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

In reply refer to:
2006/05823

JUN 19 2007

James N. Seiber
Director
U.S. Department of Agriculture
Pacific West Area, Western Regional Research Center
Agricultural Research Service
800 Buchanan Street
Albany, California 94710-1105

Dear Mr. Seiber:

This letter transmits NOAA's National Marine Fisheries Service's (NMFS) biological opinion (Enclosure 1) based on our review of the proposed *Egeria densa* Control Program (EDCP) 5-year (2007-2011) program of treatment in the Sacramento-San Joaquin Delta (Delta) in the State of California, and its effects on Federally listed endangered Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*), threatened Central Valley spring-run Chinook salmon (*O. tshawytscha*), threatened Central Valley steelhead (*O. mykiss*), threatened Southern distinct population segment (DPS) of North American green sturgeon (*Acipenser medirostris*), and designated critical habitat for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead in accordance with section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*). Your request for formal consultation was received on August 2, 2006. A response was sent on September 1, 2006, indicating that NMFS would require additional information from the U.S. Department of Agriculture-Agricultural Research Services (USDA-ARS) in order to initiate the consultation process. On October 13, 2006, the USDA-ARS and the California Department of Boating and Waterways (DBW) furnished the requested information in the form of an updated Biological Assessment for the new 5-year EDCP action. The DBW also furnished additional information with a priority matrix for the EDCP application sites (December 18, 2006) and an addendum to the 2001 Environmental Impact Report (December 21, 2006).

This biological opinion is based in part on information provided from the annual reports for the EDCP from 2003 through 2006; the October 13, 2006, biological assessment for the 2007 through 2011 action; the supplemental information contained in the December 18, and 21, 2006, documents; and a November 9, 2006, meeting between staff from NMFS and the USDA-ARS. A complete administrative record of this consultation is on file at the Sacramento, California, Area Office of NMFS.

Based on the best available scientific and commercial information, the biological opinion concludes that the 5-year EDCP, as proposed by the USDA-ARS and DBW, is not likely to jeopardize the continued existence of the listed species or adversely modify designated critical habitat. NMFS also has included an incidental take statement with reasonable and prudent measures and non-discretionary terms and conditions that are necessary and appropriate to avoid, minimize, and/or monitor incidental take associated with the project. The listing of the Southern DPS of North American green sturgeon became effective on July 7, 2006, and some or all of the ESA section 9(a) prohibitions against take will become effective upon the future issuance of protective regulations under section 4(d). Because this biological opinion extends through the 2011 application season, green sturgeon are discussed in the incidental take statement, although prohibitions on take are not enforceable until the section 4(d) rule is published and takes effect. NMFS believes this will occur prior to the end of the current 5-year opinion.

NMFS's essential fish habitat (EFH) conservation recommendations for Pacific salmon (*O. tshawytscha*), starry flounder (*Platichthys stellatus*), and English sole (*Parophrys vetulus*), as required by the Magnuson-Stevens Fishery Conservation and Management Act (MSA), as amended (16 U.S.C. 1801 *et seq.*), are attached for your reference (Enclosure 2). This document concludes that the EDCP will adversely affect the EFH of Pacific salmon, starry flounder, and English sole in the action area and adopts certain terms and conditions of the incidental take statement of the biological opinion as the EFH conservation recommendations.

USDA-ARS has a statutory requirement under section 305(b)(4)(B) of the MSA to submit a detailed response in writing to NMFS within 30 days of receipt of these conservation recommendations that includes a description of the measures proposed for avoiding, mitigating, or offsetting the impact of the activity on EFH (50 CFR 600.920 [j]). If unable to complete a final response within 30 days, the USDA-ARS should provide an interim written response within 30 days before submitting its final response.

Please contact Mr. Jeffrey Stuart in our Sacramento Area Office at (916) 930-3607 or via e-mail at J.Stuart@noaa.gov if you have any questions regarding this response or require additional information.

Sincerely,

for Rodney R. McInnis
Regional Administrator

Enclosures (2)

cc: Copy to File: ARN151422SWR2005SA00683
NOAA Fisheries-PRD, Long Beach, CA
USDA-ARS, Lars Anderson, Weed Science Program, UC-Davis - One Shields Avenue, Davis, CA 95616

DBW, Marcia Carlock, 2000 Evergreen Street, Suite 100, Sacramento, CA 95815
U.S. Fish and Wildlife Service, Ryan Olah, 2800 Cottage Way, Suite W-2605, Sacramento, CA 95825
California Department of Fish and Game, Central Valley Bay Delta Branch, 4001 North Wilson Way, Stockton, CA 94205
California Regional Water Quality Control Board, Emily Alejandro, 3443 Routier Road, Suite A, Sacramento, CA 95827

Enclosure 1

BIOLOGICAL AND CONFERENCE OPINION

ACTION AGENCY: U.S. Department of Agriculture-Agricultural Research Service

ACTIVITY: *Egeria densa* Control Program (2007 to 2011)

CONSULTATION CONDUCTED BY: Southwest Region, National Marine Fisheries Service

FILE NUMBER: 151422SWR2005SA00683:JSS

I. CONSULTATION HISTORY

Previous consultations by NOAA's National Marine Fisheries Service (NMFS) addressing the effects of the *Egeria densa* Control Program (EDCP) on listed salmonids resulted in the issuance of biological opinions on July 23, 2001, July 3, 2002, and August 11, 2003. These biological opinions respectively concluded that the EDCP was not likely to jeopardize the continued existence of Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*), Central Valley spring-run Chinook salmon (*O. tshawytscha*), and Central Valley steelhead (*O. mykiss*), or adversely modify designated critical habitat for the 2001, 2002, and 2003 through 2005 application seasons.

On September 14, 2005, NMFS received the U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS) request for initiation of formal section 7 consultation under the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*) for the EDCP covering application seasons 2006 through 2010.

On September 28, 2005, a meeting was held at NMFS' Sacramento office between staff from the USDA-ARS, the California Department of Boating and Waterways (DBW) and NMFS to discuss the EDCP consultation and the necessary information to be included in the project's biological assessment (BA). At this meeting it was decided that USDA-ARS and the DBW would request a 1-year extension of the existing EDCP.

On October 24, 2005, NMFS received a written request from the USDA-ARS withdrawing the original request for section 7 consultation concerning a new 5-year application period, and instead requesting formal section 7 consultation regarding a 1-year extension of the EDCP via an amendment to the standing biological opinion for application seasons 2003 to 2005. Due to the recent designation of critical habitat for Central Valley spring-run Chinook salmon and Central Valley steelhead, and the proposed listing as threatened of the Southern Distinct Population Segment (DPS) of North American green sturgeon (*Ascipenser medirostris*), NMFS reissued the biological opinion (dated April 18, 2006) in its entirety with new critical habitat analyses in conjunction with a conference opinion assessing the effects of the EDCP on green sturgeon.

On November 4, 2005, a second meeting was held at NMFS' Sacramento office between staff from the aforementioned agencies to discuss the progress of the consultation.

On April 18, 2006, a 1-year extension to the 2003 to 2005 Biological Opinion for the EDCP was issued by NMFS to the USDA-ARS and DBW.

On August 2, 2006, NMFS received a request from the USDA-ARS to initiate formal section 7 consultation under the ESA for the EDCP covering application years 2007 to 2011.

On September 1, 2006, NMFS responded to the USDA-ARS with a request for additional information necessary to complete consultation on the 2007-2011 EDCP.

On October 13, 2006, the applicant (DBW) submitted a BA for the new 5-year EDCP (DBW 2006a) in response to NMFS' September 1, 2006, letter.

On November 9, 2006, a meeting between staff from the DBW, USDA-ARS, and NMFS took place to discuss the new BA and the program's objectives over the next 5-years. NMFS requested that the applicant, DBW, develop a priority matrix for the 73 application sites it proposed in the new BA.

On November 20, 2006, NMFS responded to the submitted BA and confirmed that sufficient information had been provided by the applicant and the Federal nexus to initiate consultation.

On December 18, 2006, the DBW submitted a priority matrix to NMFS as requested in the November 9, 2006, meeting.

On December 21, 2006, NMFS received an *Egeria densa* Control Program Second Addendum to the 2001 Environmental Impact Report with Five-Year Program Review and Future Operations Plan (DBW 2006b).

II. DESCRIPTION OF THE PROPOSED ACTION

The USDA-ARS has requested formal section 7 consultation pursuant to the ESA in order to implement the EDCP for an additional 5-year period (2007-2011). The Federal nexus for this activity is the USDA-ARS, which has the responsibility to conduct research and provide technical input into the control of nuisance weeds and agricultural pests. The EDCP is an aquatic weed control program that treats *Egeria densa* infestations primarily within the geographic boundaries of the legal Sacramento-San Joaquin Delta (Delta) (see Figure 1). The USDA-ARS has previously consulted with NMFS under section 7 of the ESA for the EDCP and NMFS has issued biological opinions for the program in 2001, 2002, 2003-2005, and 2006. The program, as currently proposed, will apply two different U.S. Environmental Protection Agency (EPA) registered aquatic herbicides Reward ® and Sonar ® (DBW 2006a) to the waterways of the Delta to control the non-native invasive plant, *Egeria densa*.

The USDA-ARS has contracted with the DBW to implement the control program and to conduct research activities in association with the EDCP while providing oversight during the program's implementation.

A. Project Activities

1. Treatment Sites and Herbicides

The DBW is the State lead for this project, with whom the USDA-ARS has contracted to conduct the application of the program. The proposed EDCP treatment methods for DBW to utilize in the Delta include:

1. Reward® (active ingredient [a.i.] diquat dibromide [diquat], EPA Registration Number 10182-404)

2. Sonar®, three formulations which have been identified for the program:

   Sonar® A.S. (aqueous solution of a.i. fluridone, EPA Registration Number 67690-4

   Sonar® PR ([precision release – a slowly releasing pellet] granular formulation of a.i. fluridone, EPA Registration No. 67690-12)

   Sonar® Q ([a slightly faster releasing pellet than the PR formulation] granular formulation of a.i. fluridone, EPA Registration Number 67690-3)

The EDCP has elected to eliminate both mechanical harvesting of *Egeria densa* and the use of Sonar ® slow release pellets (SRP) in the currently proposed 5-year program. The USDA-ARS has determined that mechanical harvesting of the aquatic weed is too costly for the environmental situation found in the Delta. Increased fragmentation of the aquatic weed due to the mechanical harvesting process is believed to exacerbate the spread of the plant in the Delta. Furthermore, the logistical problems of water currents, winds, and tidal flows in the Delta hinder the efficient implementation of the mechanical harvesting procedure. In addition, the USDA-ARS has elected to remove the use of Sonar ® SRP from their suite of aquatic herbicides due to its perceived inferior release characteristics in the Delta environment.

In the initial 2001 project description, the DBW identified a total of 70 sites in the Delta to be treated for *Egeria densa* infestations. Of these 70 sites, 35 sites were considered as high priority sites. The sites were chosen based on the level of infestation and impacts to navigation in the Delta (see Appendix A Table 1 [attached]). Between 2001 and 2006, the DBW treated 20 of these 35 sites (DBW 2006a). For the currently proposed EDCP (2007-2011), the DBW has proposed significant changes to the former project description. The number of project treatment sites has been increased to 73 total sites in the project area (see Appendix A Table 2 [attached]). This expanded number includes the original 70 sites in the 2001 project descriptions and the following alterations:

- Delete two previous sites

- Site 31 – Bacon Island (will be included with the Middle River – Jones Tract site)
  - Site 32 – Paradise Cut (considered non-navigable by DBW)
- Add five additional sites
  - Site 69 – Decker Island / Horseshoe Bend
  - Site 70 – Stone Lakes
  - Site 71 – Mokelumne River/ Cosumnes River (New Hope Landing area)
  - Site 72 – Georgianna Slough Ox Bow
  - Site 73 – Santa Clara Shoal
- Rename one site
  - Site 41 – formerly called Indian Slough, renamed as Indian Slough Discovery Bay area

2. Application Schedules and Methods

The DBW indicated in their project description for the 2007-2011 EDCP (DBW 2006a) their intent to treat any of the 73 listed areas starting April 1 of the treatment season. This region wide early start date is a result of the adaptive management approach to the current program's application timing and perceived efficacy of methodologies implemented through 2006. The future EDCP intends to use the following approaches in administering the program (DBW 2006a):

- *Focus treatments at sites where regulatory agencies allow earlier start dates.* The DBW and USDA-ARS seek approval to start treatments at all program sites on April 1 of each year with Sonar® herbicides. The DBW has developed a treatment priority matrix for NMFS to utilize in determining the earlier start sites in the program's action area (see Appendix A Table 3 [attached]).
- *Plan treatment methods to coincide with optimal water quality or hydrologic conditions present in the Delta.* The EDCP anticipates using a more scientific approach to applying treatment herbicides based on specific water quality parameters (such as turbidity and salinity) and hydrologic conditions (tidal stages and flows) than has previously occurred in the program.
- *Base annual treatments at a site on prior efficacy results.* The EDCP will use end of year efficacy measurements to determine whether a given site will be treated in the following year. Sites with high control efficacy may be skipped the following year according to ongoing maintenance program strategy.
- *Consider treating only the largest site(s) in a given year.* With oversight by regulatory agencies, the EDCP may apply treatments to a single, focused, large scale site, such as Franks Tract, in the Delta.
- *Plan regional treatment efforts to maximize efficacy in a given Delta area.* In contrast to the current, dispersed multiple site treatment approach in the Delta, the EDCP may consider treating only a specified area during a given year to maximize treatment efforts and enhance efficacy of the program in that specific area.
- *Deemphasize treating sites that are determined not to be critical to navigation or boating activities.* The EDCP may elect to stop treating heavily infested sites that are not essential to navigation and are considered not to be nursery sites for *Egeria densa*.

- *Utilize sequential treatments where efficacy is improved without changes to potential environmental impacts.* The EDCP will continue to experiment with "sequential" herbicide applications to increase the efficacy of the control program. The design of application protocols will follow all applicable labeling and permit guidelines pertaining to the program.
- *Compare the results of the manufacturer's proprietary "FasTest" monitoring assay at each site with the removal efficacy of Egeria densa to determine optimal Sonar® application concentrations throughout the treatment cycle.* The program will measure the efficacy of weed control as correlated to weekly Sonar® concentrations (as measured by the FasTest procedure). The EDCP will compare time-series concentrations of Sonar® with site efficacy to optimize the treatment protocol at each specific site.
- *Utilize combinations of Sonar® AS, Sonar® PR, and Sonar® Q to maximize application concentrations throughout the treatment cycle.* The EDCP intends to utilize the slower releasing Sonar® PR or Q formulations on a monthly basis, interspersed with weekly or biweekly booster applications of Sonar® AS to maintain an acceptable fluridone concentration in the waters of the treatment site.
- *Test the effectiveness of the Sonar® Q formulation in comparison to the currently used Sonar® PR formulation.* The EDCP will test the efficacy of the Sonar® Q formulation against that of the currently used Sonar® PR formulation in the field. Should the "Q" formulation prove to be more efficacious than the "PR" formulation, then the EDCP may consider revising its application protocols to use a greater amount of the "Q" formulation in the program.

3. <u>Treatment Frequencies and Duration of Applications</u>

a. *Sonar Formulations*

Applications of the Sonar® herbicides are typically made from small boats operated by a two-man field operation crew. Each crew comprises a specialist and a technician. Each field operation crew has access to two vessels, an airboat and a utility work boat. The EDCP, as of 2005, operates 12 boats and 6 field operation crews (DBW 2006b).

The herbicide is dispensed into the water via one of two ways. For the aqueous herbicide formulation (Sonar® AS), the material is dispensed through an injection hose that disperses the herbicide below the surface of the water. For pelleted formulations of the Sonar® product line (PR and Q) the boats are equipped with a broadcast spreader which sprays the pellets out over the water surface within the treatment area. Applications are typically made over a 6- to 8-week treatment period. Sonar® applications are most effective when the fluridone concentration in the water column is maintained between 15 and 40 parts per billion (ppb) for a minimum period of 45 days. For the aqueous formulation, recommended fluridone water column concentrations are targeted to be between 10 and 30 ppb, with the most common concentration being 15 ppb. The pelleted formulations have a higher target concentration ranging between 25 and 75 ppb in the water column, with the most commonly achieved level being 50 ppb.

Over the previous 5 treatment years (2001 to 2005), the EDCP has used a wide range of application schedules to achieve the desired water column concentrations during the treatment period. These application schedules have included the following (DBW 2006a):

1. Twice per week Sonar® AS applications (2003, 2004, 2005)
2. Constant Sonar® PR application rates throughout the treatment period (2001, 2002)
3. Higher Sonar® PR application rates in the first half of the treatment period followed by reduced rates in the second half of the treatment period (2002)
4. Tiered application rates of Sonar® PR which included two applications at a higher rate in the early portion of the treatment period followed by two applications at a lower rate in the later stages of the treatment period (starting in 2003)
5. Steadily reducing the application rates for Sonar® PR over the course of the treatment period (starting in 2003)
6. Combinations of Sonar® PR and Sonar® AS with:
    a. Constant application rates of Sonar® AS on a weekly basis, and constant application rates of Sonar® PR on a biweekly basis (2002)
    b. Constant application rates of Sonar® AS, on a twice per week basis, and a constant application rate of Sonar® PR on a biweekly basis (2004)
    c. Constant application rates of Sonar® AS, on a twice weekly basis, and a tiered application rate of Sonar® PR (higher to lower) on a biweekly basis (2004, 2005)
    d. Constant application rates of Sonar AS, on a twice per week basis, and two applications of Sonar® PR spread out evenly over the treatment period (2005)
    e. Increasing application rates of Sonar® AS over the treatment period with two applications of Sonar® PR spread out evenly over the treatment period (2005)
    f. Tiered application rates of Sonar® PR on a biweekly basis (higher to lower) followed by a single Sonar® AS application at the middle or end of the treatment period (2005).

The EDCP therefore has established 11 different application protocols over the past 5 years of treatment. EDCP staff currently believe that the most efficacious treatment protocol is one that utilizes the pelleted formulations to establish a baseline water column concentration of fluridone in the treatment area and subsequently uses the aqueous formulation of Sonar® to "bump up" the fluridone water column concentration with biweekly or weekly applications. The water column concentration of fluridone is routinely monitored by using the proprietary "FasTest" analysis of the herbicide manufacturer. Measured fluridone levels in the treatment area are used to adjust application rates accordingly in the application area.

b. Diquat

The EDCP typically applies diquat dibromide (Reward®) on a once or twice yearly basis at any given site. An aqueous solution of the herbicide is applied by subsurface draglines or hoses towed by the applicator's boat. Due to the depletion of oxygen in the surrounding water column following decomposition of the treated plants, applications are limited in size to allow zones of passage for fish and other aquatic animals. Diquat is applied at a target rate of 370 ppb. Within a given treatment site, Reward® applications for the control of *Egeria densa* may be applied at 14-day intervals, as needed, to ensure control of missed plants and regrowth. Because only one third to one half of the water body area may be treated at one time as per Reward® label requirements, sequential spraying of different sections of the larger site are needed to ensure complete coverage of the treatment site.

B. Proposed Conservation Measures

DBW is obliged to follow the California Department of Pesticide Regulation (DPR) procedures for pesticide application, and to file a Notice of Intent (NOI) with the County Agricultural Commissioner of each county where they will be spraying. DBW staff will perform maintenance protocols that will minimize the chance of a potential chemical spill and adopt response plans that have been developed to contain chemical spills on land and in the water. In the event of an EDCP chemical herbicide spill, the California Department of Fish and Game (CDFG), the County Agricultural Commissioners (CAC), the California Regional Water Quality Board – Central Valley (Regional Board), the Office of Emergency Services, and if applicable, the California Highway Patrol, County Health Departments, and the County Sheriff's Office will all be notified as needed.

In addition, DBW is required to adhere to the water quality monitoring protocols approved by the Regional Board per the criteria set forth in the National Pollution Discharge Elimination System (NPDES) General Permit. The General Permit does not specify numeric limits for water quality criteria, but rather gives narrative guidelines for dischargers to follow. The General Permit allows for temporary excursions above the numeric criteria listed in the California Toxics Rule (CTR) and EPA water quality criteria, as long as full restoration of water quality and beneficial uses of the receiving waters are returned to pre-treatment levels following completion of the action. However, DBW anticipates following both the EPA aquatic species toxicity limits and drinking water standards that follow:

- Reward® - the maximum labeled rate for water column concentration (*i.e.*, aquatic species toxicity limit) is 370 ppb. The EPA drinking water concentration standard (Maximum Contaminant Level [MCL]) is 20 ppb. The DBW anticipates treating within the labeled rates the day of treatment and returning to EPA criteria within 24 hours after treatment.

- Sonar® - Application rates will be targeted to achieve a water column concentration of 10-40 ppb for a minimum of 45 days for maximum herbicidal efficacy. This concentration is below the drinking water standards set by the EPA of 150 ppb. Currently, there is not an aquatic species toxicity criterion for fluridone.

DBW also has Memoranda of Understanding with regional water agencies outlining additional application restrictions relating to drinking water intakes. Prior to any work within close proximity of drinking water intakes, DBW will develop a protocol for sampling post-treatment chemical residue around the intakes. Currently, label recommendations for Sonar® applications are allowed within one quarter mile of a potable water intake as long as individual applications do not exceed 20 ppb or exceed 150 ppb for the entire treatment season. Reward® concentration cannot exceed 20 ppb in drinking water.

As a requirement of the General Permit, the DBW will follow monitoring protocol terms imposed by the Regional Board. The general goals of the monitoring plan are to:

1. Document compliance with the requirements of the General Permit;

2. Support the development, implementation, and effectiveness of the implementation of Best Management Procedures (BMPs);

3. Demonstrate the full recovery of water quality and protection of beneficial uses of the receiving waters following completion of resource or pest management projects;

4. Identify and characterize aquatic pesticide application projects conducted by the DBW; and

5. Monitor all pesticides and application methods used by the DBW.

The monitoring program includes a daily log of site-specific information (*e.g.*, location, wind, chemicals used, location of listed species/species habitat), and pre- and post-treatment measurements of variables such as dissolved oxygen (DO) level, water temperature, turbidity, *Egeria* biomass and fragments, and chemical residues and toxicity. Three times each year, monitoring will be initiated at two sites in each of the four water categories (tidal, slow-moving, fast-flowing, dead-end slough) for each of the chemicals applied. Each chemical used in the EDCP will be subject to water quality and toxicity monitoring at least once each year. Other monitoring protocols relevant to listed salmonid species include recording field observations for any dead fish or native vegetation; visual assessment of water quality and photo documentation of native vegetation pre- and post-chemical control applications. The EDCP field operation crews are trained in fish species identification and recognition of fish habitat in the Delta and associated waterways by the DBW environmental scientist assigned to the program.

C. Action Area

The project action area is the Sacramento-San Joaquin Delta region, an area of approximately 738,000 acres which is interlaced with hundreds of miles of waterways. The Delta is roughly bordered by the cities of Sacramento, Stockton, Tracy, and Pittsburgh. The Delta region also includes the cities of Antioch, Brentwood, Discovery Bay, Isleton, and about 14 unincorporated towns and villages. The Delta extends north to the I Street Bridge in Sacramento, west to the Suisun Marsh Salinity Control Gates near Pittsburgh, south to the junction of Highway 5 and 205 near Tracy, and east to the Port of Stockton (Appendix B Figure 1 [attached]). Within this region, DBW has designated 73 sites (see Appendix A Table 2 and Appendix B Figure 2 [attached]) which encompass nearly 5,000 acres of infested waterways. DBW has proposed that any of these designated sites could be treated within an application season, starting as early as April 1st of the application season.

III. STATUS OF THE SPECIES AND CRITICAL HABITAT

The following Federally listed and proposed species (Evolutionarily Significant Units [ESUs] or Distinct Population Segments [DPSs]) and designated critical habitat occurs in the action area and may be affected by the proposed project:

Sacramento River winter-run Chinook salmon ESU
Listed as endangered (70 FR 37160, June 28, 2005), see also (58 FR 33212, June 16, 1993 – critical habitat)

Central Valley spring-run Chinook salmon ESU
Listed as threatened (70 FR 37160, June 28, 2005), see also (70 FR 52488, September 2, 2005 - critical habitat)

Central Valley steelhead DPS
Listed as threatened (71 FR 834, January 5, 2006) see also (70 FR 52488, September 2, 2005 – critical habitat)

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

A. Species and Critical Habitat Listing Status

NMFS has recently completed an updated status review of 16 salmon ESUs, including Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon, and concluded that the species' status should remain as previously listed (70 FR 37160). On January 5, 2006, NMFS published a final listing determination for ten steelhead DPSs, including Central Valley steelhead. The new listing concludes that Central Valley steelhead will remain listed as threatened (71 FR 834).

Sacramento River winter-run Chinook salmon originally were listed as threatened in August 1989, under emergency provisions of the ESA, and formally listed as threatened in November 1990 (55 FR 46515). The ESU consists of only one population that is confined to the upper Sacramento River in California's Central Valley. The Livingston Stone National Fish Hatchery population has been included in the listed Sacramento River winter-run Chinook salmon population as of June 28, 2005 (70 FR 37160). NMFS designated critical habitat for winter-run Chinook salmon on June 16, 1993 (58 FR 33212). The ESU was reclassified as endangered on January 4, 1994 (59 FR 440), due to increased variability of run sizes, expected weak returns as a result of two small year classes in 1991 and 1993, and a 99 percent decline between 1966 and 1991. Critical habitat was delineated as the Sacramento River from Keswick Dam (river mile [RM] 302) to Chipps Island (RM 0) at the westward margin of the Delta, including Kimball Island, Winter Island, and Brown's Island; all waters from Chipps Island westward to the Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and the Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge, and all waters of San Francisco Bay north of the San Francisco-Oakland Bay Bridge. The critical habitat designation identifies those physical and biological features of the habitat that are essential to the conservation of the species and that may require special management consideration and protection. Within the Sacramento River this includes the river water, river bottom (including those areas and associated gravel used by winter-run Chinook salmon as spawning substrate), and adjacent riparian zone used by fry and juveniles for rearing. In the areas west of Chipps Island, including San Francisco Bay to the Golden Gate Bridge, this designation includes the estuarine water column, essential foraging habitat, and food resources utilized by winter-run Chinook salmon as part of their juvenile outmigration or adult spawning migrations. As governed by the critical habitat definition for winter-run Chinook salmon, critical habitat occurs within the project area, pertaining to the reaches of the Sacramento River within the legal Delta adjacent to Sherman and Decker Islands and the waters of the San Joaquin River surrounding Kimball, Winter, and Brown's Islands.

Central Valley spring-run Chinook salmon were listed as threatened on September 16, 1999 (50 FR 50394). This ESU consists of spring-run Chinook salmon occurring in the Sacramento River basin. The Feather River Hatchery (FRH) spring-run Chinook salmon population has been included as part of the Central Valley spring-run Chinook salmon ESU as of June 28, 2005 (70 FR 37160). Critical habitat was designated for spring-run Chinook salmon in the Central Valley on September 2, 2005 (70 FR 52488). The project area includes designated critical habitat along the Sacramento River reaches adjacent to Sherman and Decker Islands.

Central Valley steelhead were listed as threatened under the ESA on March 19, 1998 (63 FR 13347). This DPS consists of steelhead populations in the Sacramento and San Joaquin River (inclusive of and downstream of the Merced River) basins in California's Central Valley. The Coleman National Fish Hatchery and FRH steelhead populations have been included in the listed population of steelhead as of January 5, 2006 (71 FR 834). These populations were previously included in the DPS but were not deemed essential for conservation and thus not part of the listed steelhead population. Critical habitat was designated for steelhead in the Central Valley on September 2, 2005 (70 FR 52488). Critical habitat includes the stream channels to the ordinary high water line within designated stream reaches such as those of the American, Feather, and Yuba Rivers, and Deer, Mill, Battle, Antelope, and Clear Creeks in the Sacramento River basin; the Calaveras, Mokelumne, Stanislaus, and Tuolumne Rivers in the San Joaquin River basin; and, the Sacramento and San Joaquin Rivers and Delta. The project site is located within the San Joaquin Delta, which is included within the critical habitat designation for Central Valley steelhead.

The Southern DPS of North American green sturgeon was proposed for listing as threatened on April 6, 2005 (70 FR 17386) and listed as threatened on April 7, 2006 (71 FR 17757). The southern DPS presently contains only a single spawning population in the Sacramento River, and rearing individuals may occur in the action area. No critical habitat has been designated or proposed for the Southern DPS of North American green sturgeon.

B. Species Life History and Population Dynamics

1. Chinook Salmon

a. *General Life History*

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

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

During their upstream migration, adult Chinook salmon require streamflows sufficient to provide olfactory and other orientation cues used to locate their natal streams. Adequate streamflows are necessary to allow adult passage to upstream holding habitat. The preferred temperature range for upstream migration is 38 °F to 56 °F (Bell 1991, CDFG 1998). Adult winter-run Chinook salmon enter San Francisco Bay from November through June (Hallock and Fisher 1985) and migrate past 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. Adult spring-run Chinook salmon enter the Delta from the Pacific Ocean beginning in January and enter natal streams from March to July (Myers *et al.* 1998). In Mill Creek, Van Woert (1964) noted that of 18,290 spring-run Chinook salmon observed from 1953 to 1963, 93.5 percent were counted between April 1 and July 14, and 89.3 percent were counted between April 29 and June 30. 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.

Spawning Chinook salmon require clean, loose gravel in swift, relatively shallow riffles or along the margins of deeper runs, and suitable water temperatures, depths, and velocities for redd construction and adequate oxygenation of incubating eggs. Chinook salmon spawning typically occurs in gravel beds that are located at the tails of holding pools (USFWS 1995). The range of water depths and velocities in spawning beds that Chinook salmon find acceptable is very broad. Bell (1991) identifies the preferred water temperature for adult spring-run Chinook salmon migration as 38 °F to 56 °F. Boles (1988) recommends water temperatures below 65 °F for adult Chinook salmon migration, and Lindley *et al.* (2004) report that adult migration is blocked when temperatures reach 70 °F, and that fish can become stressed as temperatures approach 70 °F. The Bureau of Reclamation (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. The upper preferred water temperature for spawning Chinook salmon is 55 °F to 57 °F (Chambers 1956, Bjornn and Reiser 1991). Winter-run Chinook salmon spawning occurs primarily from mid-April to mid-August, with the peak activity occurring in May and June in the Sacramento River reach between Keswick dam and RBDD (Vogel and Marine 1991). The majority of winter-run Chinook salmon spawners are 3 years old. Physical Habitat Simulation Model (PHABSIM) results (USFWS 2003) indicate winter-run Chinook salmon suitable spawning velocities in the upper Sacramento River are between 1.54 feet per second (fps) and 4.10 fps, and suitable spawning substrates are between 1 and 5 inches in diameter. Initial habitat suitability curves (HSCs) show spawning suitability rapidly decreases for water depths greater than 3.13 feet (USFWS 2003). 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). PHABSIM results indicate spring-run Chinook salmon suitable spawning velocities in Butte Creek are between 0.8 fps and 3.22 fps, and suitable spawning substrates are between 1 and 5 inches in diameter (USFWS 2004). The initial HSC showed suitability rapidly decreasing for depths greater than 1.0 feet, but this effect was most likely due to the low availability of deeper water in Butte Creek with suitable velocities and substrates rather than a selection by spring-run Chinook salmon of only shallow depths for spawning (USFWS 2004).

The optimal water temperature for egg incubation is 44 °F to 54 °F (Rich 1997). Incubating eggs are vulnerable to adverse effects from floods, siltation, desiccation, disease, predation, poor gravel percolation, and poor water quality. Studies of Chinook salmon egg survival to hatching conducted by Shelton (1995) indicated 87 percent of fry emerged successfully from large gravel with adequate subgravel flow. The length of time required for eggs to develop and hatch is dependent on water temperature and is quite variable. Alderdice and Velsen (1978) found that the upper and lower temperatures resulting in 50 percent pre-hatch mortality were 61 °F and 37 °F, respectively, when the incubation temperature was held constant.

Winter-run Chinook salmon fry begin to emerge from the gravel in late June to early July and continue through October (Fisher 1994), with emergence occurring generally at night. Spring-run Chinook salmon fry emerge from the gravel from November to March and spend about 3 to

15 months in freshwater habitats prior to emigrating to the ocean (Kjelson *et al.* 1981). Post-emergent fry disperse to the margins of their natal stream, seeking out shallow waters with slower currents, finer sediments, and bank cover such as overhanging and submerged vegetation, root wads, and fallen woody debris, and begin feeding on small insects and crustaceans.

When juvenile Chinook salmon reach a length of 50 to 57 mm, they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures. In the mainstems of larger rivers, juveniles tend to migrate along the margins and avoid the elevated water velocities found in the thalweg of the channel. When the channel of the river is greater than 9 to 10 feet in depth, juvenile salmon tend to inhabit the surface waters (Healey 1982). Stream flow and/or turbidity increases in the upper Sacramento River basin are thought to stimulate emigration. 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 in dry years (Vogel and Marine 1991, NMFS 1997). From 1995 to 1999, all winter-run Chinook salmon outmigrating as fry passed RBDD by October, and all outmigrating pre-smolts and smolts passed RBDD by March (Martin *et al.* 2001). The emigration timing of Central Valley spring-run Chinook salmon is highly variable (CDFG 1998). Some fish may begin emigrating soon after emergence from the gravel, whereas others over summer and emigrate as yearlings with the onset of intense fall storms (CDFG 1998). The emigration period for spring-run Chinook salmon extends from November to early May, with up to 69 percent of the young-of-the-year (YOY) fish outmigrating through the lower Sacramento River and Delta during this period (CDFG 1998).

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

As Chinook salmon fry and fingerlings mature, they prefer to rear further downstream where ambient salinity may reach 1.5 to 2.5 parts per thousand (Healy 1980, 1982; Levings *et al.* 1986). Juvenile winter-run Chinook salmon occur in the Delta from October through early May based on data collected from trawls, beach seines, and salvage records at the Central Valley Project (CVP) and State Water Project (SWP) pumping facilities (CDFG 1998). The peak of listed juvenile salmon arrivals in the Delta generally occurs from January to April, but may extend into June. Upon arrival in the Delta, winter-run Chinook salmon spend the first 2 months rearing in the more upstream, freshwater portions of the Delta (Kjelson *et al.* 1981, 1982). Data from the CVP and SWP salvage records indicate that most spring-run Chinook salmon smolts are present in the Delta from mid-March through mid-May depending on flow conditions (CDFG 2000).

Within the estuarine habitat, juvenile Chinook salmon movements are dictated by the tidal cycles, following the rising tide into shallow water habitats from the deeper main channels, and returning to the main channels when the tide recedes (Levy and Northcote 1982, Levings 1982, Healey 1991). As juvenile Chinook salmon increase in length, they tend to school in the surface waters of the main and secondary channels and sloughs, following the tides into shallow water habitats to feed (Allen and Hassler 1986). In Suisun Marsh, Moyle *et al.* (1986) reported that Chinook salmon fry tend to remain close to the banks and vegetation, near protective cover, and in dead-end tidal channels. Kjelson *et al.* (1982) reported that juvenile Chinook salmon demonstrated a diel migration pattern, orienting themselves to nearshore cover and structure during the day, but moving into more open, offshore waters at night. The fish also distributed themselves vertically in relation to ambient light. During the night, juveniles were distributed randomly in the water column, but would school up during the day into the upper 3 meters of the water column. Available data indicates that juvenile Chinook salmon use Suisun Marsh extensively both as a migratory pathway and rearing area as they move downstream to the Pacific Ocean. Winter-run Chinook salmon fry remain in the estuary (Delta/Bay) until they reach a fork length of about 118 mm (*i.e.*, 5 to 10 months of age) and then begin emigrating to the ocean perhaps as early as November and continuing through May (Fisher 1994, Myers *et al.* 1998). Little is known about estuarine residence time of spring-run Chinook salmon. Juvenile Chinook salmon were found to spend about 40 days migrating through the Delta to the mouth of San Francisco Bay and grew little in length or weight until they reached the Gulf of the Farallones (MacFarlane and Norton 2002). Based on the mainly ocean-type life history observed (*i.e.*, fall-run Chinook salmon) MacFarlane and Norton (2002) concluded that unlike other salmonid populations in the Pacific Northwest, Central Valley Chinook salmon show little estuarine dependence and may benefit from expedited ocean entry. Spring-run yearlings are larger in size than fall-run yearlings and are ready to smolt upon entering the Delta; therefore, they are believed to spend little time rearing in the Delta. Tables 4 and 5 (Appendix A) illustrate the temporal occurrence of Sacramento River winter-run and Central Valley spring-run Chinook salmon in the Central Valley watersheds.

b. *Population Trend – Sacramento River Winter-run Chinook Salmon*

The distribution of winter-run Chinook salmon spawning and rearing historically was limited to the upper Sacramento River and its tributaries, where spring-fed streams allowed for spawning, egg incubation, and rearing in cold water (Slater 1963, Yoshiyama *et al.* 1998). The headwaters of the McCloud, Pit, and Little Sacramento Rivers, and Hat and Battle Creeks, historically provided clean, loose gravel; cold, well-oxygenated water; and optimal stream flows in riffle habitats for spawning and incubation. These areas also provided the cold, productive waters necessary for egg and fry development and survival, and juvenile rearing over the summer. The construction of Shasta Dam in 1943 blocked access to all of these waters except Battle Creek, which has its own impediments to upstream migration (*i.e.*, the fish weir at the Coleman National Fish Hatchery and other small hydroelectric facilities situated upstream of the weir) (Moyle *et al.* 1989, NMFS 1997, 1998). Approximately 299 miles of tributary spawning habitat in the upper

Sacramento River is now inaccessible to winter-run Chinook salmon. Yoshiyama *et al.* (2001) estimated that in 1938, the Upper Sacramento had a "potential spawning capacity" of 14,303 redds. Most components of the winter-run Chinook salmon life history (*e.g.*, spawning, incubation, freshwater rearing) have been compromised by the habitat blockage in the upper Sacramento River.

Following the construction of Shasta Dam, the number of winter-run Chinook salmon initially declined but recovered during the 1960s. The initial recovery was followed by a steady decline from 1969 through the late 1980s following the construction of the RBDD. Since 1967, the estimated adult winter-run Chinook salmon population ranged from 117,808 in 1969, to 186 in 1994 (USFWS 2001a, b; CDFG 2002b). The population declined from an average of 86,000 adults in 1967 to 1969 to only 1,900 in 1987 to 1989, and continued to remain low, with an average of 2,500 fish for the period from 1998 to 2000 (see Appendix B: Figure 3). Between the time Shasta Dam was built and the listing of winter-run Chinook salmon as endangered, major impacts to the population occurred from warm water releases from Shasta Dam, juvenile and adult passage constraints at RBDD, water exports in the southern Delta, acid mine drainage from Iron Mountain Mine, and entrainment at a large number of unscreened or poorly screened water diversions (NMFS 1997, 1998).

Population estimates in 2001 (8,224), 2002 (7,441), 2003 (8,218), 2004 (7,701), 2005 (15,730), and 2006 (17,205) show a recent increase in the escapement of winter-run Chinook salmon. The 2005 run was the highest since the listing. Winter-run Chinook salmon abundance estimates and cohort replacement rates since 1986 are shown in Table 6. The population estimates from the RBDD counts has increased since 1986 (CDFG 2004a), there is an increasing trend in the 5 year moving average (491 from 1990-1994 to 5,451 from 1999-2003); and the 5 year moving average of cohort replacement rates has increased and appears to have stabilized over the same period (Table 6).

c. *Status - Sacramento River Winter-run Chinook Salmon*

Numerous factors have contributed to the decline of winter-run Chinook salmon through degradation of spawning, rearing, and migration habitats. The primary impacts include blockage of historical habitat by Shasta and Keswick Dams, warm water releases from Shasta Dam, juvenile and adult passage constraints at RBDD, water exports in the southern Delta, heavy metal contamination from Iron Mountain Mine, high ocean harvest rates, and entrainment in a large number of unscreened or poorly screened water diversions within the Central Valley. Secondary factors include smaller water manipulation facilities and dams, loss of rearing habitat in the lower Sacramento River and Delta from levee construction, marshland reclamation, and interactions with, and predation by, and non-native species (NMFS 1997, 1998).

Since the listing of winter-run Chinook salmon, several habitat problems that led to the decline of the species have been addressed and improved through restoration and conservation actions. The impetus for initiating restoration actions stem primarily from the following: (1) ESA section 7 consultation Reasonable and Prudent Alternatives (RPAs) on temperature, flow, and operations of the CVP and SWP; (2) Regional Board decisions requiring compliance with Sacramento River

Table 6. Winter-run Chinook salmon population estimates from RBDD counts (1986 to 2001) and carcass counts (2001 to 2006), and corresponding cohort replacement rates for the years since 1986 (CDFG 2004a, Grand Tab CDFG February 2007).

Year	Population Estimate (RBDD)	5-Year Moving Average of Population Estimate	Cohort Replacement Rate	5-Year Moving Average of Cohort Replacement Rate	NMFS Calculated Juvenile Production Estimate (JPE)[a]
1986	2,596	-	-	-	
1987	2,186	-	-	-	
1988	2,885	-	-	-	
1989	696	-	0.27	-	
1990	433	1,759	0.20	-	
1991	211	1,282	0.07	-	40,100
1992	1,240	1,092	1.78	-	273,100
1993	387	593	0.90	0.64	90,500
1994	186	491	0.88	0.77	74,500
1995	1,297	664	1.05	0.94	338,107
1996	1,337	889	3.45	1.61	165,069
1997	880	817	4.73	2.20	138,316
1998	3,002	1,340	2.31	2.48	454,792
1999	3,288	1,961	2.46	2.80	289,724
2000	1,352	1,972	1.54	2.90	370,221
2001	8,224	3,349	2.74	2.76	1,864,802
2002	7,441	4,661	2.26	2.22	2,136,747
2003	8,218	5,705	6.08	3.02	1,896,649
2004	7,701	6,587	0.94	2.71	881,719
2005	15,730	9,463	2.11	2.83	3,556,995
2006	17,205	11,259	2.09	2.70	3,890,534
median	**2,186**	**1,759**	**1.94**	**2.59**	**354,164**

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

water temperatures objectives which resulted in the installation of the Shasta Temperature Control Device in 1998; (3) a 1992 amendment to the authority of the CVP through the Central Valley Improvement Act (CVPIA) to give fish and wildlife equal priority with other CVP objectives; (4) fiscal support of habitat improvement projects from the California Bay Delta Authority (CALFED) Bay-Delta Program (*e.g.*, installation of a fish screen on the Glenn-Colusa Irrigation District (GCID) diversion); (5) establishment of the CALFED Environmental Water Account (EWA); (6) EPA actions to control acid mine runoff from Iron Mountain Mine; and (7) ocean harvest restrictions implemented in 1995.

