United States Department of the Interior

FISH AND WILDLIFE SERVICE

San Francisco Bay-Delta Fish and Wildlife Office
650 Capitol Mall, Suite 8-300
Sacramento, California 95814

IN REPLY REFER TO:
81410-2013-F-0005

Dr. Raymond Carruthers
Research Leader/Ecologist
United States Department of Agriculture
Agriculture Research Service
Exotic and Invasive Weed Research Unit
800 Buchanan Street
Albany, California 94710

MAR 13 2013

Subject: 2013 Water Hyacinth Control Program in the Sacramento-San Joaquin Delta within Eleven Counties, California

Dear Dr. Carruthers:

This letter is in response to the U.S. Department of Agriculture's Agriculture Research Service's (USDA-ARS) October 25, 2012, letter requesting consultation with the U.S. Fish and Wildlife Service (Service) on the proposed State of California Department of Boating and Waterways (CDBW) 2013-2017 Water Hyacinth Control Program (WHCP) in the Sacramento-San Joaquin Delta (Delta) and its tributaries. Your consultation initiation letter was received in our San Francisco Bay-Delta Office (BDFWO) on October 25, 2012, and your subsequent February 14, 2013, electronic mail (e-mail) was received in our office with updates to your project description. USDA-ARS requested consultation for the federally-threatened valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) (VELB) and its critical habitat, giant garter snake (*Thamnophis gigas*) (GGS), and the delta smelt (*Hypomesus transpacificus*) and its critical habitat. This response is in accordance with Section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*) (Act).

The USDA-ARS determined that the action may affect, but is not likely to adversely affect the federally-threatened GGS and VELB and its critical habitat. The applicant proposes to implement Conservation Measures (page 21), as described in the Project Description, to avoid adverse effects to GGS and VELB and its critical habitat. The Service concurs with your determination that the project may affect, but will not likely adversely affect the federally-listed GGS or VELB as a result of the proposed action based on the applicant's strict implementation of the proposed Conservation Measures and the proposed WHCP treatment restrictions. No critical habitat has been designated for GGS, and as such none will be adversely modified or destroyed. Critical habitat has been designated for VELB on the American River in Sacramento County; however, the WHCP does not conduct operations within the area and therefore no destruction or adverse modification of VELB critical habitat is anticipated.

On June 1, 2001, the Service issued a biological opinion (BO) for the WHCP (Service file No. 1-1-01-F-0050). This biological opinion was subsequently amended five times (Service file No.'s 1-1-02-F-0157, 1-1-03-F-0114, 1-1-04-F-0113, and 81410-2011-F-0035). This current consultation for the 2013-2017 WHCP was submitted to the Service due to changes in the project description and updates to the delta smelt status of the species that have occurred since issuance of the previous BOs and amendments.

This document hereby represents the Service's BO on the effects of CDBW's WHCP the Sacramento-San Joaquin Delta and its tributaries on the federally-threatened delta smelt and its critical habitat. This BO supersedes the Service's June 1, 2001, biological opinion and its amendments.

This biological opinion is based on the following information:

1) The USDA-ARS and CDBW October 25, 2012, *Water Hyacinth Control Program Biological Assessment* (BA) and *Supplemental Materials Binder* (BA Binder);

2) The CDBW's November 20, 2009, Programmatic Environmental Impact Report Volume I, II, and III;

3) The CDBW's WHCP 2009, 2010, 2011, and 2012 Annual Reports;

4) The CDBW's February 14, 2013, e-mail titled *WHCP-Responses to Questions Raised by the Service*;

5) Numerous electronic mails, phone conversations, and meetings between the CDBW, USDA-ARS, National Marine Fisheries Service (NMFS), and the Service between October 2012 and March 2013; and

6) other information available to the service.

CONSULTATION HISTORY

June 1, 2001	The Service issued a BO (Service file No. 1-1-01-F-0050) to the USDA-ARS. Associated amendments were written by the Service the following three years (Service file No.'s 1-1-02-F-0157, 1-1-03-F-0114, and 1-1-04-F-0113).
April 27, 2011	USDA-ARS issued a letter requesting reinitiation of formal consultation for the WHCP.

June 30, 2011	The Service issued a letter to USDA-ARS for the WHCP requesting additional information regarding potential effects. The Service determined the WHCP may continue to operate under the Service's May 21, 2004, biological opinion (Service file number 1-1-04-F-0149) for the 2011 treatment season.
October 19, 2011	USDA-ARS issued a letter requesting to extend the WHCP to November 30, 2011.
October 31, 2011	The Service issued a letter stating that no extension was required as long as the WHCP was operating as the project was described within the latest May 21, 2004, amended biological opinion (Service File No. 1-1-04-F-0113).
January 18, 2012	The Service met with CDBW, USDA-ARS, and NMFS to discuss the proposed 2012 WHCP and the project's federal nexus.
March 5, 2012	The USDA-ARS issued a letter requesting reinitiation of formal consultation.
March 23, 2012	The USDA-ARS provided additional information to the Service responding to the Service's June 30, 2011, request for more information.
March 30, 2012	The Service met with CDBW, USDA-ARS, and NMFS to further discuss the 2012 WHCP.
December 2011 through June 2012	The Service, the USDA-ARS and the CDBW exchanged e-mail communications regarding the 2012 project description.
October 25, 2012	The Service received a letter from USDA requesting formal ESA section 7 consultation on the 2013-2017 WHCP. The Service also received a BA and a BA Binder prepared by USDA and CDBW for the consultation.
December 12, 2012	The Service requested a meeting to discuss numerous updates to the 2013–2017 WHCP project description.
January 3, 2013	The Service received a copy of information regarding changes to the project description that had been provided to the National Marine Fisheries Service (NMFS) by the USDA-ARS on January 3, 2013.

January 16, 2013	The Service held a meeting with USDA-ARS, CDBW and the Newpoint Group at the BDFWO to discuss 2013-2017 WHCP project description changes.
January 2013 to March 1, 2013	The Service, the USDA-ARS, and the CDBW communications regarding the 2013-2017 WHCP project description.

BIOLOGICAL OPINION

Description of the proposed action

The WHCP is an aquatic weed program designed to control the growth and spread of the non-native invasive plant, water hyacinth (*Eichhornia crasipes)*, in the Delta and its tributaries. Water hyacinth forms dense mats that interfere with navigation, recreation, irrigation, power generation, and native aquatic flora and fauna. These mats competitively exclude native submersed and floating-leaved plants which are part of the habitat used by listed species and their forage base. Low oxygen conditions develop beneath water hyacinth mats and the dense floating mats impede water flow and create good breeding conditions for mosquitoes (CALFED, ERP Vol. 1, 2000).

The USDA-ARS serves as the Federal nexus for the WHCP which is managed by the CDBW. The proposed program consists of an integrated and adaptive approach, emphasizing chemical treatment, supported by hand-picking, herding, mechanical removal, and continued assessment of biological controls, adjusting over time, as treatment methods, technology, and environmental factors change.

Selected primary program herbicides will be 2,4-Dichlorophenoxyacetic acid, dimethylamine (DMA) salt, or 2,4-D) and glyphosate, with 2,4-D being used for the majority of treatments. Beginning in 2013, WHCP proposes to add two new herbicides that have recently been approved by the California Department of Pesticide Regulation (CDPR) for water hyacinth treatment in aquatic environments: penoxsulam and imazamox. In addition, WHCP had proposed to utilize a third new herbicide, imazapyr, but it was rescinded because it has not been approved by CDPR for use on water hyacinth. CDBW applies herbicides with an adjuvant to increase adhesion to water hyacinth leaves. WHCP proposes to utilize the adjuvant Agridex and the vegetable oil-based adjuvant, Competitor.

In addition to herbicide treatments, the WHCP proposes to utilize hand-picking, herding, and mechanical removal. These approaches can help reduce the need for herbicides. Hand-picking would primarily be utilized to reduce plant biomass in nursery areas. Herding would be used in order to push water hyacinth mats (1) into main channels where it would flow naturally out of the Delta and die in the more saline water of San Francisco Bay; or (2) toward mechanical removal sites. The WHCP proposes to utilize two mechanical removal methods: (1) use of specialized mechanical equipment with conveyors to physically remove plants, and (2) use of small excavators sited on concrete boat ramps to scoop plants into trucks/trailers for disposal. In addition, the USDA-ARS, CDBW, and their partners initially proposed biological control methods, but withdrew them from the proposed action.

Action Area

USDA-ARS and CDBW propose to apply herbicide products and physical removal methods to control water hyacinth in the Delta (See Figure 1; Treatment Areas 1, 2, 3, and a portion of 4) and the San Joaquin River (SJR; See Figure 2; Treatment Area a portion of 3 and 4) waterways for 5 years (2013-2017). Figures 1 and 2 below illustrate the WHCP treatment Areas 1, 2, 3, and 4 and are referred to as such throughout this document. There are approximately 350 treatment sites with water hyacinth mats that average between one and two miles in length. Only waterways within any given treatment site are actually part of the action area, and in any given treatment season water hyacinth is growing, and treated in, only a portion of the 350 total treatment sites. The general boundaries for the treatment area are as follows:

- West up to and including Sherman Island at the confluence of the Sacramento and San Joaquin Rivers;
- West up to the Sacramento Northern Railroad to include water bodies north of the southern confluence of the Sacramento River and Sacramento River Deep Water Ship Channel;
- North to the northern confluence of the Sacramento River and Sacramento River Deep Water Ship Channel, plus waters within Lake Natoma;
- South along the San Joaquin River to Mendota, just east of Fresno;
- East along the San Joaquin River to Friant Dam on Millerton Lake;
- East along the Tuolumne River to LaGrange Reservoir below Don Pedro Reservoir; and
- East along the Merced River to Merced Falls, below Lake McClure.

Figure 1: WHCP Project – Treatment Areas # 1, 2, 3, and a portion of 4

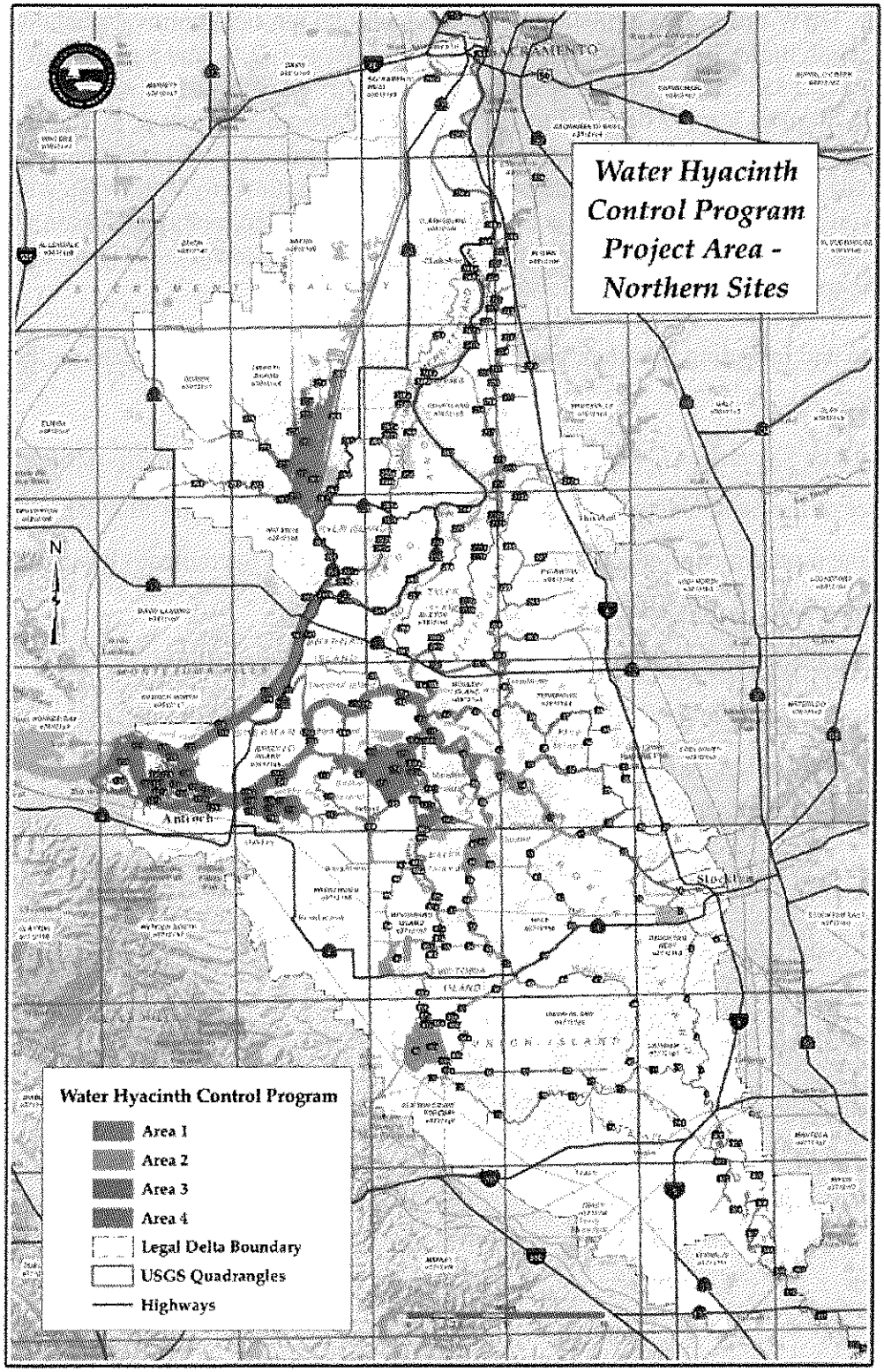
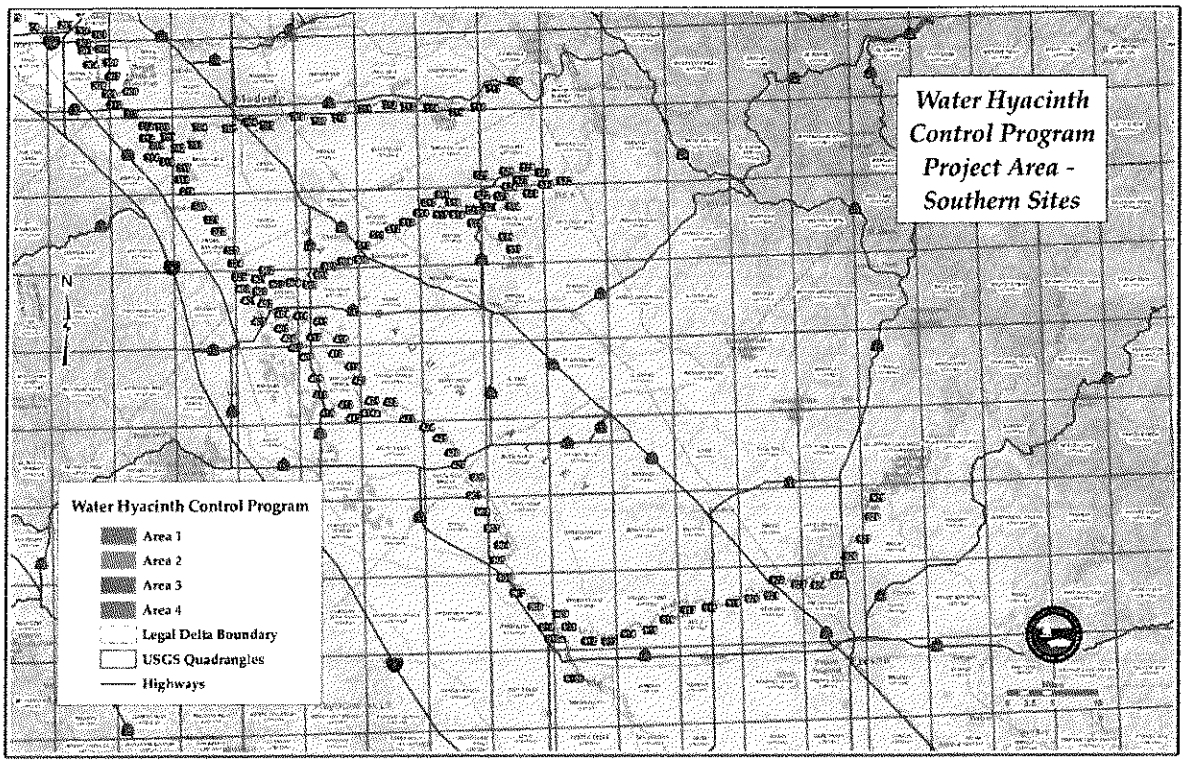


