and Game, Inland Fisheries Division, Sacramento, California.

Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and D.H. Thomson. 1995. Marine mammals and noise. Academic Press, San Diego, California.

Robison, G.E., and Beschta, R.L. 1990. Identifying trees in riparian areas that can provide coarse woody debris to streams. Forest USFWS 36:790-801.

Romano, T.A., M. J. Keogh, C. Kelly, P. Feng, L. Berk, C. E. Schlundt, D. A. Carder, and J. J. Finneran. 2003. Anthropogenic sound and marine mammal health: measures of the nervous and immune systems before and after intense sound exposure. Canadian Journal of Fisheries and Aquatic Sciences 61: 1124-1134.

Ross, P. S., G. M. Ellis, M. G. Ikonomou, L. G. Barrett-Lennard, and R. F. Addison. 2000. High PCB concentrations in free-ranging Pacific killer whales, *Orcinus orca*: effects of age, sex and dietary preference. Marine Pollution Bulletin 40: 504-515.

Rutter, C. 1904. Natural history of the quinnat salmon. Investigations on Sacramento River, 1896-1901. Bulletin of the U.S. Fish Commission. 22:65-141.

Rutter, L.G. 1997. Salmon fisheries in the Pacific Northwest: How are harvest decisions made? *In,* D.J. Stouder, P.A. Bisson, and R.J. Naiman (editors). Pacific salmon and their ecosystems: status and future options. Chapman and Hall.

Ryman, N., P.E. Jorde, and L. Laikre. 1995. Supportive breeding and variance effective population size. Conserv. Biol. 9: 1619-1628.

S.P. Cramer and Associates, Inc. 2000. Stanislaus River data report. Oakdale California.

S.P. Cramer and Associates, Inc. 2001. Stanislaus River data report. Oakdale California.

Salonius, K. and G.K. Iwama. 1993. Effects of Early Rearing Environment on Stress Response, Immune Function, and Disease Resistance in Juvenile Coho (Oncorhynchus kisutch) and Chinook Salmon (O. tshawytscha). Canadian Journal of Fisheries and Aquatic Sciences 50: 759-766.

Saunders, R.L. 1991. Potential interaction between cultured and wild Atlantic salmon. Aquaculture, 98:51-61.

Saulitis, E., C. Matkin, L. Barett-Lennard, K. Heise, and G. Ellis. 2000. Foraging strategies of sympatric killer whale (*Orcinus orca*) populations in Prince William Sound, Alaska. Marine Mammal Science, 16(1): 94-109.

Schaffter, R. 1980. Fish occurrence, size, and distribution in the Sacramento River near Hood, California during 1973 and 1974. California Department of Fish and Game.

Schaffter, R. 1997. White sturgeon spawning migrations and location of spawning habitat in the Sacramento River, California. California Department of Fish and Game 83: 1-20.

Scheffer, V.B. and J.W. Slipp. 1948. The whales and dolphins of Washington State with a key to the cetaceans of the west coast of North America. American Midland Naturalist 39: 257-337.

Scheuerell, M.D. and J.G. Williams. 2005. Forecasting climate-induced changes in the survival of Snake River spring/summer Chinook salmon (*Oncorhynchus tshawytscha*). Fisheries Oceanography 14(6): 448-457.

Schmetterling, D. A., C. G. Clancy, and T. M. Brandt. 2001. Effects of riprap bank reinforcement on stream salmonids in the western United States. Fisheries 26(7): 6-13.

Schreck, C.B., A.G. Maule, and S.L. Kaattari. 1993. Stress and disease resistance, p. 170-175. *In*, J.F. Muir and R.J. Roberts [ed.] Recent Advances in Aquaculture, Vol. 4. Blackwell Scientific Publications, Oxford, UK.

Shaffer, M.L. 1981. Minimum population sizes for species conservation. BioScience 31: 131-134.

Shapovalov, L. and A.C. Taft 1954. The life histories of the steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. California Department of Fish and Game, Fish Bulletin 98:1-375.

Simenstad, C.A. and W.J. Kinney. 1978. Trophic relationships of out-migrating chum salmon in Hood Canal, Washington, 1977. Univ. of Washington, Fish. Res. Inst., Final Rep., FRI-UW-7810. 75p.

Simon, R.C., J.D. McIntyre, and A.R. Hemmingsen. 1986. Family size and effective population size in a hatchery stock of coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 43:2434-2442.