The susceptibility of winter-run Chinook salmon to extinction remains linked to the elimination of access to most of their historical spawning grounds and the reduction of their population structure to a small population size. Recent trends in winter-run Chinook salmon abundance and cohort replacement are positive and may indicate some recovery since the listing. Although NMFS recently proposed that this ESU be upgraded from endangered to threatened status, it made the decision in its Final Listing Determination (June 28, 2005, 70 FR 37160) to continue to list the Sacramento River winter-run Chinook salmon ESU as endangered. This population remains below the recovery goals established for the run (NMFS 1997, 1998) and the naturally spawned component of the ESU is dependent on one extant population in the Sacramento River. In general, the recovery criteria for winter-run Chinook salmon include a mean annual spawning abundance over any 13 consecutive years of at least 10,000 females with a concurrent geometric mean of the cohort replacement rate greater than 1.0.

d. *Population Trend – Central Valley Spring-run Chinook Salmon*

Historically, the predominant salmon run in the Central Valley was the spring-run Chinook salmon, which occupied the upper and middle reaches (1,000 to 6,000 feet) of the San Joaquin, American, Yuba, Feather, Sacramento, McCloud, and Pit Rivers, with smaller populations in most tributaries with sufficient habitat for over-summering adults (Stone 1874, Rutter 1904, Clark 1929). The Central Valley drainage as a whole is estimated to have supported spring-run Chinook salmon runs as large as 600,000 fish between the late 1880s and 1940s (CDFG 1998). 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 Central Valley spring-run Chinook salmon from these watersheds. Naturally spawning populations of Central Valley spring-run Chinook salmon currently are restricted to accessible reaches of the upper Sacramento River, Antelope Creek, Battle Creek, Beegum Creek, Big Chico Creek, Butte Creek, Clear Creek, Deer Creek, Feather River, Mill Creek, and Yuba River (CDFG 1998).

On the Feather River, significant numbers of spring-run Chinook salmon, as identified by run timing, return to the FRH. In 2002, the FRH reported 4,189 returning spring-run Chinook salmon, which is 22 percent below the 10-year average of 4,727 fish. However, coded-wire tag (CWT) information from these hatchery returns indicates substantial introgression has occurred between fall-run and spring-run Chinook salmon populations within the Feather River system due to hatchery practices. Because Chinook salmon are not temporally separated in the hatchery, spring-run and fall-run Chinook salmon are spawned together, thus compromising the genetic integrity of the spring-run Chinook salmon stock. 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 two fish in 1978 to 2,908 in 1964. However, the genetic integrity of this population is questionable because of the significant temporal and spatial overlap between spawning populations of spring-run and fall-run Chinook salmon (Good *et al.* 2005). For the reasons discussed above, the Feather River spring-run Chinook population numbers are not included in the following discussion of ESU abundance.

Since 1969, the Central Valley spring-run Chinook salmon ESU (excluding Feather River fish) has displayed broad fluctuations in abundance ranging from 25,890 in 1982 to 1,403 in 1993 (CDFG unpublished data). Even though the abundance of fish may increase from one year to the next, the overall average population trend has a negative slope during this time period (see Appendix B: Figure 4). The average abundance for the ESU was 12,499 for the period of 1969 to 1979, 12,981 for the period of 1980 to 1990, and 6,542 for the period of 1991 to 2001. In 2002 and 2003, total run size for the ESU was 13,218 and 8,775 adults respectively, well above the 1991 to 2001 average.

The evaluation of the population of the entire ESU masks significant changes that are occurring among individual watershed subpopulations. For example, while the mainstem Sacramento River population has undergone a significant decline, the tributary populations have demonstrated substantial increases. The average population abundance of Sacramento River mainstem spring-run Chinook salmon recently has declined from a high of 12,107 fish for the period 1980 to 1990, to a low of 609 for the period between 1991 and 2001, while the average abundance of Sacramento River tributary populations increased from a low of 1,227 to a high of 5,925 over the same period. Although tributaries such as Mill and Deer Creeks have shown positive escapement trends since 1991, recent escapements to Butte Creek, including 20,259 in 1998, 9,605 in 2001, and 8,785 in 2002, are responsible for the overall increase in tributary abundance (CDFG 2002a, 2004b; CDFG, unpublished data). The Butte Creek estimates, which account for the majority of this ESU, do not include prespawning mortality. In the last several years as the Butte Creek population has increased, mortality of adult spawners has increased from 21 percent in 2002 to 60 percent in 2003 due to over-crowding and diseases associated with high water temperatures. This trend may indicate that the population in Butte Creek may have reached its carrying capacity (Ward *et al.* 2003) or has reached historical population levels (*i.e.*, Deer and Mill creeks). Table 7 shows the population trends from the three tributaries since 1986, including the 5-year moving average, cohort replacement rate, and estimated juvenile protection estimate (JPE).

Table 7. Spring-run Chinook salmon population estimates from CDFG Grand Tab (February 2007) with corresponding cohort replacement rates for years since 1986.

Year	*Sacramento River Basin Escapement Run Size*	*5-Year Moving Average of Population Estimate*	*Cohort Replacement Rate*	*5-Year Moving Average of Cohort Replacement Rate*	*NMFS Calculated JPE*[a]
1986	24,263	-	-	-	4,396,998
1987	12,675	-	-	-	2,296,993
1988	12,100	-	-	-	2,192,790
1989	7,085	-	0.29	-	1,283,960
1990	5,790	12,383	0.46	-	1,049,277
1991	1,623	7,855	0.13	-	294,124
1992	1,547	5,629	0.22	-	280,351
1993	1,403	3,490	0.24	0.27	254,255
1994	2,546	2,582	1.57	0.52	461,392
1995	9,824	3,389	6.35	1.70	1,780,328
1996	2,701	3,604	1.93	2.06	489,482
1997	1,431	3,581	0.56	2.13	259,329
1998	24,725	8,245	2.52	2.58	4,480,722
1999	6,069	8,950	2.25	2.72	1,099,838
2000	5,457	8,077	3.81	2.21	988,930
2001	13,326	10,202	0.54	1.94	2,414,969
2002	13,218	12,559	2.18	2.26	2,395,397
2003	8,902	9,394	1.63	2.08	1,613,241
2004	9,872	10,155	0.74	1.78	1,789,027
2005	14,312	11,926	1.08	1.23	2,593,654
2006	8,716	11,004	0.98	1.32	1,579,534
median	**8,716**	**9,394**	**1.08**	**1.70**	**1,579,534**

[a]NMFS calculated the spring-run JPE using returning adult escapement numbers to the Sacramento River basin prior to the opening of the RBDD for spring-run migration, and then escapement to Mill, Deer, and Butte Creeks for the remaining period, and assuming a female to male ratio of 6:4 and pre-spawning mortality of 25 percent. NMFS utilized the female fecundity values in Fisher (1994) for spring-run Chinook salmon (4,900 eggs/female). The remaining survival estimates used the winter-run values for calculating JPE.

The extent of spring-run Chinook salmon spawning in the mainstem of the upper Sacramento River is unclear. Very few spring-run Chinook salmon redds (less than 15 per year) were observed from 1989 through 1993, and none in 1994, during aerial redd counts (USFWS 2003). Recently, the number of redds in September has varied from 29 to 105 during 2001 though 2003 depending on the number of survey flights (CDFG, unpublished data). In 2002, based on RBDD ladder counts, 485 spring-run Chinook salmon adults may have spawned in the mainstem Sacramento River or entered upstream tributaries such as Clear or Battle Creek (CDFG 2004b). In 2003, no adult spring-run Chinook salmon were believed to have spawned in the mainstem Sacramento River. Due to geographic overlap of ESUs and resultant hybridization since the construction of Shasta Dam, Chinook salmon that spawn in the mainstem Sacramento River during September are more likely to be identified as early fall-run rather than spring-run Chinook salmon.

e. *Status of Spring-run Chinook Salmon*

The initial factors that led to the decline of spring-run Chinook salmon in the Central Valley were related to the loss of upstream habitat behind impassable dams. Since this initial loss of habitat, other factors have contributed to the instability of the spring-run Chinook salmon population and have negatively affected the ESU's ability to recover. These factors include a combination of physical, biological, and management factors such as climatic variation, water management activities, hybridization with fall-run Chinook salmon, predation, and over-harvesting (CDFG 1998). Since spring-run Chinook salmon adults must hold over for months in small tributaries before spawning, they are much more susceptible to the effects of high water temperatures.

During the drought from 1986 to 1992, Central Valley spring-run Chinook salmon populations declined substantially. Reduced flows resulted in warm water temperatures that impacted adults, eggs, and juveniles. For adult spring-run Chinook salmon, reduced instream flows delayed or completely blocked access to holding and spawning habitats. Water management operations (*i.e.*, reservoir release schedules and volumes) and the unscreened and poorly screened diversions in the Sacramento River, Delta, and tributaries compounded drought-related problems by reducing river flows, elevating river temperatures, and entraining juveniles into the diversions.

Several actions have been taken to improve habitat conditions for spring-run Chinook salmon, including: improved management of Central Valley water (*e.g.*, through use of CALFED EWA and CVPIA (b)(2) water accounts); implementing new and improved screen and ladder designs at major water diversions along the mainstem Sacramento River and tributaries; and changes in ocean and inland fishing regulations to minimize harvest. Although protective measures likely have contributed to recent increases in spring-run Chinook salmon abundance, the ESU is still below levels observed from the 1960s through 1990. Threats from hatchery production (*i.e.*, competition for food between naturally spawned and hatchery fish, run hybridization and genomic homogenization), climatic variation, high temperatures, predation, and water diversions still persist. Because the Central Valley spring-run Chinook salmon ESU is confined to relatively few remaining watersheds and continues to display broad fluctuations in abundance, the population is at a moderate risk of extinction.

2. Steelhead

a. *General Life History*

Steelhead can be divided into two life history types, based on their state of sexual maturity at the time of river entry and the duration of their spawning migration, stream-maturing and ocean-maturing. Stream-maturing steelhead enter freshwater in a sexually immature condition and require several months to mature and spawn, whereas ocean-maturing steelhead enter freshwater with well-developed gonads and spawn shortly after river entry. These two life history types are more commonly referred to by their season of freshwater entry (*i.e.*, summer (stream-maturing) and winter (ocean-maturing) steelhead). Only winter steelhead currently are found in Central Valley rivers and streams (McEwan and Jackson 1996), although there are indications that summer steelhead were present in the Sacramento river system prior to the commencement of large-scale dam construction in the 1940s (Interagency Ecological Program (IEP) Steelhead Project Work Team 1999). At present, summer steelhead are found only in North Coast drainages, mostly in tributaries of the Eel, Klamath, and Trinity River systems (McEwan and Jackson 1996).

Winter steelhead generally leave the ocean from August through April, and spawn between December and May (Busby *et al.* 1996). Timing of upstream migration is correlated with higher flow events, such as freshets or sand bar breaches, and associated lower water temperatures. In general, the preferred water temperature for adult steelhead migration is 46 °F to 52 °F (McEwan and Jackson 1996, Myrick 1998, Myrick and Cech 2000). Thermal stress may occur at temperatures beginning at 66 °F and mortality has been demonstrated at temperatures beginning at 70 °F, although some races of steelhead may have higher or lower temperature tolerances depending upon their evolutionary history. Lower latitudes and elevations would tend to favor fish tolerant of higher ambient temperatures (see Matthews and Berg (1997) for discussion of *O. mykiss* from Sespe Creek in Southern California). The preferred water temperature for steelhead spawning is 39 °F to 52 °F, and the preferred water temperature for steelhead egg incubation is 48 °F to 52 °F (McEwan and Jackson 1996, Myrick 1998, Myrick and Cech 2000). The minimum stream depth necessary for successful upstream migration is 13 cm (Thompson 1972). Preferred water velocity for upstream migration is in the range of 40-90 cm/s, with a maximum velocity, beyond which upstream migration is not likely to occur, of 240 cm/s (Thompson 1972, Smith 1973).

Unlike Pacific salmon, steelhead are iteroparous, or capable of spawning more than once before death (Busby *et al.* 1996). However, it is rare for steelhead to spawn more than twice before dying; most that do so are females (Nickelson *et al.* 1992, 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. Most steelhead spawning takes place from late December through April, with peaks from January though March (Hallock *et al.* 1961). Steelhead spawn in cool, clear streams featuring suitable gravel size, depth, and current velocity, and may spawn in intermittent streams as well (Everest 1973, Barnhart 1986).

The length of the incubation period for steelhead eggs is dependent on water temperature, DO concentration, and substrate composition. In late spring and following yolk sac absorption, fry emerge from the gravel and actively begin feeding in shallow water along stream banks (Nickelson *et al.* 1992).

Steelhead rearing during the summer takes place primarily in higher velocity areas in pools, although YOY also are abundant in glides and riffles. Winter rearing occurs more uniformly at lower densities across a wide range of fast and slow habitat types. Productive steelhead habitat is characterized by complexity, primarily in the form of large and small woody debris. Cover is an important habitat component for juvenile steelhead both as velocity refugia and as a means of avoiding predation (Shirvell 1990, Meehan and Bjornn 1991). Some older juveniles move downstream to rear in large tributaries and mainstem rivers (Nickelson *et al.* 1992). Juveniles feed on a wide variety of aquatic and terrestrial insects (Chapman and Bjornn 1969), and older juveniles sometimes prey upon emerging fry.

Steelhead generally spend two years in freshwater before emigrating downstream (Hallock *et al.* 1961, Hallock 1989). Rearing steelhead juveniles prefer water temperatures of 45 EF to 58 EF and have an upper lethal limit of 75 EF. They can survive up to 81 EF with saturated DO conditions and a plentiful food supply. Reiser and Bjornn (1979) recommended that DO concentrations remain at or near saturation levels with temporary reductions no lower than 5.0 mg/l for successful rearing of juvenile steelhead. During rearing, suspended and deposited fine sediments can directly affect salmonids by abrading and clogging gills, and indirectly cause reduced feeding, avoidance reactions, destruction of food supplies, reduced egg and alevin survival, and changed rearing habitat (Reiser and Bjornn 1979). Bell (1973) found that silt loads of less than 25 mg/l permit good rearing conditions for juvenile salmonids.

Juvenile steelhead emigrate episodically from natal streams during fall, winter, and spring high flows. Emigrating Central Valley steelhead use the lower reaches of the Sacramento River and the Delta for rearing and as a migration corridor to the ocean. Some may utilize tidal marsh areas, non-tidal freshwater marshes, and other shallow water areas in the Delta as rearing areas for short periods prior to their final emigration to the sea. Barnhart (1986) reported that steelhead smolts in California range in size from 140 to 210 mm (fork length). 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 (see Appendix A Table 8).

b. *Population Trends – Central Valley Steelhead*

Steelhead historically 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 inaccessable due to Shasta and Keswick Dams) south to the Kings and possibly the Kern River systems (now inaccessible due to extensive alterations from numerous 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). The California Advisory Committee on Salmon and Steelhead (1988) reported a reduction of steelhead habitat from 6,000 miles historically to 300 miles currently. Historically, steelhead probably ascended Clear Creek past the French Gulch area, but access to the upper basin was blocked by Whiskeytown Dam in 1964 (Yoshiyama *et al.* 1996).

Historic Central Valley steelhead run sizes are difficult to estimate given the paucity of data, but may have approached 1 to 2 million adults annually (McEwan 2001). By the early 1960s the steelhead run size had declined to about 40,000 adults (McEwan 2001). Over the past 30 years, the naturally spawned steelhead populations in the upper Sacramento River have declined substantially (see Appendix B: Figure 5). Hallock *et al.* (1961) estimated an annual average of 20,540 adult steelhead in the Sacramento River upstream of the Feather River, up through 1960. Steelhead counts at the RBDD declined from an average of 11,187 for the period of 1967 to 1977, to an average of approximately 2,000 through the early 1990s, with an estimated total annual run size for the entire Sacramento-San Joaquin system, based on RBDD counts, to be no more than 10,000 adults (McEwan and Jackson 1996, McEwan 2001). Steelhead escapement surveys at RBDD ended in 1993 due to changes in dam operations.

Nobriga and Cadrett (2003) compared CWT and untagged (wild) steelhead smolt catch ratios at Chipps Island trawl from 1998 through 2001 to estimate that about 100,000 to 300,000 steelhead juveniles are produced naturally each year in the Central Valley. In the *Updated Status Review of West Coast Salmon and Steelhead* (Good *et al.* 2005), the Biological Review Team (BRT) made the following conclusion based on the Chipps Island data:

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

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 (see Appendix B, Figure 6) indicate a decline in steelhead numbers in the early 1990s, which have remained low through 2002 (CDFG 2003). In 2003, 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, Deer, and Mill Creeks and the Yuba River. Populations may exist in Big Chico and Butte Creeks and a few wild steelhead are produced in the American and Feather Rivers (McEwan and Jackson 1996).

Recent snorkel surveys (1999 to 2002) indicate that steelhead are present in Clear Creek (J. Newton, USFWS, pers. comm. 2002, as reported in Good *et al.* 2005). Because of the large resident *O. mykiss* population in Clear Creek, steelhead spawner abundance has not been estimated.

Until recently, 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 devoid of steelhead (McEwan 2001). On the Stanislaus River, steelhead smolts have been captured in rotary screw traps at Caswell State Park and Oakdale each year since 1995 (Demko *et al.* 2000). After 5 years of operating a fish counting weir on the Stanislaus River only eight adult steelhead have been observed moving upstream, although several large rainbow trout have washed up on the weir in late winter (S.P. Cramer 2005). It is possible that naturally spawning populations exist in many other streams but are undetected due to lack of monitoring programs (IEP Steelhead Project Work Team 1999). Incidental catches and observations of steelhead juveniles also have occurred on the Tuolumne and Merced Rivers during fall-run Chinook salmon monitoring activities, indicating that steelhead are widespread, if not abundant, throughout accessible streams and rivers in the Central Valley (Good *et al.* 2005). CDFG staff has prepared juvenile migrant Central Valley steelhead catch summaries on the San Joaquin River near Mossdale representing migrants from the Stanislaus, Tuolumne, and Merced Rivers. Based on trawl recoveries at Mossdale between 1988 and 2002, as well as rotary screw trap efforts in all three tributaries, CDFG staff stated that it is "clear from this data that rainbow trout do occur in all the tributaries as migrants and that the vast majority of them occur on the Stanislaus River" (Letter from Dean Marston, CDFG, to Madelyn Martinez, NMFS, January 9, 2003). The documented returns on the order of a single fish to a few individual fish in these tributaries suggest that existing populations of Central Valley steelhead on the Tuolumne, Merced, and lower San Joaquin Rivers are severely depressed.

Lindley *et al.* (2003) indicated that prior population census estimates completed in the 1990s found the Central Valley steelhead spawning population above RBDD had a fairly strong negative population growth rate and small population size. Good *et al.* (2005) indicated the decline was continuing as evidenced by new information (Chipps Island trawl data). The future of Central Valley steelhead is uncertain due to limited data concerning their status. Central Valley steelhead populations generally show a continuing decline, an overall low abundance, and fluctuating return rates.

c. *Status - Central Valley Steelhead*

Both the BRT (Good *et al.* 2005) and the Artificial Propagation Evaluation Workshop (69 FR 33102) concluded that the Central Valley steelhead DPS presently is "in danger of extinction". Steelhead have been extirpated from most of their historical range in this region. Habitat concerns in this DPS focus on the widespread degradation, destruction, and blockage of freshwater habitat within the region, and water allocation problems. Widespread hatchery steelhead production within this DPS also raises concerns about the potential ecological interactions between introduced stocks and native stocks. Because the Central Valley steelhead population has been fragmented into smaller isolated tributaries without any large source population and the remaining habitat continues to be degraded by water diversions, the population remains at an elevated risk for future population declines.

3. North American Green Sturgeon

a. *General Life History*

The North American green sturgeon have morphological characteristics of both cartilaginous fish and bony fish. The fish has some morphological traits similar to sharks, such as a cartilaginous skeleton, heterocercal caudal fin, spiracles, spiral valve intestine, electro-sensory pores on its snout, and an enlarged liver. However, like more modern teleosts, it has five gill arches contained within one branchial chamber, covered by one opercular plate and a functional swim bladder for bouyancy control. Adult green sturgeon have a maximum fork length of 2.3 meters and 159 kg body weight (Miller and Lea 1980, Moyle *et al.* 1992, Moyle 2002). It is believed that green sturgeon can live at least 60 years, based on data from the Klamath River (Emmett *et al.* 1991).

The green sturgeon is the most widely distributed of the *acipenseridae*. They are amphi-Pacific and circumboreal, ranging from the inshore waters of Baja California northwards to the Bering Sea and then southwards to Japan. They have been recorded from at least six different countries: Mexico, United States, Canada, Russia (Sakhalin Island), Japan, and Korea (Emmett *et al.* 1991, Moyle *et al.* 1992). Although widely distributed, they are not very abundant in comparison to the sympatric white sturgeon (*Acipenser transmontanus*).

(1) ***Adult Distribution and Feeding***. In North America, spawning populations of green sturgeon currently are found in only three river systems: the Sacramento and Klamath Rivers in California and the Rogue River in southern Oregon. Spawning has only been reported in one Asian river, the Tumin River in eastern Asia. 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 (NMFS 2005). 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). Particularly large concentrations occur in the Columbia River estuary, Willapa Bay, and Grays Harbor, with smaller aggregations in San Francisco and San Pablo Bays (Emmett *et al* 1991, Moyle *et al.* 1992, Beamesderfer *et al.* 2004). Recent acoustical tagging studies on the Rogue River (Erickson *et al.* 2002) have shown that adult green sturgeon will hold for as long as 6 months in deep (> 5m), low-gradient reaches, off channel sloughs, or coves of the river during summer months when water temperatures were between 15 °C and 23 °C. When ambient temperatures in the river dropped in autumn and early winter (<10 °C) and flows increased, fish moved downstream and into the ocean.

Two green sturgeon DPSs were identified based on evidence of spawning site fidelity (indicating multiple DPS tendencies), and on the preliminary genetic evidence that indicates differences at least between the Klamath River and San Pablo Bay samples (Adams *et al.* 2002). The Northern DPS includes all green sturgeon populations starting with the Eel River and extending northward. The Southern DPS includes all green sturgeon populations south of the Eel River, with the only known spawning population being in the Sacramento River.

The Southern DPS of North American green sturgeon life cycle can be broken into four distinct phases based on developmental stage and habitat use (it was suggested by Nakamoto *et al.* 1995, to break them into three parts); (1) adult females greater than or equal to 13 years of age and males greater than or equal to 9 years of age, (2) larvae and post-larvae less than 10 months of age, (3) juveniles less than or equal to 3 years of age, and (4) coastal migrant females between 3 and 13, and males between 3 and 9 years of age (Nakamoto *et al.* 1995).

New information regarding the migration and habitat use of the Southern DPS of North American green sturgeon has emerged. Lindley (2006) presents preliminary results of large-scale green sturgeon migration studies. Lindley's analysis verified past population structure delineations based on genetic work and found frequent large-scale migrations of green sturgeon along the Pacific Coast. It appears Southern DPS green sturgeon are migrating considerable distances up the Pacific Coast into other estuaries, particularly the Columbia Estuary. This information also agrees with the results of green sturgeon tagging studies completed by CDFG where they tagged a total of 233 green sturgeon in San Pablo Bay between 1954 and 2001. A total of 17 tagged fish were recovered: 3 in the Sacramento-San Joaquin Delta, 2 in the Pacific Ocean off of California, and 12 from commercial fisheries off of Oregon and Washington. Eight of the 12 recoveries were in the Columbia Estuary (CDFG 2002c). In addition, recent analysis by Israel (2006a) indicates a substantial portion (*i.e.*, 50-80 percent) of green sturgeon present in the Columbia Estuary may be Southern DPS fish.

Kelley *et al.* (2006) indicated that green sturgeon enter the San Francisco Estuary during the spring 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 the authors surmised they are related to resource availability (Kelley *et al.* 2006). Green sturgeon were most often found at depths greater than 5 meters with low or no current during summer and autumn months (Erickson *et al.* 2002). The majority of green sturgeon in the Rogue River emigrated from freshwater habitat in December after water temperatures dropped (Erickson *et al.* 2002). The authors surmised that this holding in deep pools was to conserve energy and utilize abundant food resources. Based on captures of adult green sturgeon in holding pools on the Sacramento River above the GCID diversion (RM 205) and the documented presence of adults in the Sacramento River during the spring and summer months and the presence of larval green sturgeon in late summer in the lower Sacramento River, it appears green sturgeon could possibly utilize a variety of freshwater and brackish habitats for up to nine months of the year (Ray Beamesderfer, S.P. Cramer & Associates, Inc., pers. comm. 2006).

Adult green sturgeon are believed to feed primarily upon benthic invertebrates such as clams, mysid shrimp, grass shrimp, and amphipods (Radtke 1966, J. Stuart, unpublished data). Adult sturgeon caught in Washington State waters were found to have fed on Pacific sand lance (*Ammodytes hexapterus*) and callianassid shrimp (Moyle *et al.* 1992).

(2) *Spawning*. Adult green sturgeon are gonochoristic (sex genetically fixed), oviparous and iteroparous. They are believed to spawn every 3 to 5 years and reach sexual maturity only after several years of growth (10 to 15 years based on sympatric white sturgeon sexual maturity). Younger females may not spawn the first time they undergo oogenesis and subsequently they

reabsorb their gametes. Adult female green sturgeon produce between 60,000 and 140,000 eggs, depending on body size, with a mean egg diameter of 4.3 mm (Moyle *et al.* 1992, Van Eenennaam *et al.* 2001). They have the largest egg size of any sturgeon, and the volume of yolk ensures an ample supply of energy for the developing embryo. The eggs themselves are slightly adhesive, much less so than the sympatric white sturgeon, and are more dense than than those of white sturgeon (Kynard *et al.* 2005). Adults begin their upstream spawning migrations into freshwater in late February with spawning occuring between March and July. 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, and the fertilized eggs sink into the interstices of the substrate where they develop further (Kynard *et al.* 2005).

(3) ***Egg Development.*** 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). Studies conducted at the University of California, Davis by Van Eenennaam *et al.* (2005) indicated that an optimum range of water temperature for egg development ranged between 14 °C and 17 °C. Temperatures over 23 °C resulted in 100 percent mortality of fertilized eggs before hatching. Eggs incubated at water temperatures between 17.5 °C and 22 °C resulted in elevated mortalities and an increased occurrence of morphological abnormalities in those eggs that did hatch. At incubation temperatures below 14 °C, hatching mortality also increased significantly, and morphological abnormalities increased slightly, but not statistically so.

(4) ***Early Development.*** 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. The larvae are less developed in their morphology than older juveniles and external morphology resembles a "tadpole" with a continuous fin fold on both the dorsal and ventral sides of the caudal trunk. The eyes are well developed with differentiated lenses and pigmentation.

Olfactory and auditory vesicles are present while the mouth and respiratory structures are only shallow clefts on the head. At 10 days of age, the yolk sac has become greatly reduced in size and the larvae initiates exogenous feeding through a functional mouth. The fin folds have become more developed and formation of fin rays begins to occur in all fin tissues. By 45 days of age, the green sturgeon larvae have completed their metamorphosis, which is characterized by the development of dorsal, lateral, and ventral scutes; elongation of the barbels, rostrum, and caudal peduncle; reabsorption of the caudal and ventral fin folds; and, the development of fin rays. The juvenile fish resembles the adult form, including the dark olive coloring, with a dark mid-ventral stripe (Deng *et al.* 2002).

Green sturgeon larvae do not exhibit the initial pelagic swim–up behavior characteristic of other *acipenseridae*. They are strongly oriented to the bottom and exhibit nocturnal activity patterns. After 6 days, the larvae exhibit nocturnal swim-up activity (Deng *et al.* 2002) and nocturnal downstream migrational movements (Kynard *et al.* 2005). Young green sturgeon appear to rear for the first 1 to 2 months in the Sacramento River between Keswick Dam and Hamilton City (CDFG 2002c). Juvenile green sturgeon first appear in United States Fish and Wildlife Service (USFWS) sampling efforts at RBDD in June and July at lengths ranging from 24 to 31 mm fork length (CDFG 2002c, USFWS 2002). The mean yearly total length of post-larval green sturgeon captured in rotary screw traps at the RBDD ranged from 26 mm to 34 mm between 1995 and 2000 indicating they are approximately 2 weeks old. The mean yearly total length of post-larval green sturgeon captured in the GCID rotary screw trap, approximatley 30 miles downstream of RBDD ranged from 33 mm to 44 mm between 1997 and 2005 (CDFG, unpublished data) indicating they are approximately 3 weeks old (Van Eenennaam *et al.* 2001). Juvenile fish continue to exhibit nocturnal behavior beyond the metamorphosis from larvae to juvenile stages. Kynard *et al.*'s (2005) laboratory studies indicated that juvenile fish continued to migrate downstream at night for the first 6 months of life. When ambient water temperatures reached 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 several dams controlling flows on its mainstem (Shasta and Keswick Dams), and its tributaries (Whiskeytown, Oroville, Folsom, and Nimbus Dams).

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

Juvenile green sturgeon have been salvaged at the Harvey O. Banks Pumping Plant and the John E. Skinner Fish Facility (Fish Facilities) in the South Delta, and captured in trawling studies by the CDFG during all months of the year (CDFG 2002c). The majority of these fish were between 200 and 600 mm indicating they were from 2 to 3 years of age based on Klamath River age distribution work by Nakamoto *et al.* (1995). The lack of a significant proportion of juveniles smaller than approximately 200 mm in Delta captures indicates juvenile Southern DPS green sturgeon likely hold in the mainstem Sacramento River as suggested by Kyndard *et al.* (2005).

Radtke (1966) examined the stomach contents of 74 juvenile green sturgeon caught with gill net and otter trawl in the Delta. Amphipods (*Corophium spp.*) appeared to be the most important food item found in the stomachs of smaller green sturgeon and were the only item found in the eight smaller green sturgeon (190–390 mm) examined in the fall. All those examined in the spring and summer had eaten *Corophium*, which made up over half the volume of their diet during these seasons. The mysid shrimp, *Neomysis awatschensis* (also known as *N. mercedis*), was also heavily utilized during spring and summer. One fish examined in the spring had eaten shrimp that could not be identified. Growth is rapid as juveniles reach up to 300 mm the first year and over 600 mm in the first 2-3 years (Nakamoto *et al.* 1995). Little is known of the behavioral dynamics of these juveniles, such as habitat preference and water column usage; however, based on diet work reported above and the feeding morphology, juveniles are likely benthically oriented. Juveniles appear to spend one to three years in freshwater before they enter the ocean (Nakamoto *et al.* 1995). See Appendix A, Table 9 for the temporal occurrence of green sturgeon in the Central Valley.

b. *Population Trends –Southern Population of North American Green Sturgeon*

Known historic and current spawning occurs in the Sacramento River (Adams *et al.* 2002, Beamesderfer *et al.* 2004). Currently, upstream migrations of sturgeon are halted by Keswick and Shasta Dams on the mainstem of the Sacramento River. Although no historical accounts exist for identified green sturgeon spawning occuring above the current dam sites, suitable spawning habitat existed and based on habitat assessments done for Chinook salmon, the geographic extent of spawning has been reduced due to the impassable barriers constructed on the river.

Spawning on the Feather River is suspected to have occurred in the past due to the continued presence of adult green sturgeon in the river below Oroville Dam. This continued presence of adults below the dam suggests that fish are trying to migrate to upstream spawning areas now blocked by the dam which was constructed in 1968. There are at least two records of confirmed observations of adult sturgeon in the Feather River (Beamesderfer *et al.* 2004), however, there are no observations of juvenile or larval sturgeon even prior to the construction of Oroville Dam (NMFS 2005). There are also unconfirmed reports that green sturgeon may spawn in the Feather River during high flow years (CDFG 2002c).

Spawning in the San Joaquin River system has not been recorded historically or observed recently, but alterations of the San Joaquin River tributaries (Stanislaus, Tuolumne, and Merced Rivers) and its mainstem occurred early in the european settlement of the region. During the later half of the 1800s impassable barriers were built on these tributaries where the water courses left the foothills and entered the valley floor. Therefore, these low elevation dams have blocked potentially suitable spawning habitats located further upstream for approximately a century. Additional destruction of riparian and stream channel habitat by industrialized gold dredging further disturbed any valley floor habitat that was still available for sturgeon spawning. It is likely that both white and green sturgeon utilized the San Joaquin River basin for spawning prior to the onset of european influence, based on past use of the region by populations of Central Valley spring-run Chinook salmon and steelhead. These two populations of salmonids have either been extirpated or greatly diminished in their use of the San Joaquin River basin over the past two centuries.

The sizes of the northern and southern populations of North American green sturgeon are difficult to estimate due to a lack of data specific for this fish. However, inferences from the commercial and sport fisheries harvest can be used to estimate population trends over time. Based on the harvest numbers, green sturgeon catch has decreased from a high of 9,065 in 1986 to 512 in 2003. The greatest decreases in harvest were for commercial gears in the Columbia River, Willapa Bay, and Grays Harbor, Washington. The decrease was attributed to changes in the regulatory statutes for sturgeon harvest (Adams *et al.* 2002). Catch rates for the Hoopa and Yurok tribal harvests remained unchanged during this same period and accounted for approximately 59 percent of the total harvest in 2003 (NMFS 2005).

Population abundance information concerning the Southern DPS of North American green sturgeon is described in the NMFS status reviews (Adams *et al.* 2002, NMFS 2005). Limited population abundance information comes from incidental captures of North American green sturgeon from the white sturgeon monitoring program by the CDFG sturgeon tagging program (CDFG 2002c). CDFG (2002c) utilizes a multiple-census or Peterson mark-recapture method to estimate the legal population of white sturgeon captures in trammel nets. By comparing the ratio of white sturgeon to green sturgeon captures, CDFG can generate estimates of adult and sub-adult North American green sturgeon abundance. Estimated abundances between 1954 and 2001 ranged from 175 fish to more than 8,000 per year and averaged 1,509 fish per year. Unfortunately, there are many biases and errors associated with these data, and CDFG does not consider these estimates reliable. Fish monitoring efforts at RBDD and GCID on the upper Sacramento River have captured between 0 and 2,068 juvenile North American green sturgeon per year (Adams *et al.* 2002). The only existing information regarding changes in the abundance of the Southern DPS of North American green sturgeon includes changes in abundance at the John E. Skinner Fish Facility between 1968 and 2001. The average number of North American green sturgeon taken per year at the State Facility prior to 1986 was 732; from 1986 on, the average per year was 47 (70 FR 17386). 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) (see Appendix B, Figure 7). In light of the increased levels of exports, particularly during the last 10 years, it is clear that the abundance of the Southern DPS of North American 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). Catches of sub-adult and adult North American green sturgeon by the IEP between 1996 and 2004 ranged from 1 to 212 green sturgeon per year (212 occurred in 2001). However, the portion of these captures consisting of fish from the Southern DPS of North American green sturgeon is unknown. These fish primarily were captured in San Pablo Bay, which is known to consist of a mixture of both Northern and Southern DPS North American green sturgeon. Recent spawning population estimates using sibling based genetics by Israel (2006b) indicates a maximum spawning population of 32 spawners in 2002, 64 in 2003, 44 in 2004, 92 in 2005, and 124 in 2006 above RBDD (average equal to 71). Based on the length and estimated age of post-larvae captured at RBDD (approximately two weeks of age) and GCID (downstream; approximately three weeks of age), it appears the majority of Southern DPS North American green sturgeon are spawning above RBDD. Note, there are many assumptions with this interpretation (*i.e.*, equal sampling efficiency and distribution of post-larvae across channels) and this information should be considered cautiously.

c. *Status –Southern population of North American Green Sturgeon*

The southern population of green sturgeon historically was smaller than the sympatric population of white sturgeon in the San Francisco Bay estuary and its associated tributaries. The population apparently has been declining over the past several decades based on harvest numbers from sport and commercial fisheries and the entrainment rates at the CVP and SWP. The principle factor for this decline is the reduction of green sturgeon spawning habitat to a limited area below Keswick Dam on the Sacramento River. The construction of impassable barriers, particularly large dams, has greatly reduced the access of green sturgeon to their historical spawning areas. These barriers and their manipulation of the normal hydrograph for the river also have had detrimental effects on the natural life history of green sturgeon. Reduced flows have corresponded with weakened year class recruitment in the sympatric white sturgeon population and it is believed to have the same effect upon green sturgeon recruitment. Obstruction of natural sedmiment recruitment below large impoundments potentially has increased predation on larval and juvenile sturgeon due to a reduction in turbidity and loss of larger diameter substrate. In addition to the adverse effects of impassable barriers, numerous agricultural water diversions exist in the Sacramento River and the Delta along the migratory route of larval and juvenile sturgeon. Entrainment and impingement are considered serious threats to sturgeon during their downstream migration. Fish screens have not been designed with criteria that address sturgeon behavior or swimming capabilities. The benthic oriented sturgeon are also more susceptible to contaminated sediments through dermal contact and through their feeding behavior of ingesting prey along with contaminated sediments before winnowing out the sediment. Their long life spans allow them to accumulate high body burdens of contaminants that potentially will reach concentrations with deleterious physiological effects.

C. Critical Habitat Condition and Function for Species' Conservation

The designated critical habitat for Sacramento River winter-run Chinook salmon includes the Sacramento River from Keswick Dam (RM 302) to Chipps Island (RM 0) at the westward margin of the Delta; all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge; and all waters of San Francisco Estuary to the Golden Gate Bridge north of the San Francisco/Oakland Bay Bridge. In the Sacramento River, critical habitat includes the river water column, river bottom, and adjacent riparian zone used by fry and juveniles for rearing. In the areas westward of Chipps Island, critical habitat includes the estuarine water column and essential foraging habitat and food resources used by Sacramento River winter-run Chinook salmon as part of their juvenile emigration or adult spawning migration.

Critical habitat was designated for Central Valley spring-run Chinook salmon and Central Valley steelhead on September 2, 2005 (70 FR 52488). Critical habitat for Central Valley spring-run Chinook salmon includes stream reaches such as those of the Feather and Yuba Rivers, Big Chico, Butte, Deer, Mill, Battle, Antelope, and Clear Creeks, the Sacramento River, as well as portions of the northern Delta. Critical habitat for Central Valley steelhead includes stream reaches such as those of the Sacramento, Feather, and Yuba Rivers, and Deer, Mill, Battle, and Antelope Creeks in the Sacramento River basin; the San Joaquin River its tributaries, and the waterways of the Delta. Critical habitat includes the stream channels in the designated stream reaches and the lateral extent as defined by the ordinary high-water line. In areas where the ordinary high-water line has not been defined, the lateral extent will be defined by the bankfull elevation (defined as the level at which water begins to leave the channel and move into the floodplain; it is reached at a discharge that generally has a recurrence interval of 1 to 2 years on the annual flood series) (Bain and Stevenson 1999; 70 FR 52488). Critical habitat for Central Valley spring-run Chinook salmon and steelhead is defined as specific areas that contain the primary constituent elements (PCE) and physical habitat elements essential to the conservation of the species. Following are the inland habitat types used as PCEs for Central Valley spring-run Chinook salmon and Central Valley steelhead, and as physical habitat elements for Sacramento River winter-run Chinook salmon. Critical habitat for the southern DPS of the North American green sturgeon has not been designated yet, but is expected to be similar to the geographic range of Central Valley spring-run Chinook salmon and Central Valley steelhead in the Delta and Sacramento River watersheds.

1. Spawning Habitat

Freshwater spawning sites are those with water quantity and quality conditions and substrate supporting spawning, incubation, and larval development. Most spawning habitat in the Central Valley for Chinook salmon and steelhead is located in areas directly downstream of dams containing suitable environmental conditions for spawning and incubation. Spawning habitat for Sacramento River winter-run Chinook salmon is restricted to the Sacramento River primarily between RBDD and Keswick Dam. Central Valley spring-run Chinook salmon also spawn on the mainstem Sacramento River between RBDD and Keswick Dam and in tributaries such as Mill, Deer, and Butte Creeks; however, little spawning activity has been recorded in recent years on the Sacramento River mainstem for spring-run Chinook salmon. Spawning habitat for Central Valley steelhead is similar in nature to the requirements of Chinook salmon, primarily occurring in reaches directly below dams (*i.e.*, above RBDD on the Sacramento River) on perennial watersheds throughout the Central Valley. Spawning habitat has a high conservation value as its function directly affects the spawning success and reproductive potential of listed salmonids.

2. Freshwater Rearing Habitat

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

3. Freshwater Migration Corridors

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

4. Estuarine Areas

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

D. Factors Affecting the Species and Critical Habitat

1. Chinook Salmon and Central Valley Steelhead

A number of documents have addressed the history of human activities, present environmental conditions, and factors contributing to the decline of salmon and steelhead species in the Central Valley. For example, NMFS prepared range-wide status reviews for west coast Chinook salmon (Myers *et al.* 1998) and steelhead (Busby *et al.* 1996). Also, the NMFS Biological Review Team (BRT) published an updated status review for west coast Chinook salmon and steelhead in 2005 (Good *et al.* 2005). NMFS also assessed the factors for Chinook salmon and steelhead decline in supplemental documents (NMFS 1996a, 1998). Information also is available in Federal Register notices announcing ESA listing proposals and determinations for some of these species and their critical habitat (*e.g.*, 58 FR 33212; 59 FR 440; 62 FR 24588; 62 FR 43937; 63 FR 13347; 64 FR 24049; 64 FR 50394; 65 FR 7764). The Final Programmatic Environmental Impact Statement/Report (EIS/EIR) for the CALFED Program (CALFED 2000) and the Final Programmatic EIS for the CVPIA (Department of Interior (DOI) 1999) provide a summary of historical and recent environmental conditions for salmon and steelhead in the Central Valley. The following general description of the status of species for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead is based on a summary of these documents.

In general, the human activities that have affected listed anadromous salmonids and the PCEs of their habitats consist of: (1) the present or threatened destruction, modification, or curtailment of habitat or range; (2) over-utilization; (3) disease or predation; and, (4) other natural and manmade factors.

a. *The Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range*

(1) ***Habitat Blockage***

Hydropower, flood control, and water supply dams of the CVP, SWP, and other municipal and private entities permanently have blocked or hindered salmonid access to historical spawning and rearing grounds resulting in the complete loss of substantial portions of spawning, rearing, and migration PCEs. Clark (1929) estimated that originally there were 6,000 linear miles of salmon habitat in the Central Valley system and that 80 percent of this habitat had been lost by 1928. Yoshiyama *et al.* (1996) calculated that roughly 2,000 linear miles of salmon habitat was actually available before dam construction and mining, and concluded that 82 percent is not accessible today. Yoshiyama *et al.* (1996) surmised that steelhead habitat loss was even greater than salmon loss, as steelhead migrated farther into drainages. The California Advisory Committee on Salmon and Steelhead Trout (1988) estimated that there has been a 95 percent reduction of Central Valley anadromous fish spawning habitat.