Figure 2: WHCP Project – Treatment Area: a portion of #3 and #4



In any given year, WHCP will treat only a portion of the total treatment sites. Table 1 below provides the acres treated over 29 years of the WHCP. The highest treatment area was 2,770 acres in 2004 and the lowest was 166 acres in 1985, accounting for 4.1% and 0.2%, respectively, of the total waterway area (~67,800 acres) including the Delta and the San Joaquin River basin. In 2013, CDBW may treat up to 5,000 acres of water hyacinth mats within the 350 treatment sites. From years 2014 to 2017 CDBW may treat up to 3,500 acres of water hyacinth mats within the 350 treatment sites. However, the action area is expected to encompass a greater area than the actual treatment area due to water movement resulting from flow and tidal influences.

Multiple treatments within a treatment site may be necessary because many sites in the Delta cannot be treated during the ideal early growth phase due to the potential presence of listed fish species. In addition, some larger sites may have more water hyacinth than can be treated at one time in order to reduce DO (DO) impacts. These sites will be treated in more than one application.

Table 1: Treatment area from 1983 to 2011

Year	Treatment area (acre)	Year	Treatment area (acre)
1983	507	1998	2,434
1984	244	1999	521
1985	166	2000	-
1986	227	2001	1,013
1987	384	2002	1,854
1988	633	2003	2,222
1989	849	2004	2,770
1990	699	2005	2,208
1991	350	2006	2,446
1992	798	2007	1,137
1993	1,506	2008	421
1994	2,743	2009	705
1995	1,826	2010	1,024
1996	2,051	2011	787
1997	1,907		

Project Activities

Prior to the start of each treatment season, CDBW will conduct environmental awareness training for all field crew members. The training includes: species identification and impact avoidance guidelines; protocol for identification and protection of valley elderberry shrubs; protocol for identification and protection of delta smelt, Chinook salmon, steelhead, green sturgeon, and associated protected habitats; and protocol for take of protected species, if any. In addition, field crew members also will be trained on use and calibration of spray equipment and the WHCP Operations Management Plan.

The WHCP will implement pre- and post-season surveys to identify locations and coverage of water hyacinth, and supplement these formal surveys with mid-season evaluations of water hyacinth coverage. Starting in February, and again in October and November, field crews will conduct visual surveys of all treatment sites. For each site, crews will record the extent of water hyacinth coverage (acres and percent coverage), and status of water hyacinth at the site.

In the February survey, field crews will identify problem areas such as those with the greatest impact on navigation, public safety, nursery areas, and sites close to pumps or other structures in the southern-most portion of the northern sites as well as the southern sites. Treatment crews will also identify crops adjacent to treatment sites in order to help select the appropriate herbicide for treatment. Crews will validate field survey information with data from the prioritization process and note any changes. This survey information will be used to help prioritize treatment locations at the start of the treatment season, and to measure efficacy of water hyacinth treatments at the end of the season. Following the prioritization and site selection, USDA-ARS and CDBW will identify likely treatment sites and acres prior to each treatment season and will provide a list of these sites to the Service. Based on the extent of water hyacinth infestation, only a portion of any given site may be treated to comply with herbicide label requirements.

During the treatment season, as crews are working throughout the Delta, they will continue to monitor and record water hyacinth coverage by site. This ongoing survey will assist the management team in identifying mid-season adjustments to prioritizing treatment sites and determining treatment effectiveness.

Each year USDA and CDBW will prepare an annual report for the WHCP and submit it to the Service. This annual report will summarize infestation levels, treatment acreage and types, amount of herbicide use, materials and methods, water quality monitoring results (including herbicide concentration and dissolved oxygen (DO), and daily treatment logs.

Chemical Treatment

The WHCP proposes to use four herbicides 2,4-D, glyphosate, penoxulam, and imazamox to control water hyacinth. All herbicides will be applied with an adjuvant, either Agridex or Competitor. Two of these herbicides, 2,4-D and glyphosate, have been used since the inception of the WHCP. Penoxulum and imazamox are new to the WHCP and have received approval from the

United States Environmental Protection Agency (USEPA). Treatment timelines and Areas proposed for each of the herbicides and adjuvants can be found in the *Conservation Measures* The utilization of additional herbicides on the treatment of water hyacinth reduces the potential for target species to develop resistance. While there are no indications of water hyacinth resistance to date, some terrestrial species of weeds have developed resistance to glyphosate (Powles 2008) or acetolactate synthase (ALS) inhibitors (Wisconsin Department of Natural Resources 2012). Resistance is an important consideration in use of any herbicide over a long period of time. In terrestrial applications, some plants have become resistant to glyphosate or the ALS inhibitors after many (over ten) years of use. Resistance is not necessarily the same across terrestrial and aquatic plants, and generally is species specific. However, because WHCP is a long-term control program, it will be prudent to increase the portfolio of herbicide active ingredients and of non-herbicide treatment options in order to reduce the potential for resistance. Rotating treatments after several years among herbicides with different modes of action reduces the potential for a plant to develop resistance. USDA-ARS, WHCP environmental scientists and Pest Control Advisors will evaluate water hyacinth response to program herbicides over time to identify potential resistance problems.

Crews will conduct treatments with hand-held sprayers applied from aluminum airboats or aluminum outboard motor boats. The work boats will be equipped with direct metering of herbicides, adjuvants, and water pump systems. The crews will spray the chemical mixture directly onto the plants utilizing pump-driven hand-held spray nozzles. The pump will mix calibrated amounts of herbicide, adjuvant, and water. The WHCP will apply the chemicals at the herbicide label-specified rates. Treatment crews will follow specific requirements, as described, to account for wind, DO, drinking water intakes, agricultural intakes, and total acres treated. Treatment crews will follow all label requirements, and implement the new Fish Passage Protocol (to ensure that migratory fish are not impacted by the WHCP).

WHCP will only treat those sites that have water hyacinth infestations, treating only the water hyacinth plants within those sites. WHCP may also be limited by time and resource constraints. Within a given treatment location, WHCP will treat according to current herbicide label requirements to limit potential for decaying plants to result in low DO levels.

Treatment sites within the Delta range from 6.5 acres to 1,707 acres in size, with an average of 219 acres. Thus, there may be several different water hyacinth infestations spread out within a site that require treatment. In these cases, WHCP will treat all water hyacinth mats in the site as time and resources allow. Repeat treatments may utilize a different herbicide, depending on conditions at the site.

When determining whether a given mat of water hyacinth will be treated again, WHCP crews will utilize the following guidelines:

1) Only one treatment will occur if after the herbicide has had time to take effect, the initial treatment was effective in killing the majority of water hyacinth plants at that site.

2) A second treatment will occur if buffer strips for fish passage were left untreated. In this case, CBDW will return to treat the remainder of the site (new or previously untreated plants) after the specified time between treatments (per herbicide requirements).

3) A second treatment of previously treated water hyacinth will occur if the first treatment was not effective in killing the plants. In this case, CDBW will not conduct the second treatment until the specified time period, per label directions.

4) The actual number of locations and numbered treatment sites that will be treated more than once depends on factors such as herbicide efficiency, growth of the water hyacinth plants and tidal movement that cannot be easily predicted. WHCP will seek to minimize the number of times that a given water hyacinth mat will be treated and will follow herbicide labels regarding total number of applications allowed.

Daily treatments occur Monday through Thursday when weather, wind-speed, and other environmental conditions are favorable for treatment to be maximized. On any given treatment day, treatment acres per day are limited by: (1) the number of crews available; (2) travel time to reach the site; (3) time required to set-up, conduct monitoring, and treat a site; (4) the amount of water hyacinth growing at a particular site; (5) the herbicide label restrictions; (6) fish passage protocols; and (7) weather and tide conditions. The crew can treat, on average, between 5 and 16 acres based on historical data from 2007 through 2011.

Herbicides used in WHCP

2,4-D

2,4-D is a systemic herbicide specific to broadleaf plants. The active ingredient in this phenoxy herbicide is 2, 4-Dichlorophenoxyacetic acid dimethylamine salt. 2,4-D is soluble in water and chemically stable. 2,4-D is absorbed through the leaves and takes approximately four to six hours to enter the phloem of the plant where it mimics plant regulating hormones leading to abnormal growth patterns and death of the plant. 2,4-D has a relatively short half-life and is rather immobile in the soil. Breakdown in soil and groundwater: 2, 4-D has low soil persistence. The half-life in soil is less than 7 days (Wauchope *et al.* 1992). Soil microbes are primarily responsible for its disappearance (Howard 1991). Despite its short half-life in soil and in aquatic environments, the compound has been detected in groundwater supplies in at least five States and in Canada (Howard 1991). Monitoring data indicates that concentrations of 2,4-D have been detected in ground, surface, and finished drinking water (EPA 2005).

Decomposition of herbicides in water depends on a number of characteristics, including: water quality, sediments in the water, temperature, and chemical properties of the herbicide. A review of 34 research papers concerning the persistence of 2,4-D in water under both laboratory and field conditions concluded that (1) under laboratory conditions, 2,4-D in water decomposed in periods of hours to days; and (2) under some warm water field conditions, 2,4-D has consistently been

shown to be reduced to non-detectable levels in closed water bodies in approximately one month; and (3) persistence of 2,4-D at extremely low levels may be encouraged by water movements in lakes, reservoirs, and streams (Gren 1983).

The chemical 2,4-D breaks down due to photodecomposition or by algal or bacterial decomposition (ESA/Madrone 1984). The aqueous half-life of 2,4-D (time in which one-half of the material is degraded) in a set of pools was 10 to 11 days. In a study with natural waters, 2,4-D half-life ranged from 0.5 to 6.6 days (HSDB 2001). Walters (1999) reported an aqueous photolysis half-life for 2,4-D, at 25C, of 13.0 days, and an aqueous aerobic half-life of 15.0 days. Breakdown in water: In aquatic environments, microorganisms readily degrade 2, 4-D. Rates of breakdown increase with increased nutrients, sediment load, and dissolved organic carbon. Under oxygenated conditions the half-life is one to several weeks (Howard 1991).

For treating water hyacinth, 2, 4-D will applied at a rate of between two and four quarts per acre, per label specifications. This is equivalent to 1.9 to 3.8 pounds of active ingredient per acre. It will be applied using a broadcast spray method.