Skinner, J.E. 1958. Some observations regarding the King salmon runs of the central Valley. Water Projects Miscellaneous Report #1. Submitted 3/19/1958. Revised 10/14/1958. 8 pages plus figures and tables.

Slater, D.W. 1963. Winter-run Chinook salmon in the Sacramento River, California, with notes on water temperature requirements at spawning. U.S. Fish and Wildlife USFWS, Special Science Report Fisheries 461:9.

Snider, B. 2001. Evaluation of effects of flow fluctuations on the anadromous fish populations in the lower American River. California Department of Fish and Game, Habitat Conservation Division. Stream Evaluation Program. Tech. Reports No. 1 and 2 with appendices 1-3. Sacramento, California.

Snider, B. and R. G. Titus. 2000. Timing, composition, and abundance of juvenile anadromous salmonid emigration in the Sacramento River near Knights Landing, October 1996-September 1997. California Department of Fish and Game, Habitat Conservation Division, Stream Evaluation Program Technical Report No. 00-04.

SIWG (Species Interaction Work Group). 1984. Evaluation of potential interaction effects in the planning and selection of salmonid enhancement projects. J. Rensel, chairman and Section 7 Biological Opinion USFWS MCR-LCR Art. Prop. 250.

Spence, B. C., G. A. Lomnicky, R. M. Hughes, and R. P. Noviztki. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057. ManTech Environmental Research USFWSs Corp., Corvallis, Oregon. Copy available at: http://www.nwr.noaa.gov/Publications/Reference-Documents/ManTech-Report.cfm

Stachowicz, J. J., J. R. Terwin, R. B. Whitlatch, and R. W. Osman. 2002. Linking climate change and biological invasions: Ocean warming facilitates non-indigenous species invasions. PNAS, November 26, 2002. 99:15497–15500.

Stansby, M.E. 1976. Chemical characteristics of fish caught in the northeast Pacific Ocean. Marine Fisheries Review 38: 1-11.

Stephenson, A.E. and D.E. Fast. 2005. Monitoring and evaluation of avian predation on juvenile salmonids on the Yakima River, Washington. Annual Report 2004. March 2005.

Stevens, D.E. 1961. Food habits of striped bass, *Roccus saxatilis* (Walbaum) in the Rio Vista area of Sacramento River. Master's Thesis. University of California. Berkeley, California.

Steward, C.R. and T.C. Bjornn. 1990. Supplementation of Salmon and Steelhead Stocks with Hatchery Fish: A Synthesis of Published Literature. In: Analysis of Salmon and Steelhead Supplementation, William H. Miller editor. Report to Bonneville Power Administration (BPA), Portland, Oregon. Project No. 88-100. 126p.

Stewart, I. T., D. R. Cayan, and M. D. Dettinger. 2005. Changes toward earlier streamflow timing across western North America. Journal of Climate 18: 1136-1155.

Stillwater Sciences. 2002. Merced River corridor restoration plan. Stillwater Sciences, Berkeley, California. 245 pages.

Stone, L. 1874. Report of operations during 1872 at the U.S. salmon-hatching establishment on the McCloud River, and on the California Salmonidae generally; with a list of specimens collected. Report to U.S. Commissioner of Fisheries for 1872-1873, 2:168-215.

Sweeney, B. W., Bott, T. L. Jackson, J. K. Kaplan, L. A. Newbold, J. D. Standley, L. J. Hession, W. C., and R. J. Horwitz. 2004. Riparian deforestation, stream narrowing, and loss of stream ecosystem USFWSs. National Academy of Sciences 101:14132-14137.

Taylor, E.B. 1991. Behavioral interaction and habitat use in juvenile Chinook, Oncorhynchus tshawytscha, and coho O. kisutch salmon. Animal Behav. 42: 729-744.

Tehama-Colusa Canal Authority and U.S. Bureau of Reclamation. 2002. Draft Environmental Impact Statement/Environmental Impact Report Fish Passage Improvement Project at the Red Bluff Diversion Dam, Attachment B1. Willows and Sacramento, California.

Tillman, T.L., G.W. Edwards, and K.A.F. Urquhart. 1996. Adult salmon migration during the various operational phases of Suisun Marsh Salinity Control Gates in Montezuma Slough: August-October 1993. Agreement to California Department of Water Resources, Ecological USFWSs Office by California Department of Fish and Game, Bay-Delta and Special Water Projects Division, 25 pages.