In general, large dams on every major tributary to the Sacramento River, San Joaquin River, and the Delta block salmon and steelhead access to the upper portions of their respective watersheds. On the Sacramento River, Keswick Dam blocks passage to historic spawning and rearing habitat in the upper Sacramento, McCloud, and Pit Rivers. Whiskeytown Dam blocks access to the upper watershed of Clear Creek. Oroville Dam and associated facilities block passage to the upper Feather River watershed. Nimbus and Folsom Dams block access to most of the American River basin. Friant Dam construction in the mid 1940s has been associated with the elimination of spring-run Chinook salmon in the San Joaquin River upstream of the Merced River. On the Stanislaus River, construction of Goodwin Dam (1912), Tulloch Dam (1957), and New Melones Dam (1979) blocked both spring- and fall-run Chinook salmon as well as Central Valley steelhead. Similarly, La Grange Dam (1893) and New Don Pedro Dam (1971) blocked upstream access to salmonids on the Tuolumne River. Upstream migration on the Merced River was blocked in 1910 by the construction of Merced Falls and Crocker-Huffman Dams and later New Exchequer Dam (1967) and McSwain Dam (1967).

As a result of the dams, winter-run Chinook salmon, spring-run Chinook salmon, and steelhead populations on these rivers have been confined to lower elevation mainstems that historically only were used for migration. Population abundances have declined in these streams due to decreased quantity and quality of spawning and rearing habitat. Changes in the thermal profiles and hydrographs of the Central Valley rivers have presumably subjected salmonids to strong selective forces (Slater 1963). The degree to which current life history traits reflect predevelopment characteristics is largely unknown, especially since most of the habitat degradation occurred before salmonid studies were undertaken late in the nineteenth century. Increased temperatures as a result of reservoir operations during winter and fall can affect emergence rates of Chinook salmon; thereby significantly altering the life history of a species (CALFED 2005). Shifts in life history have the potential to seriously affect survival (CALFED 2005).

Central Valley Chinook salmon exhibit an ocean-type life history; large numbers of juvenile Chinook salmon emigrate during the winter and spring (Kjelson *et al.* 1982, Gard 1995). High summer water temperatures in the lower Sacramento River (temperatures in the Delta can exceed 72 °F) create a thermal barrier to up- and downstream migration and may be partially responsible for the evolution of the fry migration life history (Kjelson *et al.* 1982).

The initial factors that led to the decline of Central Valley spring-run Chinook salmon in the Central Valley also were related to the loss of upstream habitat behind impassable dams. Since spring-run Chinook salmon adults must hold over for months in small tributaries before spawning, they are much more susceptible to the effects of high water temperatures. The loss of upstream habitat required Central Valley spring-run Chinook salmon to hold in less hospitable reaches below dams.

Likewise, the Central Valley steelhead, which also prefer smaller, higher elevation streams with constant cool water flows, experienced significant population declines when dams blocked access to these preferred spawning reaches. Even more so than the Central Valley spring-run Chinook salmon, steelhead required constant cool water conditions for their juvenile rearing stages, which typically span one to two years in the natal stream. The loss of substantal habitat above dams resulted in decreased juvenile and adult steelhead survival during migrational movements, and in many cases, resulted in the dewatering and loss of important spawning and rearing habitats in the valley floor reaches of streams below the sites of current dams.

(2) *Water Diversion*

The diversion and storage of natural flows by dams and diversion structures on Central Valley waterways have depleted stream flows and altered the natural cycles by which juvenile and adult salmonids have evolved. Changes in stream flows and diversions of water affect spawning habitat, freshwater rearing habitat, freshwater migration corridors, and estuarine habitat PCEs. As much as 60 percent of the natural historical inflows to Central Valley watersheds and the Delta have been diverted for human uses. Depleted flows have contributed to higher temperatures, lower DO levels, and decreased recruitment of gravel and instream woody debris. More uniform flows year-round have resulted in diminished natural channel formation, altered food web processes, and slower regeneration of riparian vegetation. These stable flow patterns have reduced 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. In addition, Brown and May (2000) found stream regulation to be associated with declines in benthic macroinvertebrate communities in Central Valley rivers. Macroinvertebrates are key forage species for salmonids.

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

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

Outmigrant juvenile salmonids in the Delta have been subjected to adverse environmental conditions created by water export operations at the CVP/SWP. Specifically, juvenile salmonid survival has been reduced by the following: (1) water diversion from the mainstem Sacramento River into the central Delta via the Delta Cross Channel (DCC); (2) upstream or reverse flows of water in the lower San Joaquin River and southern Delta waterways (*i.e.*, net negative flows); (3) entrainment at the CVP/SWP export facilities and associated problems at Clifton Court Forebay; and, (4) increased exposure to introduced, non-native predators such as striped bass (*Morone saxatilis*), largemouth bass (*Micropterus salmoides*), and sunfishes (*Centrarchidae* spp.).

(3) ***Water Conveyance and Flood Control***

The development of the water conveyance system in the Delta has resulted in the construction of more than 1,100 miles of channels and diversions to increase channel elevations and flow capacity of the channels (Mount 1995). Levee development in the Central Valley affects spawning habitat, freshwater rearing habitat, freshwater migration corridors, and estuarine habitat PCEs. As Mount (1995) indicates, there is an "underlying, fundamental conflict inherent in this channelization." Natural rivers strive to achieve dynamic equilibrium to handle a watersheds supply of discharge and sediment (Mount 1995). The construction of levees disrupts the natural processes of the river, resulting in a multitude of habitat-related effects.

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

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

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

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

(4) ***Land Use Activities***

In a parallel relationship with the activities associated with water conveyance and flood control (*i.e.* reclamation actions), changes in upland land use in areas adjacent to salmonid bearing waters have greatly impacted those aquatic habitats. Land use activities such as agricultural conversion, and industrial and urban development continue to have large impacts on salmonid habitat in the Central Valley watershed, affecting spawning habitat, freshwater rearing habitat, freshwater migration corridors, estuarine areas, and nearshore marine area PCEs. 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). 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 degradation and fragmentation of riparian habitat had resulted mainly from flood control and bank protection projects, together with the conversion of riparian land to agriculture. Removal of snags and driftwood in the Sacramento and San Joaquin River basins for navigational safety has reduced sources of LWD needed to form and maintain stream habitat that salmon depend on in their various life stages. 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. Since the 1850s, wetlands reclamation for urban and agricultural development has caused the cumulative loss of 79 and 94 percent of the tidal marsh habitat in the Delta downstream and upstream of Chipps Island, respectively (Conomos *et al.* 1985, Nichols *et al.* 1986, Wright and Phillips 1988, Monroe *et al.* 1992, Goals Project 1999). 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).

Land use activities associated with road construction, urban development, logging, mining, agriculture, and recreation have significantly altered fish habitat quantity and quality through the alteration of 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 (Meehan 1991).

Road construction frequently requires the crossing of waterways by the road alignment. Poorly conceived and constructed crossings adversely impact the waterways they cross. Constricting channels with culverts, bridge approaches, and streamside roads can reduce stream meandering, partially constrict or channelize flows, reduce pool maintenance, and can preclude passage of anadromous salmonids by creating either vertical passage barriers or velocity barriers at the crossing site. Diverse habitats support diverse species assemblages and communities. This diversity contributes to sustained production and provides stability for the entire ecosystem. Further, habitat diversity can also mediate biotic interactions such as competition and predation. Attributes of habitat diversity include a variety and range of hydraulic parameters, abundance and size of woody substrates, and the variety and composition of bed substrates (NMFS 1996b).

Increased sedimentation resulting from agricultural and urban practices within the Central Valley is one of the primary causes of salmonid habitat degradation (NMFS 1996a). Sedimentation can adversely affect salmonids during all freshwater life stages by: (1) clogging or abrading gill surfaces, (2) adhering to eggs, (3) hampering fry emergence (Phillips and Campbell 1961), (4) burying eggs or alevins, (5) scouring and filling in pools and riffles, (6) reducing primary productivity and photosynthesis activity (Cordone and Kelley 1961), and (7) affecting intergravel permeability and DO levels. Furthermore, excessive sedimentation over time can cause substrates to become embedded, which reduces successful salmonid spawning and egg and fry survival (Waters 1995).

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 U.S. Army Corps of Engineers (Corps) and other private consortiums began straightening river channels and artificially deepening them to enhance shipping commerce. This has led to declines in the natural meandering of river channels and the formation of pool and riffle segments. The deepening of channels beyond their natural depth also has led to a significant alteration in the transport of 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 season and the spring snow melt periods. These annual inundations provided necessary habitat for rearing and foraging of juvenile native fish that evolved with this flooding process. The armored riprapped levee banks and active maintenance actions of Reclamation Districts precluded the establishment of ecologically important riparian vegetation, introduction of valuable LWD from these riparian corridors, and the productive intertidal mudflats characteristic of the undisturbed Delta habitat.

Urban stormwater and agricultural runoff may be contaminated with pesticides, oil, grease, heavy metals, polynuclear aromatic hydrocarbons (PAHs), and other organics and nutrients (Regional Board 1998) that can potentially destroy aquatic life necessary for salmonid survival (NMFS 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 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.

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). As discussed previously, 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.

b. *Over-Utilization*

(1) ***Ocean Commercial and Sport Harvest***

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

Since 1970, the CVI for Sacramento River winter-run Chinook salmon generally has ranged between 0.50 and 0.80. In 1990, when ocean harvest of winter-run Chinook salmon was first evaluated by NMFS and the Pacific Fisheries Management Council (PFMC), the CVI harvest rate was near the highest recorded level at 0.79. NMFS determined in a 1991 biological opinion that continuance of the 1990 ocean harvest rate would not prevent the recovery of Sacramento River winter-run Chinook salmon. Through the early 1990s, the ocean harvest index was below the 1990 level (*i.e.*, 0.71 in 1991 and 1992, 0.72 in 1993, 0.74 in 1994, 0.78 in 1995, and 0.64 in 1996). In 1996 and 1997, NMFS issued a biological opinion which concluded that incidental ocean harvest of Sacramento River winter-run Chinook salmon represented a significant source of mortality to the endangered population, even though ocean harvest was not a key factor leading to the decline of the population. As a result of these opinions, measures were developed and implemented by the PFMC, NMFS, and CDFG to reduce ocean harvest by approximately 50 percent. In 2001 the CVI dropped to 0.27, most likely due to the reduction in harvest and the higher abundance of other salmonids originating from the Central Valley (Good *et al.* 2005).

Ocean fisheries have affected the age structure of Central Valley spring-run Chinook salmon through targeting large fish for many years and reducing the numbers of 4- and 5-year-old fish (CDFG 1998). Ocean harvest rates of Central Valley spring-run Chinook salmon are thought to be a function of the CVI (Good *et al.* 2005). Harvest rates of Central Valley spring-run Chinook salmon ranged from 0.55 to nearly 0.80 between 1970 and 1995 when harvest rates were adjusted for the protection of Sacramento River winter-run Chinook salmon. The drop in the CVI in 2001 as a result of high fall-run escapement to 0.27 also reduced harvest of Central Valley spring-run Chinook salmon. There is essentially no ocean harvest of steelhead.

(2) *Inland Sport Harvest*

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

In-river recreational fisheries historically have taken Central Valley spring-run Chinook salmon throughout the species' range. During the summer, holding adult Central Valley spring-run Chinook salmon are easily targeted by anglers when they congregate in large pools. Poaching also occurs at fish ladders, and other areas where adults congregate; however, the significance of poaching on the adult population is unknown. Specific regulations for the protection of Central Valley spring-run Chinook salmon in Mill, Deer, Butte, and Big Chico Creeks were added to the existing CDFG regulations in 1994. The current regulations, including those developed for Sacramento River winter-run Chinook salmon, provide some level of protection for spring-run fish (CDFG 1998).

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

c. *Disease and Predation*

Infectious disease is one of many factors that influence adult and juvenile salmonid survival. Salmonids are exposed to numerous bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, hatcheries, migratory routes, and the marine environment (NMFS 1996a, 1996b, 1998). Specific diseases such as bacterial kidney disease, *Ceratomyxosis shasta*

(C-shasta), columnaris, furunculosis, infectious hematopoietic necrosis, redmouth and black spot disease, whirling disease, and erythrocytic inclusion body syndrome are known, among others, to affect steelhead and Chinook salmon (NMFS 1996a, 1996b, 1998). 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 native fish tend to be less susceptible to pathogens than are hatchery-reared fish. Salmonids may contract diseases that are spread through the water column (*i.e.*, waterborne pathogens) as well as through interbreeding with infected hatchery fish.

A fish may be infected yet not present clinically with reduced physiological performance or external symptoms. Salmonids typically are infected with several pathogens during their life cycle. However, high infection levels (number of organisms per host) and stressful conditions such as overcrowding in hatchery raceways, release from the hatchery environment into a riverine environment, and significant fluctuations in water temperatures usually characterize the system before a clinically observable disease state presents in the fish.

Accelerated predation also may be a factor in the decline of Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon, and to a lesser degree Central Valley steelhead. Human-induced habitat changes such as alteration of natural flow regimes and installation of bank revetment and structures such as dams, bridges, water diversions, piers, and wharves often provide conditions that both disorient juvenile salmonids and attract predators (Stevens 1961).

On the mainstem Sacramento River, high rates of predation are known to occur at the RBDD, Anderson-Cottonwood Irrigation District's (ACID) diversion dam, GCID's diversion dam, areas where rock revetment has replaced natural river bank vegetation, and at south Delta water diversion structures (*e.g.*, Clifton Court Forebay; CDFG 1998). Predation at RBDD on juvenile winter-run Chinook salmon is believed to be higher than normal due to factors such as water quality and flow dynamics associated with the operation of this structure. Due to their small size, early emigrating winter-run Chinook salmon may be very susceptible to predation in Lake Red Bluff when the RBDD gates remain closed in summer and early fall. In passing the dam, juveniles are subject to conditions which greatly disorient them, making them highly susceptible to predation by fish or birds. Sacramento pikeminnow (*Ptychocheilus grandis*) and striped bass congregate below the dam and prey on juvenile salmon in the tail waters. The Sacramento pikeminnow is a species native to the Sacramento River basin and has co-evolved with the anadromous salmonids in this system. However, rearing conditions in the Sacramento River today (*e.g.*, warm water, low-irregular flow, standing water, and water diversions) compared to its natural state and function decades ago in the pre-dam era, are more conducive to warm water species such as Sacramento pikeminnow and striped bass than to native salmonids. Tucker *et al.* (1998) reported that predation during the summer months by Sacramento pikeminnow on juvenile salmonids increased to 66 percent of the total weight of stomach contents in the predatory pikeminnow. Striped bass showed a strong preference for juvenile salmonids as prey during this study. This research also indicated that the percent frequency of occurrence for juvenile salmonids nearly equaled other fish species in the stomach contents of the predatory fish. Tucker *et al.* (2003) showed the temporal distribution for these two predators in the RBDD area relative to the potential foraging impacts to juvenile salmonids. This report concluded that flow management was important to minimize the potential for congregating juvenile salmonids in the predator's foraging area.

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).

Predation on juvenile salmonids has increased as a result of water development activities which have created ideal habitats for predators and non-native 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 Fish Facilities, and the Suisun Marsh Salinity Control Gates (SMSCG). Predation on salmon by striped bass and pikeminnow at salvage release sites in the Delta and lower Sacramento River has been documented (Orsi 1967, Pickard *et al.* 1982); however, accurate predation rates at these sites are difficult to determine. CDFG conducted predation studies from 1987 to 1993 at the SMSCG to determine if the structure attracts and concentrates predators. The dominant predator species at the SMSCG was striped bass, and the remains of juvenile Chinook salmon were identified in their stomach contents (Edwards *et al.* 1996, Tillman *et al.* 1996, NMFS 1997).

Although the behavior of salmon and steelhead reduces the potential for any single predator to focus exclusively on them, predation by certain species can be seasonally and locally significant. Changes in predator and prey populations along with changes in the environment, both related and unrelated to development, have been shown to reshape the role of predation (Li *et al.* 1987). Of the aquatic fish predators, Sacramento pikeminnow and striped bass, have the greatest potential to negatively affect the abundance of juvenile salmonids. These are large, opportunistic predators that feed on a variety of prey and switch their feeding patterns when spatially or temporally segregated from a commonly consumed prey. Catfish also have the potential to significantly affect the abundance of juvenile salmonids. Likewise, prickly (*Cottus asper*) and riffle (*C. gulosus*) sculpins, as well as larger salmonids also prey on juvenile salmonids (Hunter 1959; Patten 1962, 1971a, 1971b).

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

d. *Other Natural and Manmade Factors*

(1) *Climate Change*

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

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

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

In light of the predicted impacts of global warming, the Central Valley has been modeled to have an increase of between 2 °C and 7 °C by 2100 (Dettinger *et al.* 2004, Hayhoe *et al.* 2004, Van Rheenen *et al.* 2004, Dettinger 2005), with a drier hydrology predominated by precipitation rather than snowfall. This will alter river runoff patterns and transform the tributaries that feed the Central Valley from a spring/summer snowmelt dominated system to a winter rain dominated system. It can be hypothesized that summer temperatures and flow levels will become unsuitable for salmonid survival. The cold snowmelt that furnishes the late spring and early summer runoff will be replaced by warmer precipitation runoff. This should truncate the period of time that suitable cold-water conditions exist below existing reservoirs and dams due to the warmer inflow temperatures to the reservoir from rain runoff. Without the necessary cold water pool developed from melting snow pack filling reservoirs in the spring and early summer, late summer and fall temperatures below reservoirs, such as Lake Shasta, could potentially rise above thermal tolerances for juvenile and adult salmonids (*i.e.* Sacramento River winter-run Chinook salmon and Central Valley steelhead) that must hold below the dam over the summer and fall periods.

(2) *Artificial Propagation*

Five hatcheries currently produce Chinook salmon in the Central Valley and four of these also produce steelhead. Releasing large numbers of hatchery fish can pose a threat to wild Chinook salmon and steelhead stocks through genetic impacts, competition for food and other resources between hatchery and wild fish, predation of hatchery fish on wild fish, and increased fishing pressure on wild stocks as a result of hatchery production (Waples 1991). The genetic impacts of artificial propagation programs in the Central Valley primarily are caused by straying of hatchery fish and the subsequent interbreeding of hatchery fish with wild fish. In the Central Valley, practices such as transferring eggs between hatcheries and trucking smolts to distant sites for release contribute to elevated straying levels. For example, Nimbus Hatchery on the American River rears Eel River steelhead stock and releases these fish in the Sacramento River basin. One of the recommendations in the Joint Hatchery Review Report (NMFS and CDFG 2001) was to identify and designate new sources of steelhead brood stock to replace the current Eel River origin brood stock.

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

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

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

The relatively low number of spawners needed to sustain a hatchery population can result in high harvest-to-escapements ratios in waters where fishing regulations are set according to hatchery population. This can lead to over-exploitation and reduction in the size of wild populations existing in the same system as hatchery populations due to incidental bycatch (McEwan 2001).

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

(3) *Ocean Conditions*

Natural changes in the freshwater and marine environments play a major role in salmonid abundance. Recent evidence suggests that marine survival among salmonids fluctuates in response to 20- to 30-year cycles of climatic conditions and ocean productivity (Hare *et al.* 1999, Mantua and Hare 2002). This phenomenon has been referred to as the Pacific Decadal Oscillation. In addition, large-scale climatic regime shifts, such as the El Ni•o condition, appear to change productivity levels over large expanses of the Pacific Ocean. A further confounding effect is the fluctuation between drought and wet conditions in the basins of the American west.

During the first part of the 1990s, much of the Pacific Coast was subject to a series of very dry years, which reduced inflows to watersheds up and down the west coast.

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

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

(4) *Floods and Droughts*

During flood events, land disturbances resulting from logging, road construction, mining, urbanization, livestock grazing, agriculture, fire, and other uses may contribute sediment directly to streams or exacerbate sedimentation from natural erosive processes (California Advisory Committee on Salmon and Steelhead Trout 1988, NMFS 1996a, b). Sedimentation of streambeds has been implicated as a principle cause of declining salmonid populations throughout their range. In addition to problems associated with sedimentation, flooding can cause scour and deposition of spawning gravels in typically inaccessible areas. As streams and pools fill in with sediment, flood flow capacity is reduced. Such changes cause decreased stream stability and increased bank erosion, and subsequently exacerbate existing sedimentation problems (NMFS 1996a, b). All of these sources contribute to the sedimentation of spawning gravels and filling of pools and estuaries used by all anadromous salmonids. Channel widening and loss of pool-riffle sequence due to aggradation has damaged spawning and rearing habitat of all salmonids.

Unusual drought conditions may warrant additional consideration in California. Flows in 2001 were among the lowest flow conditions on record in the Central Valley. The available water in the Sacramento watershed and San Joaquin watershed was 70 percent and 66 percent of normal, according to the Sacramento River Index and the San Joaquin River Index, respectively. Back-to-back drought years could be catastrophic to small populations of listed salmonids that are dependent upon reservoir releases for their success (*e.g.*, Sacramento River winter-run Chinook salmon). Therefore, reservoir carryover storage (usually referred to as end-of-September storage) is a key element in providing adequate reserves to protect salmon and steelhead during extended drought periods. In order to buffer the effect of drought conditions and over allocation of resources, NMFS in the past has recommended that minimum carryover storage be maintained in Shasta and other reservoirs to help alleviate critical flow and temperature conditions in the fall.

(5) *Invasive Species*

The extensive introductions of NIS have dramatically altered the biological relationships between and among salmonids and the natural communities that share rivers (NMFS 1998). As currently seen in the San Francisco Estuary, NIS can alter the natural food webs that existed prior to their introduction. Perhaps the most significant example is illustrated by the Asiatic freshwater clams *Corbicula fluminea* and *Potamocorbula amurensis*. The arrival of these clams in the estuary disrupted the normal benthic community structure and depressed phytoplankton levels in the estuary due to the highly efficient filter feeding of the introduced clams (Cohen and Moyle 2004). The decline in the levels of phytoplankton reduces the population levels of zooplankton that feed upon them, and hence reduces the forage base available to salmonids transiting the Delta and San Francisco Estuary which feed either upon the zooplankton directly or their mature forms. This lack of forage base can adversely impact the health and physiological condition of these salmonids as they emigrate through the Delta region to the Pacific Ocean.

Attempts to control the NIS also can adversely impact the health and well being of salmonids within the affected water systems. For example, the control programs for the invasive water hyacinth 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 has 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.

(6) *Ecosystem Restoration*

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

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

The EPA's Iron Mountain Mine remediation involves the removal of toxic metals in acidic mine drainage from the Spring Creek Watershed with a state-of-the-art lime neutralization plant. Contaminant loading into the Sacramento River from Iron Mountain Mine has shown measurable reductions since the early 1990s. Decreasing the heavy metal contaminants that enter the Sacramento River should increase the survival of salmonid eggs and juveniles. However, during periods of heavy rainfall upstream of the Iron Mountain Mine, Reclamation substantially increases Sacramento River flows in order to dilute heavy metal contaminants being spilled from the Spring Creek debris dam. This rapid change in flows can cause juvenile salmonids to become stranded or isolated in side channels below Keswick Dam.

The California Department of Water Resource's (DWR) Four Pumps Agreement Program has approved approximately $49 million for projects that benefit salmon and steelhead production in the Sacramento-San Joaquin basins and Delta since the agreement's inception in 1986. Four Pumps projects that benefit Central Valley spring-run Chinook salmon and steelhead include water exchange programs on Mill and Deer Creeks; enhanced law enforcement efforts from San Francisco Estuary upstream to the Sacramento and San Joaquin Rivers and their tributaries; design and construction of fish screens and ladders on Butte Creek; and, screening of diversions in Suisun Marsh and San Joaquin tributaries. Predator habitat isolation and removal, and spawning habitat enhancement projects on the San Joaquin tributaries benefit steelhead.

The Spring-run Salmon Increased Protection Project provides overtime wages for CDFG wardens to focus on reducing illegal take and illegal water diversions on upper Sacramento River tributaries and adult holding areas, where the fish are vulnerable to poaching. This project covers Mill, Deer, Antelope, Butte, Big Chico, Cottonwood, and Battle Creeks, and has been in effect since 1996. Through the Delta-Bay Enhanced Enforcement Program, initiated in 1994, a team of 10 wardens focus their enforcement efforts on salmon, steelhead, and other species of concern from the San Francisco Estuary upstream into the Sacramento and San Joaquin River basins. These two enhanced enforcement programs have had significant, but un-quantified benefits to spring-run Chinook salmon attributed to CDFG.

The Mill and Deer Creek Water Exchange projects are designed to provide new wells that enable diverters to bank groundwater in place of stream flow, thus leaving water in the stream during critical migration periods. On Mill Creek several agreements between Los Molinos Mutual Water Company (LMMWC), Orange Cove Irrigation District, CDFG, and DWR allows DWR to pump groundwater from two wells into the LMMWC canals to pay back LMMWC water rights for surface water released downstream for fish. Although the Mill Creek Water Exchange project was initiated in 1990 and the agreement allows for a well capacity of 25 cubic feet per second (cfs), only 12 cfs has been developed to date. In addition, it has been determined that a base flow of greater than 25 cfs is needed during the April through June period for upstream passage of adult spring-run Chinook salmon in Mill Creek. In some years, water diversions from the creek are curtailed by amounts sufficient to provide for passage of upstream migrating adult spring-run Chinook salmon and downstream migrating juvenile steelhead and spring-run Chinook salmon. However, the current arrangement does not ensure adequate flow conditions will be maintained in all years. DWR, CDFG, and USFWS have developed the Mill Creek Adaptive Management Enhancement Plan to address the instream flow issues. A pilot project using 1 of the 10 pumps originally proposed for Deer Creek was tested in summer 2003. Future testing is planned with implementation to follow.

2. Southern Distinct Population Segment of North American Green Sturgeon

The principal factors for the decline in the Southern DPS of North American green sturgeon are reviewed in the proposed listing notice (70 FR 17386) and status reviews (Adams *et al.* 2002, NMFS 2005), and primarily consist of: (1) the present or threatened destruction, modification, or curtailment of habitat or range; (2) poor water quality; (3) over-utilization; (4) increased water temperatures, (5) NIS, and (6), other natural and manmade factors. At this time, critical habitat for the southern DPS of the North American green sturgeon has not been designated by publication in the Federal Register. However it is anticipated that it will be similar to that already published for the Central Valley spring-run Chinook salmon ESU and the Central Valley steelhead DPS.

a. *The Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range*

(1) ***Habitat Blockage and Range***

NMFS (2005) evaluated the ability to rank threats, but concluded that this was not possible due to the lack of information about their impact on the Southern DPS of North American green sturgeon; however, the principle threat considered is the impassible barriers, primarily Keswick and Shasta Dams on the Sacramento River and Feather River that likely block and prevent access to historic spawning habitat (NMFS 2005). Recent habitat evaluations conducted in the upper Sacramento River for salmonid recovery planning suggests that significant potential green sturgeon spawning habitat was made inaccessible or altered by dams (historical habitat characteristics, temperature, and geology summarized by Lindley *et al.* 2004). This spawning habitat may have extended up into the three major branches of the Sacramento River; the Little

Sacramento River, the Pit River system, and the McCloud River (NMFS 2005). Green and white sturgeon adults have been observed periodically in the Feather River (USFWS 1995, Beamesderfer *et al.* 2004). There are no records of larval or juvenile white or green sturgeon; however, there are reports that green sturgeon may reproduce in the Feather River during high flow years (CDFG 2002c), but these are unconfirmed. No green sturgeon have been observed in the San Joaquin River; however, the presence of white sturgeon has been documented (USFWS 1995, Beamesderfer *et al.* 2004) making the presence of green sturgeon likely historically as the two species require similar habitat and their ranges overlap in the Sacramento River. In addition, the San Joaquin River had the largest spring-run Chinook salmon population in the Central Valley prior to the construction of Friant Dam (Yoshiyama *et al.* 2001) with escapements approaching 500,000 fish. Thus it is very possible, based on prior spring-run Chinook salmon distribution and habitat use of the San Joaquin River, that green sturgeon were extirpated from the San Joaquin Basin in a similar manner to spring-run. The loss of potential green sturgeon spawning habitat on the San Joaquin River also may have contributed to the overall decline of the Southern DPS of North American green sturgeon.

(2) ***Water Diversion***

Based on the limited information regarding the size of green sturgeon larvae and nocturnal behavior during their development as well as the high number of diversions on the Sacramento River, it is reasonable to assume the potential threats of water diversions to green sturgeon are relatively high. Under laboratory conditions, green sturgeon larvae cling to the bottom during the day, and move into the water column at night (Van Eenennaam *et al.* 2001). After 6 days, the larvae exhibit nocturnal swim-up activity (Deng *et al.* 2002) and nocturnal downstream migrational movements (Kynard *et al.* 2005). At 5 days of age, larvae are approximately 22 mm in total length (Van Eenennaam *et al.* 2001). Based on this information, it is assumed larvae green sturgeon are suseptable to entrainment primarily from benthic water diversion facilities during the first 5 days of development and suseptable to diversion entrainment from facilities drawing water from the bottom and top of the water column when they are exhibiting noctornal behavior (starting at day 6), and at a total length of approximatley 22 mm.

Herren and Kawasaki (2001) documented up to 431 diversions in the Sacramento River between Sacramento and Shasta Dam, most of which were unscreened and of the vertical or slant pump type. Entrainment information regarding larval and post-larval Southern DPS of North American green sturgeon is paltry, as the field identification of green sturgeon larvae is difficult. USFWS staff are working on identification techniques and are optimistic that green sturgeon greater than 40 mm can be identified in the field (Bill Poytress, USFWS, pers. comm. 2006). Captures reported by GCID are not identified to species but are assumed to primarily consist of green sturgeon as white sturgeon are known to spawn primarily between Knights Landing and Colusa (Schaffter 1997). Screens at GCID satisfy both the NMFS and CDFG screening criteria; however, the effectiveness of NMFS and CDFG screen criteria is unknown for sturgeon and there is a possibility that larval and post-larval green sturgeon are taken at GCID. Low numbers of Southern DPS of North American green sturgeon have also been identified and entrained at the Red Bluff Research Pumping Plant (Borthwick *et al.* 1999) and the efficacy of identification and enumeration of entrained post-larval green sturgeon is unknown at this location. The ACID diversion facility also may threaten larval and post-larval Southern DPS of North American green sturgeon as the upstream location of this facility exposes larvae and post-larval stages to entrainment. Information on the entrainment and impacts of this diversion on Southern DPS North American green sturgeon are unknown. Information regarding the impacts of other small-scale diversions indicated in Herren and Kawaski report (2001) on the Sacramento River is unknown.

Presumably, as green sturgeon juveniles grow, they become less susceptible to entrainment as their capacity to escape diversions improve. The majority of Southern DPS North American green sturgeon captured in the Delta and San Francisco Estuary are between 200 and 500 mm (CDFG 2002c). Herren and Kawasaki (2001) inventoried water diversions in the Delta finding a total of 2,209 diversions of various types, only 0.7 percent of which were screened. The majority of these diversions were between 12 and 24 inches in diameter, likely with relatively little threat to larger juvenile sturgeon. The largest diversions recorded were those of the Fish Facilities in the south Delta. Based on historical data and captures at the Fish Facilities (CDFG 2002c), it is reasonable to assume an unknown portion of the juvenile and adult population is excessively stressed, injured, harassed, or killed by the pumping plants.

Eight large diversions greater than 10 cfs and approximately 60 small diversions between 1 and 10 cfs exist on the Feather River between the Thermalito Afterbay outlet and the confluence with the Sacramento River (USFWS 1995). No studies to date have specifically addressed sturgeon entrainment on the Feather River; however, studies related to Chinook salmon entrainment at the Sutter Extension Water District's sunrise pumps found significant losses of juvenile salmon (USFWS 1995). Based on potential entrainment problems of green sturgeon elsewhere in the Central Valley and the presence of multiple screened and unscreened diversions in the Feather River, it is assumed that water diversions on the Feather River are a possible threat to juvenile Southern DPS North American green sturgeon.

A significant number of studies have been completed indicating that water exports are a limiting factor on native fish in the Delta (Kjelson *et al.* 1981, Kjelson *et al.* 1990, Meng *et al.* 1994, Meng and Moyle 1995, Arthur *et al.* 1996, and Bennett and Moyle 1996, and Meng and Matern 2001). CDFG (1992) found a strong correlation between mean daily freshwater outflow (April to July) and white sturgeon year class strength in the Delta (many of the studies concerning sturgeon in the Delta involve the more abundant white sturgeon; however, the threats to green sturgeon are thought to be similar). Additional evidence supporting this relationship was also found when comparing annual production of young sturgeon in the San Francisco Estuary and salvage of young sturgeon at the Skinner Fish Facility between 1968 and 1987 during the months of April and May (CDFG 1992). This association of year class strength with outflow is also found in other anadromous fishes inhabiting the Estuary, such as striped bass, Chinook salmon, American shad, and longfin smelt (Stevens and Miller 1983). It is postulated that increased outflows could improve survival by: (1) dispersing larvae to areas of greater food availability, (2) dispersing larvae over a wider area of the regional rivers and the San Francisco Estuary thereby taking advantage of all available habitat, (3) quickly moving larvae downstream of any influence of the multiple water diversions located in the Delta, and (4) enhancing productivity in the nursery area by increasing nutrient supply (CDFG 1992). Because the YOY abundance-flow correlation exists in the Delta, it is also assumed to exist with tributary flows.

In an effort to quantify the flow requirements necessary to double sturgeon populations on the Sacramento River, USFWS (1995) used the YOY age class estimates and corresponding flow data on the Sacramento River to identify years with good recruitment of white sturgeon. Year class estimates greater than two times the mean year class estimates were classified as good recruitment years. All other years were classified as poor recruitment years. Flow measured in the Sacramento River at Grimes and at Verona between February 1 and May 31 was then compared with corresponding YOY year class estimates between 1968 and 1990. All good recruitment years occurred in both wet or above-normal years and the flow from the good recruitment year with the lowest flow was used as a minimum flow standard (USFWS 1995). A minimum flow of 17,700 cfs between February 1 and May 31 at Grimes (RM 125) on the Sacramento River for wet and above normal water year types was recommended to provide adequate flows to allow adult migration from the San Francisco Estuary or ocean to spawning grounds, spawning, and downstream larval transport (USFWS 1995). Flows at or above 17,700 cfs occurred 6-times (26 percent of the time) over the 22-year period of measurements. This level of river flow was not reached during the 6-year period between 1999 and 2004, though the 1999 and 2000 water years were close at 17,054 and 17,154 cfs respectively. Until additional instream flow studies relating to sturgeon are complete, these flow recommendations offer an approximate target. Additional flow recommendations as measured at Verona on the Sacramento River (RM 80) are also provided in USFWS (1995).

No specific studies of the effects of water diversions on the Southern DPS of North American green sturgeon have been completed to date; however, based on the considerable amount of evidence regarding the effects of diversions on other native fish, including white sturgeon, it is likely that water diversions also impact the Southern DPS of North American green sturgeon. Beamesderfer *et al.* (2006) estimated that juvenile green sturgeon would be susceptible to entrainment for the first 2 years of their life.

(3) *Water Conveyance*

The impacts of the development of the water conveyance system in the Central Valley have been reviewed in section C: *Factors Affecting the Species and Critical Habitat, Chinook Salmon and Central Valley Steelhead* of this biological option. As mentioned previously, the impacts of channelization and bank riprapping adversely affects important ecosystem functions (Stillwater Sciences 2006). 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, mayflies, oligochaetes, and chironomids per unit channel length decreases with an associated affect on the availability of secondary consumer food supply (*i.e.*, for green sturgeon). Living space and food for terrestrial and aquatic invertebrates is lost, eliminating an important food source for juvenile fish. Loss of riparian vegetation and soft substrates reduces inputs of organic material to the stream ecosystem in the form of leaves, detritus, and woody debris, which can affect biological production at all trophic levels. Information on the lateral dispersion of green sturgeon across channel profiles is limited. Based on the benthic orientation of green sturgeon it is assumed habitat related impacts of channelization and riprapping would primarily consist of ecosystem related impacts, such as food source changes, and altered predator densities. The impacts of channelization and riprapping are thought to affect larval, post-larval, juvenile and adult stages of Southern DPS North American green sturgeon, as they are all dependent upon the food web in freshwater for at least a portion of their life cycle.

(4) *Migration Barriers*

Adult migration barriers to green sturgeon include structures such as the RBDD, ACID, Sacramento Deep Water Ship Channel locks, Fremont Weir, Sutter Bypass, and DCC Gates. Major physical barriers to adult sturgeon migration on the mainstem Sacramento River are the RBDD and ACID diversion dam (USWFS 1995). Unimpeded migration past RBDD occurs when gates are raised between mid September and May for winter-run Chinook salmon passage measures. Fish ladders at RBDD are designed for salmonid passage and are used when dam gates are raised; however, improvements to the fish ladders may be possible if they can be designed to emulate the north ladder on Bonneville Dam on the Columbia River, which passes sturgeon successfully (CDFG 2002c).

The Sacramento River Deep Water Ship Channel connects with the Sacramento River near the Cache Slough confluence above Rio Vista and provides a deepened and straightened channel to West Sacramento for commercial shipping purposes. A set of locks at the end of the channel at the connection with Sacramento River (in West Sacramento) "blocks the migration of all fish from the deep water ship channel back to the Sacramento River" (DWR 2003).

The Fremont Weir is located at the northern end of Yolo Bypass, a 40-mile long basin that functions as a flood control outlet. DWR (2003) indicates that "sturgeon and sometimes salmon are attracted by high flows into the Yolo Bypass basin and then become concentrated behind Fremont Weir." They are then subject to heavy legal and illegal fishing pressure. In addition, field and anecdotal evidence shows that adult green sturgeon migrate up the Yolo Bypass up the Toe Drain in autumn and winter regardless of Fremont Weir spills (DWR 2003). The weir is approximately 2 miles long and 5 feet high and contains a poorly functioning fish ladder.

Numerous weirs and barriers in the Yolo Bypass that are known to be passage issues for Chinook salmon also could block sturgeon migration. Sturgeon are attracted to discharges into the toe drains of the Yolo Bypass and subsequently can't re-enter the Sacramento River once they enter. In addition, sturgeon attempt to pass over the Fremont weir during flood flows and become stranded behind the concrete weir when the flows recede. Though most of these barriers have fish passage structures that work during certain flows (DWR 2003), they are mostly designed for salmonid passage and would likely block sturgeon.

Upstream migrating adult Chinook salmon are known to utilize the DCC as a migratory pathway (Hallock *et al.* 1970). When the gates are open, Sacramento River water flows into the Mokelumne and San Joaquin Rivers providing migration cues. Attraction to this diverted water is thought to be one of the factors delaying and increasing the straying rate of Chinook salmon (CALFED Science Program 2001, McLaughlin and McLain 2004). In addition to increased travel distances, gate closures can completely block anadromous fish migrations forcing the fish to hold or retrace their routes through the Delta to reach spawning grounds upstream. DCC gate closures typically occur during the winter and early spring months when sturgeon are believed to migrate. Evidence suggests that female sturgeon reabsorb eggs and forego spawning if prevented from reaching spawning grounds (USFWS 1995).

In addition, potential spawning habitat is blocked by the closure of the RBDD in May. Habitat between RBDD and Jelly's Ferry Bridge (RM 267) contains swift current and pools over 20 feet deep as well as sand to sand-gravel mixtures found to be preferred by spawning white sturgeon (USFWS 1995, Schaffter 1997, CDFG 2002c). Significant evidence exists that green sturgeon prefer similar spawning habitat, yet spawn above white sturgeon spawning areas on the Sacramento River (CDFG 2002c).

Exact sturgeon spawning locations in Feather River are unknown; however, based on angler catches, most spawning is believed to occur downstream of Thermalito Afterbay and upstream of Cox's Spillway, just downstream of Gridley Bridge (USFWS 1995). The upstream migration barrier is likely a steep riffle 1 mile upstream of the Afterbay outlet with a depth of approximately 6 inches and length of 394 feet. Potential physical barriers to upstream migration include the rock dam associated with Sutter Extension Water District's sunrise pumps, shallow water caused by a head cut at Shanghai Bend, and several shallow riffles between the confluence of Honcut Creek upstream to the Thermalito Afterbay outlet (USFWS 1995). These structures are likely to present barriers to sturgeon during low flows blocking and or delaying migration to spawning habitat.

b. *Poor Water Quality*

PS and NPS pollution occurs at almost every point that urbanization activity influences the watershed. Impervious surfaces (*i.e.*, concrete) reduce water infiltration and increase runoff, thus creating greater flood hazard (NMFS 1996a, 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. Runoff from residential and industrial areas also contributes to water quality degradation (Regional Board 1998). Urban stormwater runoff contains pesticides, oil, grease, heavy metals, polynuclear aromatic hydrocarbons (PAHs), other organics and nutrients (Regional Board 1998) that contaminate drainage waters and destroy aquatic life necessary for sturgeon survival (NMFS 1996a, 1996b).

Environmental stresses as a result of low water quality can lower reproductive success and may account for low productivity rates of green sturgeon (Klimley 2002). Organic contaminants from agricultural drain water, urban and agricultural runoff from storm events, and high trace element concentrations may deleteriously affect early life-stage survival of fish in the Sacramento River (USFWS 1995). Principle sources of organic contamination in the Sacramento River are rice field discharges from Butte Slough, Reclamation District 108, Colusa Basin Drain, Sacramento Slough, and Jack Slough (USFWS 1995). Discharge of rice irrigation water has caused mortality to both *Ceriodaphnia* and fathead minnows (*Pimephales promelas*) in the Sacramento River and it is believed that rice field discharges in May and June could affect sturgeon larvae survival (USFWS 1995). No specific information is available on contaminant loads or impacts in green sturgeon and the difference in distribution of green and white sturgeon (ocean migrants vs.

estuarine inhabitants) probably makes green sturgeon less vulnerable than white sturgeon to bioaccumulation of contaminants found in the estuary (CDFG 2002c).

High levels of trace elements can also decrease sturgeon early life-stage survival, causing abnormal development and high mortality in yolk-sac fry sturgeon at concentrations at the levels of parts per billion (Dettlaff *et al.* 1981, as referenced in USFWS 1995). Water discharges from Iron Mountain Mine, contaminated with heavy metals, have affected survival of fish downstream of Keswick Dam and storage limitations and limited availability of dilution flows cause downstream copper and zinc levels to exceed salmonid tolerances (USFWS 1995). Although the impact of trace elements on Southern DPS of North American green sturgeon production is not completely understood, negative impacts are suspected (USFWS 1995).