For the majority of sites treated with 2,4-D, it will be preferable to conduct spot treatments directly onto water hyacinth leaves. For sites that are heavily vegetated, buffer strips will be created and another treatment will occur, if needed, after the treated vegetation has decayed. Treatment crews may return to a site to spray locations within a site that were not previously treated, or to retreat regrowth in previously treated plants only after plants killed in the initial treatment have decayed or floated away, no sooner than 21 days.

Glyphosate

Glyphosate is a broad spectrum, non-selective, systemic herbicide. The active ingredient is glyphosate isopropylamine salt. It is water soluble and mixes readily with water and non-ionic surfactants. Glyphosate moves through the plant from the foliage to the root system. Glyphosate prevents the synthesis of certain amino acids essential for plant survival. Visible effects on the plant occur within 3 or more weeks and include gradual wilting and yellowing of the plant, advancing to complete browning.

Glyphosate is moderately persistent in soil, with an estimated average half-life of 47 days (Weed Science Society 1994; Wauchope *et al.* 1992). Reported field half-life range from 1 to 174 days (Wauchope *et al.* 1992). It is strongly adsorbed to most soils, even those with lower organic and clay content (Wauchope *et al.* 1992 and Weed Science Society 1994). Thus, even though it is highly soluble in water, field and laboratory studies show it does not leach appreciably, and has low potential for runoff (except as adsorbed to colloidal matter) (Wauchope *et al.* 1992). One estimate indicated that less than 2 percent of the applied chemical is lost to runoff (Malik *et al.* 1989). Microbes are primarily responsible for the breakdown of the product, and volatilization or photodegradation losses will be negligible (Weed Science Society 1994).

Breakdown in water: In water, glyphosate is strongly adsorbed to suspended organic and mineral matter and is broken down primarily by microorganisms (Schuette 1998). Its half-life in pond water ranges from 35 to 63 days (Schuette 1999).

Breakdown in vegetation: Glyphosate may be translocated throughout the plant, including to the roots. It is extensively metabolized by some plants, while remaining intact in others (Kidd and James 1991).

For treating water hyacinth, glyphosate will be applied at a rate of three quarts per acre, per label requirements. This will be equivalent to 3 pounds active ingredient per acre. Glyphosate will be applied via a broadcast sprayer. The majority of the sites treated with glyphosate will be spot treatments. For the sites that are heavily vegetated, buffer strips will be created, and another treatment will occur, if needed.

The herbicide label requirements for glyphosate have no restrictions for use of treated water for irrigation, recreation, or domestic purposes. The herbicide label specifies that glyphosate is not to be applied within 0.5 miles of an active potable water intake; or intakes must be turned off for a minimum of 48 hours after the application, or until glyphosate concentrations are less than 0.7 ppm. When treating large infestations, the label recommends treating the area in strips to avoid oxygen depletion

Penoxsulam

Penoxsulam (2-(2,2-difluoroethoxy)-N-(5,8-dimethoxyl[1,2,4] triazolo [1,5-c] pyrimidin-2-yl)-6-trifluoromethyl)benzenesulfonamide) received USEPA approval through the reduced risk program for use on aquatic weeds from the USEPA in 2007 and from the California DPR in 2009. Penoxsulam was initially approved for use on rice crops by USEPA in 2004. Penoxsulam is a broad spectrum systemic herbicide in the triazolopyrimidine sulfonamide family. This herbicide inhibits the enzyme acetolactate synthase (ALS), which regulates the production of three essential amino acids: valine, leucine, and isoleucine (Washington DOE 2012).
ALS inhibitors such as penoxsulam slowly starve plants of these amino acids, eventually killing the plants by halting DNA synthesis. These biochemical pathways are not present in animals. Plants absorb penoxsulam through leaves, shoots, and roots. The herbicide affects new growth more rapidly than older plant tissue. Symptoms following treatment with penoxsulam include immediate growth inhibition, a chlorotic growing point with reddening, and slow plant death over a period of 60 to 120 days (Washington DOE 2012). Madsen and Wersal (2008) found that four weeks after treatment with 1.4 oz/acre, up to the maximum rate of 5.6 oz/acre, penoxsulam (with a surfactant) provided 95 percent control of water hyacinth in 100-gallon outdoor tanks. Langeland et al. (2009) identified penoxsulam as providing excellent control for water hyacinth in Florida.

Penoxsulam has low to moderate water solubility, and is very mobile in soil. The organic carbon sorption coefficient, Koc, of penoxsulam is between 13 and 305 in soil (indicating weak adsorption), with higher adsorption in sediment, Koc = 1,130 (USEPA 2007). Penoxsulam

follows two complex degradation pathways, and degrades into eleven major and two minor degradates, listed in Table 3-10, on the next page (USEPA 2007). None of these metabolites or degradates have been identified as having a higher toxicity potential than penoxsulam (Washington DOE 2012).

There was some concern in the first review of penoxsulam (USEPA 2004) that some of the major degradates of penoxsulam might pose phytoxicity concerns; however, additional testing found no observable injury by the eleven metabolites to pre-emergent seeds, and that only two caused injury to seedlings at high-levels (USEPA 2007).

In water, penoxsulam breaks down primarily by photolysis, with some microbial degradation. Water depth, water clarity, plant density, and season of application can influence photolytic degradation. Penoxsulam breaks down faster in higher water clarity and lower plant density. The water solubility of penoxsulam increases in more alkaline conditions. The half-life of penoxsulam in water ranges from 1.5 to 14 days (USEPA 2007). The total system half-life of penoxsulam is 16 to 38 days (Washington DOE 2012). In sediment, penoxsulam is expected to degrade rapidly through anaerobic degradation (USEPA 2007). Penoxsulam is adsorbed by soil and has low to moderate leaching potential in most soil types, where it is broken down by microbial degradation (The Dow Chemical Company 2008). However, California DPR has identified penoxsulam (along with many other herbicides including 2,4-D and glyphosate) as having the potential to pollute ground water. Penoxsulam has low vapor pressure, and will not dissipate by volatization.

For treating water hyacinth, penoxsulam will be applied at between 2.0 to 5.6 ounces per acre, per label requirements, with higher rates for denser plants and plants not at their peak growing phase. This will be equivalent to between 0.03125 and 0.0875 pounds of active ingredient per acre. Penoxsulam will be applied with a surfactant (at concentrations on the surfactant label), with a spray volume in accordance to label specifications.

There are no label restrictions for penoxsulam regarding DO, as the slow-acting nature of this herbicide should have minimal impact on DO levels (Washington DOE 2012). However, WHCP will maintain existing monitoring measures related to DO to evaluate potential reductions in DO.

Waters treated with penoxsulam will not to be used for food crop irrigation until concentrations are determined to be equal to, or less than, 1 ppb. Water samples will be collected using Enzyme-Linked Immunoassay (ELISA) or other approved analytical methods. There are no restrictions on consumption of treated water for potable use or by livestock, pets, or other animals, and no restrictions on the use of treated water for recreational use, including swimming and fishing. Penoxsulam will be used with a surfactant, and applied with a course high flow spray nozzle to avoid drift. Penoxsulam will not be applied when wind speeds are below 2 mph, or above 10 mph.

Imazamox

Imazamox is a relatively new aquatic herbicide active ingredient. The chemical structure of imazamox is illustrated in Figure 3-12, left. The aquatic formulation of imazamox, Clearcast®, received USEPA approval through the reduced risk program in 2008 (SERA 2010). The WHCP will initially utilize this imazamox active ingredient product.

CDPR approved imazamox for aquatic use in August, 2012. Imazamox was approved for terrestrial use by the USEPA in 1997, and by the California DPR, in 2002. Clearcast consists of 12.1 percent solution of the ammonium salt of imazamox (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-(methyoxymethyl)-3-pyridinecarboxylic acid). It is in the imidazolinone herbicide family, along with imazapyr. The mode of action is similar to penoxsulam and imazapyr, inhibiting the acetolactate synthase (ALS) enzyme, blocking the synthesis of three essential amino acids, leucine, isoleucine, and valine (Washington DOE 2012). Imazamox is a relatively fast-acting systemic herbicide. It is rapidly absorbed into the foliage and translocated throughout the plant by phloem and xylem tissues (Washington DOE 2012).

Imazamox inhibits plant growth within the first 24 hours, with visual symptoms appearing about one week after treatment. Symptoms include yellowing leaves and general discoloration. Water hyacinth plants are dead within six weeks after treatment (Burns 2009). In one greenhouse study, Clearcast was more effective at controlling water hyacinth within five weeks (94 percent control) than Habitat® (imazapyr) (79 percent control), but slightly less effective than glyphosate (99 percent control). However, Clearcast and Habitat required less than 25 percent as much active ingredient as glyphosate treatment (Emerine et al. 2010). Langeland et al. (2009) identify imazamox as excellent in controlling water hyacinth in Florida.

Imazamox is highly soluble in water, and is mobile to highly mobile in soil (Washington DOE 2012; USEPA 2008). The organic carbon sorption coefficient, K_{oc}, of imazamox is between 5 and 143 (indicating weak adsorption). Volatization of imazamox is not significant (USEPA 1997). Imazamox has a low potential for bioaccumulation (Washington DOE 2012).

The primary method of degradation of imazamox in surface water is photolytic (Washington DOE 2012). Photolytic degradation is influenced by water depth, water clarity, and season, and continues via microbial action to carbon dioxide. The half-life in water ranges from five to fifteen days (Washington DOE 2012). CDPR identified imazamox as having the potential to pollute groundwater due to its high water solubility; however, in well-lit waters, imazamox breaks down quickly (Washington DOE 2012). US EPA concluded that even if imazamox persists in dark or turbid waters it is unlikely to present a risk to fish, invertebrates, birds, or mammals (Washington DOE 2012).

Imazamox is moderately persistent in soil, degrading aerobically to a non-herbicidal metabolite which is immobile or moderately mobile in soil (USEPA 1997). The primary metabolite is a demethylated parent chemical with intact ring structures and two carboxylic acid groups. A secondary metabolite is a demethylated, decarboxylated parent with intact rings and one

carboxylic acid group (USEPA 2008). Leaching of imazamox in field studies was very limited, and microbial breakdown products under aerobic soil conditions are not herbicidal. The range of half-lives in terrestrial field dissipation studies was fifteen to 130 days, with typical half-lives ranging from 35 to 50 days (USEPA 1997; USEPA 2008). Imazamox is unlikely to accumulate in sediments.

For treating water hyacinth, imazamox will be applied at a rate of 16 to 64 ounces per acre, per label requirements. This is equivalent to 0.125 to 0.5 pounds active ingredient per acre. Imazamox is most effective when applied to actively growing plants. Imazamox will be applied with an adjuvant at rate of one quart per 100 gallons of solution.

There are no label restrictions regarding DO; however, CDBW will follow the same monitoring approaches as for other herbicides to evaluate potential for low DO levels to impact endangered species. Waters treated with imazamox will not be used for irrigation until concentrations are less than 50 ppb. The label requires a 24 hour period after treatment to irrigate from still and quiescent waters. There are no wait restrictions for irrigation when imazamox is applied to flowing waters at a rate of less than or equal to 4 quarts (64 ounces) per acre to waters with an average depth of at least four feet. There are no restrictions on livestock watering, swimming, fishing, domestic use, or use of treated water for agricultural sprays (SePRO 2010). To reduce drift, imazamox will be used with a surfactant, and applied in a course spray with the nozzle height at approximately no more than four feet above the plant canopy. Imazamox will not to be applied in a temperature inversion, or when wind speeds are less than 2 miles per hour or greater than 10 miles per hour.

As imazamox will be a new WHCP herbicide, there are no prior test data regarding actual herbicide concentrations following water hyacinth treatment. The WHCP will conduct monitoring at the initial imazamox treatment sites to develop a baseline for expected herbicide concentrations in treatment sites and receiving waters following treatment.

Adjuvant used in the WHCP

The WHCP will utilize adjuvants with herbicides to ensure contact and translocation of herbicides. The WHCP will not utilize polyethoxylated tallow amine (POEA) surfactants, which are known to be toxic to amphibians, or nonylphenoloethoxylate (NPE) surfactants, which are known to be toxic to fish and some invertebrates. The WHCP will utilize two adjuvants. Agridex®, a crop oil concentrate adjuvant, has been used for several years by WHCP. Competitor®, a vegetable oil based adjuvant, will be incorporated into WHCP.

Agri-dex

Agri-dex (the active ingredients are Paraffin Base Petroleum Oil/Polyoxyethylate Polyol Fatty Acid Esters) is a non-ionic blend of surfactants and spray oil that is designed for use with a broad range of pesticides where oil concentrate adjuvant is recommended. Agri-Dex® improves pesticide application by modifying the wetting and deposition characteristics of the spray

solution, resulting in a more even and uniform spray deposit. It will be used with all three herbicides at a rate of approximately one to four pints per 100 gallons.

Competitor

Competitor is a modified vegetable oil containing a non-ionic emulsifier system. It may be used as an adjuvant with aquatically labeled pesticides. The active ingredients in Competitor are ethyl oleate, sorbitan alkylpolyethoxylate ester, and dialkyl polyoxyethylene glycol. These ingredients make up 98 percent by weight, with the remaining 2 percent constituents that are ineffective as spray adjuvant. Competitor will be used at a rate of one to four pints per acre (to a maximum of 1 percent volume/ volume ratio).