Tschaplinski, P.J. 2000. The effects of harvesting, fishing, climate-variation, and ocean conditions on salmonid populations in Carnation Creek, Vancouver Island, British Columbia. In *Sustainable fisheries management: Pacific salmon*, edited by E. E. Knudsen, C. R. Steward, D. D. MacDonald, J. E. Williams and D. W. Reiser. Boca Raton: CRC Press.

Tucker, Mike. 2004. NMFS. Personal communication between NMFS, USFWS, and CDFW; multi-agency verbal agreement to block fish passage at the Coleman barrier weir in August.

Tucker, M. E., C. D. Martin, and P. D. Gaines. 2003. Spatial and temporal distributions of Sacramento pikeminnow and striped bass at the Red Bluff Diversion Complex, including the research pumping plant, Sacramento River, California: January, 1997 to August, 1998. Red Bluff Research Pumping Plant Report Series, Vol. 10. U.S. Fish and Wildlife USFWS, Red Bluff, California. 32 pages.

Tucker, M. E., C. M. Williams, and R. R. Johnson. 1998. Abundance, food habits, and life history aspects of Sacramento squawfish and striped bass at the Red Bluff Diversion Complex, including the research pumping plant, Sacramento River, California: 1994 to 1996. Red Bluff Research Pumping Plant Report Series, Vol. 4. U.S. Fish and Wildlife USFWS, Red Bluff, California. 54 pages.

U.S. Bureau of Reclamation. 2003. Supplemental Environmental Assessment and Finding of No Significant Impact, Proposed 2003 Instream Interim Flow Agreement for Temporary Reduction in Water Diversions from Battle Creek. July 2003. Sacramento, 2003.

U.S. Bureau of Reclamation. 2008. Biological Assessment on the Continued Long-term Operations of the Central Valley Project and the State Water Project. Mid-Pacific Region, Sacramento, California.

U. S. Department of the Interior. 1999. Final Programmatic Environmental Impact Statement for the Central Valley Project Improvement Act. October 1999. Technical Appendix, 10 volumes.

U.S. District Court, Eastern District of California (Sacramento Division), Case No. CIV. S-88-1658 LKK/GGH Notice of Lodgment of Stipulation of Settlement: NRDC, et al., v. Kirk Rodgers, et al., Lodgment as of September 13, 2006.

U.S. Fish and Wildlife. 1963. Winter-run Chinook salmon in the Sacramento River, California, with notes on water temperature requirements at spawning. U.S. Fish and Wildlife USFWS Special Scientific Report 461.

USFWS. 1995. Fish Health Policy and Implementation, 713 FW., U.S. Fish and Wildlife Service Manual (FWM). U.S. Fish & Wildlife Service, Washington, D.C.

U.S. Fish and Wildlife. 1996. Biological Assessment on the effects of CNFH operations on winter-run Chinook salmon. U.S. Fish and Wildlife USFWS, Northern Central Valley Fishery Resource Office, Red Bluff, California. September 1996.

U.S. Fish and Wildlife. 1999. Effects of temperature on early-life survival of Sacramento River fall- and winter-run Chinook salmon. U.S. Fish and Wildlife USFWS Final Report, January 1999.

U.S. Fish and Wildlife. 2000. Impacts of riprapping to ecosystem functioning, lower Sacramento River, California. U.S. Fish and Wildlife USFWS, Sacramento Field Office, CA. Prepared for USACOE Sacramento District. 40 pp.

U. S. Fish and Wildlife. 2001a. Abundance and Survival of Juvenile Chinook salmon in the Sacramento-San Joaquin Estuary: 1997 and 1998. Annual progress report Sacramento-San Joaquin Estuary. 131 pages.

U.S. Fish and Wildlife. 2001b. Biological Assessment of Artificial Propagation at CNFH and Livingston Stone National Fish Hatchery: program description and incidental take of Chinook salmon and steelhead trout. Prepared by U.S. Fish and Wildlife USFWS Red Bluff Field Office. June 2001.

U. S. Fish and Wildlife. 2003. Abundance and survival of juvenile Chinook salmon in the Sacramento-San Joaquin Estuary: 1999. Annual progress report. 68 pages.

USFWS. 2004. Fish Health Policy and Implementation, 713 FW 1-5, U.S. Fish and Wildlife Service Manual (FWM) U.S. Fish & Wildlife Service, Washington, D.C.