Organic contaminants from agricultural returns, urban and agricultural runoff from storm events, and high trace element concentrations may deleteriously affect early life-stage survival of fish in the Feather River (USFWS 1995). Feather River water collected at Verona on May 27 and June 5, 1987, resulted in 50 and 60 percent mortality in *Ceriodaphnia* and fathead minnow bioassays, respectively. Similar effects were also found in the Feather River in 1988 and 1989 (Regional Board, 1991, as cited in USFWS 1995). Toxic effects were attributed to organic contaminants in rice irrigation water released into Jack Slough and into Honcut Creek and Bear River to a lesser degree. Elevated levels of arsenic, chromium, copper, and mercury exceeding median international standards were found in various fish species in the Feather River between 1978 and 1987.

Water quality in the San Joaquin River has degraded significantly since the late 1940s (2001, 2004). During this period, salt concentrations in the river near Vernalis have doubled. Concentrations of boron, selenium, molybdenum and other trace elements have also increased (Regional Board 2004). The extent of this problem as it relates to green sturgeon viability is unknown; however, it is clear that water quality on the San Joaquin River is potentially a problem for sturgeon (USFWS 1995).

c. *Over-Utilization and Poaching*

Commercial harvest for green sturgeon occurs primarily along the Oregon and Washington coasts and within their coastal estuaries. Adams *et al.* (2002) reported harvest of green sturgeon from California, Oregon, and Washington between 1985 and 2001. Total captures of green sturgeon in the Columbia River Estuary by commercial means ranged from 240 fish per year to 6,000. Catches in Willapa Bay and Grays Harbor by commercial means combined ranged from 9 fish to 2,494 fish per year. Emmett *et al.* (1991) indicated that an average of 4.7 to 15.9 tons of green sturgeon are landed annually in Grays Harbor and Willapa Bay respectively. Overall, captures appear to be dropping through the years; however, this could be related to changing fishing regulations. Adams *et al.* (2002) also reported sport fishing captures in California, Oregon, and Washington. Within the San Francisco Estuary, green sturgeon are captured by sport fisherman targeting the more desirable white sturgeon, particularly in San Pablo and Suisun bays (Emmett *et al.* 1991). While no sport fishing capture numbers for green sturgeon can be enumerated in California, as all green sturgeon captured are captured incidentally, sport fishing in the Columbia River, Willapa Bay, and Grays Harbor captured from 22 to 553 fish per year between 1985 and 2001. Again, it appears sport fishing captures are dropping through time; however, it is not known if this is a result of abundance, changed fishing regulations, or other factors. Based on new research by Israel (2006a) and past tagged fish returns reported by CDFG (2002c), a high proportion of green sturgeon present in the Columbia River, Willapa Bay, and Grays Harbor (as much as 80 percent in the Columbia River) may be Southern DPS North American green sturgeon. This indicates a potential threat to the Southern DPS North American green sturgeon population. It is estimated that green sturgeon will be vulnerable to slot limits (outside of California) for approximately 14 years of their life span (Beamesderfer *et al.* 2006). Fishing gear mortality presents an additional risk to the long-lived sturgeon species such as the green sturgeon (Boreman 1997). Although sturgeon are relatively hardy and generally survive being hooked, their long life makes them vulnerable to repeated hooking encounters, which leads to an overall significant hooking mortality rate over their lifetime. An adult green sturgeon may not become sexually mature until they are 13 to 18 years of age for males (152-185cm), and 16 to 27 years of age for females (165-202 cm) (Van Eenennaam 2006). Even though slot limits "protect" a significant proportion of the life history of green sturgeon from harvest, they do not protect them from fishing pressure.

Green sturgeon are caught incidentally by sport fisherman targeting the more highly desired white sturgeon within the Delta waterways and the Sacramento River. Due to previous slot limits imposed on the sport fishery by the CDFG (2004c), only white sturgeon between 46 and 72 inches may be retained by sport fisherman with a daily bag limit of 1 fish in possession. New regulations that went into effect March 2007, will reduce the slot limit of sturgeon from 72 inches to 66 inches, and limit the retention of white sturgeon to one fish per day with a total of 3 fish retained per year. In addition, a non-transferable sturgeon punch card with tags must be purchased by each angler fishing for sturgeon. All sturgeon caught must be recorded on the card, including those released. All green sturgeon incidentally caught while fishing for white sturgeon must be released unharmed and recorded on the sturgeon punch card by the angler. CDFG (2002c) indicates high sturgeon vulnerability to the fishery in areas where sturgeon are concentrated, such as the Delta to San Pablo Bay area in late winter and the upper Sacramento River during the spawning migration. In addition, the trophy status of white sturgeon and the consequent incentive for retaining oversize (>183 cm) fish is another impetus for active enforcement of sturgeon angling regulations (CDFG 2002c).

Poaching rates on the Feather River are unknown; however, catches of sturgeon occur during all years, especially during wet years. There is no catch, effort, and stock size data precluding exploitation estimates (USFWS 1995). Areas just downstream of Thermalito Afterbay outlet and Cox's Spillway, and several barriers impeding migration may be areas of high adult mortality from increased fishing effort and poaching.

Poaching rates on the San Joaquin River are unknown; however, catches of sturgeon occur during all years, especially during wet years. There is no catch, effort, and stock size data precluding exploitation estimates. What is known is that the small population of sturgeon inhabiting the San Joaquin River experiences heavy fishing pressure, particularly regarding illegal snagging and it may be more than the population can support (USFWS 1995).

d. *Increased Water Temperature*

Water temperatures greater than 63 °F can increase sturgeon egg and larval mortality (Van Eenennaam *et al.* 2005). Temperatures near RBDD on the Sacramento River historically occur within optimum ranges for sturgeon reproduction; however, temperatures downstream of RBDD, especially later in the spawning season, were reported to be frequently above 63 °F (USFWS 1995). High temperatures in the Sacramento River during the February to June period no longer appear to be a concern as temperatures in the upper Sacramento River are actively managed for Sacramento River winter-run Chinook salmon, and the Shasta temperature curtain device installed at Shasta Dam in 1997 appears to maintain cool water conditions. A review of temperatures at RBDD during May and June between the years of 1995 and 2004 found no daily temperatures greater than 60 °F (California Data Exchange Center preliminary data, RBDD daily water temperature data).

Approximately 5 miles downstream of Oroville Dam, water is diverted at the Thermalito Diversion Dam, into the Thermalito Power Canal, then to the Thermalito Forebay and another powerhouse and finally into the Thermalito Afterbay. The Oroville-Thermalito Complex provides water conservation, hydroelectric power, recreation, flood control, and fisheries benefits. Feather River flows downstream of Oroville Dam to the Thermalito Diversion Dam are often referred to as the "low-flow" river section and maintain a constant 600 cfs. Thus, water temperatures downstream of the Thermalito Afterbay outlet are considerably higher than temperatures in the low-flow channel (USFWS 1995). It is likely that high water temperatures (greater than 63 °F) may deleteriously affect sturgeon egg and larval development, especially for late-spawning fish in drier water years (USFWS 1995). CDFG (2002c) also indicated water temperatures may be inadequate for spawning and egg incubation in the Feather River during many years as the result of releases of warmed water from Thermalito Afterbay. They believed that this may be one the reasons neither green nor white sturgeon are found in the river during low-flow years. It is not expected that water temperatures will become more favorable in the near future (CDFG 2002c) and this temperature problem will continue to be a threat.

The lack of flow in the San Joaquin River as a result of Friant Dam operations and agricultural return flows also contributes to higher temperatures in the mainstem San Joaquin River offering less water to keep temperatures cool for anadromous fish. Temperatures can both directly and indirectly affect survival, growth rates, distribution, and development rates of anadromous fish (Myrick and Cech 2004). Though these effects are difficult to measure, temperatures in the lower San Joaquin River continually exceed preferred temperatures for sturgeon migration and development during spring months. Optimal temperatures for egg and larval survival of white sturgeon are between 50 and 63 °F and survival at early-developmental stages is severely reduced at temperatures greater than 68 °F (USFWS 1995). CDFG indicates water temperatures during May when Vernalis flow is less than 5,000 cfs were at levels causing chronic stress in juvenile Chinook salmon (Reynolds *et al.* 1993). Temperatures at Stevenson on the San Joaquin River near Merced River confluence on May 31 between 2000 and 2004 ranged from 77.2 to 81.7 °F (California Data Exchange Center, preliminary data). Juvenile sturgeon are exposed to increased water temperatures in the Delta during the late spring and summer due to the loss of riparian shading, and by thermal inputs from municipal, industrial, and agricultural discharges.

High water temperatures on the San Joaquin River and in the Delta likely are a threat to the Southern DPS of North American green sturgeon.

e. *Non-native Invasive Species*

Green sturgeon have most likely been impacted by NIS introductions resulting in changes in trophic interactions in the Delta. Many of the recent introductions of invertebrates have greatly affected the benthic fauna in the Delta and bays. CDFG (2002c) reviewed many of the recent NIS introductions and the potential consequences to green sturgeon. Most notable species responsible for altering the trophic system of the Sacramento-San Joaquin Estuary include the overbite clam, the Chinese mitten crab, the introduced mysid shrimp *Acanthomysis bowmani*, and another introduced *Gammarid* spp. amphipod. Likewise, introductions of invasive plant species such as the water hyacinth (*Eichhornia crassipes*) and *Egeria densa* have altered nearshore and shallow water habitat by raising temperatures and inhibiting access to shallow water habitat. *Egeria densa* forms thick "walls" along the margins of channels in the Delta. This growth prevents juvenile native fish from accessing their preferred shallow water habitat along the channel's edge. Water hyacinth creates dense floating mats that can impede river flows and alter the aquatic environment beneath the mats. DO levels beneath the mats often drop below sustainable levels for fish due to the increased amount of decaying vegetative matter produced from the overlying mat. Like *Egeria*, water hyacinth is often associated with the margins of the Delta waterways in its initial colonization, but can eventually cover the entire channel if conditions permit. This level of infestation can produce barriers to anadromous fish migrations within the Delta. The introduction and spread of *Egeria* and water hyacinth have created the need for aquatic weed control programs that utilize herbicides targeting these species. The effects of these herbicides on green sturgeon are unknown and should be investigated.

f. *Other Natural and Manmade Factors*

(1) ***Dredging***

Hydraulic dredging is a common practice in the Delta and San Francisco Estuary to allow commercial vessel traffic. Such dredging operations use a cutterhead dredge pulling water upwards through intake pipelines, past hydraulic pumps, and down outflow pipelines to disposal sites placing bottom oriented fish such as North American green sturgeon at risk. In addition, dredging operations can elevate toxics such as ammonia, heavy metals, and organic compounds by disturbing the sediment horizons. Other factors include bathymetry changes and acoustic impacts.

(2) ***Climate Change***

The potential effects of climate change on the listed salmonids were discussed in the *Chinook Salmon and Central Valley Steelhead* section and primarily consist of altered ocean temperatures and stream flow patterns in the Central Valley. Changes in Pacific Ocean temperatures can alter predator prey relationships and affect migratory habitat of the Southern DPS of North American green sturgeon. Increases in rainfall and decreases in snow pack in the Sierra Nevada range will affect cold-water pool storage in reservoirs affecting river temperatures. As a result, the quantity and quality of water that may be available to the Southern DPS of North American green sturgeon will likely significantly decrease.

(3) *Conservation Measures*

The AFRP specifically applies the doubling effort toward Chinook salmon, Central Valley steelhead, striped bass, and white and green sturgeon. Though most efforts of the AFRP have primarily focused on Chinook salmon as a result of their listing history and status, Southern DPS of North American green sturgeon may receive some unknown amount of benefit from these restoration efforts. For example, the acquisition of water for flow enhancement on tributaries to the Sacramento River, fish screening for the protection of Chinook salmon and Central Valley steelhead, or riparian revegetation and instream restoration projects would likely have some ancillary benefits to the Southern DPS. The AFRP has also invested in one green sturgeon research project that has helped improve our understanding of the life history requirements and temporal patterns of the of the Southern DPS of North American green sturgeon.

Many notable beneficial actions have originated and been funded by the CALFED program including such projects as floodplain and instream restoration, riparian habitat protection, fish screening and passage projects, research regarding NIS and contaminants, restoration methods, and watershed stewardship and education and outreach programs. Prior Federal Register notices have reviewed the details of CVPIA and CALFED programs and potential benefits towards anadromous fish, particularly Chinook salmon and Central Valley steelhead (50 CFR 33102). Projects potentially benefiting North American green sturgeon primarily consist of fish screen evaluation and construction projects, restoration evaluation and enhancement activities, contaminations studies, and DO investigations related to the San Joaquin River Deep Water Ship Channel. Two evaluation projects specifically addressed green sturgeon while the remaining projects primarily address listed salmonids and fishes of the area in general. The new information from research will be used to enhance our understanding of the risk factors affecting recovery thereby improving our ability to develop effective management measures.

IV. ENVIRONMENTAL BASELINE

The environmental baseline "includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process" (50 CFR §402.02).

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

1. Status of the Species Within the Action Area

The action area functions as a migratory corridor for adult Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead, and provides migration and rearing habitat for juveniles of these species. A large proportion of all Federally listed Central Valley salmonids from the Sacramento River watershed is expected to utilize aquatic habitat within the northern portion of the action area. All Central Valley steelhead originating in the San Joaquin River watershed will have to migrate through the action area. The action area also functions as a migratory and holding corridor for adult and rearing and migratory habitat for juvenile Southern DPS of North American green sturgeon.

a. *Sacramento River Winter-run Chinook Salmon*

Sacramento River winter-run Chinook salmon currently are present only in the Sacramento River below Keswick Dam, and are composed of a single breeding population (see the *Status of the Species and Critical Habitat* section). The entire population of migrating adults and emigrating juveniles must pass through the northern portion of the action area.

A detailed assessment of the migration timing of Sacramento River winter-run Chinook salmon was reviewed in the *Status of the Species and Critical Habitat* section. Adult Sacramento River winter-run Chinook salmon are expected to be present in the Sacramento River portion of the action area between November and June (Myers *et al.* 1998, Good *et al.* 2005) as they migrate to spawning grounds. Juvenile Sacramento River winter-run Chinook salmon migration patterns in the action area can best be described by temporal migration characteristics found by the USFWS (2001b) in beach seine captures on the lower Sacramento River downstream of Sacramento. Because beach seining samples the shoreline rather than the center of the channel as is often the case in rotary screw traps and trawls, it is considered the most accurate sampling effort in predicting the nearshore presence of juvenile salmonids. In the Delta area, juveniles are expected between November and April with the highest densities occurring between December and March. Sacramento River winter-run Chinook juveniles have been found to rear for up to 90-days in the Delta before moving out of the Delta towards the ocean (Pat Brandes, USFWS, unpublished data). Emigrating smolts are expected to continue passing by Chipps Island in the western Delta until mid-May, with peak emigration occurring in March.

b. *Central Valley Spring-run Chinook Salmon*

Central Valley spring-run Chinook salmon populations currently spawn in the Sacramento River below Keswick Dam, the low-flow channel of the Feather River, and in Sacramento River tributaries including Mill, Deer, Antelope, and Butte Creeks (CDFG 1998). The entire population of migrating adults and emigrating juveniles must pass through the northern portion of the action area to enter or leave the Sacramento River watershed.

A detailed assessment of the migration timing of Central Valley spring-run Chinook salmon was reviewed in the *Status of the Species and Critical Habitat* section. Adult Central Valley spring-run Chinook salmon are expected on the Sacramento River between March and July (Myers *et al.* 1998, Good *et al.* 2005). Peak presence of adults moving through the action area is believed to be during February and March (CDFG 1998). In the Sacramento River, juveniles may begin migrating downstream almost immediately following emergence from the gravel with most emigration occurring from December through March (Moyle *et. al.* 1989, Vogel and Marine 1991). Snider and Titus (2000) observed that up to 69 percent of spring-run Chinook salmon emigrate during the first migration phase between November and early January. The remainder of the Central Valley spring-run Chinook salmon emigrate during subsequent phases that extend into early June. The age structure of emigrating juveniles is comprised of YOY and yearlings. The exact composition of the age structure is not known, although populations from Mill and Deer Creek primarily emigrate as yearlings (Colleen Harvey-Arrison, CDFG, pers. comm. 2004), and populations from Butte Creek primarily emigrate as fry (Ward *et. al.* 2002). Younger juveniles are found closer to the shoreline than older individuals (Healey 1991). Records from the CVP and SWP for the period between 1999 and 2005 indicate that 66 percent of the annual spring-run Chinook salmon smolt salvage occurred in the month of April, with approximately 10 percent of the salvaged spring-run Chinook salmon smolts occurring in May (9 percent) and June (1 percent).

c. *Central Valley Steelhead*

Central Valley steelhead populations currently spawn in tributaries to the Sacramento and San Joaquin Rivers. The action area encompasses the confluence of both watersheds (*i.e.*, the Delta), therefore, 100 percent of the Central Valley steelhead DPS must pass through the action area to gain access to the ocean. Adult steelhead may be present in the action area from June through March, with the peak occurring between August and October (Bailey 1954, Hallock *et al.* 1957). Juvenile steelhead emigrate through the Sacramento River from late fall to spring. Snider and Titus (2000) observed that juvenile steelhead emigration primarily occurs between November and May at Knights Landing. The majority of juvenile steelhead emigrate as yearlings and are assumed to be primarily utilizing the center of the channel rather than the shoreline. Records from the CVP and SWP for the period between 1999 and 2005 indicate that nearly all juvenile steelhead salvaged occurred between the months of January and March, however nearly 6 percent of the population emigrated during the period between April and June.

d. *Southern DPS of North American Green Sturgeon*

The spawning population of the Southern DPS of North American green sturgeon currently is restricted to the Sacramento River below Keswick Dam, and is composed of a single breeding population (*Status of the Species and Critical Habitat* section); thus, the entire population of adults and juveniles must pass through the action area. Anecdotal evidence as well as habitat analysis by Lindley *et al.* (2004) indicates that the Southern DPS of North American green sturgeon may have been present on the Feather River (NMFS 2005) and the USFWS (1995) indicates they may be present on the Bear River, particularly during high water years.

A detailed assessment of the migration timing and life-history of the Southern DPS of North American green sturgeon was reviewed in the *Status of the Species and Critical Habitat* section. Adult North American green sturgeon migrate upstream through the action area primarily between March and June (Adams *et al.* 2002, 2006, Beamesderfer *et al.* 2006). Larva and post-larvae are present on the lower Sacramento River between May and October, primarily during June and July (CDFG 2002, Beamesderfer *et al.* 2006). Small numbers of juvenile North American green sturgeon have been captured at various locations on the Sacramento River as well as in the Delta (in the action area downstream of Sacramento) during all months of the year (IEP Database, Borthwick *et al.* 1999).

2. Status of Critical Habitat Within the Action Area

a. *Sacramento River Winter-run Chinook salmon, Central Valley Steelhead and Central Valley Spring-run Chinook Salmon*

The action area is within designated critical habitat for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead. Habitat requirements for these species are similar. The PCEs of salmonid habitat within the action area include: freshwater rearing habitat, freshwater migration corridors, and estuarine areas, containing adequate substrate, water quality, water quantity, water temperature, water velocity, cover/shelter, food; riparian vegetation, space, and safe passage conditions. Habitat within the action area is primarily used as freshwater rearing and migration and as freshwater migration for adults. The condition and function of this habitat has been severely impaired through several factors discussed in the *Status of the Species and Habitat* section of this biological opinion. The result has been the reduction in quantity and quality of several PCEs of migration and rearing habitat required by juveniles to grow, and survive. In spite of the degraded condition of this habitat, the area's conservation value (*i.e.*, the importance of the area to species conservation) is high because miles of its interconnected waterways are used for extended periods of time by a large proportion of all Federally listed anadromous fish species in the Central Valley.

The diversion and storage of natural flows by dams and diversion structures on Central Valley waterways have depleted streamflows and altered the natural cycles under which juvenile and adult salmonids have evolved. Changes in streamflows and diversions of water affect freshwater rearing habitat and freshwater migration corridor PCEs in the action area. Various land-use activities in the action area such as urbanization and agricultural encroachment have resulted in habitat simplification. Runoff from residential and industrial areas, as well as widespread recreational boating activities, also contributes to water quality degradation (Regional Board 1998, 2001). Urban stormwater runoff contains pesticides, oil, grease, heavy metals, PAHs, other organics and nutrients (Regional Board 1998, 2001) that contaminate drainage waters and destroy aquatic life necessary for salmonid survival (NMFS 1996a,b). In addition, juvenile salmonids are exposed to increased water temperatures as a result of thermal inputs from municipal, industrial, and agricultural discharges in the action area. Accelerated predation as a result of habitat changes in the action area, such as the alteration of natural flow regimes and the installation of bank revetment structures such as dams, bridges, water diversions, piers and wharves, likely are a factor in the decline of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead.

3. Southern DPS of North American Green Sturgeon

The action area is utilized by the Southern DPS of North American green sturgeon adults for migration and rearing purposes. The high number of diversions in the action area on both the Sacramento River and in the legal Delta are a potential threat to the Southern DPS of North American green sturgeon. It is assumed larval green sturgeon are susceptible to entrainment primarily from benthic water diversion facilities during the first 5 days of development and susceptible to diversion entrainment from facilities drawing water from the bottom and top of the water column when they are exhibiting nocturnal swim-up behavior (starting at day 6). Reduced flows in the action area likely affect year class strength of the Southern DPS of North American green sturgeon as increased flows have been found to improve year class strength of white sturgeon (CDFG 1992). Various land-use activities in the action area such as urbanization and agricultural encroachment have resulted in habitat simplification. Runoff from residential and industrial areas also contributes to water quality degradation (Regional Board 1998, 2001). Urban stormwater runoff contains pesticides, oil, grease, heavy metals, PAHs, other organics and nutrients (Regional Board 1998, 2001) that contaminate drainage waters and destroy aquatic life necessary for green sturgeon survival (NMFS 1996a,b). In addition, juvenile and adult green sturgeon are exposed to increased water temperatures as a result of thermal inputs from municipal, industrial, and agricultural discharges in the action area (*i.e.*, waster water treatment plants).

The transformation of the Sacramento River, San Joaquin River, and legal Delta from a meandering complex of waterways lined with dense riparian corridors, to a highly leveed system under varying degrees of control over riverine erosional processes resulted in homogenization of the river, including decreases in the river's sinuosity (USFWS 2000). In addition, the change in the ecosystem as a result of the removal of riparian vegetation and LWD likely impacted potential prey items and species interaction that green sturgeon would experience while holding in deep water. The effects of channelization on upstream migration of green sturgeon are unknown.

The lower Sacramento River and legal Delta are utilized by post-larvae and juvenile Southern DPS of North American green sturgeon for rearing and migration purposes. Although it is believed that post-larvae and juveniles primarily are benthically oriented (with the exception of the post-larvae nocturnal swim-up believed to be a dispersal mechanism), the massive channelization effort in the action area has resulted in a loss of ecosystem properties (USFWS 2000, Sweeney *et al.* 2004). Channelization results in reduced food supply (aquatic invertebrates) and reduced pollutant processing, organic matter processing, and nitrogen uptake (Sweeney *et al.* 2004).

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

The action area encompasses an important portion of the area utilized by the Sacramento River winter-run and Central Valley spring-run Chinook salmon ESUs, the Central Valley steelhead DPS, as well as the Southern DPS of North American green sturgeon. All of these listed species must pass through some proportion of the action area to emigrate to the ocean. Many of the factors affecting these species throughout their range are discussed in the *Status of the Species and Habitat* section of this biological opinion, and are considered the same in the action area. This section will focus on the specific factors in the action area that are most relevant.

1. <u>Sacramento River Winter-run Chinook Salmon, Central Valley Steelhead, and Spring-run Chinook Salmon</u>

The magnitude and duration of peak flows during the winter and spring are reduced by water impoundment in upstream reservoirs affecting listed salmonids in the action area. Instream flows during the summer and early fall months have increased over historic levels for deliveries of municipal and agricultural water supplies. Overall, water management now reduces natural variability by creating more uniform flows year-round. Current flood control practices require peak flood discharges to be held back and released over a period of weeks. Consequently, the mainstream of the river often remains too high and turbid to provide conditions for high quality rearing habitat. High water temperatures also limit habitat availability for listed salmonids in the lower Sacramento River and San Joaquin River. High summer water temperatures in the lower Sacramento River, lower San Joaquin River, and Delta can exceed 72 °F, and create a thermal barrier to the migration of adult and juvenile salmonids (Kjelson *et al.* 1982). In addition, water diversions, for agricultural and municipal purposes, have reduced river flows and increased temperatures during the critical summer months limiting the survival of juvenile salmonids (Reynolds *et al.* 1993).

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

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

2. Southern DPS of North American Green Sturgeon

PS and NPS pollution resulting from agricultural discharge and urban and industrial development occurs upstream of and in the action area. The effects of these impacts are discussed in detail in the *Status of the Species and Habitat* section. Environmental stresses as a result of low water quality can lower reproductive success and may account for low productivity rates of green sturgeon (Klimley 2002). Organic contaminants from recreational boat uses, agricultural drain water, urban and agricultural runoff from storm events, and high trace element concentrations may deleteriously affect early life-stage survival of fish in the Sacramento River (USFWS 1995).

Principle sources of organic contamination in the Sacramento River are rice field discharges from Butte Slough, Reclamation District 108, Colusa Basin Drain, Sacramento Slough, and Jack Slough (USFWS 1995). In addition, the high number of diversions in the action area (*i.e.*, Sacramento River, San Joaquin River, and in the Delta) are a potential threat to the Southern DPS of North American green sturgeon as these diversions could entrain juveniles resulting in mortality. Other impacts to adult migration present in the action area, such as migration barriers, water conveyance factors, water quality, NIS, *etc.*, are discussed in the *Status of Species and Critical Habitat* section.

V. EFFECTS OF THE ACTION

Pursuant to section 7(a)(2) of the ESA (16 U.S.C. §1536), Federal agencies are directed to ensure that their activities are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat. This biological opinion assesses the effects of the EDCP on the endangered Sacramento River winter-run Chinook salmon ESU, the threatened Central Valley spring-run Chinook salmon ESU, the threatened Central Valley steelhead DPS and the threatened southern population of the North American green sturgeon DPS. The biological opinion also assesses the effects of the EDCP upon the critical habitat of these two Chinook salmon ESUs and the one steelhead DPS. The EDCP is likely to adversely affect listed species and critical habitat through application of herbicides to waters of the Delta and the resulting short-term alterations in the natural environment. In the *Description of the Proposed Action* section of this opinion, NMFS provided an overview of the action. In the *Status of the Species* and *Environmental Baseline* sections of this Opinion, NMFS provided an overview of the threatened and endangered species and critical habitat that are likely to be adversely affected by the activity under consultation.

Regulations that implement section 7(b)(2) of the ESA require that biological opinions evaluate the direct and indirect effects of Federal actions and actions that are interrelated with or interdependent to the Federal action to determine if it would be reasonable to expect them to appreciably reduce listed species' likelihood of surviving and recovering in the wild by reducing their reproduction, numbers, or distribution (16 U.S.C. §1536; 50 CFR 402.02). Section 7 of the ESA also requires biological opinions to determine if Federal actions would destroy or adversely modify the conservation value of critical habitat (16 U.S.C. §1536).

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

The regulatory definition of adverse modification has been invalidated by the courts. Until a new definition is adopted, NMFS will evaluate destruction or adverse modification of critical habitat by determining if the action reduces the value of critical habitat for the conservation of the species.

A. Approach to the Assessment

1. Information Available for the Assessment

To conduct the assessment, NMFS examined 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 peer reviewed scientific journals, primary reference materials, governmental and non-governmental reports, and scientific meetings as well as the supporting information supplied with the action's environmental documents.

2. Assumptions Underlying This Assessment

In the absence of definitive data or conclusive evidence, NMFS must make a logical series of assumptions to overcome the limits of the available information. These assumptions will be made using sound, scientific reasoning that can be logically derived from the available information. The progression of the reasoning will be stated for each assumption, and supporting evidence cited.

In assessing the effects of fluridone upon listed salmonids, NMFS has utilized data provided by the applicant as well as that which is available in the literature. In instances where information is insufficient to make these assessments, NMFS must make assumptions based on sound logic. These assumptions are derived from the various scientific disciplines associated with the effects of the project and are based on the available scientific literature. In particular, the effects of low doses (or concentrations) of the fluridone compound which do not elicit obvious, visually observable effects must be interpolated from the various disciplines of science, including toxicology, ecology, and physiology. The exposure data provided by the applicant is gross in its generality, and has limited tissue, cellular, or molecular based data to determine the true extent of effects resulting from exposure to the fluridone compound.

No toxicity data pertinent to the proposed project could be found for North American green sturgeon. Therefore, NMFS extrapolated the available toxicity data for other fish species, including other sturgeon species exposed to a variety of toxicants, to green sturgeon, and then examined the level of expected exposure to both juveniles and adults by using the known behavioral characteristics of sturgeon to assess risk.

B. Assessment

1. Effects on Listed Species

a. *Overview of Species presence in the Action Area*

The USDA-ARS and DBW have requested formal consultation for a five-year program (2007 to 2011) to control and manage the invasive aquatic weed *Egeria densa* (the EDCP). This formal consultation will assesses the effects of fluridone treatments on listed salmonids and the Southern DPS of North American green sturgeon in the Delta region, and which limits the application season from April 1 to October 15 in the water bodies of the action area. Within the Delta, this treatment period overlaps three months (April, May, and June) of Sacramento River adult winter-run Chinook salmon migration and two months (April and May) of juvenile Sacramento River winter-run Chinook salmon emigration; six months of the Central Valley spring-run Chinook salmon adult migration (April through September) and three months of Central Valley juvenile spring-run Chinook salmon emigration (April, May and June); and approximately seven months of adult and juvenile Central Valley steelhead migration in the Delta (April through October). During out-migration, the winter-run Chinook salmon juveniles are at sub-yearling stage (age 0); spring-run Chinook salmon juveniles are at sub yearling and yearling stage (age 0-1) and steelhead smolts are post-yearlings (age >1) (see Appendix A, Table 4, 5, and 8).

Adults and juveniles of the Southern DPS of North American green sturgeon are expected to be present within the waters of the Delta year-round. While specific information regarding the timing and location of sturgeon within the Delta is limited, it is known that adults tend to migrate upstream through the Delta towards spawning grounds in the upper Sacramento River starting in mid winter, with downstream migration occurring over a prolonged period following spawning in late spring. Juveniles are expected to enter the Delta towards the end of summer and into fall following their downstream migration.. Older juveniles are then expected to rear for several months to years within the Delta, before moving offshore into marine environments (see Appendix A, Table 9).

Listed salmonids are known to be present in the waters of the action area during the time period that DBW intends to apply the fluridone-based herbicides. Listed salmonids from the Sacramento River basin gain access to these waters from the lower Sacramento River, Georgiana Slough, Threemile Slough and the lower reaches of the San Joaquin River. Listed Central Valley steelhead may access these waters from either the Sacramento River basin or from the San Joaquin River basin, including all of the east side tributaries that flow into the central Delta. Individuals of the southern DPS of North American green sturgeon will be present during the entire period of herbicide applications in the action area.

Adult salmonids are not expected to be adversely impacted by the EDCP, as they utilize deep water habitat which is not slated for EDCP chemical control treatments. However, the shallow water "nursery areas" targeted for chemical treatment in the Delta attract juvenile salmonids as these areas provide the necessary forage base and protective cover for them. Salmon juveniles move from tidal channels during flood tide to feed in near-shore marshes. They scatter along the edges of the marshes at the highest points reached by the tide, then with the receding tide, retreat into channels that dissect marsh areas and retain water at low tide. Larger juveniles and smolts tend to congregate in surface waters of main and secondary slough channels and move into shallow subtidal areas to feed. Although there is some evidence that salmon and steelhead may not occur inside dense infestations of *Egeria densa* (McGowan 1998, Grimaldo *et al.* 2000), juvenile salmonids occurring along the edges of these areas would be vulnerable to impacts from the activities of the EDCP. The exact range of these effects would be hard to determine with any precision as they are dependent upon local conditions and physical environment which change with the application locale. These impacts may include physical disturbance during the herbicide application process and mechanical harvesting, direct exposure to chemical herbicides, various sublethal toxicity effects, and effects upon the aquatic habitat such as reduced DO levels, reduced food supply, and removal of native submerged aquatic vegetation.

Information regarding habitat preference for sturgeon is limited. Observations by fisherman and fisheries biologists indicate that sturgeon tend to congregate in deeper channels and holes for prolonged periods, however sturgeon have been routinely captured on shallow flats during different tidal phases in Suisun and Grizzly Bays (CDFG 1957) and observed to move up onto shallow flats in Suisun Bay during radio tagging studies (Kelley *et al.* 2006). This behavior may be indicative of foraging behavior by the sturgeon. Therefore, foraging behavior by juvenile and adult green sturgeons along the shallow edges of channels within the Delta cannot be discounted and would thus increase their exposure to the actions of the EDCP.

b. *Project Timing and Locations*

DBW has stated their intent to apply herbicides to 73 different sites in the action area starting April 1 of each year and to continue applications through October 15 of each application season. DBW anticipates treating from 3,000 to 5,000 acres per a year under its new program description, up from a maximum of 1,733 acres under the project description in the 2001 EIR.

DBW developed a decision matrix to prioritize the treatment order of sites, based on the percentage of *Egeria densa* infestation (i.e., indicating the level of need for treatment) and the water flow (i.e., indicating the level of impact to listed species) in each of the 73 sites. Specifically, higher levels of infestation indicate a greater need for treatment, and higher flows indicate a greater probability of listed salmonid presence at the treatment site. The infestation level was divided into 3 categories based on the percent of acreage infested with *Egeria densa* at each of the 73 identified treatment sites:

- High – greater than 25 percent *Egeria densa* coverage, 29 sites (40 percent),
- Medium – between 10 and 25 percent *Egeria densa* coverage, 15 sites (20 percent),
- Low – less than or equal to 10 percent *Egeria densa* coverage, 29 sites (40 percent).

DBW ranked the water flow at each site based on the following divisions:

- High – flows > than 20,000 cfs, 6 sites (8 percent),
- Medium – flows > than 5,000 but ≤ 20,000 cfs, 15 sites (20 percent),
- Low – flows ≤ 5,000 cfs, 29 sites (40 percent).

DBW used water flow data for the April through June periods in 2005 and 2006 to estimate flows during the early start period (April 1 to June 1). However, this time period reflects a period of unusually high river flows, particularly in the San Joaquin River system, which is not indicative of normal or typical flows in the action area. In the San Joaquin River system, flows over 7,000 cfs below Vernalis are considered high. DWR cannot place the Head of Old River Barrier in the channel of Old River if flows exceed 5,000 cfs due to the velocity of the water sweeping away the large rock substrate it uses to construct the barriers. During the April to June period in 2005 and 2006, flows were considerably above this amount, approximately 18,000 cfs in 2005 and 30,000 cfs in 2006. Typical spring flows are considerably below this amount, particularly in dry or critically dry years when natural flows are approximately 2,000 cfs or lower. NMFS believes the decision matrix under-represents the number of high-flow sites and over-represents the number of low-flow sites. Therefore, NMFS has used historical migration records of listed salmonids to determine the likelihood of their presence within Delta channels.

c. *Mode of Action for the Preferred Herbicide Fluridone*

Fluridone (1-methyl-3-phenyl-5-(3-(trifluoromethyl) phenyl)-4(1H)-pyridinone) was developed in the mid-1970s (Waldrep and Taylor 1976) as one of the new family of "bleaching" herbicides. Its primary mode of action in plants is to inhibit the biosynthesis of carotenoids (carotenes and xanthophylls) in plant tissues by blocking the desaturation of phytoene by the enzyme phytoene desaturase (Bartels and Watson 1978). Fluridone is a reversible, noncompetitive inhibitor of phytoene desaturase (Kowalcyk-Schröder and Sandmann 1992), a key enzyme early in the carotenoid biosynthetic pathway. Carotenoids are essential to plant photosynthesis for three reasons: (1) they absorb light at wavelengths between 400 and 550 nanometer (nm) and transfer it to chlorophylls (an accessory light harvesting role); (2) they protect the photosynthetic apparatus by quenching a triplet sensitizer (Chl^3), singlet oxygen, and other harmful free radicals formed during photosynthesis (an antioxidant role), and (3) they are important for the photosystem assembly and the stability of the light harvesting complex proteins as well as thylakoid membrane stabilization (a structural role). Kim *et al.* (2004) found that in developed tissues with green chlorophyll and functional photosystem units already present, cellular death due to fluridone exposure was related to excessive oxidative stress induced through photosynthetic electron transport blockade. In tissue that had not developed functional chlorophyll and photosynthetic apparatus, death was related to the inability to form functional photosystem units and the subsequent depletion of carbohydrate stores in the plant.

In addition to the roles described above, carotenoids also play a role in the formation of phytohormones in the plant, which are responsible for cell-to-cell communications. One such phytohormone is abscisic acid (ABA) which regulates a multitude of physiological processes in plants, such as seed and bud dormancy, apical dominance, senescence and abscission, fruit set and development, stress resistance, and response to drought (Huddart *et al.* 1986). Interestingly, ABA has been found in animals, including mammals (Le Page-Degivry *et al.* 1986) and invertebrates (Zocchi *et al.* 2001, Zocchi *et al.* 2002, Puce *et al.* 2004). ABA plays a role in the release of intracellular calcium, an important secondary messenger crucial to many physiological responses in animals and plants (Huddart *et al.* 1986, Hetherington and Quatrano 1991, Zocchi *et al.* 2001, Zocchi *et al.* 2002, Himmelbach *et al.* 2003, Puce *et al.* 2004). This suggests that fluridone's inhibition of ABA synthesis may interfere with intercellular messengers in animals as well as plants.

d. *Acute Toxicity of EDCP Herbicides*

Numerous studies have been conducted to assess the acute toxicity of fluridone on fish and other aquatic animals. These studies are discussed in detail below, but in general they suggest that some level of acute effects may be expected to occur to salmonids and green sturgeon at a fluridone concentration of about 1 part per million (ppm), and substantial acute mortality (i.e., 50 percent of the exposed population) of fish may occur at about 5 ppm. These fluridone levels are expected to occur only for a brief period near the herbicide application point prior to dilution in the surrounding water (see discussion at the end of this section).

In a study on toxicities of fluridone to aquatic invertebrates and fish, the acute median lethal concentrations of fluridone were 4.3 ± 3.7 ppm for invertebrates, and 10.4 ± 3.9 ppm for fish (Hamelink *et al.* 1986). Invertebrates were approximately three times more sensitive than fish on an acute basis but about equally sensitive on a chronic basis. However, Paul *et al.* (1994) found that life stage was a critical factor in determining the sensitivity of fish to fluridone. This research found that the early life stages of fish were more sensitive than older life stages and that there were distinct species-related sensitivities to the toxicity of fluridone. Paul *et al.* (1994) found that larval walleye (*Stizostedion vitreum*) were the most sensitive of the four different species of fish tested in their studies (1.8 ppm, 96 hr LC_{50}; *i.e.*, the concentration that was lethal to 50 percent of individuals exposed for 96 hours). This study found that the No Observed Adverse Effect Concentration was 0.780 ppm for the same age walleye. Hamelink *et al.* (1986) found that rainbow trout exposed to fluridone had a 96 hr LC_{50} ranging from 4.2 to 11.7 ppm with an average of 7.15 ppm in the 12-different studies reviewed. Similar toxicity ranges are found in the EPA's ECOTOX database for rainbow trout. Exposure data submitted by the applicant found that the 96 hr LC_{50} concentrations for delta smelt (*Hypomesus transpacificus*) larvae was 6.1 ppm (3.8-9.6: 95 percentage upper and lower confidence levels [CL]), for splittail (*Pogonicthys macrolepididotus*) juveniles the LC_{50} was 23.8 ppm (20.7 – 27.7 CL) and that for fathead minnows (*Pimephales promelas*) the LC_{50} was 6.2 ppm (5.6 -6.7 CL) (CDFG 2004 d, e). Further exposure data sponsored by the chemical manufacturer, the SePro Corporation, found that a 61-day early life stage exposure to Chinook salmon eggs starting at 36 days post fertilization, did not elicit significant differences between exposed eggs and control eggs for percentage hatching, fry survival, or growth. Organogenesis in salmon fry is complete prior to 36 days post fertilization and water hardening of the chorion following fertilization minimizes the diffusion of large molecular weight compounds through the chorion. Histopathological examination of surviving fry did not find any significant abnormalities at the end of the 61-day exposure period for brain tissue. Based on the histopathology done by the applicant's laboratory, the No Observable Effects Concentration and Lowest Observable Effects Level for gill tissues were 0.222 and 0.430 ppm and for liver tissue 0.848 and 1.71 ppm respectively. There was a clear dose dependent trend in both the prevalence and severity of diffuse hypertrophy of the gill epithelium in fish exposed to 0.430, 0.848, and 1.71 ppm fluridone. Epithelial cells were more affected than chloride cells. Decreased hepatocellular vacuolization was clearly seen in Chinook salmon fry exposed to the highest concentration of fluridone (1.71 ppm). Similar, but more subtle changes occurred at the other fluridone concentrations tested but were not statistically significant compared to the control fish. A significant reduction in mean standard length of test fish (4.5 percent) was observed at the highest concentration tested (1.71 ppm) compared to the control fish. A subsequent study sponsored by the SePro Corporation comprised an acute toxicity test and a seawater challenge test to assess the effects of the fluridone compound on juvenile Chinook salmon. The acute toxicity test exposed fish to nominal fluridone concentrations of 0.0 (control), 0.40, 0.80, 1.6, 3.2, and 6.3 ppm active ingredient for 96 hours. The second portion of the exposure test challenged Chinook salmon juveniles to 24-hour direct seawater exposures following 96-hour exposures to nominal fluridone concentrations of 0, 0.030 and 0.210 ppm active ingredient. Mortalities were seen in fish exposed to fluridone concentrations over 0.725 ppm fluridone. Mortalities occurring in the fish exposed to 1.53 and 3.06 ppm fluridone were due to fish jumping out of the tank following exposure to the compound. No fish jumped out of the lower concentration exposure tanks. Gross behavioral and physical signs of sublethal effects were observed in exposure tanks with fluridone concentrations higher than 1.53 ppm. These effects included dark coloration, loss of equilibrium, erratic swimming patterns, quiescent resting on the bottom of the tank for prolonged periods, and surfacing behavior. There were slight differences in the hematocrit of saltwater challenged fish that reflected a dose dependent shift in the hematocrit values. Only the highest fluridone concentration (0.209 ppm) and the control were statistically different. Both the highest dose and the control overlapped with the intermediate concentration in hematocrit levels. All hematocrit values fell within the normal physiological ranges reported for Chinook salmon. The values for serum sodium concentrations did not show any significant trends for the different fluridone exposure concentrations, indicating that sodium levels in the blood did not appear to be affected by fluridone exposure following a salt water challenge. The applicant has also referred to unpublished studies at the University of Washington in which both Chinook salmon and coho salmon (*O. kitsuch*) were exposed to different concentrations of fluridone and then challenged with seawater. Preliminary results indicate that Chinook salmon exposed to 0.090 ppm fluridone did not have any statistically significant differences from the control group in measured parameters (*i.e.*, smolt survival, body weight, fork length, hepatosomatic index, muscle water content, assays of plasma Na^+ and Cl^- concentrations, assays of gill ATPase activity and gill histology). Likewise, coho salmon exposed to 0.010 ppm fluridone did not exhibit any statistically different responses to the compound than they did to control conditions. NMFS has not had the opportunity to review these reports first hand, but has requested them from the authors at the University of Washington.