Mechanical Control Methods

Handpicking

Hand-picking of water hyacinth will be conducted primarily when or where chemical treatment cannot be made, and may occur throughout the year. As treatment crews survey for water hyacinth, they will conduct hand-picking in selected areas. The goals of the hand-picking aspect of the program are to aid in the control of water hyacinth and reduce impacts of chemical application by clearing areas that are not accessible to chemical treatment, subject to high infestation, nurseries, and within emergent vegetation. Crews will follow specific hand-picking protocols to ensure the protection of water quality and special status species. Reflecting a typical season of hand-picking, between October 15, 2007, and April 1, 2008, treatment crews collected over 4,000 thirty-gallon barrels of water hyacinth. Once collected, water hyacinth will be deposited on at authorized disposal sites, to decompose.

Herding

Herding refers to the moving of water hyacinth mats by pushing or pulling mats from one location to another. Mats will be moved to removal locations or to the main channel. Once in a main channel, the water hyacinth will flow out of the Delta, into saline waters and die. Water hyacinth cannot survive in waters of greater than 2 ppt to 2.5 ppt saline water (brackish water).

For herding water hyacinth out of the Delta, field supervisors will take into account tides, storm events, and dam releases to select appropriate days and times for herding to take place. Crews will not herd in areas where physical damage to emergent, native vegetation is likely to occur such as among stands of cattails (*Typha* spp.), *Phragmites* spp., bulrushes (*Scirpus* spp.), or native cordgrass (*Spartina foliosa*). In addition, the total amount of water hyacinth herded in one area will be limited to avoid impeding navigation. Due to timing and logistical limitations of herding activities, this method may not be used as frequently as handpicking.

Mechanical Removal

The WHCP will utilize two different mechanical removal approaches. The first approach will be to park a small excavator and dump truck on a concrete boat ramp and mechanically lift water hyacinth from the waterway surrounding the ramp. Crews will support the excavation by herding water hyacinth that is outside of the excavator's reach closer to the equipment. This mechanical removal approach will be used only in limited locations when water hyacinth growth is concentrated near a boat ramp. There may be relatively few locations within the Delta that are appropriate for excavation.

The second approach will utilize mechanical equipment designed specifically to safely remove aquatic weeds from waterways. This mechanical equipment utilizes cutters and conveyors to physically remove the plant from the water, and onto the bed of the equipment. The equipment will collect and unload vegetation using a conveyor system on a boom, adjustable to the appropriate cutting height (two to three feet below the surface for water hyacinth). Cutter bars will collect material and bring it aboard the vessel using the conveyor; when the vessel has reached capacity (between 2,000 and 15,000 pounds of plant material), the cut plant material will be offloaded to a dump truck parked at a nearby boat ramp to offload water hyacinth. Water hyacinth will be disposed of at an authorized location, typically utilizing nearby farm fields. Mechanical removal can be costly, it will be used to supplement chemical treatment and when immediate removal of weeds is required. Mechanical removal will primarily be utilized to remove dense mats of water hyacinth in locations where chemical treatment must be avoided, such as sites with many valley elderberry shrubs along the shoreline. WHCP environmental scientists will consult the IEP database and survey mechanical removal sites immediately prior to weed removal to ensure that no listed species are present. If listed species are present, mechanical removal operations at that site will be postponed. Similar mechanical equipment is regularly used to control water hyacinth in Florida and other Southeastern states.

The WHCP will implement an operation protocol similar to the protocol for chemical treatment prior to conducting mechanical removal. WHCP environmental scientists will check IEP monitoring data to ensure that salmon species are not present at the removal site. In addition, the equipment operator will utilize the same Environmental Checklist to evaluate presence of listed species or sensitive habitats. If listed species or sensitive habitats are present, the operator will not conduct mechanical removal at that site.

The WHCP has not utilized this method of mechanical removal in prior years. Studies of mechanical removal conducted during 2003 and 2004 in the Delta by the San Francisco Estuary Institute (SFEI) (Greenfield et al 2007; Spencer at al 2005; Greenfield and McNabb, 2005) raised concerns about the potential for water hyacinth plant cuttings from mechanical removal to grow and spread within the Delta.

WHCP Monitoring Program

The CDBW, with assistance from USDA-ARS and California Department of Food and Agriculture (CDFA), conducts extensive monitoring for the WHCP. The WHCP will conduct extensive monitoring for the program. The WHCP will be responsible for collecting water quality monitoring data, as well as collecting water samples for chemical residue testing.

Based on NPDES permit requirements, WHCP will follow a monitoring protocol. This protocol has historically fulfilled requirements of the Regional Water Quality Control Board, NOAA Fisheries, and USFWS. At each monitoring site, WHCP's environmental scientists will take samples immediately pre-application (upstream and adjacent to the water hyacinth mat), and immediately post-application (downstream of the treatment area). WHCP environmental scientists will also take samples one week following treatment (upstream, adjacent to, and downstream of the treatment area).

At each sampling event, environmental scientists will take samples from the following six locations:

1) Pre-treatment, in site
2) Pre-treatment, control
3) Immediately post-treatment, downstream
4) Within 7 days, in site
5) Within 7 days, downstream
6) Within 7 days, control

The WHCP will select monitoring sites that reflect a mix of water types (tidal, riverine, and tidal dead-end), herbicides, and different habitat types. The WHCP will revise the monitoring approach to comply with the new NPDES General Permit, as described below.

At each monitoring site, WHCP environmental scientists will monitor DO, turbidity, pH, and several other water quality measures. WHCP environmental scientists will collect water in bottles, packed in ice, and submit them to a Certified Analytical Laboratory to measure chemical residue levels.

Coordination between treatment crews and monitoring crews will be very structured. Treatment and monitoring plans will be established in advance. Before any treatment or monitoring, crews will confer to make sure both crews know what sites will be treated and monitored on that day. The treatment crew will stand by until the monitoring crew completes the pre-treatment sampling, at which time the monitoring crew will give the treatment crew the "all clear" to begin treatment. The treatment crew will contact the monitoring crew as soon as treatment is complete so post-treatment monitoring can begin as required. Treatment and monitoring crews will be in separate vessels. Monitoring vessels will not carry herbicide to minimize any contamination that might occur.

Environmental scientists plan to also conduct special monitoring of DO to determine the impact of water hyacinth and the WHCP on DO levels. For this study, crews will measure DO to evaluate the impact of water hyacinth and water hyacinth treatments on DO.
WHCP treatment crews will conduct daily monitoring, in addition to the extensive monitoring to be conducted by WHCP environmental scientists. Treatment crews will monitor and report pre- and post-treatment DO, wind speed, temperature, acres treated, quantity of herbicide and adjuvant, presence of elderberry shrubs or other species of concern, and coordinates of treatment location. The table below lists monitoring requirements for WHCP environmental scientists and WHCP treatment crews.

Table 2: WHCP Environmental Monitoring Requirements

Treatment Crews (for each site treated)	Environmental Scientists (for each sample event)
1. Water temperature (°C) 2. Dissolved oxygen (DO, mg/L or parts per million (ppm)) 3. Wind speed (mph) 4. Coordinates of treatment location 5. Presence of elderberry shrubs 6. Presence of species of concern 7. Acres treated 8. Quantity of herbicide and adjuvant	1. Water temperature (°C) 2. Dissolved oxygen (DO, mg/L or ppm) 3. Turbidity (NTU) 4. pH 5. Salinity (ppt) 6. Specific conductance (mS/cm) 7. Water depth (feet) 8. Tide cycle 9. Water samples (pre-treatment, post-treatment, control; submitted to a Certified Analytical Laboratory)

The State Water Quality Control Board is updating the NPDES General Permit, with a draft for public comment released on June 27, 2012, and a final version for Board approval expected in spring 2013. A copy of the draft NPDES General Permit is provided in the BA Binder. The new General Permit requires a sampling frequency of six application events per year for each environmental setting (flowing water and non-flowing water), per herbicide. Glyphosate will require sampling for only one application event per year, based on the low herbicide levels found in prior year sampling.

Once WHCP has provided the SWRCB with results from six consecutive application events showing concentrations that are less than the receiving water limitation/trigger for an active ingredient in a specific environmental setting, WHCP sampling shall be reduced to one application event per year for that active ingredient in that environmental setting. The Table above, provides the receiving water limits and monitoring triggers for the four potential WHCP herbicides. These maximum limitations are all above the calculated maximum concentrations for 2,4-D, glyphosate, penoxsulam, and imazamox and can be found in Appendix 1.

Conservation Measures

The CDBW proposes that this action may result in incidental take of delta smelt. Additionally, GGS and VELB, federally listed species, occur within the project area. The Service has determined GGS and VELB may be affected, but are not likely to be adversely affected by the project based on avoidance measures and the applicant's proposed conservation measures for GGS and VELB, which have been included below. CDBW proposes the following conservation measures be implemented into the project:

1) Personnel involved with the WHCP will participate in a worker environmental awareness program taught by a Service-approved biologist. Under this program, workers will be informed about the presence of delta smelt, GGS, VELB, and its associated habitat, and that unlawful take of the animal or destruction of its habitat is a violation of the Act. Prior to chemical application activities, a qualified biologist approved by the Service will instruct all personnel about:

    a. Species identification and adverse effect avoidance/minimization guidelines for delta smelt, GGS, and VELB;

    b. The life history of the delta smelt, GGS and VELB;

    c. The importance of delta smelt migratory routes, the importance of irrigation canals, marshes/wetlands, and seasonally flooded areas to GGS, the importance of elderberry shrubs as habitat for VELB and maps marking these areas will be created for WHCP personnel; and

    d. All terms and conditions of this biological opinion for protection, avoidance and minimization of adverse effects to protected species under the Act.

2) All herbicide applications will be made according to registered pesticide label specifications, California code of regulations, and NPDES guidelines.

3) Herbicide application near special status species and their associated habitat to include sensitive riparian and wetland habitat; and other biologically important resources will be avoided.

4) All treatment crews will implement best management practices to minimize the risk of spilling herbicides.

CDBW proposes the following avoidance and minimization measures to reduce possible effects to delta smelt and its critical habitat in the project areas:

1) USDA-ARS and CDBW will conduct a DO monitoring study to evaluate the ongoing impacts of water hyacinth and water hyacinth treatment on DO. During the 2013 treatment season, USDA-ARS and CDBW will place stationary logging DO meters at up to three pair locations (under a water hyacinth mat and at an adjacent open water site). Meters will be left in place for several weeks, including at least one week prior to treatment, and three weeks post-treatment. The DO meters will log DO and temperature every one-half hour during the entire period. Data will be summarized graphically and in a written report. The study will include, at a minimum, two sites with different characteristics, for example, one site in a dead-end slough, and one site with stronger tidal influence.

2) USDA-ARS will first coordinate with the Service to develop, and then implement a toxicological study plan relating to the effects of imazamox and penoxsulam on delta smelt, larvae, and eggs. The study will be approved by the Service and completed prior to the utilization of these herbicides in Areas 1 and 2.

3) Area 1 will be managed by the WHCP as follows:

    a. For WHCP treatment sites located in Area 1, the usage of the herbicides 2,4-D and Glyphosate, as well as the adjuvant Agri-dex, will be limited to the period between June 1 and November 30 to avoid and minimize adverse effects to delta smelt and/or their critical habitat.

4) Areas 2, 3, and 4 will be managed by the WHCP as follows:

    a. CDBW will begin conducting regular field surveys in late-February to identify re-growing water hyacinth (seen as re-greening of winter stunted plants). Surveys will focus on back-water and dead end locations and other known nursery areas. CDBW will document the locations and photograph the sites with areas of more than 100 square feet of re-growing water hyacinth.

    b. A CDBW environmental scientist will compare these surveyed locations to the most recent state and federal fish monitoring data.

    c. Between March 1 and July 1, A CDBW environmental scientist will prepare a weekly summary list for the Service's primary contact. If the Service has concerns or issue, the Service will contact DCBW. The information provided to the Service will include:

i. Site number(s), size of the water hyacinth mat, and map of potential early treatment sites

ii. Whether or not listed fish species are known to be present

d. For WHCP treatment sites located in Area 2, the usage of the herbicides 2,4-D and Glyphosate as well as the adjuvant Agri-dex will be limited, based on the above criteria, to the period between March 1 and November 30 to avoid and minimize effects to delta smelt and/or its critical habitat.

e. For WHCP treatment sites located in Area 3, the usage of the herbicides 2,4-D, Glyphosate, imazamox, and penoxsulam as well as the adjuvants Agri-dex and/or Competitor will be limited, based on the above criteria, to the period between March 1 and November 30 to avoid and minimize effects to delta smelt and/or its critical habitat.

f. For WHCP treatment sites located in Area 4, the usage of the herbicides 2,4-D, Glyphosate, imazamox, and penoxsulam as well as the adjuvants Agri-dex and/or Competitor will be limited, based on the above criteria, to the period between March 1 and November 30 to avoid and minimize effects to delta smelt and/or its critical habitat.