U. S. Fish and Wildlife. 2006. Upper Sacramento River winter-run Chinook salmon carcass survey compendium report: return years 2001 – 2005. U.S. Fish and Wildlife.

U.S. Fish and Wildlife. 2009. Upper Sacramento River winter-run Chinook salmon carcass survey 2008 annual report. U.S. Fish and Wildlife USFWS, Red Bluff, California. December 2009.

U.S. Fish and Wildlife. 2010. Fish salvage in the Coleman National Fish Hatchery Canal concurrent with the operation of unscreened Intake 2 during March 2010. U.S. Fish and Wildlife Service, Red Bluff, California. July 2010.

U.S. Fish and Wildlife. 2011. Biological assessment of artificial propagation at Coleman National Fish Hatchery and Livingston Stone National Fish Hatchery: program description and incidental take of Chinook salmon and steelhead. Prepared by U.S. Fish and Wildlife Service, Red Bluff, California and the U.S. Fish and Wildlife Service, Coleman National Fish Hatchery Complex, Anderson, California.

U.S. Fish and Wildlife. 1994-2011. Unpublished data. Stockton Fish and Wildlife Office Mossdale trawls monitoring data. http://www.fws.gov/stockton/jfmp/datamanagement.asp

Van Eenennaam, Joel. 2011. Summary of Egg Verification by U.C. Davis Animal Sciences Feather River Green Sturgeon Eggs Collected from Egg Mats during 2011. 2 pgs.

Van Eenennaam, J.P., J. Linares-Casenave, J-B. Muguet, and S.I. Doroshov. 2009. Induced artificial fertilization and egg incubation techniques for green sturgeon. Revised manuscript to North American Journal of Aquaculture.

Van Eenennaam, J. P., J. Linares-Casenave, X. Deng, and S. I. Doroshov. 2005. Effect of incubation temperature on green sturgeon embryos, *Acipenser medirostris*. Environmental Biology of Fishes 72:145-154.

Van Eenennaam, J.P., J. Linares, and S.I. Doroshov. 2006. Reproductive conditions of the Klamath River green sturgeon. Transactions of the American Fisheries Society 135: 151-163.

Van Eenennaam, J. P., M. A. H. Webb, X. Deng, S. I. Doroshov, R. B. Mayfield, J. J. Cech, D. C. Hillemeier, and T. E. Willson. 2001. Artificial spawning and larval rearing of Klamath River green sturgeon. Transactions of the American Fisheries Society 130:159-165.

Van Kirk, R. W., and S. W. Naman. 2008. Relative effects of climate and water use on base-flow trends in the lower Klamath Basin. Journal of the American Water Resources Association. 44): 1035-1052.

Van Rheenen, N.T., A.W. Wood, R.N. Palmer, D.P. Lettenmaier. 2004. Potential implications of PCM climate change scenarios for Sacramento-San Joaquin river basin hydrology and water resources. Climate Change 62:257-281.

Van Woert, W. 1964. Mill Creek counting station. Office memorandum to Eldon Hughes, May 25, 1964. California Department of Fish and Game, Water Projects Branch, Contract USFWSs Station.

Vicuna, S., E. P. Maurer, B. Joyce, J. A. Dracup, and D. Purkey. 2007. The sensitivity of California water resources to climate change scenarios. Journal of the American Water Resources Association 43: 482-498.

Vigg, S. and C.C. Burley. 1991. Temperature-Dependent Maximum Daily Consumption of Juvenile Salmonids by Northern Squawfish (*Ptychocheilus-Oregonensis*) from the Columbia River. Canadian Journal of Fisheries and Aquatic Sciences 48: 2491-2498.

Vogel, D.A. 2005. Evaluation of adult sturgeon migration at the Glenn-Colusa Irrigation District Gradient Facility on the Sacramento River during 2003. Natural Resource Scientist, Inc. May 2005. 14 pages.

Vogel, D.A. 2008. Evaluation of adult sturgeon migration at the Glenn-Colusa Irrigation District Gradient Facility on the Sacramento River. Natural Resource Scientist, Inc. May 2008. 33 pages.

Vogel, D. A. and K. R. Marine. 1991. Guide to Upper Sacramento River Chinook salmon life history. Prepared for the U.S. Bureau of Reclamation, Central Valley Project. 55 pages.