Exposure studies of fathead minnows, Delta smelt and Sacramento splittail to the compound fluridone by the CDFG (2004d, 2004e) indicated that mortality decreased with decreasing fluridone concentration under laboratory conditions. The lowest concentration tested in the laboratory was 0.690 ppm and resulted in a 5 percent mortality of the test fish over the 7-day exposure period. The test data appears to follow a geometric progression with mortality falling by approximately one-half for every 50 percent reduction in fluridone concentration. Extrapolating from the small sample sizes utilized in this series of experiments, 7-day mortalities for fathead minnows at field concentrations would give a mortality rate of approximately 1 to 5 fish per 1,000 fish exposed (0.1 to 0.5 percent). This is a crude estimate based upon test concentrations 1 to 2 orders of magnitude higher than ambient field concentrations and a small sample size (40 fish).

In none of the experimental studies were the mechanisms of morbidity or mortality related to fluridone exposure identified. This lack of identification of the affected physiological pathway or site of cellular failure is a significant source of uncertainty in the understanding of the toxicity of the fluridone compound in aquatic organisms.

NMFS has queried the EPA AQUIRE database for fluridone toxicity exposure studies concerning sturgeon and did not find any entries. However NMFS did find toxicity data for sturgeon using other compounds (Dwyer *et al.* 2000, Dwyer *et al.* 2005a, b). From these studies, sturgeon species appeared to have similar sensitivities to contaminants comparable to salmonids and other highly sensitive fish species. Therefore, NMFS will assume that green sturgeon will respond to fluridone in a fashion similar to that of salmonids and should have similar mortality and morbidity responses.

CDFG prepared reports (2004e) on the exposure of *Ceriodaphnia dubia*, a freshwater invertebrate, to fluridone. The *C. dubia* were exposed to five concentrations of fluridone in addition to the control water for seven days (7-d) under static chamber conditions. The 7-d LC_{50} value for fluridone was 6.9 ppm. There was a statistically significant difference in reproductive capacity between the control and daphnia exposed to fluridone concentrations ≥4.6 ppm. The effects curve indicated that the slope was very steep for the fluridone exposure tests, indicating a very narrow margin of safety for fluridone at concentrations that elicit obvious observable effects. In other studies, no chronic effects were appreciably detected in daphnids (*Daphnia magna*) at 0.2 ppm concentration, amphipods (*Gammarus pseudolimnoeus*) at 0.6 ppm, or midge larvae (*Chironomus plumosus*) at 0.6 ppm. Channel catfish (*Ictalurus punctatus*) were not adversely affected by an exposure to 0.5 ppm fluridone; however, their tissue had fluridone concentrations at two to nine times greater than that in the water column. Rainbow trout had an even higher bio-concentration ratio of fluridone in their tissue, ranging from 2.3 times ambient water concentration in the edible tissue to 23.4 in the inedible portions with a whole body average of 15.5 (West *et al.* 1983). An initial fluridone concentration of 0.1 ppm or less is recommended to not adversely affect aquatic life (Hamelink *et al.* 1986).

Reward® (*i.e.*, diquat) is moderately toxic to fish in fresh water with 96-hr LC_{50} values ranging from 10 - 30 ppm (Lorz *et al.* 1979, Extoxnet 2001). Toxicity of diquat to fish varies with species and life stage, and with water hardness and pH (Lorz *et al.* 1979; Shaw and Hamer 1995). There is also some data that suggest that diquat is more toxic at higher temperatures (Paul *et al.* 1994). Photodegradation plays a small part in the removal of diquat from the water column, but the Delta's hard water affords some protection to fish by the chelation of diquat. Label instructions for diquat specify that application rates in shallow water (<1 m) should be reduced, and diquat use should be discouraged in water bodies containing sensitive fish species during their early life stages (Paul *et al.* 1994). Aquatic organisms are usually exposed to multiple lower-level exposures (Campbell *et al.* 2000). *Hyalella azteca*, an amphipod, is one of the most sensitive aquatic organisms tested, with a 96-hour LC_{50} of 0.048 ppm (Wilson and Bond 1969). The 8-hr LC_{50} for diquat is 12.3 ppm in rainbow trout and 28.5 ppm in Chinook salmon. The 96-hr. LC_{50} for diquat is12 ppm for rainbow trout and 28.5 ppm for fingerling trout (Kamrin 1997). The use of diquat at recommended treatment levels could delay downstream migration of smolts and possibly affect their survival in seawater (Lorz *et al.* 1979). The EPA's water quality criteria has established a criterion of 0.5 ppm diquat (instantaneous maximum) as the concentration that is protective of freshwater aquatic life. According to the stated application schedule for the EDCP (2007 to 2011), diquat will not be applied until after June of the application season in the waterways of the Delta.

NMFS has queried the EPA AQUIRE database for diquat toxicity exposure studies concerning sturgeon and did not find any entries. Therefore, NMFS will assume that green sturgeon will be protected by the lowest toxicity levels found in the literature that are protective of salmonids.

Juvenile salmonids could be exposed to elevated concentrations of fluridone or diquat from the EDCP if they are present near the herbicide application point during the treatment process. Concentrations would remain high until the chemical is diluted from mixing with Delta waters. Rough estimates for herbicide concentration immediately following the initial application range from ten to twenty times the target concentration in the first six inches of water around the point of application. Lethal concentration of diquat may be reached temporarily in waters immediately adjacent to the injection point and prior to any mixing, but the duration of these concentrations is anticipated to be very short. Pelleted fluridone (Sonar® PR), due to its slow release characteristics, is not anticipated to reach the very high concentrations in close proximity to the compound application point as seen with the aqueous formulations of the two herbicides. Mixing is expected to occur fairly rapidly (*i.e.*, minutes to hours) in most application sites utilizing an aqueous herbicide formulation. Dissipation studies conducted by the applicant (USDA-ARS 2004) indicate that following an aqueous herbicide application (Sonar® AS), the highest concentrations are reached in the surface layers of the water column within the first 1 to 2 hours. Maximal surface concentrations of fluridone reached 0.050 to 0.075 ppm in these first few hours (averaging 0.020 to 0.050 ppm), and then gradually declined over time. Fluridone concentrations from the bottom of the water column indicated that concentrations gradually rose over time, indicating water column mixing from the surface application. Full water column mixing was generally achieved by 24 hours and leveled off at approximately 20 percent of the maximal surface concentration (approximately 0.010 to 0.015 ppm). It was apparent from the data submitted that dilution and mixing of the fluridone application was strongly influenced by channel geometry and water flow through the channel. In one of the channels monitored, a bimodal peak in surface concentration of the fluridone was observed following the change of the tidal flow past the monitoring station.

Once the fluridone application occurs, then assuming the worst case scenario, and using the highest predicted environmental concentration (*i.e.*, 0.075 ppm) and the LC_{50} for rainbow trout (*i.e.*, 4.2 ppm), the instantaneous concentration for fluridone in the treatment area is expected to be approximately 56 times lower than the 96 hour LC_{50} for fluridone for approximately two hours. Taking the 24-hour averaged water column concentration of 0.012 ppm, the ratio between the LC_{50} and the averaged water column concentration is approximately 380 times lower. Likewise for diquat when complete mixing occurs, then assuming the worst case scenario, and using the highest predicted environmental concentration (*i.e.*, 0.37 ppm) and the most sensitive LC_{50} (*i.e.*, 0.74 ppm), the instantaneous diquat concentration is still two times lower than the most sensitive LC_{50} values which are for larval fish. The instantaneous concentration for diquat, following complete mixing, is almost 77 times lower than the published LC_{50} values for Chinook salmon and 31 times lower than those for rainbow trout. NMFS could not find published toxicity values for sturgeon species exposed to fluridone or diquat.

Both fluridone and diquat are expected to be adsorbed to particulate matter suspended in the water and onto sediments on the bottom of the Delta waterways. Bacterial degradation will remove fluridone from the system and metabolize it to simple carbon compounds. Fluridone will also undergo photolytic decomposition. The half-life for fluridone in aquatic environments is approximately 21 days (Extoxnet 2002), but it may remain in bottom sediments from several weeks to one year (Muir and Grift 1982). Diquat chemically binds to sediment quickly (Ritter *et al.* 2000). Paul *et al.* (1994) found that sediment removed 60 percent of the diquat after four days in a shallow container which continued to be mixed by aeration. Several other field studies with variable results indicate the difficulty in ascertaining the time and rate of diquat dissipation (Yeo 1967), but apparently it can remain bioavailable for several days (Paul *et al.*1994). The environmental fate characteristics of both Sonar® and Reward® and the application rates used in the EDCP indicate that the long-term concentration levels of the herbicides achieved in Delta waters should be significantly below the acute toxicity levels of listed salmonids. However, recent medical studies in humans have shown correlations with the usage of herbicides, particularly phenoxy acetic acid herbicides (*e.g.*, 2,4-D) to increases in spontaneous abortions (Arbuckle, Lin and Mery 2001) in Ontario farm populations, presence of phenoxy residues in Ontario farmers' sperm (Arbuckle *et al.* 1999), parkinsonism from glyphosate exposure (Barbosa *et al.* 2001), short term decreases in immunological indices in farmers exposed to phenoxy herbicides (Faustini *et al.* 1996), and an increased risk of non-Hodgkin lymphoma from herbicide and pesticide exposures (Lynge 1998, Hardell and Eriksson 1999, McDuffie *et al.* 2001). The epidemiological data for humans exposed to herbicides would indicate that there is sufficient concern to warrant restricted usage of the compounds in aquatic environmental settings until more extensive physiological research is conducted.

In any case, sublethal effects and effects on habitat resulting from the EDCP that may ultimately increase the likelihood of mortality of salmon and steelhead are of concern, and are the category of effects that are most likely to occur during this program. Sublethal effects are characterized as those that occur at concentrations that are below those that lead directly to death. Sublethal effects may impact the fish's behavior, biochemical and/or physiological functions, and create histological alterations of the fish's anatomy. In addition, changes in the sensitivities of fish to other contaminants (*i.e.*, chemical synergism), particularly pesticides and other aromatic hydrocarbons, may increase the mortality of exposed fish. Degradation of habitat is expected to occur due to decreases in DO level due to *Egeria* decomposition, decreases in native vegetative cover, decreases in the invertebrate standing population which reduces the forage base available to juvenile salmonids, and changes in ambient water temperature due to changes in the amount of vegetative cover.

e. *Sublethal Effects*

In contrast to the acute lethality endpoints associated with the EDCP, nonlethal or sublethal endpoints may be more appropriate to the levels of exposure likely to be seen in the herbicide application protocol employed in the EDCP. Sublethal or nonlethal endpoints do not require that mortality be absent; rather, they indicate that death is not the primary toxic endpoint being examined. Rand (1995) states that the most common sublethal endpoints in aquatic organisms are behavioral (*e.g.*, swimming, feeding, attraction-avoidance, and predator-prey interactions), physiological (*e.g.*, growth, reproduction, and development), biochemical (*e.g.*, blood enzyme and ion levels), and histological changes (*e.g.*, degenerative necrosis of the liver, kidneys, and gill lamellae; Lorz *et al.* 1979). Some sublethal effects may indirectly result in mortality. Changes in certain behaviors, such as swimming or olfactory responses, may diminish the ability of the salmonids to find food or escape from predators and may ultimately result in death. Some sublethal effects may have little or no long-term consequences to the fish because they are rapidly reversible or diminish and cease with time. Individual fish may exhibit different responses to the same concentration of toxicant. The individual condition of the fish can significantly influence the outcome of the toxicant exposure. Fish with greater energy stores will be better able to survive a temporary decline in foraging ability, or have sufficient metabolic stores to swim to areas with better environmental conditions. Fish that are already stressed are more susceptible to the deleterious effects of contaminants, and may succumb to toxicant levels that are considered sublethal to a healthy fish.

(1) ***Narcosis***. Fish, when exposed to elevated concentrations of polar and nonpolar organic compounds such as the herbicides used in the EDCP, can become narcotized. Narcosis is a generalized nonselective toxicity response that is the result of a general disruption of cell membrane function. The process of narcosis is poorly understood, but is thought to involve either a "critical volume" change in cellular membranes due to the toxicant dissolving into the lipid membrane and altering its function, or by the "protein binding" process in which hydrophobic portions of receptor proteins in the lipid membrane are bound by the toxicant molecules, thus changing the receptor protein's function (Rand 1995). Exposure to elevated concentrations of the herbicides would occur in the immediate area of herbicide application, prior to dilution in the surrounding water column. A fish with narcosis would be more susceptible to predation as a result of a loss of equilibrium, a reduction in swimming ability or a lack of predator avoidance behavior. Furthermore, a fish with narcosis would also have difficulty maintaining its position in the water column, and could potentially be carried by water currents into areas of sub-optimal water quality where conditions may be lethal to salmonids (*e.g.*, hypoxic regions within *Egeria* mats). Behavior seen in the applicant's studies for the acute response of Chinook salmon smolts to increasing concentrations of fluridone indicate that grossly observable responses to the compound occurred at concentrations $\geq$ 1.53 ppm. Reductions in the behavioral response time or response level to stimuli (*e.g.* food or predators) frequently occur at concentrations lower than those that elicit grossly observable responses.

(2) ***Rheotropism***. Rheotropism refers to fish behavior in a current of water, either directly as a response to water flowing over the body surface or indirectly as a response to the visual, tactile or inertial stimuli resulting from the displacement of fish in space (Dodson and Mayfield 1979). Fish respond physically and behaviorally to foreign stimuli (see Appendix C). Rainbow trout yearlings exposed to 0.5 ppm and 1.5 ppm of diquat for 24 hours exhibited no significant variation in the frequency of positive rheotaxis, exhibiting an increase in the frequency of no response and a significant decrease in swimming speeds caused by short-term exposure to diquat (Dodson and Mayfield 1979). Subtoxic effects of diquat on yellow perch (*Perca flavescens*) include a level of respiratory stress indicated by the cough response and reduced swimming speeds in exposure to 1.0 to 5.0 ppm diquat over 48 hours to 72 hours (Bimber *et al.* 1976). Fish exposed to diquat over longer periods of time may move passively downstream and into decreasing concentrations of diquat, exhibiting a passive avoidance response. The level of

chemical absorption is dependent upon the fish species as well as individual fish characteristics. Hiltebran *et al.* (1972) exposed bluegills (*Lepomis macrochirus*) to diquat and demonstrated that as the length of exposure time increased, proportionally less diquat appeared to have been absorbed. It was unknown if this result was due to the metabolism, or elimination, of diquat. A "leveling off" of diquat residues in fish tissue was observed in increasing diquat concentrations rather than with increasing exposure time (Dodson and Mayfield 1979). No information was found concerning fluridone's effects on rheotropism.

(3) ***Chemical Interactions.*** Rand (1995) states that in "assessing chemically induced effects (responses), it is important to consider that in the natural aquatic environment organisms may be exposed not to a single chemical but rather to a myriad or mixture of different substances at the same or nearly the same time. Exposures to mixtures may result in toxicological interactions." A toxicological interaction is one in which exposure to two or more chemical residues results in a biological response quantitatively or qualitatively different from that expected from the action of each chemical alone. Exposure to two or more chemicals simultaneously may produce a response that is simply additive of the individual responses or one that is greater (synergistic) or less (antagonistic) than expected from the addition of their individual responses. Application of herbicides from the EDCP project may contribute to elevated toxicological responses caused by unknown sources of chemical compounds within the project area. Over 30 different herbicides are applied annually on agricultural lands in the Delta, and an additional 5 million pounds are applied upstream in the Sacramento River, San Joaquin River, and French Camp Slough (Kuivila *et al.* 1999). Chemicals used by the EDCP may build up on sediments at treatment sites. High additive concentrations of the various herbicides utilized in the Central Valley can potentially impair primary production in a defined geographic area (Kuivila *et al.* 1999) if contaminated waters come together in a confined area. Waters that flow through treated locations can carry herbicides to adjacent areas while concentrations in the water are still high enough to cause adverse impacts to aquatic organisms, if present, and possibly irrigation, municipal waste supplies and recreation.

Exposure of fish to the aromatic hydrocarbons typical of many families of herbicides and pesticides may result in the biotransformation of these compounds by various enzyme systems in the fish. Most organic contaminants are lipophilic, a property that makes these compounds readily absorbed across the lipid membranes of the gill, skin, and gastrointestinal tract. Following absorption, compounds that are susceptible to biotransformation are converted to more water soluble metabolites that are easier to excrete than the parent compound. Compounds that are resistant to metabolism are often sequestered in the lipid-rich tissues of the body. Although biotransformation is often considered a positive event in the detoxification of the contaminant, the parent compound of some contaminants are actually less toxic than the metabolites formed. These reactive intermediate metabolites can cause significant problems in other metabolic pathways, including alterations in the synthesis of DNA and RNA, redox cycling of reactive compounds, and induction of enzymatic systems that could lead to altered metabolism of environmentally encountered contaminants (Di Giulo *et al.* 1995). Within the Delta, mixtures of contaminants, particularly organophosphate pesticides are common. Induction of the biotransforming enzymatic pathways, particularly the p450 monooxygenases, may actually increase the sensitivity of a fish to environmental contaminants. Organophosphate insecticides often are activated by the monooxygenase system (Murty 1986; Dr. M.J. Lydy, Southern Illinois

University, Carbondale, personal communication, 2003), thus the higher the activity of the monooxygenase system, the more reactive metabolite formed.

(4) ***Immunotoxicity.*** The fluridone compound is a three-ringed heterocyclic aromatic compound with a trifluromethyl substitution on one phenyl ring, a methyl substitution on the pyridinone ring, and the third ring being an unsubstituted phenyl ring. Exposure to PAHs and other aromatic compounds typical of hydrocarbon contamination from industry, chemical spills, and engine exhausts was shown to suppress immune responses in fall-run Chinook salmon (*O. tshawytscha*) in the Pacific Northwest by Varanasi *et al.* (1993) and Arkoosh *et al.* (1998, 2001). This research indicated a high correlation between exposure to sediments, which contained elevated levels of aromatic and chlorinated organic compounds indicative of contaminants found in urban estuaries, and reductions in the primary and secondary humoral immune responses of juvenile Chinook salmon. The 1998 study indicated that this response resulted from both direct exposure and through the benthic species in the forage base of the fish sampled from the estuaries. Significant concentrations of these organic contaminants were bioaccumulated by the juvenile Chinook salmon during their relatively short residence time in the estuary. The followup study in 2001 exposed the marine-adapted smolts of Chinook salmon to the aromatic and chlorinated organic compounds extracted from contaminated sediments through intraperitoneal injections and then measured their response to the marine bacterial pathogen, *Vibrio anguillarum.* The exposed fish suffered significantly higher pathogen-related mortality than the control fish. These results further indicated that although the exposure of juvenile fish migrating through the estuary is relatively short in duration, the immunosuppression may extend into their early ocean life, thus potentially influencing recruitment to adult stages later on. Recent studies presented at the American Fisheries Society California-Nevada Chapter meetings in Sacramento, California, indicate that exposure to certain pesticides (*i.e.*, the synthetic pyrethroid esfenvalerate) enhanced the infectious activity of the pathogen responsible for infectious hematopoietic necrosis virus (IHNV) in juvenile Central Valley fall-run Chinook salmon. Viral assays of the dead fish indicated a lethal synergism of esfenvalerate and IHNV at levels of the pesticide considered non-lethal to the exposed Chinook salmon (Clifford *et al.* 2005). Other studies presented as posters at this meeting indicated that exposure to different pesticides (*i.e.*, chlorpyrifos and esfenvalerate) induced heatshock proteins and cytokines, both indicators of environmental stress at sublethal concentrations in fall-run Chinook salmon (Eder *et al.* 2004).

(5) ***Intracellular messengers.*** Recent research on the role of ABA as a mediator of intracellular calcium messengers has implicated fluridone as an inhibitor of this important pathway. As previously stated, ABA is a phytohormone that is found throughout the plant kingdom and has been implicated in the regulation of over a thousand genes, and that these ABA mediated changes in gene expression translate to changes in proteome expression (Himmelbach *et al.* 2003). The occurrence of ABA in the animal kingdom, including mammals (Le Page-Degivry *et al.* 1986), indicates that this signaling pathway has been highly conserved along the phylogenetic tree. ABA isolated from the central nervous systems of pigs and rats had identical biochemical, immunological, and physiological properties as that isolated from plant sources. A dietary source for the ABA was ruled out by feeding 2 generations of experimental animals a synthetic diet without plant materials as a source for the ABA. In fact, the animals fed the synthetic diet had higher concentrations of ABA in their brains than the animals fed the normal diet.

ABA controls intracellular calcium messengers through the activation of ADP-ribosyl cyclase by an ABA induced protein kinase A. The cyclase forms cyclic ADP-ribose (cADPR), a universal and potent intracellular Ca^{2+} mobilizer. Ca^{2+} signaling is involved in such diverse cell functions as cell cycle regulation (protists), oocyte fertilization (invertebrates), secretion and cell proliferation (mammals), and the drought-stress response (plants). ABA was shown to mediate temperature signaling and respiration in sponges (Zocchi *et al.* 2001, 2002) through a heat sensitive cation channel. These channels share similar functional characteristics with mammalian heat-activated background K^+ channels responsible for central and peripheral thermosensing. Puce *et al.* (2004) found that ABA-mediated cADPR affected regeneration of lost branches in hydroids. This regeneration could be blocked by exposing the hydroids to fluridone, which blocked the synthesis of ABA in hydroids exposed to light. There is a strong likelihood that ABA-influenced cell functions in fluridone exposed fish are compromised and that this could be responsible for the observed toxicity in fish. Lower levels of fluridone exposure could be expected to affect numerous cellular functions in subtle, as yet undetermined ways. Likewise, other metabolic pathways, which have yet to be identified, could be inhibited by fluridone and result in diminishment of physiological status. The current level of risk assessment studies typically do not examine this level of interactions between toxicants and organisms; rather, they rely on endpoints with a gross level of sensitivity to generate "safety margins" acceptable to permitting agencies.

(6) ***Summary.*** In summation, all fish exposed to the chemical constituents in the herbicides will be expected to exhibit some level of adverse effects. Acute direct exposures to higher concentrations of the active ingredients can result in death. On the other hand, exposures to lower concentrations of the active ingredients in the herbicides will result in a spectrum of responses ranging from avoidance reactions and mild physiological disturbances to long term morbidity and shortened life span. Exposure of listed fish to these herbicides significantly can increase their vulnerability to predation from both piscine and avian predators. Symptoms of behavioral and physiological perturbations resulting from exposure often make affected fish stand out to predators from their unexposed cohorts. Longer-term impacts will include a decrease in the physiological health of exposed fish after they leave the application area, as described in the immunotoxicity subsection above. These adverse effects are expected to be magnified by the conditions present in the Delta during the project's application schedule. The degraded habitat that currently is representative of the Delta exposes listed salmonids and green sturgeon to a myriad of chemical constituents, many of which are known to have toxic effects on salmonids and presumably, green sturgeon. The multiple exposures of the fish to different compounds in the water, in addition to the exposure of the fish to the active compounds in the EDCP's proposed herbicides, is likely to exacerbate the rate of morbidity and mortality in exposed fish. The indications of these adverse effects may not present themselves for days to months following the exposure, and may be very subtle in nature, but will produce fish with a lowered chance of survival and hence a lowered chance for contributing to the recovery of the fish's population.

2. <u>Effects on Critical Habitat</u>

a. *Physical Disturbance*

Operation of the program's watercraft in the project area may result in effects due to wake turbulence, sediment resuspension, physical impact with propellers, and discharge of pollutants from the motor's exhaust and lubrication systems. These impacts may be exacerbated because the *Egeria*-infested areas tend to be shallow and the dense vegetation mats retain suspended particulates on their leaves. Wake induced turbulence in these areas disturbs the sediments captured by these plants and resuspends it all at once into the adjacent water column. The interaction of propellers with the vegetation shreds the plants into smaller fragments, some of which may retain their propagative viability if two internodes remain on the fragment.

The indirect effects of a successful EDCP program could include increased usage of motorized vessels in the Delta as navigational channels are opened up to vessel traffic (*i.e.*, jet skis, water skiers, wake boarders, cruising, fishing, *etc.*). This increased vessel traffic would add additional pollutants to the water column through additional motor exhausts, spills, and lubricants, particularly in the summer months when boating activity on the Delta is at its highest. Furthermore, additional vessel traffic more than likely would increase the volume of fragmented *Egeria densa* dislodged from infested areas, which would then be free to colonize new areas in the Delta, or recolonize treated areas.

b. *Dissolved Oxygen Levels*

Juvenile salmonids may be directly affected through the reduction in DO levels resulting from the decomposition of plants killed by the herbicide application. Low DO levels (< 3 mg/L) can result in fish kills if fish are unable to move out of the zone of hypoxic or anoxic waters. Low dissolved oxygen levels are particularly harmful to salmonids, which have a high metabolic requirement for dissolved oxygen (Bjornn and Reiser 1991). Studies have shown that dissolved oxygen levels below 5 mg/L have a significant negative effect on salmonid growth, food conversion efficiency, and swimming performance. High water temperatures, which result in reduced oxygen solubility, can compound the stress on fish caused by marginal DO concentrations (Bjornn and Reiser 1991). Stress from low DO can make juvenile salmonids more susceptible to predation and disease, and less likely to smolt due to insufficient energy reserves. Adult salmonids may experience delayed migration through Delta waters if DO is below concentrations needed for survival. Delay in upstream migration can have a negative impact on the maturation of gonadal tissue, particularly if ambient water temperatures in the Delta are also elevated. Salmonids exposed to elevated temperatures during gonadal maturation have reduced fertility and lower numbers of viable eggs (CALFED 2000). Fish exposed to DO levels below 5 mg/L for extended periods are usually compromised in their growth and survival (Piper *et al.* 1982). NMFS expects that fish and mobile invertebrates will generally avoid areas with extensive infestations of *Egeria* due to the decreased ambient levels of DO in the water column. The increased biomass of the floating *Egeria* mat will increase the respiratory burden on DO during the night and limit light penetration to submerged portions of the plants during the day. Increased detrital deposition below the *Egeria* due to reduced water flow, and plant matter falling from the overlying mats will increase biological oxygen demand (BOD) in the affected areas of the infestation. The applications of herbicides, particularly Reward® (diquat), are expected to initially decrease DO levels even further in areas treated for the plant. This results from the decomposition of the dead vegetable matter and an increase in BOD. This effect is expected to be transitory as the decaying vegetation is dispersed by tidal and river currents from the treatment area. Areas of higher tidal and river current exposure will be flushed faster than areas of low water body exchange, such as dead end sloughs and restricted peripheral channels. Additional parameters affecting the DO levels are the rate of decay for the treated vegetation which is dependent on ambient water temperature and microbial activity. Higher water temperatures should theoretically result in higher microbial activity, thus resulting in a faster decline in the DO levels. However, the duration of the depressed DO levels should be shorter than in a cooler temperature profile due to the vegetative biomass being metabolized at a faster rate. Conversely, a cooler ambient temperature would result in a prolonged DO depression, although perhaps not to the hypoxic levels reached in a warmer water profile. The applicant has argued that the application of fluridone herbicides will minimize the DO depression due to the extended period (>45 days) needed to kill treated *Egeria densa* stands. The rationale behind this is that the biomass of dead and decaying plants never reaches levels where DO depression becomes critical to aquatic organisms, such as fish.

c. *Invertebrate Populations*

Invertebrates could be exposed to elevated concentrations of fluridone or diquat from the EDCP if they occur within the immediate area of the initial application of the herbicidal concentrate to the water column. After mixing, however, the chemical compounds should not reach toxic levels to invertebrates if they are applied at the labeled rates. The volume of water available for dilution of the applied herbicide and the rate of water exchange will determine the extent of the elevated herbicide residues in the water column. The annual monitoring reports have indicated occasional elevated toxicity to *daphnia* spp. from monitored sites following herbicide applications, although direct correlations to the herbicide concentration has not been definitively made. Regions of low DO caused by drifting mats of decaying vegetation or smothering of benthic substrate may cause a localized decrease in populations and diversity of invertebrates. Many invertebrates have limited ability to migrate out of the treatment area, and thus are more susceptible to the effects of elevated herbicide concentrations or low DO levels. Following treatment, new populations of invertebrates are expected to re-establish themselves through larval recolonization of the area as soon as habitat conditions are suitable for their growth. Although the project's supporting material describes this mechanism, the project does not have actual data from the program to support this position. Nevertheless, juvenile salmonids will at least temporarily have to enlarge their foraging area to obtain sufficient prey to support their caloric needs. This may increase their exposure to predators, thereby decreasing their probability of survival. Also, the rate of survival for juvenile salmonids would be a balance between the amounts of metabolic energy expended in swimming during foraging behavior versus the amount of caloric intake achieved from the prey captured during foraging. Caloric intake needs to exceed the metabolic cost of swimming in order for the juvenile fish to have sufficient energy reserves for growth and other metabolic needs.

Furthermore, the effects of herbicides applied to natural environments are hard to predict from controlled laboratory studies, including microcosm and mesocosm tank studies. Community structure changes, especially to nontarget groups, and changes to ecosystem process variables have technical importance and are not assessed adequately in current risk assessment paradigms (Pratt *et al.* 1997). Current declines in several species of pelagic organisms (the Pelagic Organism Decline or POD) have implicated pesticides and herbicides, as well as several other potential sources in the Delta waters, as possible stressors related to this observed decline. A cursory preliminary risk assessment of the impacts of herbicides on the ecosystem has been reported, but detailed experimental evaluations have not been completed at this time.

d. *Native Vegetation*

There are potential impacts to native submerged and emergent vegetation especially if Sonar® (*i.e.*, fluridone) treatment is done adjacent to such areas and water column concentrations are sustained at treatment levels for approximately six weeks. Long-term exposure could significantly alter existing local plant community composition adjacent to these treatment sites due to the rates of recolonization and species abundance for pioneering plants. When applied at label rates, fluridone is toxic to other aquatic plants and agricultural crops it comes in contact with for an extended period of time.

Native submerged and emergent vegetation may be harmed or killed by the application of herbicides during the EDCP, depending on the level of exposure. However, as with losses of invertebrates, NMFS believes that a reduction in native vegetation would be temporary, as adjacent plants should recolonize the treated area. Removal of the thick mats of *Egeria* will allow light penetration to submerged plants in areas previously shaded by these mats. Likewise, *Egeria* will not be able to smother and abrade native emergent plants. Treated areas will also allow the native plants the opportunity to re-colonize without competing with *Egeria* for space and nutrient resources. During periods of juvenile salmonid migration, treated areas may not provide the necessary vegetative cover or food resources needed by the fish. Treatment could possibly magnify this impact, increasing the areas devoid of aquatic vegetation or having compromised water quality. NMFS believes that these localized effects will reduce the probability of survival of juveniles emigrating through or rearing in the treatment area. Adjacent untreated acreage could be available to provide shelter and foraging for the juvenile salmonids as they move out of the treated area. However, expenditures of valuable metabolic reserves will have to be utilized for swimming to these new areas, making these reserves unavailable for other physiological needs like growth or smoltification. This shift in the utilization of metabolic energy stores has the potential to decrease the survival probability and physical health of the juvenile salmonid.

e. *Development of Resistance to Fluridone in treated Plants*

Recent research (Michel *et al.* 2004, Arias *et al.* 2005) has indicated that the nonindigenous invasive aquatic plant hydrilla (*Hydrilla verticillata*) has developed resistance to fluridone through somatic mutation-mediated evolution. As previously stated, fluridone inhibits the enzyme phytoene desaturase, which forms phytofluene and ζ-carotene from phytoene in the plastids. Resistance to fluridone inhibition involves base pair substitutions at the amino acid 304 codon of the enzyme (wild type codes for the amino acid arginine (Arg)). Three separate and independent single point mutations were identified, with each mutation conveying various levels of resistance to the herbicide. Amino acids are coded for in the genetic material of organisms by linear groupings of three nucleic acid bases (called codons) in the sequence of the organism's deoxyribonucleic acid (DNA). These nucleic acids are comprised of the purines (adenine (A) or guanine (G)) and the pyrimidines (cytosine (C) and thymine (T)). The codon usage for Arg304 of phytoene desaturase in the wild-type hydrilla is CGT and single-point mutations yielding either serine (AGT), cysteine (TGT), or histidine (CAT) substitutions were identified in hydrilla populations in Florida. The investigators in these two papers believed that the usage of low concentrations of the herbicide and the growth characteristics of the weed contributed to the formation of resistant strains of hydrilla. Due to the genetic plasticity and polyploidism of hydrilla, fluridone exposure left resistant portions of the plant viable following treatment. Like *Egeria*, hydrilla only needs a small internode portion to propagate, and these fragments propagated asexually to fill the habitat void. Since the sequence of DNA coding for the phytoene desaturase enzyme appears to be highly conserved among different plant species, point mutations at the 304Arg codon may be likely to occur in the very similar plant species *Egeria densa*. If resistance to the herbicide increases, higher concentrations of the herbicide would have to be utilized to achieve efficacy. These higher application rates would pose an increased risk to exposed nontarget organisms, such as listed fish.

f. *Predator Efficiency*

A recent study in Lake Seminole, Georgia, indicated that the removal of dense hydrilla beds increased the efficiency of predatory largemouth bass and fostered changes in the types of prey consumed by different age class fish (Sammons and Maceina 2006). In heavily infested sections of the lake, bass feeding efficiency was lower than in sections with lower submerged aquatic vegetation (SAV) density. After removal of the hydrilla, largemouth bass feeding efficiency increased, particularly among smaller bass, and larger numbers of fish prey were consumed. Smaller bass (<8 inches) consumed less grass shrimp and sunfish and more damselflies, minnows, and killifish following hydrilla removal. Paradoxically, the removal of *Egeria densa* could be detrimental to migrating salmonids in the short term, as the impacts of SAV removal on the predation level of migrating fish (*i.e.*, salmonids) potentially could increase until a new equilibrium is established. Removal of dense stands of *Egeria densa* is believed to be beneficial to native fish by opening up unavailable shallow water habitat and promoting recolonization of native aquatic plants, but this benefit may be tempered by the increased predation efficiency of non-native predators such as largemouth bass and striped bass in these new habitats.

g. *Beneficial Effects*

Reductions in the percentage of *Egeria densa* infested waterways are likely to increase the habitat area available for use by salmonids and green sturgeon. It may also result in increased flows through these waterways, increased sunlight penetration, re-establishment of native aquatic vegetation, and recolonization of native invertebrate species in the treated areas. These changes may result in positive effects on the suitability of the Delta waterways for salmonid and green sturgeon rearing and migration.

h. *Summary*

The potential environmental benefits of the EDCP are balanced against the likely negative impacts of the program. The EDCP will intentionally disperse toxic compounds into the waters of the Delta to kill the invasive *Egeria densa* plant. The application concentrations of the program's herbicides are sufficiently low as to prevent substantial numbers of fish and invertebrate from experiencing acute mortalities. However, mortalities are still expected to occur, even if the percentage of organisms experiencing mortality is quite low. Secondary effects, including those that are sublethal, are harder to predict. Physical disturbance, declines in invertebrate populations and increased predator efficiency due to changes in the SAV cover, or increases in decaying biomass volume altering water quality parameters and substrate availability may adversely affect the suitability of the designated critical habitat for migration and rearing of listed fish. However, because the application of the herbicides will be to discrete sections of the Delta, and concentrations will dissipate over space and time, widespread adverse effects are not anticipated. Indirect effects (*i.e.*, occurring later in time) may include increased human activities (*e.g.*, boating) in the Delta region resulting from "cleared" channels, resulting in increased levels of other anthropogenic contaminants (e.g., petroleum products and PAHs) being discharged into the water, or development of herbicidal resistance in *Egeria densa.*

VI. CUMULATIVE EFFECTS

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

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

The Delta and East Bay 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 Services Directory 2002). Increases in urbanization and housing developments can impact habitat by altering watershed characteristics, and changing both water use and stormwater runoff patterns. Portions of the project site are within the region controlled by San Joaquin County Council of Governments. The General Plans for the City of Stockton and surrounding communities anticipate rapid growth for several decades to come. The anticipated growth will occur along both the I-5 and US-99 transit corridors. Likewise, increased growth is expected along the I-5 and highway 205 corridors in southern San Joaquin County near the cities of Lathrop and Tracy. Anticipated growth in the foothills along the eastern edge of the Central Valley will place greater strains on current water supplies. Current instream flows may be compromised if water demands switch from agricultural based needs to municipal and industrial needs, which have less flexibility in their curtailment during droughts.

Increased urbanization also is expected to result in increased wave action and propeller wash in Delta waterways due to increased recreational boating activity from the growing human population. This potentially will degrade riparian and wetland habitat by eroding channel banks and mid-channel islands, thereby causing an increase in siltation and turbidity. Wakes and propeller wash also churn up benthic sediments thereby potentially resuspending contaminated sediments and degrading areas of submerged vegetation. This in turn would reduce habitat quality for the invertebrate forage base required for the survival of juvenile salmonids. Increased recreational boat operation in the Delta will likely also result in more contamination from the operation of engines on powered craft entering the water bodies of the Delta. Furthermore, increased boating activity will produce more fragmentation of the *Egeria densa* stems through contact with the propellers, thus spreading the infestation through viable fragments into other portions of the Delta. Transport of *Egeria densa* fragments, as well as other non-native species, on boat hulls and trailers is a known problem in the spread of invasive species.

VII. INTEGRATION AND SYNTHESIS

The degree to which listed salmonids may be impacted by the EDCP is a function of their presence within the action area. The proposed period of implementation of the EDCP is from April 1 through October 15, which would overlap with more than half of the adult and juvenile migration periods for all of the runs. The period of greatest overlap with the listed juvenile salmonids in the Delta is primarily during the higher flow periods of spring (*e.g.*, from April 1 through June 1) and less so in fall (*e.g.*, October 1 through November 30, principally steelhead). The current project description expands the range of areas that can be treated, both in number and acreage, compared to the previous implementation of the EDCP. The DBW also has removed restrictions on application zone treatment acreage for the 2007 through 2011 EDCP so that all areas of an application zone may be treated without leaving strips of untreated areas for fish passage as has been previously done. This has increased the potential area for treatments from approximately 1,700 acres to a maximum of approximately 3,000 to 5,000 acres. The EDCP, as currently described by DBW, will focus the first 3 years of the 5-year program on treating Franks Tract and adjacent waterways. The final two years of the program will focus on the remaining Delta sites. However, DBW has stated that their intention is to be able to treat any of the 73 sites, if they choose to do so, during the 5-year treatment period. Based on this description, NMFS will consider the worst-case scenario as treatment of any of the 73 sites in a given season, with total treatment acreage of 5,000 acres.

NMFS anticipates that applications of Sonar® or Reward® to the waters of the Delta and its tributaries during the EDCP treatment seasons will not result in substantial acute mortality to listed salmonids (0.1 to 0.5 percent mortality rate – *i.e.*, 1 to 5 fish per 1,000 fish exposed, approximately 600 listed salmonids per year), unless fish are present in the immediate area during or immediately after the herbicide is applied and before dilution can occur through mixing. There is the potential for the loss of an additional fraction of the migrating population that is exposed to the toxicants through indirect effects such as delayed migration, morbidity, or behavioral effects which increase predation rates. An unknown number of green sturgeon are expected to die from herbicide exposure, but based on the sensitivity of different sturgeon species to contaminants (Dwyer *et al.* 2000, Dwyer *et al.* 2005a,b), NMFS expects that mortality rates will be equivalent to those experienced by the salmonids (*i.e.*, 0.1 to 0.5 percent).

Although fish should not be present in the cores of *Egeria densa* mats, they may be present along the periphery of the mats, utilizing it for cover from overhead predators or open water predators such as striped bass. Thus, fish may be exposed to lethal or sublethal concentrations of herbicides that are applied to the margins of the mat or to herbicides present in the water column directly below the mat or flowing out of the area of application. Similarly, adult and juvenile green sturgeon may be present along the periphery of *Egeria densa* beds as they move up onto shallow water flats to feed. Treatment of *Egeria densa* beds while sturgeon are present on the flats may expose some individuals to high concentrations of the herbicides, but the length of exposure is anticipated to be of a relatively short duration due to mixing and tidal flow with the surrounding water masses.

The most important impacts of the EDCP are expected to occur to juvenile salmonids and green sturgeon, and include sublethal effects and effects to habitat. As stated in Rand (1995), sublethal effects to listed salmonids and the proposed green sturgeon can be expected to take the form of behavioral, physiological, biochemical, or histological changes in the exposed fish. These changes may not be immediately lethal, but can cause fish to exhibit impaired behaviors (*e.g.*, narcosis) or eventually develop a lesser level of physical health, thus reducing their chances of survival as compared to unexposed fish. Possible consequences include loss of equilibrium and reduced swimming ability and predator avoidance behavior, which could lead to increased predation risk or reduced foraging ability. Chemical synergism between the EDCP herbicides and other contaminants in the Delta could occur and exacerbate these effects.

Based on the life histories of the four listed fish species, NMFS has developed the following assessment for project impacts:

A. Sacramento River winter-run Chinook salmon

The majority of juvenile winter-run Chinook salmon will have migrated through the action area by the end of March (97.5 percent of the annual year class) leaving approximately 2.5 percent of the run to move through the action area in April, May, and June. Using a cross Delta survival rate of 15 percent, this amounts to approximately 2,100 fish, based on salvage numbers at the CVP and SWP facilities (1999 to 2005). Calculated direct loss due to chemical exposure mortality is 11 juvenile winter-run Chinook salmon.

B. Central Valley spring-run Chinook salmon

The emigration of juvenile spring-run Chinook salmon through the Delta region peaks in April, with approximately 66 percent of the run moving through the Delta in that month alone. Approximately 9 percent of the annual spring-run juvenile population emigrates during May and only 1 percent in June. Therefore nearly three quarters of the Central Valley spring-run juvenile population will move through the Delta during the early application period. The estimated level of exposure during this time, based on salvage records and 15 percent cross Delta survival, is approximately 157,845 fish. Of this number, 789 fish are expected to die from fluridone exposure.

C. Central Valley steelhead

Steelhead estimates indicate that nearly 93 percent of the annual juvenile emigration occurs prior to April. Approximately 5 percent of the population emigrates in April, 1 percent in May, and only 0.5 percent in June, based on salvage numbers at the CVP and SWP fish collection facilities. The estimated number of juvenile steelhead exposed to the EDCP treatments is approximately 7,400 fish. Of this number, 37 are expected to die from fluridone exposure.