5) To provide a zone of passage through areas of low DO, the Fish Passage Protocol described below will be incorporated into WHCP operations:

a. In slow-moving and back-end sloughs infested with water hyacinth, CDBW will treat up to 30 percent of water hyacinth mats at one time. Mats will be treated in up to 3 acre strips, leaving at least 100 foot buffer strips between treated areas. The untreated buffer strips and remaining 70 percent of the water hyacinth mat will be treated at least three more times following the initial treatment (in 30 percent increments). Follow-up treatments will occur in three week intervals.

b. In Delta tidal waters, CDBW will treat up to 50 percent of the water hyacinth mat at one time. Mats will be treated in up to 3 acre strips, leaving at least 100 foot buffer strips between treated areas. The untreated buffer strips and remaining 50 percent of the mat will be treated three weeks following the initial treatment for 2,4-D treatments, and one week following initial treatment for other herbicides.

c. If DO levels in an area to be treated area at a level considered to be detrimental to fish species prior to treatment (below 3 mg/liter), the CDBW may treat the entire area (without the 3 area strips or buffer strips), therefore allowing the DO levels to increase to beneficial use levels once the water hyacinth is controlled.

d. For each treatment site and herbicide application, CDBW staff shall follow herbicide label requirements, as specified, to reduce the potential for low DO.

e. When follow-up herbicide applications of previously treated plants are required, CBDW staff shall follow herbicide label requirements, as specified, regarding the number of treatments and time between treatments.

6) The WHCP will operate under the regulations imposed by the NPDES. The WHCP will operate within the numeric limits of DO concentrations within the legal boundaries of the Delta, which are listed below:

a. 7.0 mg/l in the Sacramento River (below the I Street Bridge) and in all Delta waters west of the Antioch Bridge;

b. 6.0 mg/l in the San Joaquin river (between Turner Cut and Stockton), September 1 through November 30; and

c. 5.0 mg/l in all other Delta Waters.

CDBW proposes the following avoidance and minimization measures to reduce possible effects to GGS in the project areas:

1) Treatment crews will be provided electronic mapping tools that identify previously surveyed and sensitive areas for GGS.

2) Disturbance of upland GGS habitat will be conducted between May 1 and October 1. This is the "active season" for GGS and direct effects are lessened, because GGS are actively moving and avoiding danger.

3) Mechanical removal of water hyacinth in sensitive GGS habitat, or areas where GGS has been sighted in the past, will only be conducted outside of the May 1 and October 1 active GGS season.

4) The mechanical harvester will maintain a speed of 2 to 2 ½ knots in areas outside of sensitive GGS habitat, or areas where GGS has been sighted in the past, during the active season, making it likely if GGS were to be in the area, they would be able to move out of the way.

5) The mechanical harvester will stop and/or reverse the harvester if a snake is seen within water hyacinth during removal.

6) All water hyacinth collected by handpicking or mechanical removal outside of the active season (May 1- October 1) for GGS will be disposed of at an approved disposal facility to ensure no hibernating GGS are buried under piles of collected water hyacinth.

CDBW proposes the following avoidance and minimization measures to reduce possible effects to VELB in the project areas:

1) For most treatment sites, CDBW will maintain a 100 foot buffer between treatment sites and shoreline elderberry shrubs.

2) Currently numbered treatment sites with relatively large numbers of valley elderberry shrubs include: 10, 11, 46, 47, 48, 99, 234, 511, 529, 707, 708, and 710. At some of these sites, the 100 foot buffer requirement may preclude CDBW's ability to treat water hyacinth. In those cases, CDBW will utilize a 50 foot buffer between treatment sites and valley elderberry shrubs. However, when utilizing the 50 foot buffer, CDBW will only treat when winds are less than 3 mph. This will further minimize potential for drift.

3) All herbicide application will occur downwind of elderberry shrubs.

4) When utilizing the 100 foot buffer, no WHCP herbicide application will occur if the wind speed is greater than 10 mph, or 7 mph in Contra Costa County.

5) A coarse droplet size spray will be utilized to avoid the potential for drift.

6) Although it is unlikely that herbicide treatments will affect elderberry shrubs based on conservation measures implemented, pre- and post-treatment surveys of elderberry bushes will be conducted on an annual basis.

Status of the Species/Environmental Baseline

Delta Smelt

The Service proposed to list the delta smelt (*Hypomesus transpacificus*) as threatened with proposed critical habitat on October 3, 1991 (56 FR 50075). The Service listed the delta smelt as threatened on March 5, 1993 (58 FR 12854), and designated critical habitat for this species on December 19, 1994 (59 FR 65256). The delta smelt was one of eight fish species addressed in the *Recovery Plan for the Sacramento–San Joaquin Delta Native Fishes* (Service 1995). This recovery plan is currently under revision. A 5-year status review of the delta smelt was completed on March 31, 2004 (Service 2004). The 2004 review affirmed the need to retain the delta smelt as a threatened species. A 12-month finding on a petition to reclassify the delta smelt was completed on April 7, 2010 (75 FR 17667). After reviewing all available scientific and commercial information, the Service determined that re-classifying the delta smelt from a threatened to an endangered species was warranted but precluded by other higher priority listing actions (Service 2010).

Distribution

The delta smelt is endemic to the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta) in California, and is restricted to the area from San Pablo Bay upstream through the Delta in Contra Costa, Sacramento, San Joaquin, Solano, and Yolo counties (Moyle 2002). Their range extends from San Pablo Bay upstream to Verona on the Sacramento River and Mossdale on the San Joaquin River. The delta smelt was formerly considered to be one of the most common pelagic fish in the upper Sacramento-San Joaquin Estuary.

Description

Live delta smelt are nearly translucent with a steely-blue sheen to their sides and have been characterized to have a pronounced odor reminiscent of cucumber (Moyle 2002). Although delta smelt have been recorded to reach lengths of up to 120 mm (4.7 in) (Moyle 2002), mean fork length of the delta smelt from 1975 - 1991 was measured to be 64.1 ± 0.1 mm. Since then, catch data from 1992 - 2004 showed mean fork length decreased to 54.1 ± .01 mm (Bennett 2005; Sweetnam 1999). Delta smelt are also identifiable by their relatively large eye to head size. The eye can occupy approximately 25-30 percent of their head length (Moyle 2002). Delta smelt have a small, translucent adipose fin located between the dorsal and caudal fins. Occasionally one chromatophore (a small dark spot) may be found between the mandibles, but most often there is none (Moyle 2002).

Delta smelt are small slender bodied fish within the Osmeridae family of fishes (smelts) (Moyle 2002). The delta smelt is one of six species currently recognized in the *Hypomesus* genus (Bennett 2005). Genetic analyses have confirmed that *H. transpacificus* presently exists as a single intermixing population (Stanley et al. 1995; Trenham et al. 1998; Fisch et al. 2011). Within the genus, delta smelt is most closely related to surf smelt (*H. pretiosis*), a species

common along the western coast of North America. Despite morphological similarities, the delta smelt is less-closely related to the wakasagi (*H. nipponensis*), an anadromous western Pacific species introduced to Central Valley reservoirs in 1959, and may be seasonally sympatric with delta smelt in the estuary (Trenham et al. 1998). Allozyme studies have demonstrated that wakasagi and delta smelt are genetically distinct and presumably derived from different marine ancestors (Stanley et al. 1995). Genetic introgression among *H. transpacificus* and *H. nipponensis* is low.

Life History and Biology

Adults: Spawning

Adult delta smelt spawn during the late winter and spring months, with most spawning occurring during April through mid-May (Moyle 2002). Spawning occurs primarily in sloughs and shallow edge areas in the Delta. Delta smelt spawning has also been recorded in Suisun Marsh and the Napa River (Moyle 2002). Most spawning occurs at temperatures between 12-18°C. Although spawning may occur at temperatures up to 22°C, hatching success of the larvae is very low (Bennett 2005). Fecundity of females ranges from about 1,200 to 2,600 eggs, and is correlated with female size (Moyle 2002). Moyle et al. (1992) considered delta smelt fecundity to be "relatively low." However, based on Winemiller and Rose (1992), delta smelt fecundity is fairly high for a fish its size. In captivity, females survive after spawning and develop a second clutch of eggs (Mager et al. 2004); field collections of ovaries containing eggs of different size and stage indicate that this also occurs in the wild (Adib-Samii 2008). Captive delta smelt can spawn up to 4-5 times. While most adults do not survive to spawn a second season, a few (<5 percent) do (Moyle 2002; Bennett 2005). Those that do survive are typically larger (90-110 mm Standard Length [sdl]) females that may contribute disproportionately to the population's egg supply (Moyle 2002 and references therein). Two-year-old females may have 3-6 times as many ova as first year spawners.

Most of what is known about delta smelt spawning habitat in the wild is inferred from the location of spent females and young larvae captured in the California Department of Fish and Game Spring Kodiak Trawl (SKT) and 20-mm survey, respectively. In the laboratory, delta smelt spawned at night (Baskerville-Bridges et al. 2000; Mager et al. 2004). Other smelts, including marine beach spawning species and estuarine populations and the landlocked Lake Washington longfin smelt, are secretive spawners, entering spawning areas during the night and leaving before dawn. If this behavior is exhibited by delta smelt, then delta smelt distribution based on the SKT, which is conducted during daylight hours in offshore habitats, may reflect general regions of spawning activity, but not actual spawning sites.

Delta smelt spawning has only been directly observed in the laboratory and eggs have not been found in the wild. Consequently, what is known about the mechanics of delta smelt spawning is derived from laboratory observations and observations of related smelt species. Delta smelt eggs are 1 mm diameter and are adhesive and negatively buoyant (Moyle 1976, 2002; Mager et al. 2004; Wang 1986, 2007). Laboratory observations indicate that delta smelt are broadcast

spawners, discharging eggs and milt close to the bottom over substrates of sand and/or pebble in current (DWR and Reclamation 1994; Brown and Kimmerer 2002; Lindberg et al. 2003; Wang 2007). Spawning over gravel or sand can also aid in the oxygenation of delta smelt eggs. Eggs that may have been laid in silt or muddy substrates might get buried or smothered, preventing their oxygenation from water flow (Lindberg pers. comm. 2011). The eggs of surf smelts and other beach spawning smelts adhere to sand particles, which keeps them negatively buoyant but not immobile, as the sand may move ("tumble") with water currents and turbulence (Hay 2007). It is not known whether delta smelt eggs "tumble incubate" in the wild, but tumbling of eggs may moderately disperse them, which might reduce predation risk within a localized area.

The locations in the Delta where newly hatched larvae are present, most likely indicates spawning occurrence. The 20-mm trawl has captured small (~5 mm sdl) larvae in Cache Slough, the lower Sacramento River, San Joaquin River, and at the confluence of these two rivers (e.g., 20-mm trawl survey 1 in 2005). Larger larvae and juveniles (size > 23 mm sdl), which are more efficiently sampled by the 20-mm trawl gear, have been captured in Cache Slough (Sacramento River) and the Sacramento Deep Water Channel in July (e.g. 20-mm trawl survey 9 in 2008). Because they are small fish inhabiting pelagic habitats with strong tidal and river currents, delta smelt larval distribution depends on both the spawning area from which they originate and the effect of transport processes caused by flows. Larval distribution is further affected by water salinity and temperature. Hydrodynamic simulations reveal that tidal action and other factors may cause substantial mixing of water with variable salinity and temperature among regions of the Delta (Monson et al 2007). This could result in rapid dispersion of larvae away from spawning sites.

The timing of spawning may affect delta smelt population dynamics. Lindberg (2011) has suggested that smelt larvae that hatch early, around late February, have an advantage over larvae hatched during late spawning in May. Early season larvae have a longer growing season and may be able to grow larger faster during more favorable habitat conditions in the late winter and early spring. An early growing season may result in higher survivorship and a stronger spawning capability for that generation. Larvae hatched later in the season have a shorter growing season which effectively reduces survivorship and spawning success for the following spawning season.

Sampling of larval delta smelt in the Bay-Delta in 1989 and 1990 suggested that spawning occurred in the Sacramento River; in Georgiana, Prospect, Beaver, Hog, and Sycamore sloughs; in the San Joaquin River adjacent to Bradford Island and Fisherman's Cut; and possibly other areas (Wang 1991). However, in recent years, the densest concentrations of both spawners and larvae have been recorded in the Cache Slough/Sacramento Deepwater Ship Channel complex in the North Delta. Some delta smelt spawning occurs in Napa River, Suisun Bay and Suisun Marsh during wetter years (Sweetnam 1999; Wang 1991; Hobbs et al. 2007). Early stage larval delta smelt have also been recorded in Montezuma Slough near Suisun Bay (Wang 1986).

Larval Development

Mager et al. (2004) reported that embryonic development to hatching takes 11-13 days at 14-16° C for delta smelt, and Baskerville-Bridges et al. (2000) reported hatching of delta smelt eggs after 8-10 days at temperatures between 15-17° C. Lindberg et al. (2003) reported high hatching rates of delta smelt eggs in the laboratory at 15° C, and Wang (2007) reported high hatching rates at temperatures between 14-17° C. Hatching success peaks near 15° C (Bennett 2005) and swim bladder inflation occurring at 60-70 days post-hatch at 16-17° C (Mager et al. 2004). At hatching and during the succeeding three days, larvae are buoyant, swim actively near the water surface, and do not react to bright direct light (Mager et al. 2004). As development continues, newly hatched delta smelt become semi-buoyant and sink in stagnant water. However, larvae are unlikely to encounter stagnant water in the wild.