Vogel, D.A., K.R. Marine, and J.G. Smith. 1988. Fish passage action program for Red Bluff Diversion Dam. Final report on fishery investigations. Report No. FR1/FAO-88-19. U.S. Fish and Wildlife USFWS, Northern Central Valley Fishery Resource Office. Red Bluff, California.

Vreeland, R.R. 1989. Evaluation of the contribution of fall chinook salmon reared at Columbia River hatcheries to the Pacific ocean fisheries. Bonneville Power Administration, Portland, Oregon. Report No. DOE/BP-39638-4.

Wahle, R.J. and R.R. Vreeland. 1978. Bioeconomic contribution to Columbia River hatchery fall chinook salmon, 1961 to 1964 broods, to the Pacific salmon fisheries. Fisheries Bulletin 76:179-208.

Waldman, B. and J.S. McKinnon. 1993. Inbreeding and outbreeding in fishes, amphibians and reptiles. Pages 250-282 *in* N.W. Thornhill, editor. The natural history of inbreeding and outbreeding. University of Chicago Press; Chicago, Illinois.

Wallis, J. 1964. An evaluation of the Bonneville salmon hatchery. Oregon Fish Commission Research Laboratory, Clackamas, Oregon.

Waples, R.S. 1991. Pacific Salmon, *Oncorhynchus spp*., and the definition of “species” under the Endangered Species Act. Marine Fisheries Review 53:11-21.

Waples, R.S. 1996. Toward a risk/benefit analysis for salmon supplementation. Unpublished paper presented at a workshop on captive breeding in the restoration of endangered species. October 1996 in Newport, OR.

Ward, M.B. and W.M. Kier. 1999. Battle Creek salmon and steelhead restoration plan. Report by Kier Associates to Battle Creek Working Group.

Ward, E.J., E.E. Holmes, and K.C. Balcomb. 2009. Quantifying the effects of prey limitation on killer whale reproduction. Journal of Applied Ecology 46: 632-640.

Ward, P.D., T.R. McReynolds, and C.E. Garman. 2002. Butte and Big Chico Creeks spring-run Chinook salmon, *Oncorhynchus tshawytscha* life history investigation, 2000-2001. California Department of Fish and Game, Inland Fisheries Administrative Report.

Ward, P.D., T.R. McReynolds, and C.E. Garman. 2003. Butte and Big Chico Creeks spring-run Chinook salmon, *Oncorhynchus tshawytscha* life history investigation, 2001-2002. California Department of Fish and Game, Inland Fisheries Administrative Report.

WDFW (Washington Department of Fish and Wildlife). 1996. Fish Health Manual. Fish Health Division, Hatcheries Program. Washington Department of Fish and Wildlife, Olympia, Washington.

WDFW and Washington Treaty Indian Tribes. 1998. Salmonid Disease Control Policy of the Fisheries Co-Managers of Washington State. Olympia, Washington.

Waters, T.F. 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society Monograph 7.

Weber, Edward D., and Kurt D. Fausch. 2005. Competition between Hatchery-Reared and Wild Juvenile Chinook Salmon in Enclosures in the Sacramento River, California. Transactions of the American Fisheries Society 134: 44-58.

Weitkamp, L., and K. Neely. 2002. Coho salmon (Oncorhynchus kisutch) ocean migration patterns: insight from marine coded-wire tag recoveries. Canadian Journal of Fishery and Aquatic Sciences. 59: 1100-1115.

Welch, D.W., Y. Ishida, and K. Nagasawa. 1998. Thermal limits and ocean migrations of sockeye salmon (*Oncorhynchus nerka*): long-term consequences of global warming. Canadian Journal of Fisheries and Aquatic Sciences 55: 937-948.

Wells, B.K. and M.S. Mohr. 2008. Characterization of 2005-2008 central California ocean conditions. NMFS Southwest Fisheries Science Center, Fisheries Ecology Division. White paper. November 26. 3 pages.

Wells, B. K., C. B. Grimes, J. C. Field and C. S. Reiss. 2006. Covariation between the average lengths of mature coho (Oncorhynchus kisutch) and Chinook salmon (O. tshawytscha) and the ocean environment. Fisheries Oceanography 15:1, 67–79.

Wells, B.K., C.B. Grimes, J.G. Sneva, S. McPherson, and J.B. Waldvogel. 2008. Relationships between oceanic conditions and growth of Chinook salmon (*Oncorhynchus tshawytscha*) from California, Washington, and Alaska, USA. Fisheries Oceanography 17: 101-125.