D. Southern DPS of the North American green sturgeon

Both adult and juvenile green sturgeon are expected to be present year round in the waters of the Delta (*i.e.*, action area) and thus will be exposed to herbicide applications during the entire application season of the proposed EDCP. Their numbers are difficult to quantify. Based on salvage records at the CVP and SWP Diversion facilities over the past decade, salvage numbers have ranged from zero to several hundred fish with an average of a few dozen fish per year (average approximately 50 fish). This represents an unknown fraction of the juvenile population in the Delta. Estimates of cross delta survival used in the salmon population estimates are unknown for green sturgeon, as are the relative contributions of different year classes to the in-Delta population levels. Beamesderfer *et al.* (2006) developed a theoretical life table model that estimated the relative contributions of each life stage of green sturgeon to the total population at equilibrium. In this model, juveniles in the fresh water rearing stage (0 to 3 years) comprised 25 percent of the total population. Subadults (< 165 cm total length) comprised 63 percent of the total population and the majority of the wide-ranging ocean stocks. Adults comprised approximately 12 percent of the total population. Approximately one third of the adult population in any given year enters freshwater to spawn, which amounts to 4 percent of the total population. Therefore, in any given year, a minimum of approximately 29 percent of the total population of green sturgeon would be vulnerable to herbicide exposures in the Delta from the EDCP. Based on the hypothetical life model, reproductive potential for the green sturgeon is much less sensitive to additional mortality in the juvenile life stages than in the subadult and reproductive age adult stages. The modeling indicates that additional mortality rates of 30 to 60 percent are required to reduce the egg production per recruit (EPR) potential of juvenile fish 20 to 50 percent, which is the critical range proposed for species survival in sturgeon stocks (Boreman 1997, Beamesderfer *et al.* 2006). However, when additional mortality rates are examined for all ages of green sturgeon, an increase of only 2 to 5 percent additional mortality is required to reduce the EPR by 20 to 50 percent, and effectively drive the stock to collapse. Thus, the exposure of at least 28 percent of the green sturgeon population to the effects of the EDCP herbicide program each year can have far reaching consequences in this long lived species, particularly if the adverse effects exceed the 0.5 percent mortality rate expected from the herbicide exposure due to sublethal or indirect mortality associated with the program.

The EDCP is expected to result in several temporary degraded habitat conditions. These are expected to include physical disturbance, elevation of water temperature caused by reduced shading, reduction of DO levels resulting from decaying *Egeria densa*, reduction in the invertebrate forage base for juvenile salmonids and green sturgeon, and reduction of native vegetation which juvenile salmonids may utilize for cover. Even though juvenile salmonids and green sturgeon should be able to leave or avoid areas of degraded habitat, they may need to expend valuable metabolic energy to do so. This could result in depleted energy stores that could have been used for other physiological needs, such as growth or smoltification. However, the application of the herbicides will be to discrete sections of the Delta, at specific time points in the application season. Thus, the Delta will not be widely impacted at a specific point in time, exposing all listed salmonids and green sturgeon in the Delta at once to potentially toxic or adverse concentrations of herbicides. Also, the intermittent nature of the herbicide applications within a given area of the Delta will allow for a significant dilution effect from water column mixing and chemical degradation to initiate within hours. There will be negative impacts to a proportion of the listed salmonid or green sturgeon populations that are within the immediate vicinity of an herbicidal application at the moment of application or immediately following it. The proportion of fish affected by the application is difficult to determine since it is based on the density of migrating fish and the timing of migration. However, only a small segment of each listed salmonid ESU is expected to actually be exposed to concentrations sufficiently elevated to have a negative impact to the individual fish, and therefore the level of impact to the entire run will not be of a magnitude to appreciably reduce the likelihood of continued existence of that run. Similarly, it is not anticipated that individual green sturgeon will congregate in application areas in high enough numbers to represent a significant proportion of the population, but rather will be dispersed throughout the channels of the Delta.

E. Critical Habitat

Critical habitat for Sacramento River winter-run Chinook salmon in the project area is not expected to be adversely modified. The majority of the critical habitat in the project area for this ESU is in the Sacramento River. EDCP operations will be primarily to the south of these waterways in the central and southern Delta regions. Only a small proportion of the designated winter-run critical habitat lies within the action area; the Sacramento River surrounding the Decker Island site, and the western Delta waterways surrounding the Sherman Island sites. Critical habitat for the Central Valley spring-run Chinook salmon ESU includes essentially the same waterways as the winter-run critical habitat in the action area. The critical habitat for the Central Valley steelhead DPS includes all waters of the Delta that are accessible to anadromous fish, and habitat below the high water line (*i.e.*, tidal flats, commonly inundated riparian zones, *etc.*). Critical habitats for winter-run Chinook salmon, spring-run Chinook salmon, and Central Valley steelhead are not expected to be permanently affected in an adverse manner, but rather on a temporary basis following herbicide treatment. The degraded habitat conditions eventually will be attenuated as DO levels increase, invertebrates recolonize treated areas, and predatory fish-prey fish numbers re-establish equilibrium in treated regions. The removal of *Egeria* eventually may improve habitat conditions for juvenile salmonids if water flow improves and native vegetation colonizes the treated areas, creating shaded habitat and diverse foraging opportunities for juvenile salmon. Therefore, the EDCP is not expected to appreciably reduce the conservation value of designated critical habitat for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, or Central Valley steelhead over the long term, but although adverse impacts to a small area are expected over the short term. No critical habitat has been proposed for green sturgeon at this time.

VIII. CONCLUSION

After reviewing the best available scientific and commercial information, the current status of the Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, the southern DPS of the North American green sturgeon, the environmental baseline, the effects of the proposed *Egeria densa* Control Program for the 2007 to 2011 application seasons, and the cumulative effects of the action, it is NMFS' biological opinion that the EDCP, as proposed, is not likely to jeopardize the continued existence of Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, Central Valley steelhead DPS, or southern DPS of the North American green sturgeon, or result in the destruction or adverse modification of the designated critical habitat for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, or Central Valley steelhead.

Notwithstanding this conclusion, NMFS anticipates that some activities associated with this project may result in the incidental take of these species. Therefore, an incidental take statement is included with this biological opinion for these actions.

IX. INCIDENTAL TAKE STATEMENT

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

Pursuant to section 7(b)(4) of the ESA, the following reasonable and prudent measures are necessary and appropriate to minimize take of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and North American green sturgeon. Because these measures are necessary to protect listed salmonids, they are non-discretionary and must be undertaken by the USDA-ARS so that they become binding conditions of any grant or permit issued to the DBW or their agents, as appropriate, for the exemption in section 7(o)(2) to apply. The USDA-ARS has a continuing duty to regulate the activity covered in this incidental take statement. If the USDA-ARS: (1) fails to assume and implement the terms and conditions of the incidental take statement; and/or (2) fails to require the DBW or its agents to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, the USDA-ARS and the DBW must report the progress of the action and its impact on the species to NMFS as specified in this incidental take statement (50 CFR §402.14 (i)(3)).

The prohibitions against taking of listed species in section 9 of the ESA do not apply to threatened North American green sturgeon until the final section 4(d) rule under the ESA is published in the Federal Register. NMFS expects this to occur prior to the end of the 5-year EDCP program, and most likely within the next 1 to 2 years. NMFS advises the USDA-ARS to consider implementing the following reasonable and prudent measures for the threatened southern DPS of North American green sturgeon upon issuance of this biological opinion.

This incidental take statement is applicable to the operations of the EDCP as described in the EDCP environmental documents (volumes 1 and 2) (DBW 2006a) and the second Addendum to the 2001 Environmental Impact Report (DBW 2006b). All applications of permitted herbicides as described in the project description for the program will have incidental take coverage as stipulated under the terms of section 7(b)(4) and section 7(o)(2) of the ESA during the operational season approved by NMFS for the five-year period of the program (2007 through 2011), providing that the terms and conditions of this biological opinion are implemented. The incidental take coverage for this biological opinion will terminate following the close of the 2011 application season. After this time, incidental take of listed species by the EDCP will not be exempt from the take prohibitions of section 9 of the ESA under the authority of this biological opinion.

A. Amount or Extent of Take

NMFS anticipates that the 5-year duration of the EDCP from 2007 to 2011 will result in the incidental take of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and North American green sturgeon due to direct and indirect impacts caused by the application of chemical herbicides to waters of the Delta. Any incidental take resulting from the project most likely will be limited to emigrating fry and juveniles present in the Delta action area during the operational season of the EDCP (applicant's proposed implementation period from April 1 through October 15). The incidental take is expected to be in the form of death, injury, harassment, and harm.

The numbers of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and North American green sturgeon directly taken will be difficult to quantify because dead and injured individuals will be difficult to detect and recover. Since acute exposure of green sturgeon to the program's herbicides is likely to be of greater duration than that of the listed salmonids, adverse effects are not expected to be less than that experienced by listed salmonids exposed to the program's herbicides. Long-term exposure to low levels of herbicides may be greater for sturgeon due to their prolonged residency in the Delta compared to salmonids, but herbicide levels are expected to be lower due to the extensive mixing of water in the main channels preferred by sturgeon.

The greatest level of take for listed salmonids resulting from the implementation of the EDCP is expected to occur during the months of April, May, and June when listed salmonids will be present in the Delta waterways. Green sturgeon take will occur during all months of the EDCP application season based on their migratory and rearing behaviors. Take is expected to include:

1. All Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and Southern DPS of the North American green sturgeon juveniles and adults harmed or killed from exposure to lethal or sublethal concentrations of fluridone or diquat applied to waters of the Delta during the 5-year duration (2007 to 2011) of the EDCP's implementation (applicant's proposed implementation period from April 1 through October 30). Adult salmonids are considered to be unlikely to be present in areas where the herbicides are applied to the waters of the Delta. Therefore, NMFS does not expect any adult salmonids to be taken by the project, but will give a limit of 1 adult fish from each ESU/DPS in its incidental take statement. The numbers of juvenile winter-run and spring-run Chinook salmon and Central Valley steelhead that utilize Delta waterways within the EDCP action area are hard to estimate due to the high levels of uncertainty surrounding the division of migrating fish between the Sacramento River channel and the channels connecting the Sacramento River with the San Joaquin River through the Central Delta. For the past 6 years, estimates of the population of winter-run sized Chinook salmon entering the Central and South Delta have averaged approximately 2,125 fish for the 3-month period between April and June. These numbers are products of the estimated take numbers from the CVP and SWP and a theoretical cross-Delta mortality value of 85 percent (higher range estimate) based on the work of Brandes and McLain (2001) and Vogel (2004). Therefore, 2,125 winter-run Chinook salmon are expected to be exposed to the adverse conditions created by herbicide applications under the applicant's proposed EDCP herbicide treatment season (April 1 through October 15), of which 0.5 percent will suffer mortality (11 fish). This value corresponds to the proportion of the exposed population expected to be susceptible to the adverse effects of the herbicide compounds. During the same 6-year period, approximately 157,845 spring-run-sized Chinook salmon will move through the action area during the April through June period. Using the same rationale, 0.5 percent of the spring-run Chinook salmon exposed to the adverse conditions of the EDCP herbicide applications will suffer mortality (789 fish). Central Valley steelhead may move through the Delta during all months of the EDCP applications, but salvage data from the CVP and SWP indicate that approximately 7,300 steelhead will move through the Delta in the 3-month period between April and June. An additional 125 steelhead are expected to move through the Delta in the fall months of September through November based on the data from the CVP and SWP salvage records. NMFS expects that 37 Central Valley steelhead smolts will experience mortality from herbicide exposure. No estimates of the population of North American green sturgeon entering the

Central and South Delta or Sacramento River drainage are available, but the number of juveniles and sub-adults taken at the CVP and SWP per year combined has averaged approximately 50 fish over the last decade. NMFS does not have any estimates of mortality for green sturgeon transiting the Delta, but it is thought to be lower than that for salmonids, primarily based on the differential rates of predation on salmonids and sturgeon by large piscivorous fish. Therefore, the salvage numbers would be the minimum number of fish potentially exposed to the EDCP, as they would have to transit through the Delta to arrive at the State and Federal facilities and therefore would pass through the action area. Using the 0.5 percent mortality criteria, NMFS expects 1 green sturgeon will suffer mortality from the application of herbicides under the EDCP.

2. All Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and North American green sturgeon juveniles and adults harmed, harassed, or killed from indirect effects or altered habitat conditions caused by the application of fluridone or diquat to the waters of the Delta during implementation of the EDCP (applicant's proposed implementation period from April 1 through October 15) during the 5-year duration (2007 through 2011) of the program. Such conditions may include reduced DO levels, reduced food supply, physical disturbance resulting in avoidance of habitat and increased energy expenditure, and the likelihood of increased predation. NMFS anticipates that this level of take will be 1.0 percent of the exposed population.

The total incidental take associated with this project is as follows:

	Juveniles				Adults	
ESU/DPS	Direct Take	Percent of ESU/DPS	Indirect Take	Percent of ESU/DPS	Total Take	Percent of ESU/DPS
Sacramento River winter-run Chinook salmon	11	0.003	22	0.006	1	0.01
Central Valley spring-run Chinook Salmon	789	0.05	1600	0.10	1	<0.01
Central Valley Steelhead	37	0.02	80	0.04	1	0.05
Southern DPS of North American green sturgeon	1 Adult or juvenile green sturgeon					

B. Effect of the Take

NMFS determined that this level of anticipated take is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

C. Reasonable and Prudent Measures

Reasonable and Prudent Measures (RPMs) are non-discretionary measures to minimize take that may or may not already be part of the description of the proposed action. They must be implemented as binding conditions for the exemption in section 7(o)(2) to apply. The USDA-ARS has the continuing duty to regulate the activities covered in this incidental take statement. If the USDA-ARS fails to adhere to the terms and conditions of the incidental take statement, or fails to retain the oversight of its applicant to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse.

NMFS believes that the following RPMs are necessary and appropriate to minimize take of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead resulting from implementation of the action. These reasonable and prudent measures will also minimize adverse effects on designated critical habitat for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead:

1. Measures shall be taken to reduce impacts to listed salmonids, North American green sturgeon, and their habitats from chemical control treatment and/or monitoring activities.

2. Measures shall be taken to reduce the impact of DBW's EDCP boating operations on listed salmonids, North American green sturgeon, and their habitat.

3. Measures shall be taken to monitor the DBW's *Egeria densa* control operations and the ambient Delta hydrologic conditions.

4. Pending the publication of the section 4(d) rule under the ESA for the Southern DPS of North American green sturgeon, the USDA-ARS and their agents will implement additional measures to avoid, minimize, and monitor incidental take of North American green sturgeon from the actions of the EDCP.

D. Terms and Conditions

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

1. **Measures shall be taken to reduce impacts to listed salmonids, North American green sturgeon, and their habitats from chemical control treatment and/or monitoring activities.**

    A. Chemical controls for the EDCP in the Delta shall not be applied before April 1 of any application season in any portion of the action area. Application of project herbicides will cease by October 15 of the application season. Applications of herbicides may be conducted in areas of the Delta as follows:

1. The following sites may be treated starting April 1 of each application season:

   1. Big Break I
   2. Bishop Telephone Cut
   3. Disappointment Slough
   4. Franks Tract
   5. Lost Slough
   6 Pixley Slough
   7. Rhode Island
   8. Seven Mile Slough
   9. Taylor Slough
   10. Werner Dredger Cut
   11. White Slough
   12. Fourteen Mile Slough
   13. Little Potato Slough (Grindstone)
   14. Piper Slough
   15. Sandmound Slough
   16. Sycamore Slough
   17. Whiskey Slough
   18. Beaver Slough
   19. Big Break Marina
   20. Fivemile Slough
   21. Hog Slough
   22. Indian Slough (Discovery Bay)
   23. Tom Paine Slough
   24. Trapper Slough
   25. Stone Lakes
   26. Snodgrass Slough

2. The following sites may be treated as of April 15 of each application season:

   1. Old River at Del's after the temporary barriers are in place.
   2. Middle River Union after the temporary barriers are in place.

3. The following sites may be treated as of May 15 of each application season:

   1. Big Break Wetlands
   2. Grantline Canal
   3. Mokelumne Cosumnes
   4. South Mokelumne – not within 0.5 mile of confluence with Georgiana Slough

5. North Mokelumne - not within 0.5 mile of confluence with Georgiana Slough
6. Potato Slough
7. Dutch Slough

4. The following sites may be treated as of June 1 of each application season:

1. Donlon Island
2. Fisherman's Cut
3. Rock Slough
4. Sherman Lake
5. Topeka Santa Fe
6. Victoria Canal
7. Woodward Canal
8. Little Venice Island
9. Middle River at Bullfrog
10. Middle River Jones
11. Middle River Victoria
12. Old River Connection
13. Old River at Orwood
14. Old River Main
15. Quimby Island
16. Ward Island
17. Turner Empire Cut
18. Coney Island
19. Hog Island
20. Latham Slough
21. Old River Holland
22. Venice Cut
23. Burns French Camp
24. Circle Lake
25. Depue Ox Bow
26. River Club Ox Bow
27. San Joaquin Mossdale
28. San Joaquin Roberts
29. 3-Mile Slough
30. Middle River Mildred
31. Stockton Channel
32. Georgiana Slough
33. Antioch
34. Decker Island/ Horseshoe Bend
35. Hayes Reach San Joaquin River
36. San Andreas Shoal San Joaquin River
37. Santa Clara Shoal San Joaquin River
38. Bradford reach San Joaquin River

B. Any Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead mortalities found at or in the vicinity of a treatment site shall be collected, fork length measured, and the body placed in a whirl-pak bag. The bag will be labeled with the time, date, location of capture, a description of the near-shore habitat type and water conditions, and then frozen. NMFS' Sacramento Area Office (see contact information below at 3 (F)) shall be notified within 48 hours and a representative of NMFS will collect the specimen.

C. DBW staff and their assigned agents must follow all Federal and State laws applicable to the use of the herbicides and any adjuvants and apply them in a manner consistent with the product labeling, the National Pollution Discharge Elimination System (NPDES) General Permit, Proposed Action, and determinations from the California Department of Pesticide Regulation.

D. At no time shall water quality conditions be allowed to degrade due to treatment protocols so that fish passage is blocked within the treatment areas. Protocols described in the project description shall be followed to ensure that EDCP operations do not inhibit passage of fish in any area scheduled for treatment.

E. The DBW will provide a copy of each week's NOI to NMFS' Sacramento Area Office (see contact information in 3(F) below) by the Friday prior to the treatment week. This notification will include the sites scheduled for treatment and a contact person for those sites.

F. A NMFS representative will be established on the *Egeria densa* Task Force and provide technical assistance to the Task Force, along with carrying out the duties of a Task Force member. As part of the Task Force, the NMFS representative will be active in guiding decisions on prioritizing treatment sites in regards to the presence of salmonids.

2. Measures shall be taken to reduce the impact of DBW's EDCP boating operations on listed salmonids, North American green sturgeon, and their habitat.

A. USDA-ARS and DBW shall comply with the receiving water limitations of the NPDES General Permit issued for the EDCP in regards to oils, greases, waxes, floating material, or suspended material derived from the operation of program vessels or application activities.

B. The USDA-ARS and DBW shall ensure that any mixing of chemicals, or disinfecting and cleaning of any equipment, shall be done in strict accordance with the operational protocols of the EDCP and that all equipment is in working order prior to engaging in application activities, including the operation of the program's vessels.

C. Operation of program vessels in shallow water habitats shall be done in a manner that causes the least amount of disturbance to the habitat. Operational procedures for vessels in these habitats shall minimize boat wakes and prop wash.

D. Operation of program vessels shall avoid or minimize to the greatest practicable extent dislodging portions of existing *Egeria densa* beds that can drift into other areas. This avoids creating new infestations of the weed due to drifting fragments.

3. Measures shall be taken to monitor the DBW's *Egeria densa* control operations and the ambient Delta hydrologic conditions.

A. The USDA-ARS shall ensure that the DBW follows a comprehensive monitoring plan designed to collect project operational information. The monitoring plan shall adhere to the requirements of the NPDES General Permit and have at a minimum those water quality criteria stated in Attachment B of the permit, *i.e.*, data on water temperatures, DO, pH, turbidity, water hardness, electrical conductivity, and chemical concentrations in the application areas, as well as other criteria stated in the attachment. Determinations of chemical concentrations shall have at a minimum, pre- and post-application water samples taken at the furthest down current site of the application zone.

B. The USDA-ARS, in coordination with the DBW, shall provide monitoring reports of the hydrologic conditions and the amounts of chemical discharges at the midpoint of the application season (July) and at the end of the application season (October) to NMFS Sacramento Area Office (see contact information in 3(F) below). These reports shall also include information on the following parameters:

1. Pre-treatment and post-treatment measurements on chemical residues, pH and turbidity levels, as well as water temperatures and dissolved oxygen concentrations from pre-selected sites in the Delta. These sites shall be reflective of the different water types found in the range of application sites and will be determined by DBW as part of their NPDES General Permit conditions.

2. Receiving water temperatures and DO levels and resultant changes in those conditions resulting from EDCP operations.

3. Amounts, types, and dates of application of herbicides applied at each site.

4. Visual assessment of pre- and post-treatment conditions of treated sites to determine the efficacy of treatment and any effects of chemical drift on downstream habitats immediately adjacent to the treated sites. Assessments should utilize objective criteria to demonstrate efficacy.

5. Operational status of equipment and vessels, including repairs and spraying equipment calibrations as needed.

C. The USDA-ARS, in coordination with the DBW, shall summarize the above reports into an annual report of the DBW project operations, monitoring measurements, and Delta hydrological conditions for the previous treatment year for submission to NMFS by January 31 of each year. The annual report of DBW operations shall also include:

1. A description of the total number of winter-run and spring-run Chinook salmon or steelhead observed taken, the manner of the take, and the dates and locations of the take, the condition of the winter-run Chinook salmon, spring-run Chinook salmon, or steelhead trout taken, the disposition of fish taken in the event of mortality and a brief narrative of the circumstances surrounding the take of the fish. This report shall be sent to the address given below in 3(F).

2. Listed salmonids or other fish species that are observed to be behaving in an erratic manner shall be reported (see Appendix C).

3. An analysis of treatment efficacy for that season which shall include the preseason coverage of *Egeria densa* at each treatment site, the reduction (or increase) in coverage over the treatment cycle at each site, and the final coverage amount at the conclusion of the treatment season for each site.

D. The USDA-ARS and DBW shall design and implement a monitoring program to screen for the acquired resistance of *Egeria densa* to fluridone in the action area. Annual reports will be sent to NMFS reporting this information.

E. At the conclusion of the 5-year program, a comprehensive report will be developed by DBW that critically examines the efficacy and value of the EDCP as a continuing program. This report will be sent to NMFS, and made available to any other agencies or stakeholders with interest in the program.

F. All notifications or reports shall be submitted by mail or Fax to:

Office Supervisor
NMFS
Sacramento Area Office
650 Capitol Mall, Suite 8-300
Sacramento, California 95814

Phone: (916) 930-3600
Fax: (916) 930-3629

4. **Pending the finalization of the section 4(d) rule under the ESA for the Southern DPS of North American green sturgeon, the USDA-ARS and their agents will implement additional measures to avoid, minimize, and monitor incidental take of North American green sturgeon from the actions of the EDCP.**

   A. The USDA-ARS will monitor the take of green sturgeon, and record such information for their reports to NMFS required under term and condition 3(C), above.

   B. If necessary, USDA-ARS and DBW will coordinate with NMFS to alter herbicide application plans to avoid or minimize take of green sturgeon if field observations indicate that take is occurring.

X. CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the ESA directs Federal agencies to utilize their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on a listed species or critical habitat or regarding the development of pertinent information.

1. The USDA-ARS and its agents should support and promote aquatic and riparian habitat restoration within the Delta region, and encourage its contractors to modify operation and maintenance procedures through the service's authorities so that those actions avoid or minimize negative impacts to salmon and steelhead.

2. The USDA-ARS and its agents should support anadromous salmonid and green sturgeon monitoring programs throughout the Delta and Suisun Bay to improve the understanding of migration and habitat utilization by salmonids and green sturgeon in this region.

In order for NMFS to be kept informed of actions minimizing or avoiding adverse effects or benefiting listed species or their habitats, NMFS requests notification of the implementation of any conservation recommendations.

XI. REINITIATION OF CONSULTATION

This concludes consultation on the 2007 through 2011 *Egeria densa* Control Program. This biological opinion is valid for the EDCP as described in the BA and supplemental information received by NMFS for the 2007 to 2011 EDCP. As provided in 50 CFR '402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of taking specified in any incidental take statement is exceeded, (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not previously considered, (3) the agency action 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.

XII. REFERENCES

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, Southwest Fisheries Science Center, Santa Cruz, California. 49 pages.

Adams, P.B., C. Grimes, J.E. Hightower, S.T. Lindley, M.L. Moser, M.J. Parsley. In Press. Population status of North American green sturgeon *Acipenser medirostris*. Environmental Biology of Fish.

Alderdice, D.F., and F.P.J. Velsen. 1978. Relation between temperature and incubation time for eggs of Chinook salmon (*Oncorhynchus tshawytscha*). Journal of the Fisheries Research Board of Canada 35(1):69-75.

Allen, M.A., and T.J. Hassler. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates. (Pacific Southwest), Chinook salmon. U.S. Fish and Wildlife Report 82 (11.49). April 1986.

Arbuckle, T.E., S.M. Schrader, D. Cole, J.C. Hall, C.M. Bancej, L.A. Turner, and P. Claman. 1999. 2,4-Dichlorophenoxyacetic acid residues in semen of Ontario farmers. *Reprod. Toxicol.* Nov-Dec 13(6): 421-429.

Arbuckle, T.E., Z. Lin, and L.S. Mery. 2001. An exploratory analysis of the effect of pesticide exposure on the risk of spontaneous abortion in an Ontario farm population. *Environ. Health Perspect.* Aug 109(8): 851-857.

Arias, R.S., M.D. Netherland, B.E. Scheffler, A. Puri, and F.E. Dayan. 2005. Molecular evolution of herbicide resistance to phytoene desaturrase inhibitors in *Hydrilla verticillata* and its potential use to generate herbicide resistant crops. Pest Management Science 61: 258-268.

Arkoosh, M.R., E. Casillas, E. Clemons, A.N. Kagley, R. Olson, P. Reno, and J.E. Stein. 1998. Effect of Pollution on Fish Diseases: Potential Impacts on Salmonid Populations. *J. Aquatic Animal Health*. 10:182-190.

Arkoosh, M.R., E. Clemons, P. Huffman, and A.N. Kagley. 2001. Increased Susceptibility of Juvenile Chinook Salmon to Vibriosis after Exposure to Chlorinated and Aromatic Compounds Found in Contaminated Urban Estuaries. *J. Aquatic Animal Health*. 13:257-268.

Arthur, J.F., M.D. Ball, and S.Y. Baughman. 1996. Summary of Federal and State project environmental impacts in the San Francisco Bay-Delta Estuary, California. In: J.T. Holibaugh (ed.). The San Francisco Bay: the ecosystem. Further investigations into the natural history of San Francisco Bay and Delta with reference to the influence of man. Friesen Printers, Altona, Manitoba.

Ayers and Associates. 2001. Two-dimensional modeling and analysis of spawning bed mobilization, lower American River. Prepared for the U.S. Army Corps of Engineers, Sacramento District Office.

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.

Bain, M.B., and N.J. Stevenson, editors. 1999. Aquatic habitat assessment: common methods. American Fisheries Society, Bethesda, Maryland.

Barbosa, E.R., M.D. Leiros da Costa, L.A. Bacheschi, M. Scaff, and C.C. Leite. 2001. Parkonsonism after glycine-derivative exposure. *Mov. Disord.* 16(3):565-568.

Barnhart, R.A. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest), steelhead. U.S. Fish and Wildlife Service, Biological Report 82 (11.60). 21 pages.

Bartels, P.G., and C.W. Watson. 1978. Inhibition of carotenoid synthesis by fluridone and norflurazon. Weed Science 26:198.

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. 2006. Use of life history information in a population model for Sacramento green sturgeon. Environmental Biology of Fishes. (in press).

Bell, M.C. 1973. Fisheries handbook of engineering requirements and biological criteria. U.S. Amy Corps of Engineers, Portland, OR.

Bell, M.C. 1991. Fisheries handbook of engineering requirements and biological criteria (third edition). U.S. Army Corps of Engineers, Portland, OR.

Bennett, W.A., and P.B. Moyle. 1996. Where have all the fishes gone? Interactive factors producing fish declines in the Sacramento-San Joaquin Estuary. In: J.T. Holibaugh (ed.). The San Francisco Bay: the ecosystem. Further investigations into the natural history of San Francisco Bay and Delta with reference to the influence of man. Friesen Printers, Altona, Manitoba.

Bilby, R.E. 1984. Removal of woody debris may affect stream channel stability. Journal of Forestry 82:609-613.

Bimber, K.L. 1976. Respiratory stress in yellow perch induced by subtoxic concentrations of diquat. *Ohio J. Science*. 76(2):87-90.

Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of anadromous salmonids. *In* W.R. Meehan (editor). Influences of forest and rangeland management on salmonid fishes and their habitats, pages 83-138. American Fisheries Society Special Publication 19. American Fisheries Society, Bethesda, MD.

Boles, G. 1988. Water temperature effects on Chinook salmon (*Oncorhynchus tshawytscha*) with emphasis on the Sacramento River: a literature review. Report to the California Department of Water Resources, Northern District, 43 pages.

Boreman, J. 1997. Sensitivity of North American sturgeons and paddlefish to fishing mortality. Environmental Biology of Fishes. 48:399-405.

Borthwick, S.M., R.R. Corwin, and C.R. Liston. 1999. Investigations of fish entrainment by Archimedes and internal helical pumps at the Red Bluff Research Pumping Plant, Sacramento California: February 1997-June 1998.

Brandes, P.L., and J.S. McLain. 2001. Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. In: Brown, R.L., 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. 1952. Temperature tolerance of young Pacific salmon, genus *Oncorhynchus*. Journal of the Fisheries Research Board of Canada 9:265-323.

Brown, L.R., and J.R. May. 2000. Benthic Macroinvertebrate assemblages and their relations with environmental variables in the Sacramento and San Joaquin drainages, California, 1993-1997. U.S. Geological Survey. Water Resources Investigation Report. 00-4125.

Busby, P.J., T.C. Wainright, 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. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-27, 261 pages.

CALFED Bay Delta Program. 2000. Comprehensive Monitoring, Assessment and Research Program. Final Programmatic EIS/EIR Technical Appendix. Appendices found at http://calfed.ca.gov/programs/cmarp/.

CALFED Science Program. 2001. Science in action: scrutinizing the Delta Cross Channel. CALFED Bay-Delta Program. June 2001. Available online at: http://science.calwater.ca.gov/library.shtml.

CALFED. 2005. Review of the biological opinion of the Long-term Central Valley Project and State Water Project operations Criteria and Plan. Report of the Technical Review Panel. 45 pages.

California Advisory Committee on Salmon and Steelhead. 1988. Restoring the Balance, a report to the Legislature and the Department of Fish and Game, #124-J, 84 Pages.

California Commercial, Industrial and Residential Real Estate Services Directory. Available: http://www.ured.com/citysubweb.html. April 2002.

California Department of Boating and Waterways. 2006a. *Egeria densa* Control Program (EDCP) Volume I and II. Environmental Documents for Formal Consultation wit the National Marine Fisheries Service. October 13, 2006.

California Department of Boating and Waterways. 2006b. *Egeria densa* Control Program, Second Addendum to the 2001 Environmental Impact Report with Five-year Program Review and Future Operations Plan. December 8, 2006.

California Department of Fish and Game. 1957. Report to the California Fish and Game Commission regarding bycatch of striped bass during commercial salmon and shad gill net fishing within the Sacramento – San Joaquin Delta, Suisun Bay and the Carquinez Straits. 33 pages.

California Department of Fish and Game. 1992. Sturgeon in relation to water development in the Sacramento-San Joaquin Estuary. WRINT-CDFG-Exhibit 28.

California Department of Fish and Game. 1998. Report to the Fish and Game Commission. A status review of the spring-run Chinook salmon (*Oncorhynchus tshawytscha*) in the Sacramento River Drainage. Candidate species status report 98-01. Sacramento, 394 pages.

California Department of Fish and Game. 2000. Spring-run Chinook salmon annual report. Prepared for the California Fish and Game Commission. Habitat Conservation Division, Native Anadromous Fish and Watershed Branch. Sacramento, 19 pages.

California Department of Fish and Game. 2002a. Spring-run Chinook salmon annual report. Prepared for the California Fish and Game Commission. Habitat Conservation Division, Native Anadromous Fish and Watershed Branch. Sacramento, 29 pages.

California Department of Fish and Game. 2002b. Sacramento River winter-run Chinook Salmon biennial report 2000-2001. Prepared for the California State Fish and Game Commission. Habitat Conservation Division, Native Anadromous Fish and Watershed Branch. Sacramento, 25 pages.

California Department of Fish and Game. 2002c. California Department of Fish and Game comments to NMFS regarding green sturgeon listing. 79 pages plus appendices.

California Department of Fish and Game. 2003. Memorandum to Madelyn Martinez (NMFS) regarding steelhead populations in the San Joaquin River basin. 4 pages.

California Department of Fish and Game. 2004a. Sacramento River winter-run Chinook salmon 2002-2003 biennial report. Prepared for the California Fish and Game Commission. Habitat Conservation Division, Native Anadromous Fish and Watershed Branch. Sacramento, 22 pages.

California Department of Fish and Game. 2004b. Sacramento River spring-run Chinook salmon 2002-2003 biennial report. Prepared for the California Fish and Game Commission. Habitat Conservation Division, Native Anadromous Fish and Watershed Branch. Sacramento, 35 pages.

California Department of Fish and Game. 2004c. Freshwater Sport Fishing Regulations 2004-2006. California Fish and Commission and Department of Fish and Game, Sacramento, California, 64 pages.

California Department of Fish and Game. 2004d. Acute toxicities of herbicides used to control water hyacinth and Brazilian elodea on larval Delta smelt and Sacramento splittail. Administrative Report 04-003. 40 pages.

California Department of Fish and Game. 2004e. Chronic toxicities of herbicides used to control water hyacinth and Brazilian elodea on neonate cladoceran and larval fathead minnow. Administrative Report 2004-04. 32 pages.

California Department of Water Resources. 2003. Bulletin 250-2002: Fish Passage Improvement.

California Regional Water Quality Control Board-Central Valley Region. 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 Regional Water Quality Control Board-Central Valley Region. 2001. Draft staff report on recommended changes to California's Clean Water Act, section 303(d) list. Available: http://www.swrcb.ca.gov/CRWQCB5/tmdl/

California Regional Water Quality Control Board. 2004. Resolution no. R5-2004-0108. Amending the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the control of salt and boron discharges into the lower San Joaquin River.

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.

Campbell, K.R., S.M. Bartell, and J.L Shaw. 2000. Characterizing aquatic ecological risks from pesticides using a diquat dibromide case study. II. Approaches using quotients and distributions. Environmental Toxicology and Chemistry 19(3):760 - 774.

Chambers, J. 1956. Fish passage development and evaluation program. Progress Report No. 5. U.S. Army Corps of Engineers, North Pacific Division, Portland, OR.

Chapman, D.W., and T.C. Bjornn. 1969. Distribution of salmon in streams, with special reference to food and feeding. *In* T.G. Northcote (editor), Symposium on salmon and trout in streams, pages 153-176. University of British Columbia, Institute of Fisheries, Vancouver.

Clark, G.H. 1929. Sacramento-San Joaquin salmon (*Oncorhynchus tshawytscha*) fishery of California. Calif. Div. of Fish and Game, Fish Bull. No.17:73.

Clifford, M.A., K.J. Eder, I. Werner, and R.P. Hedrick. 2005. Synergistic effects of esfenvalerate and infectious hematopoietic necrosis virus on juvenile Chinook salmon mortality. Environmental Toxicology and Chemistry 24(7): 1766-1772.

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.

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. 2005. Stanislaus River rotary screw trap monitoring data. Available at: http://spcramer.com/spcramer.html

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.

Demko, D.B., C. Gemperle, A. Phillips, and S.P. Cramer. 2000. Outmigrant trapping of juvenile salmonids in the lower Stanislaus River, Caswell State Park site, 1999. Prepared for U.S. Fish and Wildlife Service. Prepared by S.P. Cramer and Associates, Inc. Gresham, OR. 146 pp plus appendices.

Deng, X., J.P. Van Eenennaam, and S.I. Doroshov. 2002. Comparison of early life stages and growth of green sturgeon and white sturgeon. Pages 237-248 *in* W. Van Winkle, P.J. Anders, D.H. Secor, and D.A. Dixon, editors. Biology, management, and protection of North American sturgeon. American Fisheries Society, Symposium 28, Bethesda, Maryland.

Dettinger, M.D. 2005. From climate-change spaghetti to climate-change distributions for 21st century California. San Francisco Estuary and Watershed Science 3(1), Article 4 (14 pages) Available at: http://repositories.cdlib.org/jmie/sfews/vol3/art4.

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).

Di Giulo, R.T., W.H. Benson, B.M. Sanders, and P.A. Van Veld. 1995. Biochemical Mechanisms: Metabolism, Adaptation, and Toxicity Rand, G.M. (editor): Fundamentals of Aquatic Toxicology: Effects, Environmental Fate, and Risk Assessment, Second Edition. Taylor and Francis, 1995. pp 523-560.

Dodson, J.J. and C.I. Mayfield. 1979. Modification of the rheotropic response of rainbow trout (Salmo gairdneri) by sublethal doses of the aquatic herbicides diquat and simazine. Environ. Pollut. 18:147-157.

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.

Dunford, W.E. 1975. Space and food utilization by salmonids in marsh habitats in the Fraser River Estuary. M.S. Thesis. University of British Colombia, Vancouver, B.C., 81 pages.

Dwyer, F.J., D.K. Hardesty, C.G. Ingersoll, J.L. Kunz, and D.W. Whites. 2000. Assessing contaminant sensitivity of American shad, Atlantic sturgeon, and shortnose sturgeon:

Final Report – February 2000. United States Geological Survey, Columbia Environmental Research Center, Columbia, Missouri. 30 pages.

Dwyer, F.J., F.L. Mayer, L.C. Sappington, D.R. Buckler, C.M. Bridges, I.E. Greer, D.K. Hardesty, C.E. Henke, C.G. Ingersoll, J.L. Kunz, D.W. Whites, T. Augspurger, D.R. Mount, K. Hattala, and G.N. Neuderfer. 2005a. Assessing Contaminant Sensitivity of endangered and threatened aquatic species: Part I. acute toxicity of five chemicals. Archives of Environmental Contamination and Toxicology 48: 143-154.

Dwyer, F.J., D.K. Hardesty, C.E. Henke, C.G. Ingersoll, D.W. Whites, T. Augspurger, T.J. Canfield, D.R. Mount, and F.L. Mayer. 2005b. Assessing contaminant sensitivity of endangered and threatened aquatic species: Part III. Effluent toxicity tests. Archives of Environmental Contamination and Toxicology 48: 174-183.

Eder, K.J., C.M. Leutenegger, B.W. Wilson, and I. Werner. 2004. Molecular and cellular biomarker responses to pesticide exposure in juvenile Chinook salmon (*Oncorhynchus tshawytscha*). Marine Environmental Research 58: 809-813.

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.

Emmett, R.L., S.L. Stone, S.A. Hinton, 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, MD, 329 pages.

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.

Everest, F.H. 1973. Ecology and management of summer steelhead in the Rogue River. Oregon State Game Commission. Fishery Research Report 7. 48 pages.

Extoxnet. 2001. Extension Toxicology Network, Toxicology Briefs. A Pesticide Information Profile of the Cooperative Extension Offices of Cornell University, Oregon State University, University of Idaho, University of California, Davis and the Institute for Environmental Toxicology at the University of Michigan. Found at: http://pmep.cce.cornell.edu/profiles/extoxnet/dienchlor-glyphosate/diquat-ex.html.

Extoxnet. 2002. Extension Toxicology Network, Toxicology Briefs. A Pesticide Information Profile of the Cooperative Extension Offices of Cornell University, Oregon State University, University of Idaho, University of California, Davis and the Institute for Environmental Toxicology at the University of Michigan. Found at: http://pmep.cce.cornell.edu/profiles/herb-growthreg/fatty-alcohol-monuron/fluridone/herb-prof-fluridone.html.

Faustini, A. L. Settimi, R. Pacifici, V. Fano, P. Zuccaro, and F. Forastiere. 1996. Immunological changes among farmers exposed to phenoxy herbicides: preliminary observations. *Occup. Environ. Med.* Sept. 53(9): 583-585.

Fisher, F.W. 1994. Past and present status of Central Valley Chinook salmon. Conservation Biology 8:870-873.

Fry, D.H. 1961. King salmon spawning stocks of the California Central Valley, 1940-1959. California Fish and Game 47:55-71.

Gadomski, D.M. and M.J. Parsely. 2005. Effects of turbidity, light level, and cover on predation of white sturgeon larvae by prickly sculpins. Transactions of the American Fisheries Society 134:369-374.

Gard, M. 1995. Upper Sacramento River IFIM study scoping report. U.S. Fish Wildlife Service. 14 pages.

Garland, R.D., K.F. Tiffan, D.W. Rondorf, and L.O. Clark. 2002. Comparison of subyearling fall 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.

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.

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, CA.

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 p.

Grimaldo, L., R. Miller, C. Peregrin, Z. Hymanson, and J. Toft. 2000. How does Brazilian waterweed (*Egeria densa*) influence the fish assemblage in the Sacramento-San Joaquin Delta (Ca): Potential conflicts with ecosystem restoration. in Aquatic Invaders: Entry, Impact, and Control. American Fisheries Society Annual Meeting, August 20 - 24, 2000, St. Louis, Mo. Missouri Chapter of the American Fisheries Society and Missouri Department of Conservation

Hallock, R.J. 1989. Upper Sacramento River steelhead (*Oncorhynchus mykiss*) 1952-1988. Prepared for the U.S. Fish and Wildlife Service. California Department of Fish and Game, Sacramento, CA.

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, CA.

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 43:271-298.

Hallock, R.J., R.F. Elwell, and D.H. Fry, Jr. 1970. Migrations of adult king salmon, *Oncorhynchus tshawytscha*, in the San Joaquin Delta. California Fish and Game 151. Sacramento. 92 p.

Hallock, R.J., W.F. Van Woert, and L. Shapavalov. 1961. An evaluation of stocking hatchery-reared steelhead rainbow trout (*Salmo gairdneri gairdneri*) in the Sacramento River system. California Fish and Game 114:73.

Hamelink, J.L., D.R. Buckler, F.L. Mayer, D.U. Palawski, and H.O. Sanders. 1986. Toxicity of fluridone to aquatic invertebrates and fish. Environ. Toxicol. Chem. 3:87-92.

Hardell, L., and M. Eriksson. 1999. A case-control study of non-Hodgkin lymphoma and exposure to pesticides. *Cancer* March 15 85(6): 1353-1360.