Growth rates of wild-caught delta smelt larvae are faster than laboratory-cultured individuals. Mager et al. (2004) reported growth rates of captive-raised delta smelt reared at near-optimum temperatures (16°C-17°C). Their fish were about 12 mm long after 40 days and about 20 mm long after 70 days. In contrast, analyses of otoliths indicated that wild delta smelt larvae were 15-25 mm, or nearly twice as long at 40 days of age (Bennett 2005). By 70 days, most wild fish were 30-40 mm long and beyond the larval stage. This suggests there is strong selective pressure for rapid larval growth in nature, a situation that is typical for fish in general (Houde 1987). The food available to larval fishes is constrained by mouth gape and status of fin development. Larval delta smelt cannot capture as many kinds of prey as larger individuals, but all life stages have small gapes that limit their range of potential prey. Prey availability is also constrained by habitat use, which affects what types of prey are encountered. Larval delta smelt are visual feeders. They find and select individual prey organisms and their ability to see prey in the water is enhanced by turbidity (Baskerville-Bridges et al. 2004). Thus, delta smelt diets are largely comprised of small crustacea that inhabit the estuary's turbid, low-salinity, open-water habitats (i.e., zooplankton). Larval delta smelt have particularly restricted diets (Nobriga 2002). They do not feed on the full array of zooplankton with which they co-occur; they mainly consume three copepods, *Eurytemora affinis*, *Pseudodiaptomus forbesi*, and freshwater species of the family Cyclopidae. Further, the diets of first-feeding delta smelt larvae are largely restricted to the larval stages of these copepods; older, larger life stages of the copepods are increasingly targeted as the delta smelt larvae grow, their gape increases, and they become stronger swimmers.

In the laboratory, a turbid environment (>25 Nephelometric Turbidity Units [NTU]) was necessary to elicit a first feeding response (Baskerville-Bridges et al. 2000; Baskerville-Bridges 2004). Successful feeding seems to depend on a high density of food organisms and turbidity, and increases with stronger light conditions (Baskerville-Bridges et al. 2000; Mager et al. 2004; Baskerville-Bridges et al. 2004). Laboratory-cultured delta smelt larvae have generally been fed rotifers at first-feeding (Baskerville-Bridges et al. 2004; Mager et al. 2004). However, rotifers rarely occur in the guts of wild delta smelt larvae (Nobriga 2002). The most common first prey of wild delta smelt larvae is the larval stages of several copepod species. These copepod 'nauplii' are larger and have more calories than rotifers. This difference in diet may enable the faster growth rates observed in wild-caught larvae.

The triggers for and duration of delta smelt larval movement from spawning areas to rearing areas are not known. Hay (2007) noted that eulachon larvae are probably flushed into estuaries from upstream spawning areas within the first day after hatching, but downstream movement of delta smelt larvae occurs much later. Most larvae gradually move downstream toward the two parts per thousand (ppt) isohaline (X2). X2 is scaled as the distance in kilometers from the Golden Gate Bridge (Jassby et al. 1995).

At all life stages, delta smelt are found in greatest abundance in the water column and usually not in close association with the shoreline. They inhabit open, surface waters of the Delta and Suisun Bay, where they presumably aggregate in loose schools where conditions are favorable (Moyle 2002). In years of moderate to high Delta outflow (above normal to wet water years), delta smelt larvae are abundant in the Napa River, Suisun Bay and Montezuma Slough, but the degree to which these larvae are produced by locally spawning fish versus the degree to which they originate upstream and are transported by tidal currents to the bay and marsh is uncertain.

Juveniles

Young-of-the-year delta smelt rear in the low salinity zone (LSZ) from late spring through fall and early winter. Once in the rearing area growth is rapid, and juvenile fish are 40-50 mm sdl long by early August (Erkkila et al. 1950; Ganssle 1966; Radtke 1966). They reach adult size (55-70 mm sdl) by early fall (Moyle 2002). Delta smelt growth during the fall months slows considerably (only 3-9 mm total), presumably because most of the energy ingested is being directed towards gonadal development (Erkkila et al. 1950; Radtke 1966).

Delta Smelt Population Dynamics and Abundance Trends

Channelization, conversion of Delta islands to agriculture, and water operations have substantially changed the physical appearance, water salinity, water clarity, and hydrology of the Delta. As a consequence of these changes, most life stages of the delta smelt are now distributed across a smaller area than historically (Arthur et al. 1996; Feyrer et al. 2007). Wang (1991) noted in a 1989 and 1990 study of delta smelt larval distribution that, in general, the San Joaquin River was used more intensively for spawning than the Sacramento River. Nobriga et al. (2008) found that delta smelt capture probabilities in the TNS are highest at specific conductance levels of 1,000 to 5,000 $\mu S\ cm^{-1}$ (approximately 0.6 to 3.0 practical salinity unit [psu]). Similarly, Feyrer et al. (2007) found a decreasing relationship between abundance of delta smelt in the FMWT and specific conductance during September through December. The location of the LSZ and changes in delta smelt habitat quality in the San Francisco Estuary can be indexed by changes in X2. The LSZ historically had the highest primary productivity and is where zooplankton populations (on which delta smelt feed) were historically most dense (Knutson and Orsi 1983; Orsi and Mecum 1986). However, this has not always been true since the invasion of the overbite clam (Kimmerer and Orsi 1996). The abundance of many local aquatic species has tended to increase in years when winter-spring outflow was high and X2 was pushed seaward (Jassby et al. 1995), implying that the quantity and quality (overall suitability) of estuarine habitat increases in years when

outflows are high. However, delta smelt is not one of the species whose abundance has statistically covaried with winter-spring freshwater flows (Stevens and Miller 1983; Moyle et al. 1992; Kimmerer 2002a; Bennett 2005).

The distribution of juvenile delta smelt has also changed over the last several decades. During the years 1970 through 1978, delta smelt catches in the TNS survey declined rapidly to zero in the Central and South Delta and have remained near zero since. A similar shift in FMWT catches occurred after 1981 (Arthur et al. 1996). This portion of the Delta has also had a long-term trend increase in water clarity during July through December (Arthur et al. 1996; Feyrer et al. 2007; Nobriga et al. 2008).

The California Department of Fish and Wildlife (CDFW) has conducted several long-term monitoring surveys that have been used to index the relative abundance of delta smelt. The 20-mm Survey has been conducted every year since 1995. This survey targets late-stage delta smelt larvae. Most sampling has occurred April-June. The Summer Townet Survey (TNS) has been conducted nearly every year since 1959. This survey targets 38-mm striped bass, but collects similar-sized juvenile delta smelt. Most sampling has occurred June-August. The Fall Midwater Trawl Survey (FMWT) has been conducted nearly every year since 1967. This survey also targets age-0 striped bass, but collects delta smelt > 40 mm in length. The FMWT samples monthly, September-December. The relative abundance index data and maps of the sampling stations used in these surveys are available at http://www.dfg.ca.gov/delta/. The methods that underlie the surveys have been described previously (Stevens and Miller 1983; Moyle and others 1992; Dege and Brown 2004). The delta smelt catch data and relative abundance indices derived from these sampling programs have been used in numerous publications (e.g., Stevens and Miller 1983; Moyle and others 1992; Jassby and others 1995; Kimmerer 2002b; Dege and Brown 2004; Bennett 2005; Feyrer and others 2007; Sommer and others 2007; Kimmerer and others 2008; Newman 2008; Nobriga and others 2008; Kimmerer and others 2009; Mac Nally and others 2010; Thomson and others 2010; Feyrer and others 2011; Maunder and Deriso 2011). These abundance index time series document the long-term decline of the delta smelt.

Early statistical assessments of delta smelt population dynamics concluded that at best, the relative abundance of the adult delta smelt population had only a very weak influence on subsequent juvenile abundance (Sweetnam and Stevens 1993). Thus, early attempts to describe abundance variation in delta smelt ignored stock-recruit effects and researchers looked for environmental variables that were directly correlated with interannual abundance variation (e.g., Stevens and Miller 1983; Moyle and others 1992; Sweetnam and Stevens 1993; Herbold 1994; Jassby and others 1995). Because delta smelt live in a habitat that varies in size and quality with Delta outflow, the authors cited above searched for a linkage between Delta outflow (or X2) and the TNS and FMWT indices. Generally, these analyses did not find strong support for an outflow-abundance linkage. These analyses led to a prevailing conceptual model that multiple interacting factors had caused the delta smelt decline (Moyle and others 1992; Bennett and Moyle 1996; Bennett 2005). It has also recently been noted that delta smelt's FMWT index is

partly influenced by concurrent environmental conditions (Feyrer and others 2007; 2011). This may be a partial explanation for why few analyses could consistently link springtime environmental conditions to delta smelt's fall index.

It is now recognized that delta smelt abundance plays an important role in subsequent abundance (Bennett 2005; Maunder and Deriso 2011). Bennett (2005) assessed (1) the influence of adult stock as indexed by the FMWT versus the next generation of juveniles indexed by the following calendar year's TNS; (2) the influence of the juvenile stock indexed by the TNS versus the subsequent adult stock indexed a few months later in the FMWT; (3) the influence of the FMWT on the following year's FMWT and on the FMWT two years later, and (4) he did the same for the TNS data. He concluded that (1) two-year-old delta smelt might play an important role in delta smelt population dynamics, (2) it was not clear whether juvenile production was a density-independent or density-dependent function of adult abundance, and (3) adult production was a density-dependent function of juvenile abundance and the carrying capacity of the estuary to support this life-stage transition had declined over time. These conclusions are also supported by Maunder and Deriso (2011).

The concept of density-dependence[1] and how it has affected the delta smelt is important because it may be used as a reason not to protect particular life stages from sources of mortality. Bennett (2005) concluded it was (statistically) unclear whether density-dependence occurs between generations. He also noted that the delta smelt indices strongly suggest that density-dependence has occurred, at least over the long-term, during the juvenile stage. The uncertainty about density-dependence between generations results because statistical assessments of the relationship between the adult stock and the next generation of recruits (juveniles) result in similar fits for linear (density-independent) and nonlinear (density-dependent) relationships (Bennett 2005; Maunder and Deriso 2011).

One reason for this is that delta smelt population dynamics may have changed over time. Previous papers have reported a delta smelt step-decline during 1981-1982 (Kimmerer 2002b; Thomson et al. 2010). Prior to this decline, the stock-recruit data are consistent with "Ricker" type density-dependence where increasing adult abundance resulted in decreased juvenile abundance. Since the decline, recruitment has been positively and essentially linearly related to prior adult abundance, suggesting that reproduction has been basically density-independent for about the past 30 years. This means that since the early 1980s, more adults translates into more juveniles and fewer adults translates into fewer juveniles without being 'compensated for' by density-dependence. In contrast to the transition among generations, the weight of scientific evidence strongly supports the hypothesis that, at least over the history of Interagency Ecological Program fish monitoring, delta smelt has experienced density-dependence during the juvenile stage of its life cycle, i.e., between the summer and fall (Bennett 2005; Maunder and Deriso 2011). This has been inferred because, statistically, the FMWT index does not increase linearly

1 Density-dependence refers to situations where vital rates like growth or survival change as a population's density changes (Rose et al. 2001). When vital rates do not vary with population density, they are considered to be density-independent. Density-dependence occurs in populations when one or more factors is in limited supply or when crowding results in predator aggregation or faster disease transmission.

with increases in the summer townet index. Rather, the best-fitting relationships between the summer townet index and the FMWT index show that the FMWT indices approach an asymptote as the summer townet increases or possibly even declines at the highest summer townet indices. From a species conservation perspective, the most relevant aspect of this juvenile density dependence is that the carrying capacity of the estuary for delta smelt has declined (Bennett 2005). Thus, the delta smelt population decline has occurred for two basic reasons. First, the compensatory density-dependence that historically enabled juvenile abundance to rebound from low adult numbers stopped happening. This change had occurred by the early 1980s as described above. The reason is still not known, but the consequence of the change is that for the past several decades, adult abundance drives juvenile production in a largely density-independent manner. Thus, if numbers of adults or adult fecundity decline, juvenile production will also decline (Kimmerer 2011). Second, because juvenile carrying capacity has declined, juvenile production hits a 'ceiling' at a lower abundance than it once did. This limits adult abundance and possibly per capita fecundity, which cycles around and limits the abundance of the next generation of juveniles. The mechanism causing carrying capacity to decline is likely due to the long-term accumulation of deleterious habitat changes – both physical and biological – during the summer-fall (Bennett and others 2008; Feyrer and others 2007; 2010; Maunder and Deriso 2011).

Stressors

Habitat

The existing physical appearance and hydrodynamics of the Delta have changed substantially from the environment in which native fish species like delta smelt evolved. The Delta once consisted of tidal marshes with networks of diffuse dendritic channels connected to floodplains of wetlands and upland areas (Moyle 2002). The in-Delta channels were further connected to drainages of larger and smaller rivers and creeks entering the Delta from the upland areas. In the absence of upstream reservoirs, freshwater inflow from smaller rivers and creeks and the Sacramento and San Joaquin Rivers were highly seasonal and more strongly and reliably affected by precipitation patterns than they are today. Consequently, variation in hydrology, salinity, turbidity, and other characteristics of the Delta aquatic ecosystem was greater in the past than it is today (Kimmerer 2002a). For instance, in the early 1900s, the location of maximum salinity intrusion into the Delta during dry periods varied from Chipps Island in the lower Delta to Stockton along the San Joaquin River and Merritt Island in the Sacramento River. Operations of upstream reservoirs have reduced spring flows while releases of water for Delta water export and increased flood control storage have increased late summer and fall inflows (Knowles 2002), though Delta outflows have been tightly constrained during late summer-fall for several decades. The following is a brief description of the changes that have occurred to delta smelt's habitat that are relevant to the environmental baseline for this consultation.