Werner, I., J. Linares-Casenave, J.P. Van Eenennaam, and S.I. Doroshov. 2007. The effect of temperature stress on development and heat-shock protein expression in larval green sturgeon (*Acipenser medirostris*). Environmental Biology of Fishes 79:191-200.

White, J.R., P.S. Hoffmann, K.A.F. Urquhart, D. Hammond, and S. Baumgartner. 1989. Selenium Verification Study, 1987-1988. A Report to the California State Water Resources Control Board from the CDFG, April 1989.

Whitton, K. S., J. M. Newton, and M. R. Brown. 2007. Juvenile salmonid monitoring in Battle Creek, California, October 2005 through September 2006. U.S. Fish and Wildlife USFWS Report. U.S. Fish and Wildlife USFWS, Red Bluff Fish and Wildlife Office, Red Bluff, California.

WLCTRT. 2006. Revised Viability Criteria for Salmon and Steelhead in the Willamette and Lower Columbia Basins. Review Draft April 1, 2006. Available at: http://www.nwfsc.noaa.gov/trt/viability_report_revised.cfm (accessed September 15, 2006).

Williams, I.V. and D.F. Amend. 1976. A natural epizootic of Infectious Hematopoietic Necrosis in fry of sockeye salmon (Oncorhynchus nerka) at Chilko Lake, British Columbia. J. Fish. Res. Board Can. 33:1564-1567.

Williams, J.G. 2006. Central Valley salmon: a perspective on Chinook salmon and steelhead in the Central Valley of California. San Francisco Estuary and Watershed Science 4(3): Article 2. 416 pages. Available at: http://repositories.cdlib.org/jmie/sfews/vol4/iss3/art2.

Williams, R., D.E. Bain, J.C. Smith, and D. Lusseau. 2009. Effects of vessels on behaviour patterns of individual southern resident killer whales (*Orcinus orca*). Endangered Species Research 6: 199-209.

Williams, R., A.W. Trites, and D.E. Bain. 2002a. Behavioural responses of killer whales (*Orcinus orca*) to whale-watching boats: opportunistic observations and experimental approaches. Journal of Zoology (London) 256: 255-270.

Williams, R., D.E. Bain, J.K.B. Ford, and A.W. Trites. 2002b. Behavioural responses of male killer whales to a 'leapfrogging' vessel. Journal of Cetacean Research and Management 4: 305-310.

Winship, A.J., and A.W. Trites. 2003. Prey consumption of Steller sea lions (*Eumetopias jubatus*) off Alaska: How much prey do they require? Fishery Bulletin 101(1): 147-167.

Withler, R.E. 1988. Genetic consequences of fertilizing chinook salmon (Oncorhynchus tshawytscha) eggs with pooled milt. Aquaculture 68:15-25.

Wright, D.A. and D.J. Phillips. 1988. Chesapeake and San Francisco Bays: A study in contrasts and parallels. Marine Pollution Bulletin 19 (9): 405-413.

Ylitalo, G. M., C. O. Matkin, J. Buzitis, M. M. Krahn, L. L. Jones, T. Rowles, and J. E. Stein. 2001. Influence of life-history parameters on organochlorine concentrations in free-ranging killer whales (*Orcinus orca*) from Prince William Sound, AK. Science of the Total Environment 281: 183-203.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 1996. Historical and present distribution of Chinook salmon in the Central Valley drainage of California. Sierra Nevada Ecosystem Project: final report to Congress. *In* Assessments, commissioned reports, and background information, volume 3, pages 309-362. University of California, Center for Water and Wildland Resources, Davis, California.

Yoshiyama, R. M., F. W. Fisher, and P. B. Moyle. 1998. Historical abundance and decline of Chinook salmon in the Central Valley Region of California. North American Journal of Fisheries Management 18:487-521.

Zhu, T., M. W. Jenkins, and J. R. Lund. 2005. Estimated impacts of climate warming on California water availability under twelve future climate scenarios. J. Am. Water Res. Assoc. 41: 1027-1038.

Zimmerman, C.E., G.W. Edwards, and K. Perry. 2009. Maternal origin and migratory history of *Oncorhynchus mykiss* captured in rivers of the Central Valley, California. Transactions of the American Fisheries Society. 138:280-291.