Hare, S.R., N.J. Mantua, and R.C. Frances. 1999. Inverse production regimes: Alaska and west coast Pacific salmon. Fisheries 24(1):6-14.

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. 1980. Utilization of the Nanaimo River estuary by juvenile Chinook salmon (*Oncorhynchus tshawytscha*). Fishery Bulletin 77:653-668.

Healey, M.C. 1982. Juvenile Pacific salmon in estuaries: the life support system. *In* V.S. Kennedy (editor), Estuarine Comparisons, pages 315-341. Academic Press. New York, N.Y.

Healey, M.C. 1991. Life history of Chinook salmon. *In* C. Groot and L. Margolis (editors), Pacific Salmon Life Histories, pages 213-393. Univ. of British Columbia Press, Vancouver, British Columbia.

Herren, J.R., and S.S. Kawasaki. 2001. Inventory of water diversions in four geographic areas in California's Central Valley. *In* R.L. Brown (editor), Contributions to the Biology of

Central Valley Salmonids, Volume 2, Pages 343-355. California Fish and Game, Fish Bulletin 179.

Hetherington, A.M. and R.S. Quatrano. 1991. Tansley Review No. 31: Mechanisms of action of abscisic acid at the cellular level. New Phytologist 119(1):9-32.

Hiltibran, R.C., D.L. Underwood and J.S. Fickle. 1972. Fate of Diquat in the Aquatic Environment. University of Illinois, Water Resources Center. Water Research Report No. 52. Final Report - Project No. A-035-Ill.

Himmelbach, A., Y. Yang, E. Grill. 2003. Relay and control of abscisic acid signaling. Current Opinion in Plant Biology 6:470-479.

Huang, B., and Z. Liu. 2000. Temperature Trend of the Last 40 Years in the Upper Pacific Ocean. Journal of Climate 4:3738–3750.

Huddart, H., R.J. Smith, P.D. Langton, A.M. Hetherington, and T.A. Mansfield. 1986. Is abscisic acid a universally active calcium agonist? New Phytologist 104(2):161-173.

Hunter, J. 1959. Survival and production of pink and chum salmon in a coastal stream. Journal of the Fisheries Research Board of Canada 16:835-886.

Interagency Ecological Program Steelhead Project Work Team. 1999. Monitoring, assessment, and research on Central Valley steelhead: Status of knowledge, review existing programs, and assessment needs. In Comprehensive Monitoring, Assessment, and Research Program Plan, Technical Appendices VII-11.

Intergovernmental Panel on Climate Change (IPCC). 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, NY, USA. 881 pages.

Israel, J. 2006a. North American green sturgeon population characterization and abundance of the Southern DPS. Presentation to NMFS on April 4, 2006.

Israel, J. 2006b. Determining spawning population estimates for green sturgeon with microsatellite DNA. Presentation at the 2006 CALFED Science Conference. Sacramento, California. October 23, 2006.

Kamrin, M.A., ed. 1997. Pesticide Profiles: Toxicity, Environmental Impact, and Fate. Institute for Environmental Toxicology, Michigan State University, East Lansing, MI. Lewis Publishers, Boca Raton, NY.

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.

Kelley, J.T., A.P. Klimley, and C.E. Crocker. 2006. Movements of green sturgeon, *Acipenser medirostris*, in the San Francisco Bay Estuary, CA. Environmental Biology of Fishes (in press).

Kim, J.S., B.W. Yun, J.S. Choi, T.J. Kim, S.S. Kwak, and K.Y. Cho. 2004. Death mechanisms caused by carotenoid biosynthesis inhibitors in green and in undeveloped plant tissues. Pesticide Biochemistry and Physiology 78:127-139.

Kjelson, M.A., P.F. Raquel, and F.W. Fisher. 1981. Influences of freshwater inflow on Chinook salmon (*Oncorhynchus tshawytscha*) in the Sacramento-San Joaquin Estuary. *In* R.D. Cross and D.L. Williams (editors), Proceedings of the National Symposium on Freshwater Inflow to Estuaries, pages 88-108. U.S. Fish and Wildlife Service, FWS/OBS-81-04.

Kjelson, M.A., P.F. Raquel, and F.W. Fisher. 1982. Life history of fall-run juvenile Chinook salmon (*Oncorhynchus tshawytscha*) in the Sacramento-San Joaquin estuary, California. *In* V.S. Kennedy (editor), Estuarine comparisons, pages 393-411. Academic Press, New York, NY.

Kjelson, M., B. Loudermilk, D. Hood, and P. Brandes. 1990. The influence of San Joaquin River inflow, Central Valley and State Water Project exports and migration route on fall-run Chinook smolt survival in the Southern Delta during the Spring of 1989. Fisheries Assistance Office, Stockton, California. WQCP-USFWS-4.

Klimley, A.P. 2002. Biological assessment of green sturgeon in the Sacramento-San Joaquin watershed. A proposal to the California Bay-Delta Authority.

Kowalczyk-Schröder and G. Sandmann. 1992. Interference of fluridone with the desaturation of phytoene by membranes of the cyanobacterium *Aphanocapsa*. Pesticide Biochemistry and Physiology *42:7-12*.

Kuivila, K.M., H.D. Barnett, and J.L. Edmunds. 1999. Herbicide concentrations in the Sacramento-San Joaquin Delta, California. in U.S. Geological Survey Toxic Substances Hydrology Program - Proceedings of the Technical Meeting. Charleston, South Carolina, March 8-12, 1999, Vol. 2, Contamination of Hydrologic Systems and Related Ecosystems, 1999, U.S. Geological Survey Water-Resources Investigations Report 99-4018B1999, pp. 69-79.

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.

Le Page-Degivry, M.-Th, J.-N. Bidard, E. Rouvier, C. Bulard, and M. Lazdunski. 1986. Presence of abscisic acid, a phytohormone, in the mammalian brain. Proceedings of the National Academy of Sciences of the United States of America 83: 1155-1158.

Levings, C.D. 1982. Short term use of low-tide refugia in a sand flat by juvenile chinook, (*Oncorhynchus tshawytscha*), Fraser River estuary. Canadian Technical Reports of Fisheries and Aquatic Sciences, Number 1111. 7 pages.

Levings, C.D., C.D. McAllister, and B.D. Chang. 1986. Differential use of the Campbell River estuary, British Columbia, by wild and hatchery-reared juvenile Chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences 43:1386-1397.

Levy, D.A., and T.G. Northcote. 1982. Juvenile salmon residency in a marsh area of the Fraser River estuary. Canadian Journal of Fisheries and Aquatic Sciences 39:270-276.

Li, H., C. Schreck, C. Bond, and E. Rexstad. 1987.. Factors influencing changes in fish assemblages of Pacific Northwest streams. Pages 193-202 in: W. Matthews and D. Heins, editors. Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press, Norman, Oklahoma.

Lindley, S.T., and M.S. Mohr. 2003. Modeling the effect of striped bass (*Morone saxatilis*) on the population viability of Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*). Fisheries Bulletin. 101:321-331.

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. 2006. Large-scale migrations of green sturgeon. Presentation at Interagency Ecological Program 2006 Annual Workshop, Pacific Grove, California. March 3, 2006.

Lorz, H.W., S.W. Glenn, R.H. Williams, and C.M. Kunkel. 1979. Effects of selected herbicides on smolting of coho salmon. U.S. Environ. Prot. Agency, Ecol. Res. Ser. EPA-600/3-79-071. Corvallis, Oregon. 101 pp.

Lynge, E. 1998. Cancer incidence in Danish phenoxy herbicide workers, 1947-1993. *Environ. Health. Perspect.* Apr 106 Suppl. 2:683-686.

MacFarlane, B.R., and E.C. Norton. 2002. Physiological ecology of juvenile Chinook salmon at the southern end of their distribution, the San Francisco Estuary and Gulf of Farallones, California. California Department of Fish and Game, Fish Bulletin 100:244-257.

Mantua, N.J., and S.R. Hare. 2002. The Pacific decadal oscillation. Journal of Oceanography. 58:35-44.

Martin, C.D., P.D. Gaines, and R.R. Johnson. 2001. Estimating the abundance of Sacramento River juvenile winter Chinook salmon with comparisons to adult escapement. Red Bluff Research Pumping Plant Report Series, Volume 5. U.S. Fish and Wildlife Service. Red Bluff, CA.

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.

Matthews, K.R., and N.H. Berg. 1997. Rainbow trout responses to water temperature and dissolved oxygen stress in two southern California stream pools. Journal of Fish Biology. 50:50-67.

Mayfield, R.B. and J.J. Cech, Jr. 2004. Temperature Effects on green sturgeon bioenergetics. Transactions of the American Fisheries Society 133:961-970.

McDonald, J. 1960. The behavior of Pacific salmon fry during the downstream migration to freshwater and saltwater nursery areas. Journal of the Fisheries Research Board of Canada 17:655-676.

McDuffie, H.H., P. Pahwa, J.R. McLaughlin, J.J. Spinelli, S. Fincham, J.A. Dosman, D. Robson, L.F. Skinnider, and N.W. Choi. 2001. Non-Hodgkin's lymphoma and specific pesticide exposures in men: cross-Canada study of pesticides and health. *Cancer Epidemiol. Biomarkers Prev.* Nov 10(11): 1155-1163.

McEwan, D. 2001. 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.

McGowan, M.F. 1998. Fishes associated with submersed aquatic vegetation, Egeria densa, in the Sacramento-San Joaquin Delta in 1998 as sampled by pop nets. Romberg Tiburon Center, San Francisco State University.

McLaughlin, L., and J. McLain. 2004. Comparison of relative abundance of adult Chinook salmon (*Oncorhynchus tshawytscha*) in the Delta Cross Channel, Georgiana Slough, and Sacramento River, California 2001. 14 pages.

Meehan, W.R. 1991. Introduction and overview. *In* W.R. Meehan (editor). Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19, pages 1-16. American Fisheries Society, Bethesda, MD.

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, MD.

Meng, L., P.B. Moyle, and B. Herbold. 1994. Changes in abundance and distribution of native and introduced fishes of Suisun March. Transactions of the American Fisheries Society 123:498-507.

Meng, L., and P.B. Moyle. 1995. Status of splittail in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 124:538-549.

Meng, L., and S.A. Matern. 2001. Native and introduced larval fishes of Suisun Marsh, California: The effects of freshwater flow. Transactions of the American Fisheries Society 130:750-765.

Michel, A., R.S. Arias, B.E. Scheffler, S.O. Duke, M. Netherland, and F.E. Dayan. 2004. Somatic mutation-mediated evolution of herbicide resistance in the nonindigenous invasive plant hydrilla (*Hydrilla verticillata*). Molecular Ecology 13: 3229-3237.

Michny, F., and M. Hampton. 1984. Sacramento River Chico Landing to Red Bluff project, 1984, Juvenile salmon study. U.S. Fish and Wildlife Service, Division of Ecological Services. Sacramento, CA.

Miller, D.J., and R.N. Lee. 1972. Guide to the coastal marine fishes of California. California Department of Fish and Game, Fish Bulletin 157.

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 1992. 269 pages.

Mount, J.F. 1995. California Rivers and Streams: The conflict between fluvial process and land use. University of California Press, Berkeley.

Moyle, P.B. 2002. Inland fishes of California. University of California Press, Berkeley.

Moyle, P.B., J.E. Williams, and E.D. Wikramanayake. 1989. Fish species of special concern of California. Final report submitted to State of California Resources Agency. October 1989.

Moyle, P.B., P.J. Foley, and R.M. Yoshiyama. 1992. Status of green sturgeon, *Acipenser medirostris*, in California. Final report submitted to National Marine Fisheries Service, Terminal Island, California. 11 pages. University of California, Davis, California.

Moyle, P.B., R.A. Daniels, B. Herbold, and D.M. Baltz. 1986. Patterns in distribution and abundance of a non-coevolved assemblage of estuarine fishes in California. Fishery Bulletin 84:105-117.

Muir, D.C.G., and N.P. Grift. 1982. Fate of fluridone in sediment and water in laboratory and field experiments. J. Agric. Food Chem. 30(2):244-247.

Murty, A.S. 1986. Toxicity of Pesticides to Fish. Boca Raton, FL. CRC Press.

Myers, J.M., R.G. Kope, G.L. 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. U.S. Department Of Commerce, NOAA Tech Memo. NMFS-NWFSC-35, 443 pages.

Myrick, C.A, and J.J. Cech. 2000. Growth and thermal biology of Feather River steelhead under constant and cyclical temperatures. Department of Wildlife, Fish, and Conservation Biology, University of California. Davis, California.

Myrick, C.A., and J.J. Cech. 2004. Temperature effects on Chinook salmon and steelhead: a review focusing on California's Central Valley populations. Bay-Delta Modeling Forum technical publication 01-1.

Myrick, C.A. 1998. Temperature, genetic, and ration effects on juvenile rainbow trout (*Oncorhynchus mykiss*) bioenergetics. Ph.D. dissertation. University of California. Davis. 165 pages.

Nakamoto, R. J., Kisanuki, T. T., and Goldsmith, G. H. 1995. Age and growth of Klamath River green sturgeon (*Acipenser medirostris*). U.S. Fish and Wildlife Service. Project # 93-FP-13. 20 pages

National Marine Fisheries Service and California Department of Fish and Game. 2001. Final report on anadromous salmon fish hatcheries in California. Prepared by Joint Hatchery Review Committee. June 27, 2001.

National Marine Fisheries Service. 1996a. Making Endangered Species Act determinations of effect for individual or group actions at the watershed scale. Prepared by NMFS, Environmental and Technical Services Branch, Habitat Conservation Branch. 31 pages.

National Marine Fisheries Service. 1996b. 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, CA.

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. 1998. Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-35. 443 pages.

National Marine Fisheries Service. 2005. Green sturgeon (*Acipenser medirostris*) status review update, February 2005. Biological review team, Santa Cruz Laboratory, Southwest Fisheries Science Center. 31 pages.

Nichols, F.H., J.E. Cloern, S.N. Louma, and D.H. Peterson. 1986. The modification of an estuary. *Science* 231: 567-573.

Nickelson, T.E., J.W. Nicholas, A.M. McGie, R.B. Lindsay, D.L. Bottom, R.J. Kaiser, and S.E. Jacobs. 1992. Status of anadromous salmonids in Oregon coastal basins. Oregon Department of Fish and Wildlife, Research Development Section and Ocean Salmon Management, 83 pages

Noakes, D.J. 1998. On the coherence of salmon abundance trends and environmental trends. North Pacific Anadromous Fishery Commission Bulletin 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.

Orsi, J. 1967. Predation study report, 1966-1967. California Department of Fish and Game

Pacific Fishery Management Council. 2004. Review of 2003 Ocean Salmon Fisheries. Available: www.pcouncil.org

Patten, B. 1962. Cottid predation upon salmon fry in a Washington stream. Transactions of the American Fisheries Society 91:427-429.

Patten, B. 1971a. Predation by sculpins on fall Chinook salmon, *Oncorhynchus tshawytscha*, fry of hatchery origin. National Marine Fisheries Service, Special Scientific Report, Fisheries Number 621.

Patten, B. 1971b. Increased predation by the torrent sculpin, *Cottus rhotheus*, on coho salmon fry, *Oncorhynchus kisutch*, during moonlight nights. Journal of the Fisheries Research Board of Canada 28:1352-1354.

Paul, E.A., H.A. Simonin, J. Symula, and R.W. Bauer. 1994. The toxicity of diquat, endothall, and fluridone to the early life stages of fish. J. Freshwater Ecology 9(3): 229-239.

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.

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.

Piper, R.G., I.B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler, and J.R. Leonard. 1982. Fish Hatchery Management. U.S. Dept. of Interior., U.S. Fish and Wildlife Serv. 517 pp.

Pratt, J.R., A.E. Melendez, R. Barriero, and N.J. Bowers. 1997. Predicting the ecological effects of herbicides. Ecological Applications 7(4): 1117-1124.

Puce, S., G. Basile, G. Bavestrello, S. Bruzzone, C. Cerrano, M. Giovine, A. Arillo, and E. Zocchi. 2004. Abscisic acid signaling through cyclic ADP-ribose in hydroid regeneration. The Journal of Biochemistry 279(38): 39783-39788.

Radtke, L.D. 1966. Distribution of smelt, juvenile sturgeon, and starry flounder in the Sacramento-San Joaquin delta, Part II. Pp115-119. *In*: S.L. Turner and D.W. Kelley (eds.), California Fish and Game Bulletin 136.

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.

Reiser, D.W., and T.C. Bjornn. 1979. Habitat requirements of anadromous salmonids. *In* W.R. Meehan, editor. Influence of Forest and Rangeland Management on Anadromous Fish Habitat in the Western United States and Canada. USDA, Forest Service General Technical Report PNW-96.

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.

Rich, A.A. 1997. Testimony of Alice A. Rich, Ph.D., regarding water rights applications for the Delta Wetlands Project, proposed by Delta Wetlands Properties for Water Storage on Webb Tract, Bacon Island, Bouldin Island, and Holland Tract in Contra Costa and San Joaquin Counties. July 1997. California Department of Fish and Game Exhibit CDFG-7. Submitted to State Water Resources Control Board.

Ritter, A.M., J.L. Shaw, W.M. Williams, and K.Z. Travis. 2000. Characterizing aquatic ecological risks from pesticides using a diquat dibromide case study. I. Probabilistic exposure estimates. Environmental Toxicology and Chemistry 19(3):749-759.

Robison, G.E., and Beschta, R.L. 1990. Identifying trees in riparian areas that can provide coarse woody debris to streams. Forest Service 36:790-801.

Rutter, C. 1904. Natural history of the quinnat salmon. Investigations on Sacramento River, 1896-1901. Bull. U.S. Fish Comm. 22:65-141.

Sammons, S.M., and M.J. Maceina. 2006. Changes in diet and food consumption of largemouth bass following large-scale hydrilla reduction in Lake Seminole, Georgia. Hydrobiologia 560: 109-120.

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.

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 26:8-13.

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, 375 pages.

Shaw, J.L., and M.J. Hamer. 1995. A rebuttal to: "The toxicity of diquat, endothall, and fluridone to the early life stages of fish." J. Freshwater Ecol. 10(3):303-310

Shelton, J. M. 1995. The hatching of Chinook salmon eggs under simulated stream conditions. Progressive Fish-Culturist 17:20-35.

Shirvell, C.S. 1990. Role of instream rootwads as juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*O. mykiss*) cover habitat under varying streamflows. Canadian Journal of Fisheries and Aquatic Sciences 47:852-860.

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 Service, Special Science Report Fisheries 461:9.

Smith, A.K. 1973. Development and application of spawning velocity and depth criteria for Oregon salmonids. Transactions of the American Fisheries Society 10:312-316.

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.

Sommer, T.R., M.L. Nobriga, W.C. Harrell, W. Batham, and W.J. Kimmerer. 2001. Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58:325-333.

Spence, B., G. Lomnicky, R. Hughes, and R. Novitzki. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057. Technical Environmental Research Services Corp., Corvallis, Oregon.

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.

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.

Stevens, D.E., and L.W. Miller. 1983. Effects of river flow on abundance of young Chinook salmon, American shad, longfin smelt, and delta smelt in the Sacramento-San Joaquin river system. North American Journal of Fisheries Management 3:425-437.

Stillwater Sciences. 2002. Merced River corridor restoration plan. Stillwater Sciences, Berkeley, California. 245 pages.

Stillwater Sciences. 2006. Biological Assessment for five critical erosion sites, river miles: 26.9 left, 34.5 right, 72.2 right, 99.3 right, and 123.5 left. Sacramento River Bank Protection Project. May 12, 2006.

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., T.L. Bott, J.K. Jackson, L.A. Kaplan, J.D. Newbold, L.J. Standley, W.C. Hession, and R.J. Horwitz. 2004. Riparian deforestation, stream narrowing, and loss of stream ecosystem services. National Academy of Sciences 101:14132-14137.

Thompson, K. 1972. Determining stream flows for fish life. *In* Proceedings, Instream Flow Requirement Workshop, pages 31-50. Pacific Northwest River Basin Commission, Vancouver, Washington.

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 Services Office by California Department of Fish and Game, Bay-Delta and Special Water Projects Division, 25 pages.

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 Services, Vol. 10. 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 Services, Vol. 4. USFWS, Red Bluff, California. 54 pages.

U.S. Department of Agriculture – Agricultural Research Service. 2004. Fluridone (4AS) dissipation during typical applications of Sonar (4AS). Report submitted to the California Department of Boating and Waterways. December 29, 2004. 21 Pages.

U.S. Department of Interior. 1999. Final Programmatic Environmental Impact Statement for the Central Valley Project Improvement Act. October 1999. Technical Appendix, 10 volumes.

U.S. Fish and Wildlife Service. 1995. Sacramento-San Joaquin Delta Native Fishes Recovery Plan. Portland, OR.

U.S. Fish and Wildlife Service. 2000. Impacts of riprapping to ecosystem functioning, lower Sacramento River, California. U.S. Fish and Wildlife Service, Sacramento Field Office, Sacramento, California. Prepared for US Army Corps of Engineers, Sacramento District.

U.S. Fish and Wildlife Service. 2001a. Abundance and seasonal, spatial, and diel distribution patterns of juvenile salmonids passing the Red Bluff Diversion Dam, Sacramento River. Draft Progress Report for Red Bluff Research Pumping Plant, Vol.14. Prepared by Philip Gaines and Craig Martin for the U.S. Bureau of Reclamation. Red Bluff, CA.

U.S. Fish and Wildlife Service. 2001b. Abundance and survival of juvenile Chinook salmon in the Sacramento-San Joaquin Estuary: 1997 and 1998. Annual progress report. 131 pages.

U.S. Fish and Wildlife Service. 2002. Spawning areas of green sturgeon *Acipenser medirostris* in the upper Sacramento River California. U.S. Fish and Wildlife Service, Red Bluff, California.

U.S. Fish and Wildlife Service. 2003. Flow-habitat relationships for steelhead and fall, late-fall, and winter-run Chinook salmon spawning in the Sacramento River between Keswick Dam and Battle Creek. Sacramento, CA. 76 pages.

U.S. Fish and Wildlife Service. 2004. Draft adult spring Chinook salmon monitoring in Clear Creek, California, 1999-2002. Prepared by J.M. Newton and M.R. Brown. Red Bluff, CA.

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-Casenave, S.I. Doroshov, D.C. Hillemeier, T.E. Wilson, and A.A. Nova. 2006. Reproductive conditions of 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, Jr., D.C. Hillemeir 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 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 Services Section.

Varanasi, U., E. Casillas, M.R. Arkoosh, T. Hom, D.A. Mistano, D.W. Brown, S-L Chan, T.K. Collier, B.B. McCain, and J.E. Stein. 1993. Contaminant Exposure and Associated Biological Effects in Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) from Urban and Nonurban Estuaries of Puget Sound. NOAA Technical Memorandum NMFS-NWFSC-8.

Vogel, D.A. 2004. Juvenile Chinook salmon radio-telemetry studies in the northern and central Sacramento-San Joaquin Delta, 2002-2003. Report to the National Fish and Wildlife Foundation, Southwest Region. January 2004. 44 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.

Waldrep, T.W. and H.M. Taylor. 1976. 1-Methyl-3-phenyl-5-(3-(trifluoromethyl) phenyl) 4-(1H)-pyridinone, a new herbicide. Journal of Agricultural Food Chemistry 24:1250.

Waples, R.S. 1991. Pacific Salmon, *Oncorhynchus spp.*, and the definition of "species" under the Endangered Species Act. Marine Fisheries Review 53:11-21.

Ward, P.D., McReynolds, T.R., 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. Reynolds, and C.E. Garman. 2003. Butte Creek spring-run Chinook salmon *Oncorhynchus tshawytscha*, pre-spawn mortality evaluation. California Department of Fish and Game, Inland Fisheries, Administrative Report No. 2004-5. Chico, CA.

Waters, T.F. 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society Monograph 7.

West, S.D., R.O. Burger, G.M. Poole, and D.H. Mowrey. 1983. Bioconcentration and field dissipation of the aquatic herbicide fluridone and its degradation products in aquatic environments. Journal of Food Chemistry 31: 579-585.

Wilson, D.C. and C.E. Bond. 1969. The Effects of the Herbicide Diquat and Dichlobenil (Casoron ®) on Pond Invertebrates Part 1. Acute Toxicity. *Trans. Amer. Fish. Soc.* 98(3): 438-443.

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.

Yeo, R.R. 1967. Dissipation of Diquat and Paraquat and Effects on Aquatic Weeds and Fish. *Weeds* 15:42.

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. *In* Sierra Nevada Ecosystem Project, Final Report to Congress, Volume III. Assessments, Commissioned Reports, and Background Information. Centers for Water and Wildland Resources, University of California. Davis, California.

Yoshiyama, R.M., E.R. Gerstung, F.W. Fisher, and P.B. Moyle. 2001. Historical and present distribution of Chinook salmon in the Central Valley Drainage of California. *In* R.L. Brown (editor), Contributions to the Biology of Central Valley Salmonids, pages 71-176. California Department of Fish and Game, Fish Bulletin 179, Volume 1.

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.

Zocchi, E., A. Carpeneto, C. Cerrano, G. Bavestrello, M. Giovine, S. Bruzzone, L. Guida, L. Franco, and C. Usai. 2001. The Temperature signaling cascade in sponges involves a heat gated cation channel, abscisic acid, and cyclic ADP-ribose. Proceedings of the National Academy of Sciences of the United States of America 98(26): 14859-14864.

Zocchi, E., G. Basile, C. Cerrano, G. Bavestrello, M. Giovine, S. Bruzzone, L. Guida, A. Carpaneto, R. Magrassi, and C. Usai. 2002. ABA- and cADPR-mediated effects on respiration and filtration downstream of the temperature-signaling cascade in sponges. Journal of Cell Science 116: 629-636.

Appendix A: Tables

Table 1: Original Priority (sites 1-35) and Secondary (sites 36-70) Treatment Sites from the 2001 EDCP.

Priority Site Number	Site name	DBW Site Numbers	Estimated Total Water Acreage	Estimated Total Water & Land Acreage	Percentage of Water Acres to Total Acres
1	Franks Tract	173, 174, 175	2,619.64	3,538.71	74
2	Venice Cut	16	841.36	3,480.31	24
3	Big Break I	115	669.19	1,032.38	65
4	Sherman lake	123-132	1,917.00	3,804.18	50
5	Rock Slough	97	126.54	3,168.06	4
6	White Slough	36, 37, 39	520.28	9,542.15	5
7	Fisherman's Cut	106	88.50	2,175.66	4
8	Taylor Slough	110, 111	167.77	2,473.31	7
9	Sandmound Slough	108, 109	347.91	3,307.42	11
10	Piper Slough	107	168.38	2,051.75	8
11	Latham Slough	65, 68, 69	926.39	6,264.83	15
12	Disappointment Slough	32, 33	377.94	3,533.24	11
13	Old River Del's	78, 79	116.19	3,384.73	3
14	Old River Connection	100	225.30	926.14	24
15	Middle River Bullfrog	58, 59	319.66	3,098.72	10
16	Middle River Jones	56	146.90	2,776.83	5
17	Fourteen mile Slough	25-28	357.20	7,662.88	5
18	Middle River Victoria	52, 53	196.80	2,316.32	8
19	Donlon Island	122	232.23	466.36	50
20	Rhode Island	99	253.75	1,268.28	20
21	Big Break Wetlands	117, 118	653.21	1,004.85	65
22	Big Break Marina	116	179.48	349.25	51
23	Sevenmile Slough	20	63.88	3,310.48	2
24	Dutch Slough	112, 113, 114	362.64	3,270.00	11
25	Little Potato Slough (Grindstone)	40, 41, 42	333.70	5,115.29	7
26	Turner Empire Cut	12, 60	261.39	4,954.66	5
27	Little Venice Island	15, 16	455.70	2,253.77	20
28	Coney Island	84, 85, 86	1,049.02	3,435.58	31
29	Hog Island	13	407.07	3,513.07	12
30	Pixley Slough	31	82.82	2,435.82	3
31	Bacon Island	56	0.00	0.00	0
32	Paradise Cut	72	109.93	1,946.44	6
33	Bishop Telephone Cut	34, 35	154.19	3,868.32	4
34	Old River Orwood	91, 92	379.18	3,626.22	10
35	Potato Slough	43, 44	460.08	3,563.49	13
Sub Total			15,571	108,920	Avg. = 14

Priority Site Number	Site name	DBW Site Numbers	Estimated Total Water Acreage	Estimated Total Water & Land Acreage	Percentage of Water Acres to Total Acres
36	Beaver Slough	207	134.61	8,175.44	2
37	Sycamore Slough	203	294.91	8,469.73	3
38	Hog Island	205	113.26	5,442.78	2
39	Ward Island	14	289.55	1,302.32	22
40	Whiskey Slough	61, 62	130.71	5,448.98	2
41	Indian Slough (includes Discovery Bay)	93	804.07	2,614.36	31
42	South Mokelumne	204, 206, 208	246.58	5,941.77	4
43	Old River Main	89, 90	213.61	5,424.60	4
44	North Mokelumne	209, 210	349.05	5,544.72	6
45	3 Mile Slough	22	704.40	5,202.55	14
46	San Joaquin Bradford	23	849.78	3,452.58	25
47	Quimby Island	101	328.27	2,252.00	15
48	Hayes Reach	17	850.66	1,874.58	45
49	Middle River Mildred	66, 67	852.97	3,020.62	28
50	Antioch	121	731.99	1,656.31	44
51	Topeka Santa Fe	57	53.27	876.59	6
52	Old River Holland	98	217.37	1,430.39	15
53	Werner Dredger Cut	94, 95, 96	127.99	4,178.34	3
54	Victoria Canal	50, 51	194.65	6,000.80	3
55	Burns French Camp	9	364.79	5,893.94	6
56	Woodward Canal	54, 55	86.21	2,299.97	4
57	Grant Line Canal	80, 81	276.71	8,645.09	3
58	Trapper Slough	64	42.36	4,133.28	1
59	Lost Slough	215	130.55	3,275.14	4
60	Snodgrass Slough	214,, 216-221	353.52	7,743.99	5
61	Middle River Union	45-49	157.24	19,358.32	1
62	Depue Ox Bow	305	35.13	2,146.50	2
63	River Club Ox Bow	306	90.74	452.38	20
64	Five Mile Slough	27	0.00	0.00	0
65	San Joaquin Roberts	2., 3, 4., 5	332.87	13,496.67	2
66	Stockton Channel	10, 11	511.37	5,697.65	9
67	San Andreas Shoals	19	888.20	3,487.96	25
68	San Joaquin Mossdale	1	116.97	2,074.35	6
69	Tom Paine Slough	74	167.60	4,204.28	4
70	Circle Lake	300	205.59	842.91	24
Subtotal 36-70			11,248	162,062	7
Total 1-70			26,819	270,981	10

Table 2: Changes to the EDCP list of treatment Sites for 2007-2011.

Deleted Sites	DBW Site Numbers	Site Name
	31	Bacon Island (counted with Middle River Jones
	32	Paradise Cut (non-navigable)
Additional Sites	**DBW Site Numbers**	**Site Name**
	69	Decker Island/ Horseshoe Bend
	70	Stone Lakes
	71	Mokelumne Cosumnes
	72	Georgiana Slough
	73	Santa Clara Shoal – San Joaquin River
Renamed Sites	**DBW Site Numbers**	**Site Name**
	41	Renamed as Indian Slough – Discovery Bay areas

Table 3: Decision Matrix for the EDCP proposed by the Department of Boating and Waterways.

Infestation Level	Definition
High	Greater than 25 percent *Egeria densa* coverage
Medium	Greater than 10 percent and less than or equal to 25 percent *Egeria densa* coverage
Low	Less than or equal to 10 percent coverage *Egeria densa* coverage

Infestation Level	Number of Sites	Percent of Total
High	29	40
Medium	15	20
Low	29	40
Total	73	100

Water Flow	Description
High	Greater than 20,000 cubic feet per second (cfs)
Medium	Greater than 5,000 cfs and less than or equal to 20,000 cfs
Low	Less than or equal to 5,000 cfs

Water Flow	Number of Sites	Percent of Total
High	6	8
Medium	25	34
Low	42	58
Total	73	100

Table 3 cont'd: Decision Matrix for the EDCP proposed by the Department of Boating and Waterways.

Ranking	Description	Sites
1	High Infestation, Low Flows (n=18 Sites) 11 new early start sites	• Big Break I • Bishop Telephone Cut • Disappointment Slough • Donlon Island • Fisherman's Cut • Franks Tract • Lost Slough • Pixley Slough • Rhode Island • Rock Slough • Seven Mile Slough • Sherman Lake • Taylor Slough • Topeka Santa Fe • Victoria Canal • Werner Dredger Cut • White Slough • Woodward Canal
2	High Infestation, Medium Flow (n=11 sites) 9 new early start sites	• Little Venice Island • Middle River Bullfrog • Middle River Jones • Middle River Victoria • Old River Connection • Old River Del's • Old River Orwood • Old River Main • Quimby Island • South Mokelumne • Ward Island
3	High Infestation, High Flow (n=0) No new early start sites	• None
4	Medium Infestation, Low Flow (n=8) 5 new early start sites	• Big Break Wetlands • Fourteenmile Slough • Little Potato Slough (Grindstone) • Piper Slough • Sandmound Slough • Sycamore Slough • Turner Empire Cut • Whiskey Slough

Ranking	Description	Sites
5	Medium Infestation, Medium Flow (n=7) no new early start sites	• Coney Island • Hog Island • Latham Slough • North Mokelumne • Old River Holland • Potato Slough • Venice Cut
6	Medium Infestation, High Flow (n=0) no new early start sites	• None
7	Low Infestation, Low Flow (n=16) 14 new early start sites	• Beaver Slough • Big Break Marina • Burns French Camp • Circle Lake • Depue Ox bow • Five Mile Slough • Grant Line Canal • Hog Slough • Indian Slough (Discovery Bay) • Middle River Union • River Club Ox Bow • San Joaquin Mossdale • San Joaquin Roberts • Tom Paine Slough • Trapper Slough • Stone Lakes
8	Low Infestation, Medium Flow (n=7) no new early start dates	• Threemile Slough • Dutch Slough • Middle River Mildred • Snodgrass Slough • Stockton Ship Channel • Mokelumne Cosumnes • Georgiana Slough

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

a) Adult

Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Sac. River basin[1]	Medium	Medium	Medium	Medium	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium									Medium	Medium
Sac. River[2]	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium									Medium	Medium	Medium	Medium

b) Juvenile

Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Sac. River @ Red Bluff[3]	Low	Low											Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Sac. River @ Red Bluff[2]													Low	Low								Medium	Medium	Medium
Sac. River @ Knights L.[4]							Low	Low							Low	Low	Low	Low	Low	Low	High	High	High	High
Lower Sac. River (seine)[5]							Low										Low	Low	Low	Low	Medium	Medium	High	High
West Sac. River (trawl)[5]	Medium	Medium	High	High	High	High	High	High													Low	Low	Medium	Medium

Source: [1]Yoshiyama *et al.* 1998; Moyle 2002; [2]Myers *et al.* 1998; [3]Martin *et al.* 2001; [4]Snider and Titus 2000; [5]USFWS 2001

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

Table 5: The temporal occurrence of adult (a) and juvenile (b) Central Valley spring-run Chinook salmon in the Sacramento River. Darker shades indicate months of greatest relative abundance

(a) Adult

Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
[1,2]Sac.River basin					Medium	Medium	Medium	Medium	High	High	High	High	Medium	Medium	Medium	Medium	Medium	Medium						
[3]Sac. River					Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium										
[4]Mill Creek					Low	Low	Medium	High	High	High	High	Medium	Medium	Low	Low									
[4]Deer Creek					Low	Low	Medium	High	High	High	High	Medium	Medium											
[4]Butte Creek			Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium										

(b) Juvenile

Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
[5]Sac. River Tribs	Medium	Medium	Medium	Medium	Medium	Medium													Medium	Medium	High	High	High	High
[6]Upper Butte Creek	High	High	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low							Low	Low	Low	Low	High	High
[4]Mill, Deer, Butte Creeks	High	High	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low							Low	Low	Low	Low	Low	Low
[3]Sac. River at RBDD	High	High	Low	Low	Low	Low	Low	Low	Low												High	High	High	High
[7]Sac. River at KL	Medium	Medium	Medium	Medium	High	High	High	High	Medium	Medium											Medium	Medium	High	High

Source:[1]Yoshiyama *et al.* 1998; [2]Moyle 2002; [3]Myers *et al.* 1998; [4]Lindley *et al.* 2004; [5]CDFG 1998; [6]McReynolds *et al.* 2005; Ward *et al.* 2002, 2003; [7]Snider and Titus 2000

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

Table 8: The temporal occurrence of adult (a) and juvenile (b) Central Valley steelhead in the Central Valley. Darker shades indicate months of greatest relative abundance

(a) Adult

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

(b) Juvenile

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

Source: [1]Hallock 1961; [2]McEwan 2001; [3]USFWS unpublished data; [4]CDFG 1995; [5]Hallock *et al.* 1957; [6]Bailey 1954; [7]CDFG Steelhead Report Card Data; [8]CDFG unpublished data; [9]Snider and Titus 2000; [10]Nobriga and Cadrett 2003; [11]Jones & Stokes Associates, Inc., 2002; [12]S.P. Cramer and Associates, Inc. 2000 and 2001; [13]Schaffter 1980

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

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

(a) Adult (≥13 years old for females and ≥9 years old for males)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dce
[1,2,3]Upper Sac. River			High	High	High	High	High	High	High	High	High	
[4,8]SF Bay Estuary			High	Medium	Medium	Medium	High	Medium	Medium			

(b) Larval and post-larval (≤10 months old)

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

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

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dee
[6]South Delta*	High	High	High	Medium	Medium	Medium	High	High	High	High	High	High
[6]Sac-SJ Delta	High	High	High	Medium	Medium	High	High	High	High	High	High	High
[5]Sac-SJ Delta				High	High	High	High	High	High	High		
[5]Suisun Bay	High	High	High	High	High	High	High	High	High	High	High	High

(d) Coastal migrant (3-13 years old for females and 3-9 years old for males)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
[3,7]Pacific Coast								Low	Low	Low	Low	Low

Source: [1]USFWS 2002; [2]Moyle *et al.* 1992; [3]Adams *et al.* 2002 and NMFS 2005; [4]Kelley *et al.* 2006; [5]CDFG 2002; [6]Interagency Ecological Program Relational Database, fall midwater trawl green sturgeon captures from 1969 to 2003; [7]Nakamoto *et al.* 1995; [8]Heublein *et al.* 2006

* Fish Facility salvage operations

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

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

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

Appendix B: Figures

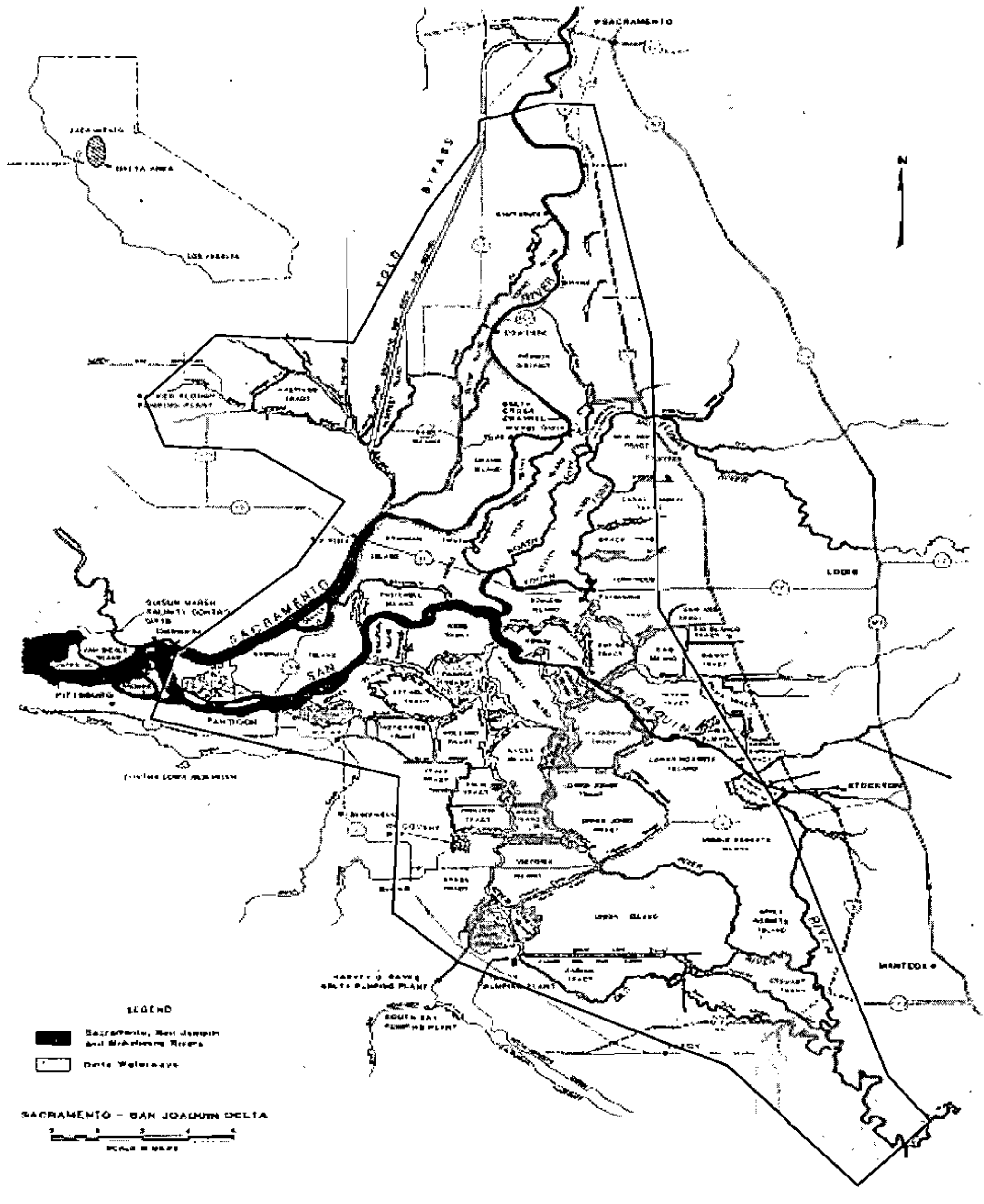


Figure 1: Generalized *Egeria densa* treatment boundaries in the legal Delta. Treatment boundaries are not to exact geographic locale.