Changes to the LSZ

There have been documented changes to the delta smelt's low-salinity zone habitat that have led to present-day, baseline habitat conditions. The close association of delta smelt with the San Francisco estuary LSZ has been known for many years (Stevens and Miller 1983; Moyle et al. 1992). Peterson (2003) developed a conceptual model that hypothesized how, "stationary and dynamic components of estuarine habitats" interacted to influence fisheries production in tidal river estuaries. Peterson's model suggests that when the dynamic and static aspects of estuarine habitat sufficiently overlap, foraging, growth, density, and survival are all high, and that enables fish production to outpace losses to predators. The result is high levels of successful recruitment of new individuals. The model also hypothesizes that when the dynamic and static aspects of an estuarine habitat do not sufficiently overlap, foraging, growth, density, and survival are impaired such that losses to predators increase and recruitment of new individuals decreases. This model was developed specifically for species spawned in marine environments that were subsequently transported into estuaries. However, the concept of X2, which was developed in the San Francisco estuary to describe how freshwater flow affected estuarine habitat (Jassby et al. 1995), played a role in the intellectual development of Peterson's model. The Peterson model also provides a useful framework to conceptualize delta smelt's LSZ habitat.

Currently available information indicates that delta smelt habitat is most suitable for the fish when low-salinity water is near 20°C, highly turbid, oxygen saturated, low in contaminants, supports high densities of calanoid copepods and mysid shrimp (Moyle et al. 1992; Lott 1998; Nobriga 2002), and occurs over comparatively static 'landscapes' that support sandy beaches and bathymetric variation that enables the fish and their prey to aggregate (Kimmerer et al. 2002; Bennett et al. 2002; Hobbs et al. 2006). Almost every component listed above has been degraded over time (see below). The Service has determined that this accumulation of habitat change is the fundamental reason or mechanism that has caused delta smelt to decline.

Alterations to estuarine bathymetry and salinity distribution (~ 1850-present)

The position of the LSZ, where delta smelt rear, has changed over the years. The first major change in the LSZ was the conversion of the landscape over which tides oscillate and river flows vary (Moyle et al. 2010). The ancestral Delta was a large tidal marsh-floodplain habitat totally approximately 700,000 acres. Most of the historic wetlands were diked and reclaimed for agriculture or other human uses by 1920 (Atwater et al. 1979). Channels were dredged deep (~12 m) to accommodate shipping traffic from the Pacific Ocean and San Francisco Bay to ports in Sacramento and Stockton. These changes left Suisun Bay and the confluence of the Sacramento-San Joaquin Rivers as the largest and most bathymetrically variable places in the LSZ. This region remained a highly productive nursery for many decades (Stevens and Miller 1983; Moyle et al. 1992; Jassby et al. 1995). However, the deepened channels created to support shipping and flood control, requires more freshwater outflow to maintain the LSZ in the large Suisun Bay and River confluence than was once required (Gartrell 2010). The construction of the CVP and SWP not only provided water supply for urban, agricultural and industrial users, but also provided water needed to combat salinity intrusion into the Delta, which was observed by the early 20th

century. California's demand for freshwater (keeps) continues to increase, thus seasonal salinity intrusion perpetually reduces the temporal overlap of the LSZ (indexed by X2) within the Suisun Bay (region), especially in the fall (Feyrer et al. 2007; 2011). Consequently, the second major habitat change in the Delta has been in the frequency with which the LSZ is maintained in Suisun Bay for any given amount of precipitation. There was a step-decline in the LSZ in 1977 from which it has never recovered for more than a few years at a time. Based on model forecasts of climate change and water demand, this trend is expected to continue (Feyrer et al. 2011).

Summer and fall environmental quality has decreased overall in the Delta because outflows are lower and water transparency is higher. These changes may be due to increased upstream water diversions for flooding rice fields (Kawakami et. al. 2008). The confluence of the Sacramento and San Joaquin Rivers has, as a result, become increasingly important as a rearing location for delta smelt, with physical environmental conditions constricting the species range to a relatively narrow area (Feyrer et al. 2007; Nobriga et al. 2008). This has increased the likelihood that most of the juvenile population is exposed to chronic and cyclic environmental stressors, or catastrophic events. For instance, all seven delta smelt collected during the September 2007 FMWT survey were captured at statistically significantly higher salinities than what would be expected based upon historical distribution data generated by Feyrer et al. (2007). During the same year, the annual bloom of toxic cyanobacteria (*Microcystis aeruginosa*) spread far downstream to the west Delta and beyond during the summer (Peggy Lehman, pers comm). This has been suggested as an explanation for the anomaly in the distribution of delta smelt relative to water salinity levels (Reclamation 2008).

Turbidity

From 1999 to present, the Delta experienced a change in estuarine turbidity that culminated in an estuary-wide step-decline in 1999 (Schoellhamer 2011). For decades, the turbidity of the modified estuary had been sustained by very large sediment deposits resulting mainly from gold mining in the latter 19th century. Sediments continued to accumulate into the mid-20th century, keeping the water relatively turbid even as sediment loads from the Sacramento River basin declined due to dam and levee construction (Wright and Schoellhamer 2004). The flushing of the sediment deposits may also have made the estuary deeper overall and thus a less suitable nursery from the 'static' bathymetric perspective (Schroeter 2008).

Delta smelt associate with highly turbid waters; there is a negative correlation between the frequency of delta smelt occurrence in survey trawls during summer, fall and early winter and water clarity. For example, the likelihood of delta smelt occurrence in trawls at a given sampling station decreases with increasing Secchi depth at the stations (Feyrer et al. 2007, Nobriga et al. 2008). This is very consistent with behavioral observations of captive delta smelt (Nobriga and Herbold 2008). Few daylight trawls catch delta smelt at Secchi depths over one half meter and capture probabilities for delta smelt are highest at 0.40 m depth or less. Turbid waters are thought to increase foraging efficiency (Baskerville-Bridges et al. 2004) and reduce the risk of predation for delta smelt.

Temperature

Temperature also affects delta smelt distribution. Swanson and Cech (1995) and Swanson et al. (2000) indicate delta smelt tolerate temperatures (<8° C to >25° C), however warmer water temperatures >25° C restrict their distribution more than colder water temperatures (Nobriga and Herbold 2008). Delta smelt of all sizes are found in the main channels of the Delta and Suisun Marsh and the open waters of Suisun Bay where the waters are well oxygenated and temperatures are usually less than 25° C in summer (Nobriga et al. 2008). Currently, delta smelt are subjected to thermally stressful temperatures every summer, and all available regional climate change projections predict central California will be warmer still in the coming decades (Dettinger 2005). We expect warmer estuary temperatures to be yet another significant conservation challenge based on climate change models. Warmer water temperatures would increase delta smelt mortality and constrict suitable habitat throughout the Delta during the summer months. Higher temperatures would shrink delta smelt distribution into the fall, limiting their presence to Suisun Bay and in waters with less than optimal salinities (Brown et al. unpublished data 2011). Water temperatures are presently above 20°C for most of the summer in core habitat areas, sometimes even exceeding the nominal lethal limit of 25°C for short periods. Coldwater fishes begin to have behavioral impairments (Marine and Cech 2004) and lose competitive abilities (Taniguchi et al. 1998) prior to reaching their thermal tolerance limits. Thus, the estuary can already be considered thermally stressful to delta smelt and can only become more so if temperatures warm in the coming decades.

Foraging Ecology

Delta smelt feed primarily on small planktonic crustaceans, and occasionally on insect larvae (Moyle 2002). Juvenile-stage delta smelt prey upon copepods, cladocerans, amphipods, and insect larvae (Moyle 2002). Historically, the main prey of delta smelt was the euryhaline copepod *Eurytemora affinis* and the euryhaline mysid *Neomysis mercedis*. The slightly larger *Pseudodiaptomus forbesi* has replaced *E. affinis* as a major prey source of delta smelt since its introduction into the Bay-Delta, especially in summer, when it replaces *E. affinis* in the plankton community (Moyle 2002). Another smaller copepod, *Limnoithona tetraspina*, which was introduced to the Bay-Delta in the mid-1990s, is now one of the most abundant copepods in the LSZ, but not abundant in delta smelt diets. *Acartiella sinensis*, a calanoid copepod species that invaded the Delta at the same time as *L. tetraspina*, also occurs at high densities in Suisun Bay and in the western Delta over the last decade. Delta smelt eat these newer copepods, but *Pseudodiaptomus* remains their dominant prey (Baxter et al. 2008).

River flows influence estuarine salinity gradients and water residence times and thereby affect both habitat suitability for benthos and the transport of pelagic plankton upon which delta smelt feed. High tributary flow leads to lower residence time of water in the Delta, which generally results in lower plankton biomass (Kimmerer 2004). In contrast, higher residence times, which result from low tributary flows, can result in higher plankton biomass but water diversions, overbite clam grazing (Jassby et al. 2002) and possibly contaminants (Baxter et al. 2008) remove a lot of plankton biomass when residence times are high. These factors all affect food availability

for planktivorous fishes that utilize the zooplankton in Delta channels. Delta smelt cannot occupy much of the Delta anymore during the summer (Nobriga et al. 2008). Thus, there is the potential for mismatches between regions of high zooplankton abundance in the Delta and delta smelt distribution now that the overbite clam has decimated LSZ zooplankton densities.

The delta smelt compete with and are prey for several native and introduced fish species in the Delta. The introduced Mississippi silverside may prey on delta smelt eggs and/or larvae and compete for copepod prey (Bennett and Moyle 1995; Bennett 2005). Young striped bass also use the LSZ for rearing and may compete for copepod prey and eat delta smelt. Centrarchid fishes and coded wire tagged Chinook salmon smolts released in the Delta for survival experiments since the early 1980s may potentially also prey on larval delta smelt (Brandes and McLain 2001; Nobriga and Chotkowski 2000). Studies during the early 1960s found delta smelt were only an occasional prey fish for striped bass, black crappie and white catfish (Turner and Kelley 1966). However, delta smelt were a comparatively rare fish even then, so it is not surprising they were a rare prey. Striped bass appear to have switched to piscivorous feeding habits at smaller sizes than they historically did, following severe declines in the abundance of mysid shrimp (Feyrer et al. 2003). Nobriga and Feyrer (2008) showed that Mississippi silverside, which is similar in size to delta smelt, was only eaten by subadult striped bass less than 400 mm fork length. While largemouth bass are not pelagic, they have been shown to consume some pelagic fishes (Nobriga and Feyrer 2007).

Other Stressors

Aquatic Macrophytes

For many decades, the Delta's waterways were turbid and growth of submerged plants was apparently unremarkable. That began to change in the mid-1980s, when the Delta was invaded by the non-native plant, Egeria densa, a fast-growing aquatic macrophyte that has now taken hold in many shallow habitats throughout the Delta (Brown and Michnuik 2007; Hestir 2010). Egeria densa and other non-native species of submerged aquatic vegetation (SAV) grow most rapidly in the summer and late fall when water temperatures are warm ($> 20^0$C) and outflow is relatively low (Hestir 2010). The large canopies formed by these plants have physical and biological consequences for the ecosystem (Kimmerer et al. 2008). First, the dense nature of SAV promotes sedimentation of particulate matter from the water column which increases water transparency. Increased water transparency leads to a loss of habitat for delta smelt (Feyrer et al. 2007; Nobriga et al. 2008). Second, dense SAV canopies provide habitat for a suite of non-native fishes that occupy the littoral and shallow habitats of the Delta, displacing native fishes (Nobriga et al. 2005; Brown and Michniuk 2007). Finally, the rise in SAV colonization over the last three decades has led to a shift in the dominant trophic pathways that fuel fish production in the Delta. Until the latter 1980s, the food web of most fishes was often dominated by mysid shrimp (Feyrer et al. 2003) that were subsidized by phytoplankton food sources (Rast and Sutton 1989). Now, most littoral and demeral fishes of the Delta have diets dominated by the epibenthic amphipods that eat SAV detritus or the epiphytic algae attached to SAV (Grimaldo et al. 2009).

Egeria densa and other non-native submerged aquatic vegetation (e.g., *Myriophyllum spicatum*) can affect delta smelt in direct and indirect ways. Directly, submerged aquatic vegetation can overwhelm littoral habitats (inter-tidal shoals and beaches) where delta smelt may spawn making them unsuitable for spawning. Indirectly, submerged aquatic vegetation decreases turbidity (by trapping suspended sediment) which has contributed to a decrease in both juvenile and adult smelt habitat (Feyrer et al. 2007; Nobriga et al. 2008). Increased water transparency may delay feeding and may also make delta smelt more susceptible to predation pressure.

Predators

Delta smelt is a rare fish and has been a rare fish (compared to other species) for at least the past several decades (Nobriga and Herbold 2008). Therefore, it has also been rare in examinations of predator stomach contents. Delta smelt were occasional prey fish for striped bass, black crappie and white catfish in the early 1960s (Turner and Kelley 1966) but went undetected in a recent study of predator stomach contents (Nobriga and Feyrer 2007). Striped bass are likely the primary predator of juvenile and adult delta smelt given their spatial overlap in pelagic habitats. Despite major declines in age-0 abundance, there remains much more biomass of striped bass in the upper estuary than delta smelt. This means it is not possible for delta smelt to support any significant proportion of the striped bass population. It is unknown whether incidental predation by striped bass (and other lesser predators) represents a substantial source of mortality for delta smelt.