Federal Register Cited

54 FR 32085. August 4, 1989. National Marine Fisheries Service. 1989. Endangered and Threatened species; Critical Habitat; Winter-run Chinook Salmon: Emergency interim rule. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register*, Volume 58 pages 32085-32088.

55 FR 10260. March 20, 1990. Endangered and Threatened species; Winter-run Chinook Salmon: Proposed rule. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register*, Volume 58 pages 10260-10267.

55 FR 46515. November 5, 1990. Final Rule: Endangered and Threatened Species; Sacramento River Winter-run Chinook Salmon. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register*, Volume 58 pages 46515-46523.

58 FR 33212. June 16, 1993. Final Rule: Endangered and Threatened Species: Designated Critical Habitat; Sacramento River winter-run Chinook salmon. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register*, Volume 58 pages 33212-33219.

59 FR 440. January 4, 1994. Final Rule: Endangered and Threatened Species; Status of Sacramento River Winter-run Chinook Salmon. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register*, Volume 59 pages 440-450.

63 FR 13347. March 19, 1998. Final Rule: Notice of Determination. Endangered and Threatened Species: Threatened Status for Two ESUs of Steel head in Washington, Oregon, and California. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register*, Volume 63 pages 13347-13371.

64 FR 50394. November 15, 1999. Final Rule: Threatened Status for Two Chinook Salmon Evolutionary Significant Units in California. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register*, Volume 64 pages 50394-50415.

67 FR 1116. January 9, 2002. Final Rule: Endangered and Threatened Species; Final Rule Governing Take of Four Threatened Evolutionarily Significant Units (ESUs) of West Coast Salmonids. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register*, Volume 67 pages 1116-1133.

68 FR 31980. May 29, 2003. Regulations Governing Taking and Importing of Marine Mammals; Eastern North Pacific Southern Resident Killer Whales. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register*, Volume 68 pages 31980-31983

69 FR 33102. June 14, 2004. Proposed Rule: Endangered and Threatened Species: Proposed Listing Determinations for 27 ESUs of West Coast Salmonids. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register*, Volume 69 pages 33102-33179.

70 FR 17386. April 6, 2005. Endangered and Threatened Wildlife and Plants: Proposed Threatened Status for Southern Distinct Population Segment of North American Green Sturgeon. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register*, 70 pages 17386-17401.

70 FR 37160-37204. June 28, 2005. Final Rule: Endangered and Threatened Species: Final Listing Determinations for 16 ESUs of West Coast Salmon, and Final 4(d) Protective Regulations for Threatened Salmonid ESUs Designation of Critical Habitat for Seven

Evolutionarily Significant Units of Pacific Salmon and Steelhead in California. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register*, Volume 70 pages 37160-37204.

70 FR 52488. September 2, 2005. Final Rule: Endangered and Threatened Species: Designation of Critical Habitat for Seven Evolutionarily Significant Units of Pacific Salmon and Steelhead in California. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register*, Volume 70 pages 52487-52627.

70 FR 69903. November 18, 2005. Final Rule: Southern Resident killer whales (*Orcinus orca*) Endangered and Threatened Wildlife and Plants: Endangered Status for Southern Resident Killer Whales. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register*, Volume 70 pages 69903-69912.

71 FR 834. January 5, 2006. Final Rule: Endangered and Threatened Species: Final Listing Determinations for 10 Distinct Population Segments of West Coast Steelhead. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register*, Volume 71 pages 834-862.

71 FR 17757. April 7, 2006. Final Rule: Endangered and Threatened Wildlife and Plants: Threatened Status for Southern Distinct Population Segment of North American Green Sturgeon. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register*, Volume 71 pages 17757-17766.

74 FR 23822. May 21, 2009. Proposed rule: Endangered and threatened wildlife and plants: Proposed rulemaking to establish take prohibitions for the threatened Southern Distinct Population Segment of North American green sturgeon. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register*, Volume 74 pages 23822-23837.

74 FR 52300. October 9, 2009. Endangered and Threatened Wildlife and Plants: Final Rulemaking to Designate Critical Habitat for the Threatened Southern Distinct Population Segment of North American Green Sturgeon. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register*, Volume 71 pages 17757-17766.

76 FR 50447-50448. August 15, 2011. Endangered and Threatened Species; 5-Year Reviews for 5 Evolutionarily Significant Units of Pacific Salmon and 1 Distinct Population Segment of Steelhead in California.