Figure 2a: 2007 to 2010 EDCP Treatment Sites listed by Name

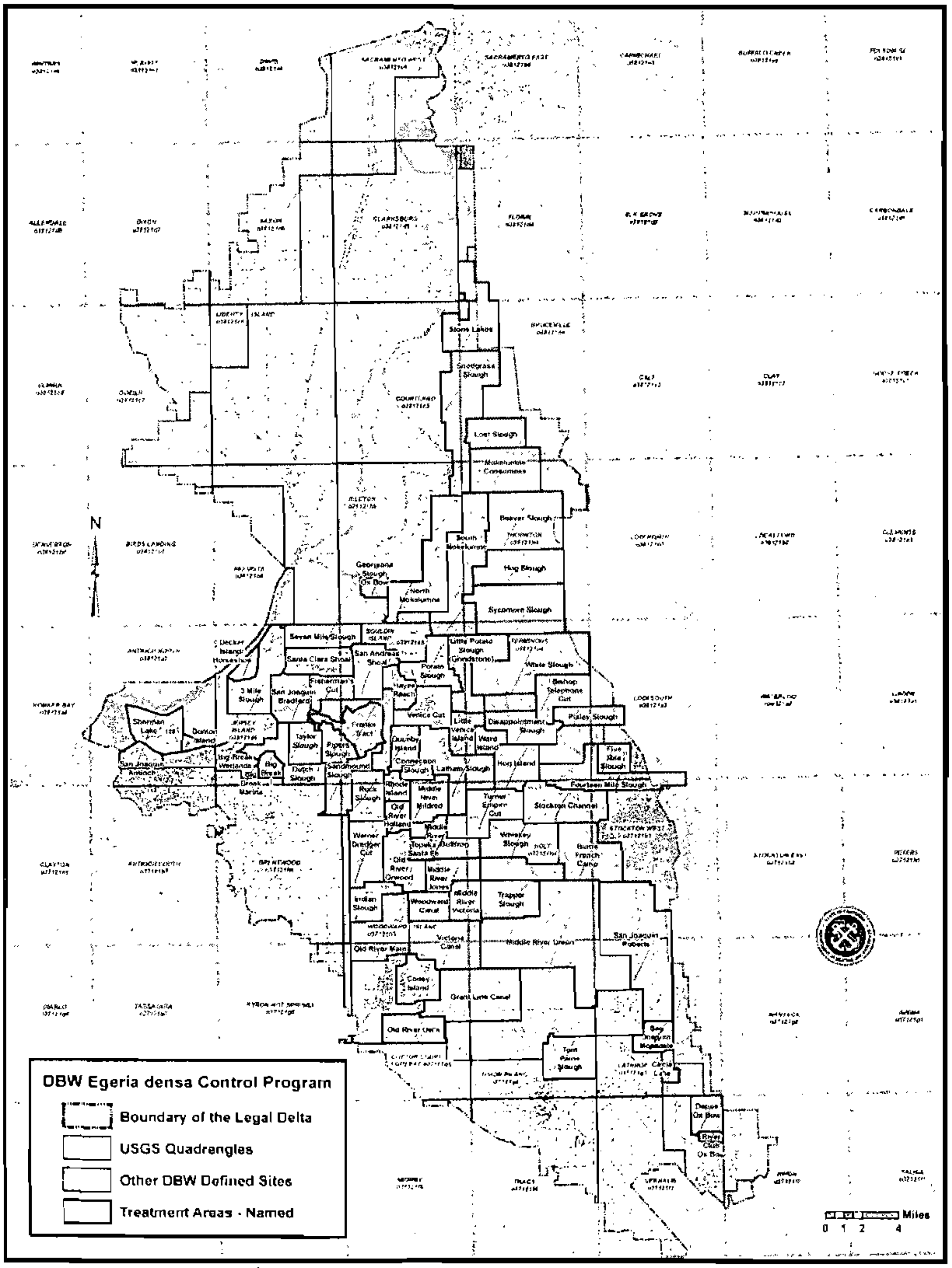
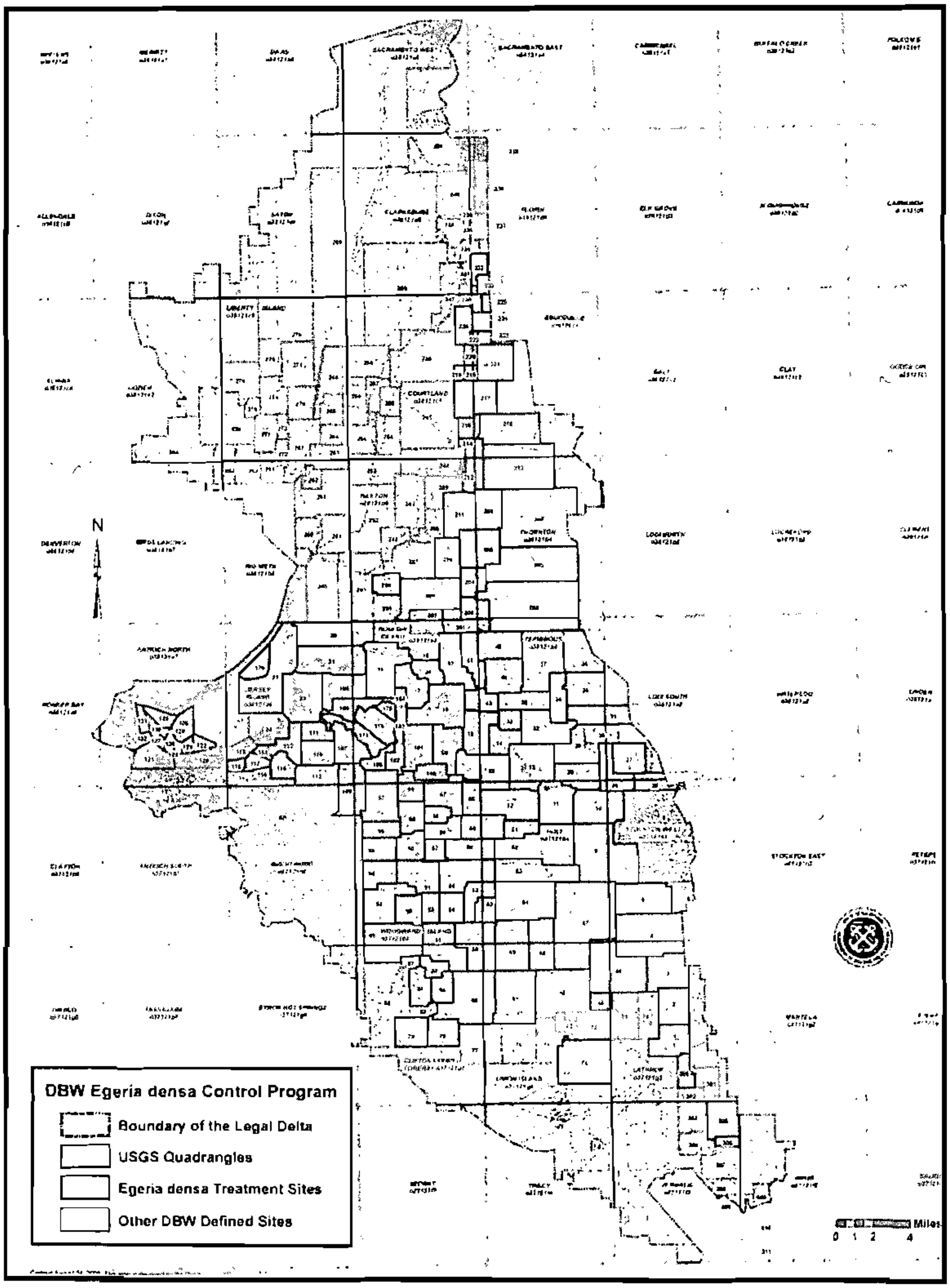


Figure 2b: 2007 to 2010 EDCP Treatment Sites listed by DBW Site Number



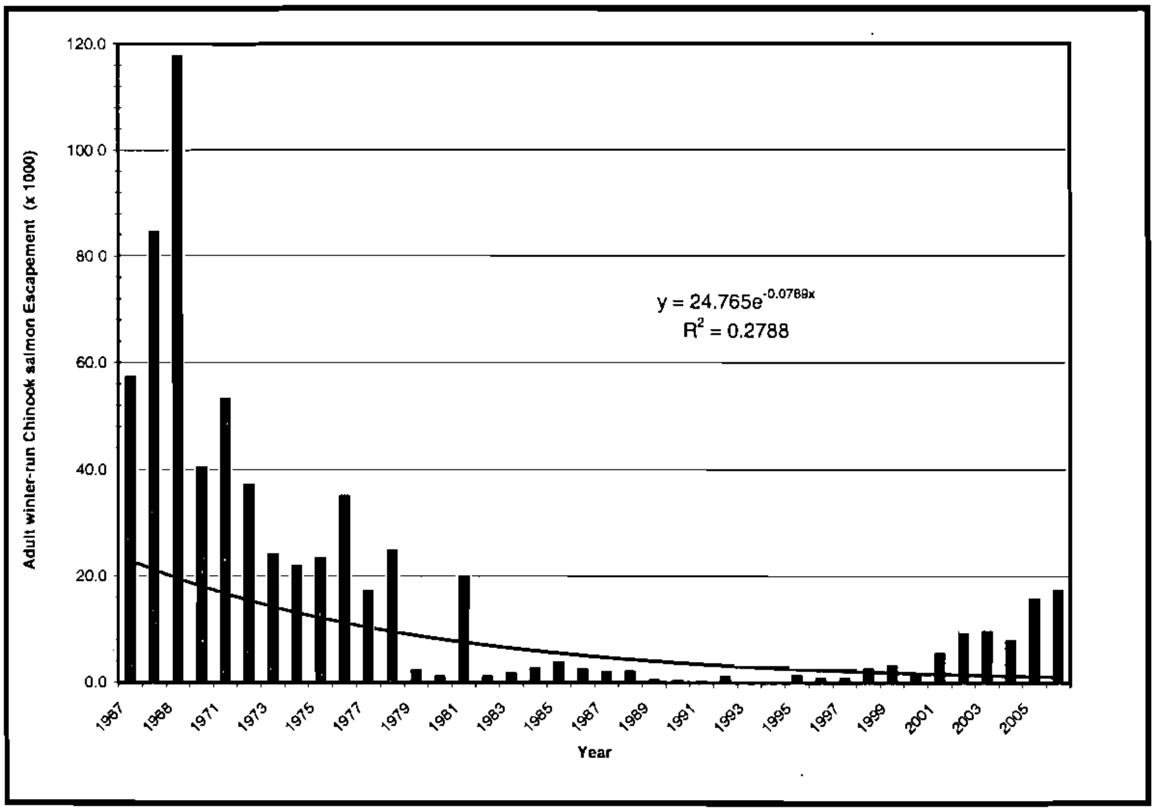


Figure 3:
Annual estimated Sacramento River winter-run Chinook salmon escapement population.
Sources: PFMC 2002, CDFG 2004a, NMFS 1997
Trendline for figure 3 is an exponential function: $Y=24.765\ e^{-0.0789x}$, $R^2=0.2788$.

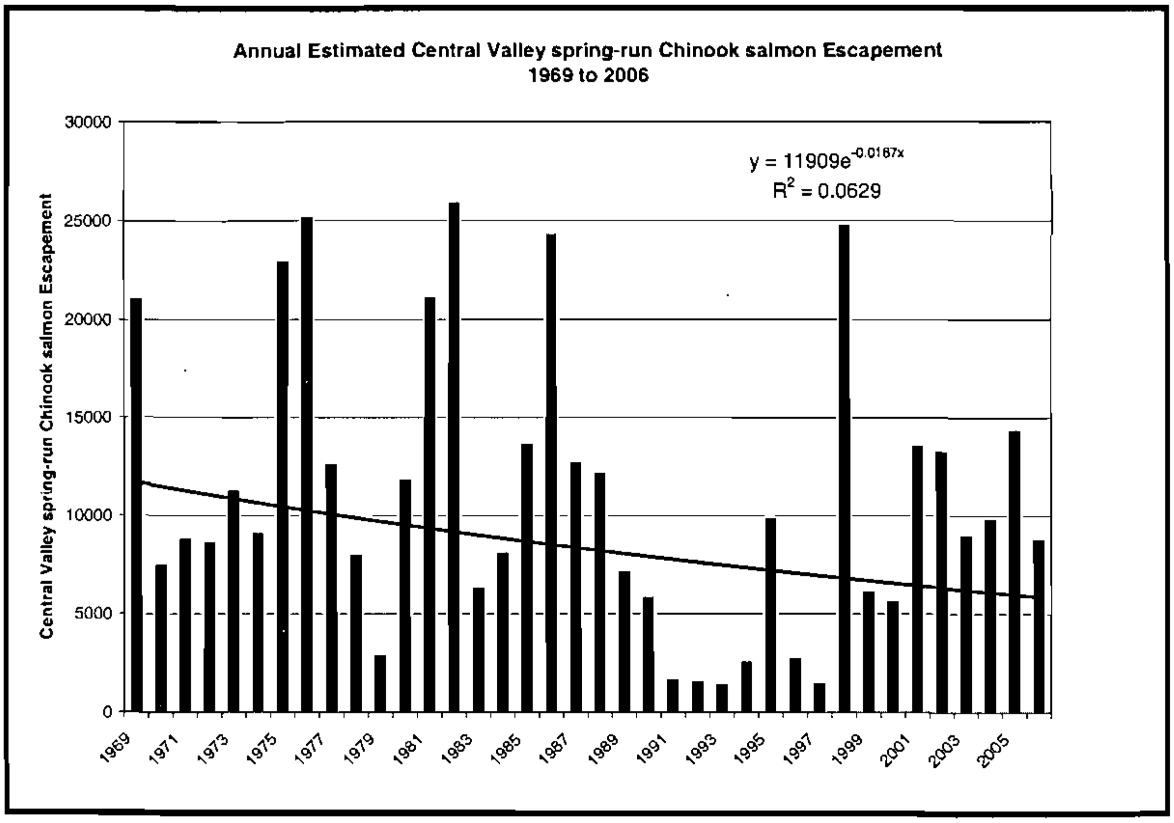
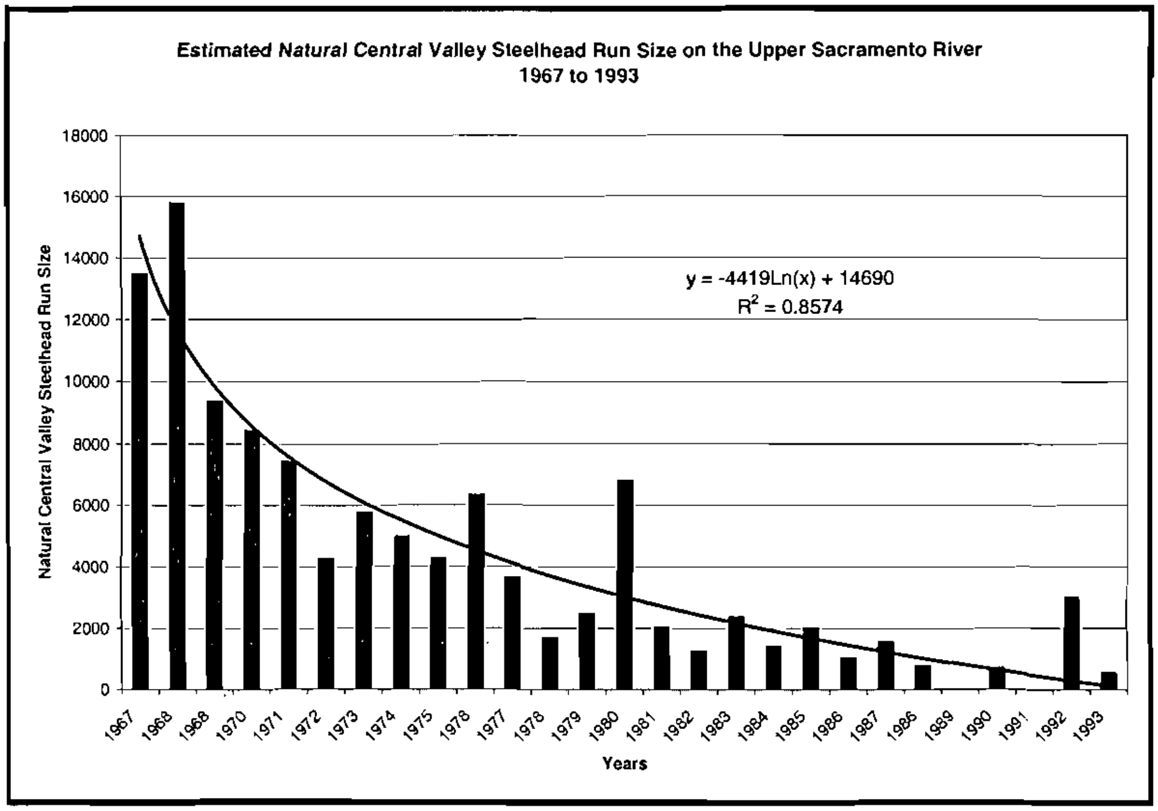


Figure 4:
Annual estimated Central Valley spring-run Chinook salmon escapement population for the Sacramento River watershed for years 1967 through 2003.
Sources: PFMC 2002, CDFG 2004b, Yoshiyama 1998, Grandtab 2006.
Trendline for figure 4 is an exponential function: $Y=11909\ e^{-0.0187}$, $R^2 = 0.0629$.



Note: Steelhead escapement surveys at RBDD ended in 1993

Figure 5:
Estimated Central Valley natural steelhead escapement population in the upper Sacramento River based on RBDD counts.
Source: McEwan and Jackson 1996.
Trendline for Figure 5 is a logarithmic function: Y= -4419 Ln(x) + 14690 R^2= 0.8574

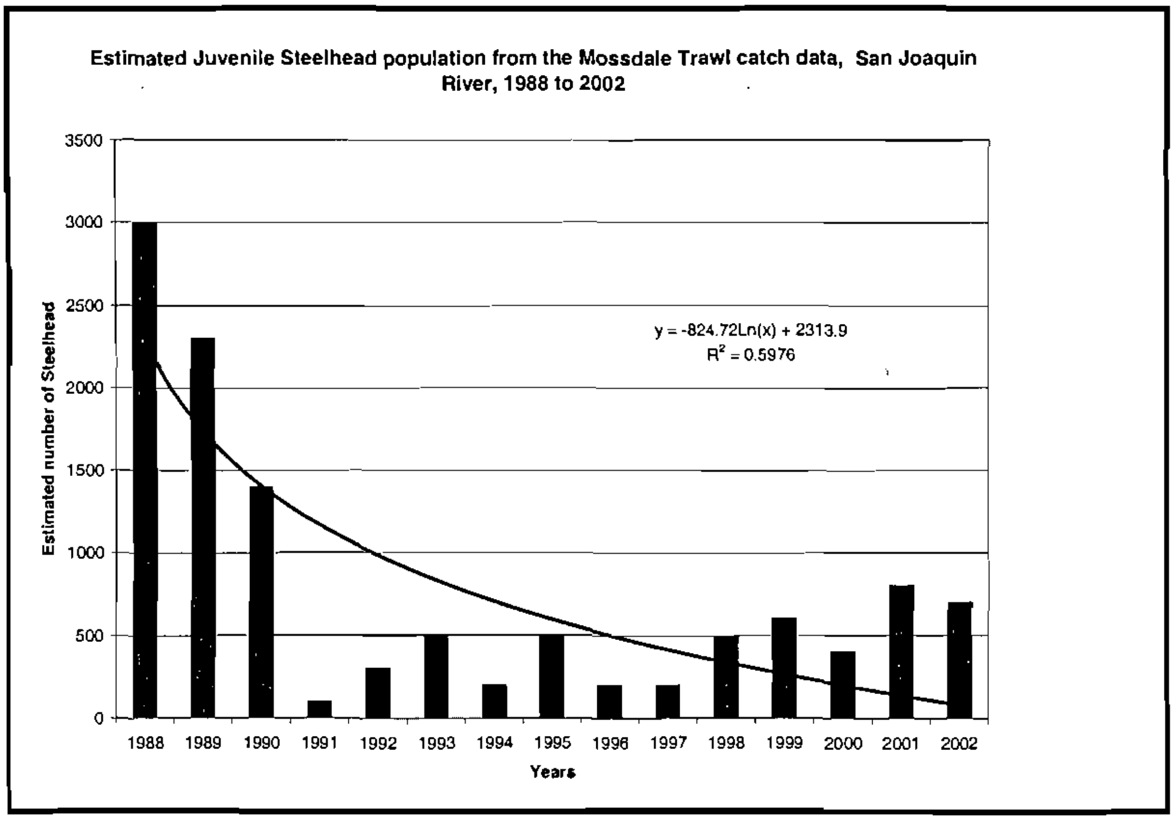


Figure 6:
Estimated number of juvenile Central Valley steelhead derived from the Mossdale trawl surveys on the San Joaquin River from 1988 to 2002.
Source: Marston (CDFG), 2003.

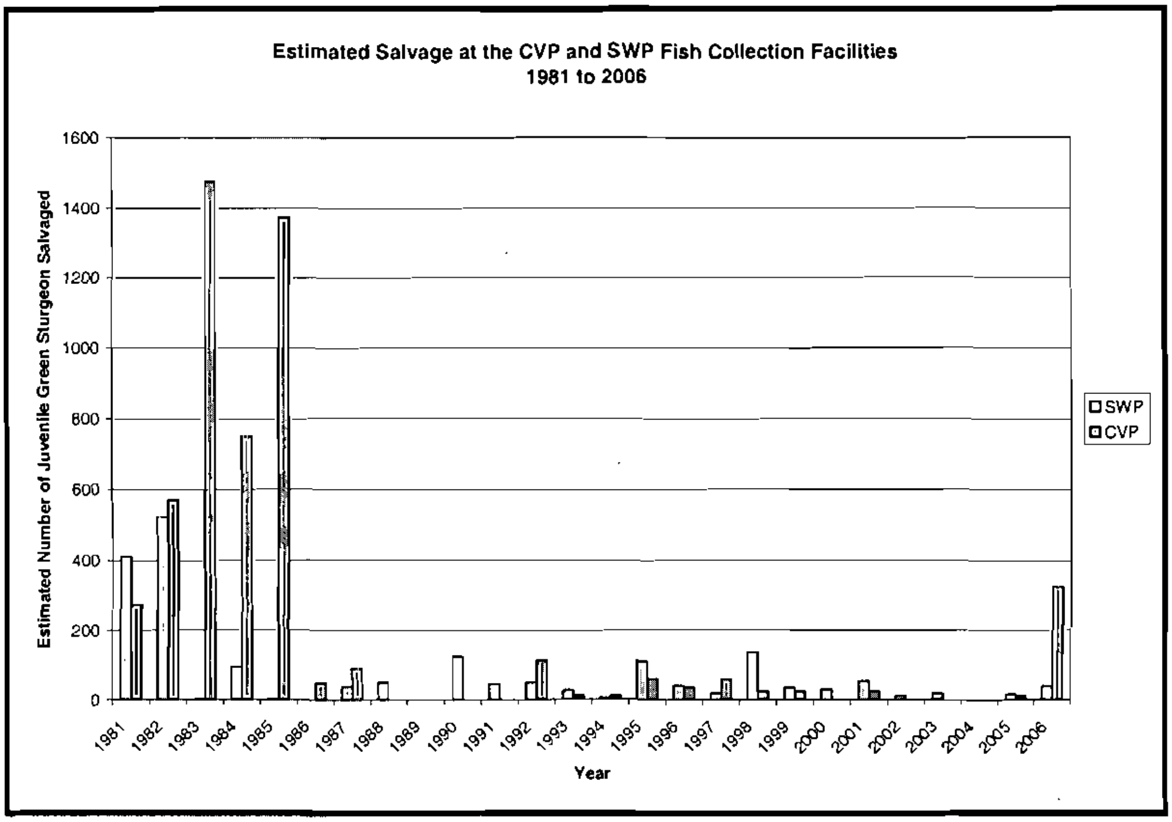


Figure 7a: Estimated number of North American green sturgeon (Southern DPS) salvaged from the State Water Project and the Central Valley Project fish collection facilities.

Sources: Beamesderfer *et al.*, 2006 (in press), CDFG 2002c, Adams *et al.* 2006 (in press).

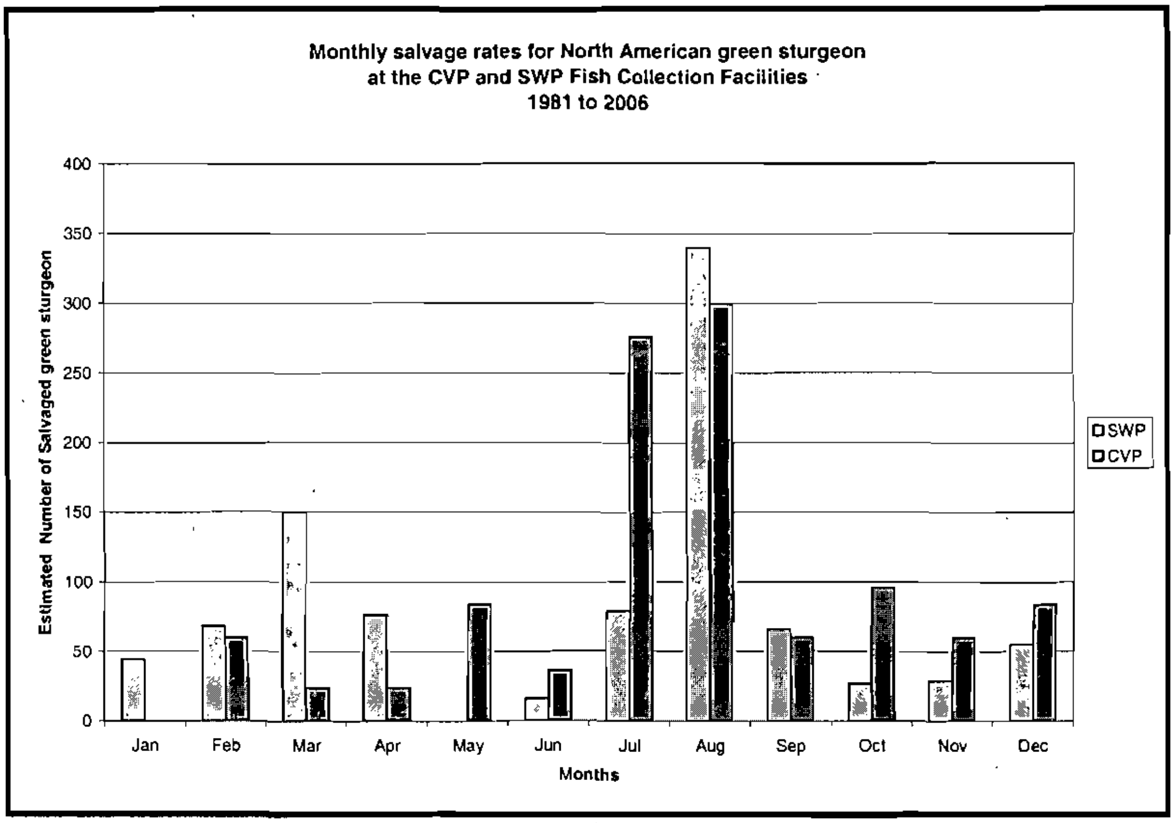


Figure 7b: Estimated number of North American green sturgeon (Southern DPS) salvaged monthly from the State Water Project and the Central Valley Project fish collection facilities.

Source: CDFG 2002c, unpublished CDFG records.

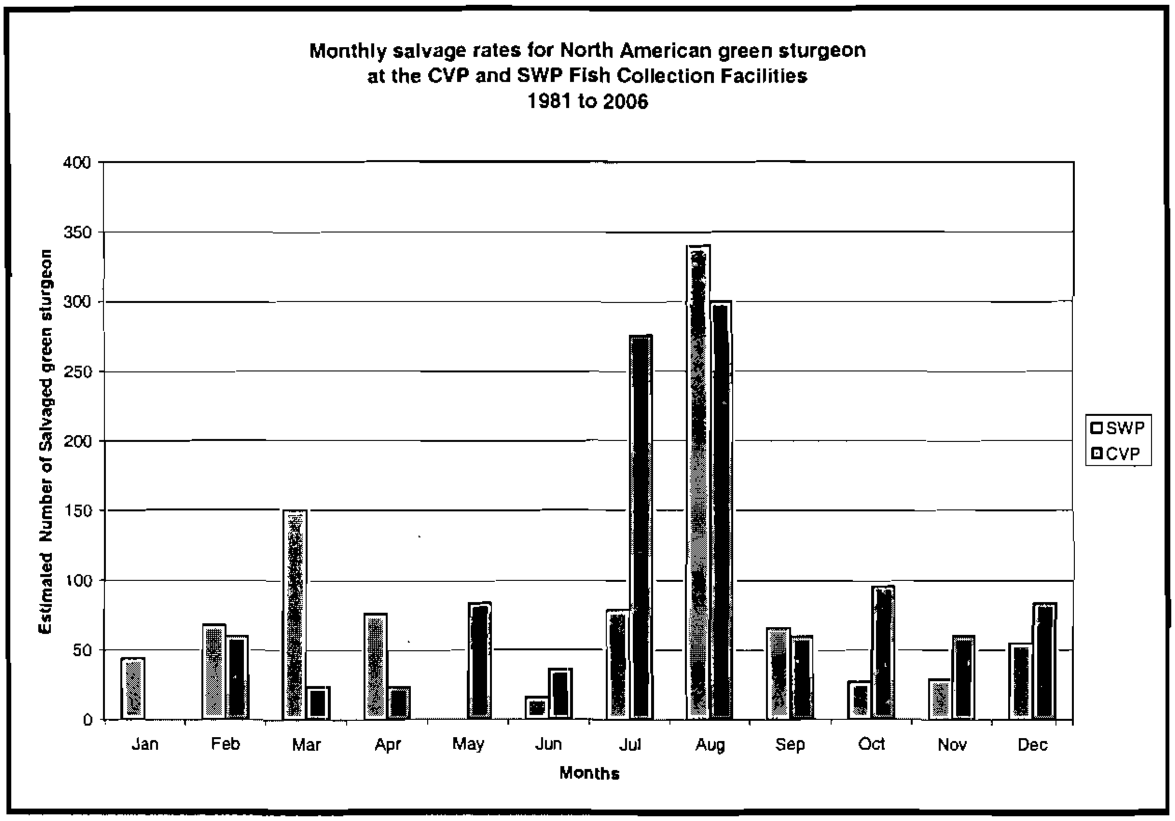


Figure 7b: Estimated number of North American green sturgeon (Southern DPS) salvaged monthly from the State Water Project and the Central Valley Project fish collection facilities.

Source: CDFG 2002c, unpublished CDFG records.

Appendix C:

Physical Effects and Avoidance Behavior in Fish due to Chemical Contamination

"The death of some organisms, such as mysids and larval fish, is easily detected because of a change in appearance from transparent or translucent to opaque. General observations of appearance and behavior, such as erratic swimming, loss of reflex, discoloration, excessive mucus production, hyperventilation, opaque eyes, curved spine, hemorrhaging, molting, and cannibalism, should also be noted in the daily record" (Section 10.1.3, Weber, 1993).

Overt Signs of Fish Distress

I. Respiratory stress - hyperventilation
II. Disorientation in swim pattern, induced by narcosis*
III. Mucus secretions from gills, mouth distension or 'cough' reflex

Behavioral Response:

I. Actively move from area of contamination
II. Reduced swimming rate
III. Passively be carried away from the area (some chemical impact to fish)
IV. Lethal concentration causes fish mortality. Fish rise to water surface, ventral-side up, with distended belly, no respiration, rigor mortis

*Narcosis: a general, nonspecific, reversible mode of toxic action that can be produced in most living organisms by the presence of sufficient amounts of many organic chemicals. Effects result from the general disruption of cellular activity. The mechanism producing this effect is unknown, with the main theories being binding to proteins in cell membranes and 'swelling' of the lipid portion of cell membranes resulting from the presence of organic chemicals. Hydrophobicity dominated the expression of toxicity in narcotic chemicals.

References:

Rand, G.M.(ed.). 1995. Fundamentals of aquatic toxicology: effects, environment fate, and risk assessment. 2nd edition. Taylor & Francis, publ. 1125 pp.

Weber, C.I. 1993. Methods for measuring the acute toxicity of effluents and receiving waters to freshwater and marine organisms. EPA/600/4-90/027F.

Enclosure 2

Magnuson-Stevens Fishery Conservation and Management Act

ESSENTIAL FISH HABITAT CONSERVATION RECOMMENDATIONS

I. IDENTIFICATION OF ESSENTIAL FISH HABITAT

The Magnuson-Stevens Fishery Conservation and Management Act (MSA), as amended (U.S.C. 180 *et seq.*), requires that Essential Fish Habitat (EFH) be identified and described in Federal fishery management plans (FMPs). Federal action agencies must consult with NOAA's National Marine Fisheries Service (NMFS) on any activity which they fund, permit, or carry out that may adversely affect EFH. NMFS is required to provide EFH conservation and enhancement recommendations to the Federal action agencies.

EFH is defined as those waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity. For the purposes of interpreting the definition of EFH, Awaters@ includes aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include areas historically used by fish where appropriate; Asubstrate@ includes sediment, hard bottom, structures underlying the waters, and associated biological communities; Anecessary" means habitat required to support a sustainable fishery and a healthy ecosystem; and, Aspawning, breeding, feeding, or growth to maturity@ covers all habitat types used by a species throughout its life cycle. The proposed project site is within the region identified as EFH for Pacific salmon in Amendment 14 of the Pacific Salmon FMP and for starry flounder (*Platichthys stellatus*) and English sole (*Parophrys vetulus*) in Amendment 11 to the Pacific Coast Groundfish FMP.

The Pacific Fishery Management Council (PFMC) has identified and described EFH, Adverse Impacts and Recommended Conservation Measures for salmon in Amendment 14 to the Pacific Coast Salmon FMP (PFMC 1999). Freshwater EFH for Pacific salmon in the California Central Valley includes waters currently or historically accessible to salmon within the Central Valley ecosystem as described in Myers *et al.* (1998), and includes not only the watersheds of the Sacramento and San Joaquin River basins but also the San Joaquin Delta (Delta) hydrologic unit (*i.e.*, number 18040003), Suisun Bay hydrologic unit (18050001) and the Lower Sacramento hydrologic unit (18020109). Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*), Central Valley spring-run Chinook salmon (*O. tshawytscha*), and Central Valley fall-/late fall-run Chinook salmon (*O. tshawytscha*) are species managed under the Salmon Plan that occur in the theses basins as well as the Delta, Suisun Bay, and Lower Sacramento units.

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

A. Life History and Habitat Requirements

1. Pacific Salmon

General life history information for Central Valley Chinook salmon is summarized below. Information on Sacramento River winter-run and Central Valley spring-run Chinook salmon life histories is summarized in the preceding biological opinion for the proposed project (Enclosure 1). Further detailed information on Chinook salmon Evolutionarily Significant Units (ESU) are available in the NMFS status review of Chinook salmon from Washington, Idaho, Oregon, and California (Myers *et al.* 1998, Good *et al.* 2005), and the NMFS proposed rule for listing several ESU of Chinook salmon (63 FR 11482).

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

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

2. Starry Flounder

The starry flounder is a flatfish found throughout the eastern Pacific Ocean, from the Santa Ynez River in California to the Bering and Chukchi Seas in Alaska, and eastwards to Bathurst Inlet in Arctic Canada. Adults are found in marine waters to a depth of 375 meters. Spawning takes place during the fall and winter months in marine to polyhaline waters. The adults spawn in shallow coastal waters near river mouths and sloughs, and the juveniles are found almost exclusively in estuaries. The juveniles often migrate up freshwater rivers, but are estuarine dependent. Eggs are broadcast spawned and the buoyant eggs drift with wind and tidal currents. Juveniles gradually settle to the bottom after undergoing metamorphosis from a pelagic larva to a demersal juvenile by the end of April. Juveniles feed mainly on small crustaceans, barnacle larvae, cladocerans, clams and dipteran larvae. Juveniles are extremely dependent on the condition of the estuary for their health. Polluted estuaries and wetlands decrease the survival rate for juvenile starry flounder. Juvenile starry flounder also have a tendency to accumulate many of the anthropogenic contaminants found in the environment. Recent fish community monitoring conducted for the U.S. Army Corps of Engineers has captured juvenile starry flounder well up into the channels of the Sacramento River (Rio Vista) and Stockton Ship Deepwater Channel (Jersey Point) as part of their ongoing dredging operations. Repeated captures of juvenile starry flounder at the Central Valley Project (CVP) and State Water Project (SWP) fish collection facilities indicate that this flatfish occurs in waterways at least through the south Delta, towards the CVP and SWP diversion facilities. It is believed that starry flounder are difficult to capture as part of the salvage operations due to their benthic oriented behavior, and thus would be rare in the salvage enumeration of species.

3. English Sole

The English sole is a flatfish found from Mexico to Alaska. It is the most abundant flatfish in Puget Sound, Washington and is abundant in the San Francisco Bay estuary system. Adults are found in nearshore environments. English sole generally spawn during late fall to early spring at depths of 50 to 70 meters over soft mud bottoms. Eggs are initially buoyant, then begin to sink just prior to hatching. Incubation may last only a couple of days to a week depending on temperature. Newly hatched larvae are bilaterally symmetrical and float near the surface. Wind and tidal currents carry the larvae into bays and estuaries where the larvae undergo metamorphosis into the demersal juvenile. The young depend heavily on the intertidal areas, estuaries, and shallow near-shore waters for food and shelter. Juvenile English sole primarily feed on small crustaceans (*i.e.* copepods and amphipods) and on polychaete worms in these rearing areas. Polluted estuaries and wetlands decrease the survival rate for juvenile English soles. The juveniles also have a tendency to accumulate many of the contaminants found in their environment and this exposure manifests itself as tumors, sores, and reproductive failures.

II. PROPOSED ACTION

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

III. EFFECTS OF THE PROJECT ACTION

The effects of the proposed action on salmonid habitat (*i.e.,* for winter, spring and fall/late fall-run Chinook salmon) are described at length in section V (*Effects of the Action*) of the preceding biological opinion, and generally are expected to apply to Pacific salmon EFH. The general effects on the quality of EFH for the two species of flatfish are expected to be similar to those for green sturgeon due to their similar benthic life history in the Delta. Benthic dwelling flatfish will have prolonged exposure to habitat changes in the western Delta resulting from the application of herbicides to the waters of the Delta. Both the starry flounder and the English sole will spend more time as juveniles rearing in the action area than the Chinook salmon smolts. Therefore, these fish species will have a greater duration of exposure to the changes in water quality and the resulting habitat alterations than the juvenile Chinook salmon, leading to greater levels of adverse effects to the individual organisms.

IV. CONCLUSION

Based on the best available information, NMFS believes that the proposed EDCP may adversely affect EFH for Pacific salmon and groundfish during its normal long-term operations due to applications of pesticides to waters of the Delta and upstream tributaries adjacent to the Delta. This application of pesticides may cause direct mortality or increased morbidity of exposed fish, resulting in a diminishment of the overall health of these fish.

V. ESSENTIAL FISH HABITAT CONSERVATION RECOMMENDATIONS

NMFS recommends that the reasonable and prudent measures from the biological opinion, with their associated terms and conditions, be adopted as EFH conservation recommendations for EFH in the action area. In addition, certain other conservation measures need to be implemented in the project area, as addressed in Appendix A of Amendment 14 to the Pacific Coast Salmon FMP (PFMC 1999). NMFS anticipates that implementing those conservation measures intended to minimize disturbance and sediment and pollutant inputs to waterways would benefit groundfish as well.

Riparian Habitat ManagementBIn order to prevent adverse effects to riparian corridors, the U.S. Department of Agriculture – Agricultural Research Service (USDA-ARS) should:

$ Maintain riparian management zones of appropriate width in the San Joaquin River, Sacramento River and eastside tributary watersheds that influence EFH;

$ Reduce erosion and runoff into waterways within the project area; and

$ Minimize the use of chemical treatments within the riparian management zone to manage nuisance vegetation along the levee banks and reclamation district=s irrigation drains.

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

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

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

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

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

$ Plan development sites to minimize clearing and grading;

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

$ Where feasible, reduce impervious surfaces.

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

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

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

$ Establish and update, as necessary, pollution prevention plans, spill control practices, and spill control equipment for the handling and transport of toxic substances in salmon EFH (*e.g.*, oil and fuel, organic solvents, raw cement residue, sanitary wastes, *etc.*). Consider bonds or other damage compensation mechanisms to cover clean-up, restoration, and mitigation costs.

VI. STATUTORY REQUIREMENTS

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

VII. LITERATURE CITED

California Advisory Committee on Salmon and Steelhead Trout. 1998. Restoring the balance. California Department of Fish and Game, Inland Fisheries Division, Sacramento, California, 84 pages.

Dettman, D.H., D.W. Kelley, and W.T. Mitchell. 1987. The influence of flow on Central Valley salmon. Prepared by the California Department of Water Resources. Revised July 1987. 66 pages.

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 p.

Healey, M.C. 1991. Life history of Chinook salmon. *In* C. Groot and L. Margolis (editors) Pacific salmon life histories, pages 213-393. University of British Columbia Pres, Vancouver.

Kjelson, M.A., P.F. Raquel, and F.W. Fisher. 1982. Life history of fall-run juvenile Chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento-San Joaquin estuary, California. *In* V.S. Kennedy (editor). Estuarine comparisons, pages 213-393. Academic Press, New York, New York.

Kondolf, G.M., J C. Vick, and T.M. Ramirez. 1996a. Salmon spawning habitat rehabilitation in the Merced, Tuolumne, and Stanislaus Rivers, California: an evaluation of project planning and performance. University of California Water Resources Center Report No. 90, ISBN 1-887192-04-2, 147 pages.

Kondolf, G.M., J.C. Vick, and T.M. Ramirez. 1996b. Salmon spawning habitat on the Merced River, California: An evaluation of project planning and performance. Transactions of the American Fisheries Society 125:899-912.

Lister, D.B., and H.S. Genoe. 1970. Stream habitat utilization by cohabiting underyearlings of Chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon in the Big Qualicum River, British Columbia. Journal of the Fisheries Research Board of Canada 27:1215-1224.

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. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-35, 443 pages.

National Marine Fisheries Service. 1997. Proposed recovery plan for the Sacramento River winter-run Chinook salmon. National Marine Fisheries Service, Southwest Region, Long Beach, California, 288 pages plus appendices.

Pacific Fishery Management Council. 1999. Description and identification of essential fish habitat, adverse impacts and recommended conservation measures for salmon. Amendment 14 to the Pacific Coast Salmon Plan, Appendix A. Pacific Fisheries Management Council, Portland, Oregon.

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, Sacramento, California, 129 pages.

U.S. Fish and Wildlife Service. 1998. Central Valley Project Improvement Act tributary production enhancement report. Draft report to Congress on the feasibility, cost, and desirability of implementing measures pursuant to subsections 3406(e)(3) and (e)(6) of the Central Valley Project Improvement Act. U.S. Fish and Wildlife Service, Central Valley Fish and Wildlife Restoration Program Office, Sacramento, California.