Nothing is known about the historic predators of delta smelt or their possible influence on delta smelt population dynamics. Fish eggs and larvae can be opportunistically preyed upon by many invertebrate and vertebrate animals. There has always been a very long list of potential predators of delta smelt's eggs and larvae. The eggs and newly-hatched larvae of delta smelt are thought to be prey for Mississippi silversides in littoral habitats (Bennett 2005). Other potential predators of eggs and larvae of smelt in littoral habitats are yellowfin goby, centrarchids, and Chinook salmon. Potential native predators of juvenile and adult delta smelt would also have included numerous bird and fish species and this may be reflected in delta smelt's annual life-history. Annual fish species, also known as "opportunistic strategists", are adapted to high mortality rates in the adult stage (Winemiller and Rose 1992). This high mortality is usually due to predation or highly unpredictable environmental conditions, both of which could have characterized the ancestral niche of delta smelt.

The introduction of striped bass into the San Francisco Estuary in 1879 added a permanently resident, large piscivorous fish to the low-salinity zone. The LSZ is a habitat not known to have had an equivalent predator prior to the establishment of striped bass (Moyle 2002). Striped bass likely changed predation rates on delta smelt, but there are no data available to confirm this hypothesis. For many decades the estuary supported higher striped bass and delta smelt numbers than it does currently (Moyle 2002). This is evidence that delta smelt is able to successfully coexist with striped bass.

The current influence of striped bass and other predators on delta smelt population dynamics is unknown, mainly because predator effects on rare prey are extremely difficult to quantify. Delta smelt were observed in the stomach contents of striped bass and other fishes in the 1960s (Stevens 1963; Turner and Kelley 1966), but have not been in more recent studies (Feyrer et al. 2003; Nobriga and Feyrer 2007). Predation is a common source of density-dependent mortality in fish populations (Rose et al. 2001). Thus, it is possible that predation was a mechanism that historically generated the density-dependence observable in delta smelt population dynamics that has been noted by Bennett (2005) and Maunder and Deriso (2011). As is the case with other fishes, the vulnerability of delta smelt to predators may be influenced primarily by habitat suitability. It is widely documented that pelagic fishes, including many smelt species, experience lower predation risks under turbid water conditions (Thetmeyer and Kils 1995; Utne-Palm 2002; Horpilla et al. 2004,). Growth rates, a result of feeding success plus water temperature, are also well known to affect fishes' cumulative vulnerability to predation (Sogard 1997).

Competition

It has been hypothesized that delta smelt are adversely affected by competition from other introduced fish species that use overlapping habitats, including Mississippi silversides, (Bennett and Moyle 1995) striped bass, and wakasagi (Sweetnam 1999). Laboratory studies show that delta smelt growth is inhibited when reared with Mississippi silversides (Bennett 2005) but there is no empirical evidence to support the conclusion that competition between these species is a factor that influences the abundance of delta smelt in the wild. There is some speculation that the overbite clam competes with delta smelt for copepod nauplii (Nobriga and Herbold 2008). It is unknown how intensively overbite clam grazing and delta smelt directly compete for food, but overbite clam consumption of shared prey resources does have other ecosystem consequences that appear to have affected delta smelt indirectly.

Microcystis

Large blooms of toxic blue-green alga, *Microcystis aeruginosa*, were first detected in the Delta during the summer of 1999 (Lehman et al. 2005). Since then, *M. aeruginosa* has bloomed each year, forming large colonies throughout most of the Delta and increasingly down into eastern Suisun Bay. Blooms typically occur between late spring and early fall (peak in the summer) when temperatures are above 20 °C. *Microcystis aeruginosa* can produce natural toxins that pose animal and human health risks if contacted or ingested directly. Preliminary evidence indicates that the toxins produced by local blooms are not toxic to fishes at current concentrations. However, it appears that *M. aeruginosa* is toxic to copepods that delta smelt eat (Ali Ger 2008 pers comm). In addition, *M. aeruginosa* could out-compete diatoms for light and nutrients. Diatoms are a rich food source for zooplankton in the Delta (Mueller-Solger et al. 2002). Studies are underway to determine if zooplankton production is compromised during *M. aerguinosa* blooms to an extent that is likely to adversely affect delta smelt. *Microcystis* blooms may also decrease DO to lethal levels for fish (Saiki et al. 1992), although delta smelt do not strongly overlap the densest *Microcystis* concentrations, so DO is not likely a problem. *Microcystis* blooms are a symptom of eutrophication and high ammonia to nitrate ratios in the water.

Contaminants

Contaminants can change ecosystem functions and productivity through numerous pathways. However, contaminant loading and its ecosystem effects within the Delta are not well understood. Although a number of contaminant issues were first investigated during the Pelagic Organism Decline (POD) years, concern over contaminants in the Delta is not new. There are long-standing concerns related to mercury and selenium levels in the watershed, Delta, and San Francisco Bay (Linville et al. 2002; Davis et al. 2003). Phytoplankton growth rate may, at times, be inhibited by high concentrations of herbicides (Edmunds et al. 1999). New evidence indicates that phytoplankton growth rate is chronically inhibited by ammonium concentrations in and upstream of Suisun Bay (Wilkerson et al. 2006, Dugdale et al. 2007). Contaminant-related toxicity to invertebrates has been noted in water and sediments from the Delta and associated watersheds (e.g., Kuivila and Foe 1995, Giddings et al. 2000, Werner et al. 2000, Weston et al. 2004). Undiluted drainwater from agricultural drains in the San Joaquin River watershed can be acutely toxic (quickly lethal) to fish and have chronic effects on growth (Saiki 1998). Evidence for mortality of young striped bass due to discharge of agricultural drainage water containing rice herbicides into the Sacramento River (Bailey et al. 1994) led to new regulations for water discharges. Bioassays using caged Sacramento sucker (*Catostomus occidentalis*) have revealed deoxyribonucleic acid strand breakage associated with runoff events in the watershed and Delta (Whitehead et al. 2004). Kuivila and Moon (2004) found that peak densities of larval and juvenile delta smelt sometimes coincided in time and space with elevated concentrations of dissolved pesticides in the spring. These periods of co-occurrence lasted for up to 2-3 weeks, but concentrations of individual pesticides were low and much less than would be expected to cause acute mortality. However, the effects of exposure to the complex mixtures of pesticides actually present are unknown.

Current science suggests a possible link between contaminants and POD, may be the effects of contaminant exposure on prey items, resulting in an indirect effect on the survival of POD species (Johnson et al. 2010). The POD investigators initiated several studies beginning in 2005 to address the possible role of contaminants and disease in the declines of Delta fish and other aquatic species. Their primary study consists of twice-monthly monitoring of ambient water toxicity at fifteen sites in the Delta and Suisun Bay. In 2005 and 2006, standard bioassays using the amphipod *Hyalella azteca* had low (<5 percent) frequency of occurrence of toxicity (Werner et al. 2008). The results indicated that 2007, a dry year, showed a higher incidence of toxic events than in the previous (wetter) year, 2006 (Werner et al. 2010). Parallel testing with the addition of piperonyl butoxide, an enzyme inhibitor, indicated that both organophosphate and pyrethroid pesticides may have contributed to the pulses of toxicity. Most of the tests that were positive for *H. azteca* toxicity have come from water samples from the lower Sacramento River. Pyrethroids are of particular interest because use of these insecticides has increased within the Delta watershed (Amweg et al. 2005, Oros and Werner 2005) as use of some organophosphate insecticides has declined. Urban source waters have shown toxicity to *H. azteca* with high mortality rates and swimming impairment in fishes due to pyrethroid pesticides (Weston and Lydy 2010). Toxicity of sediment-bound pyrethroids to macroinvertebrates has also been

observed in small, agriculture-dominated watersheds tributary to the Delta (Weston et al. 2004, 2005). The association of delta smelt spawning with turbid winter runoff and the association of pesticides including pyrethroids with sediment is of potential concern.

In conjunction with the POD investigation, larval delta smelt bioassays were conducted simultaneously with a subset of the invertebrate bioassays. The water samples for these tests were collected from six sites within the Delta during May-August of 2006 and 2007. Results from 2006 indicate that delta smelt are highly sensitive to high levels of ammonia, low turbidity, and low salinity. There is some preliminary indication that reduced survival may be due to disease organisms (Werner et al. 2008). No significant mortality of larval delta smelt was found in the 2006 bioassays, but there were two instances of significant mortality in June and July of 2007. In both cases, the water samples were collected from sites along the Sacramento River and had relatively low turbidity and salinity levels and moderate levels of ammonia. It is also important to note that no significant *H. azteca* mortality was detected in these water samples. While the *H. azteca* tests are very useful for detecting biologically relevant levels of water column toxicity for zooplankton, interpretation of the *H. azteca* test results with respect to fish should proceed with great caution. The relevance of the bioassay results to field conditions remains to be determined. Werner et al. (2010) conducted *in situ* testing in the laboratory and compared contaminant sensitivity of delta smelt to common bioassay organisms, including *H. azteca.* The investigations included contaminants commonly observed in the Delta, such as organophosphate and pyrethroid insecticides, copper, and total ammonia. In the laboratory, delta smelt were 1.8 to >11 times more sensitive than fathead minnow to ammonia, copper, and all insecticides tested (except permethrin). The invertebrates tested were more sensitive to contaminants than delta smelt or fathead minnows. *Eurytemora affinis* and *Ceriodaphnia dubia* were the most sensitive to total ammonia. *C. dubia* was the most sensitive to copper and organophosphates pesticides. *H. azteca* was the most sensitive test organism to pyrethroids. Toxicity was not detected for the Sacramento River at Hood or the San Joaquin River at Rough and Ready Island during the 2009 *in situ* testing period. Delta smelt survival was low in treatment and control waters. Werner et al. (2010) concluded that larval smelt may be too sensitive to salinity, temperature and transport stress for *in situ* exposures and recommended using surrogate species in future tests.

Persistent confinement of the spawning population of delta smelt to the Sacramento River increases the likelihood that a substantial portion of the spawners will be affected by a catastrophic event or localized chronic threat. For instance, large volumes of highly concentrated ammonia released into the Sacramento River from the Sacramento Regional County Sanitation District may affect embryo survival or inhibit prey production. Further, agricultural fields in the Yolo Bypass and surrounding areas are regularly sprayed by pesticides, and water samples taken from Cache Slough sometimes exhibited toxicity to *H. azteca* (Werner et al. 2008; 2010). The thresholds of toxicity for delta smelt for most of the known contaminants have not been determined, but the exposure to a combination of different compounds increases the likelihood of adverse effects. The extent to which delta smelt larvae are exposed to contaminants varies with

flow entering the Delta. Flow pulses during spawning increase exposure to many pesticides (Kuivila and Moon 2004) but decrease ammonia concentrations entering the Delta from wastewater treatment plants.

The POD investigations into potential contaminant effects also include the use of biomarkers that have been used previously to evaluate toxic effects on POD fishes (Bennett et al. 1995, Bennett 2005). The results to date have been mixed. A pathogen survey of 105 adult delta smelt, sampled from January through May, at several sites in the Delta, found that disease did not appear to overtly influence the health of the surveyed population for that year (Foott and Bigelow 2010). Histopathological and viral evaluation of young longfin smelt collected in 2006 indicated no histological abnormalities associated with exposure to toxics or disease (Foott and Stone 2007). There was also no evidence of viral infections or high parasite loads. Similarly, young threadfin shad showed no histological evidence of contaminant effects or of viral infections (Foott and Stone 2007). Parasites were noted in threadfin shad gills at a high frequency but the infections were not considered severe. Both longfin smelt and threadfin shad were considered healthy in 2006. Adult delta smelt collected from the Delta during the winter of 2005 also were considered healthy, showing little histopathological evidence for starvation or disease (Teh 2007). However, there was some evidence of low frequency endocrine disruption. In 2005, nine of 144 (six percent) of adult delta smelt males sampled were intersex, having immature oocytes in their testes (Teh 2007). Bennett (2005) reported that about 10% of the delta smelt analyzed for histopathological anomalies in 1999-2000 showed evidence of deleterious contaminant exposure. In contrast, 30%-60% of these fish had liver glycogen depletion consistent with food limitation. In contrast, preliminary histopathological analyses have found evidence of significant disease in other species and for POD species collected from other areas of the estuary. Massive intestinal infections with an unidentified myxosporean were found in yellowfin goby (*Acanthogobius flavimanus*) collected from Suisun Marsh. Severe viral infection was also found in Mississippi silverside and juvenile delta smelt collected from Suisun Bay during summer 2005. Lastly, preliminary evidence suggests that contaminants and disease may impair survival of age-0 striped bass. Baxter et al. (2008) found high occurrence and severity of parasitic infections, inflammatory conditions, and muscle degeneration in young striped bass collected in 2005; levels were lower in 2006. Several biomarkers of contaminant exposure including P450 activity (i.e., detoxification enzymes in liver), acetylcholinesterase activity (i.e., enzyme activity in brain), and vitellogenin induction (i.e., presence of egg yolk protein in blood of males) were also reported from striped bass collected in 2006 (Ostrach 2008). Delta smelt can also be exposed to other toxic substances. Recent toxicological research has provided dose-response curves for several contaminants (Connon et al. 2009; 2011; in review). This research has also shown that gene expression changes and impairment of delta smelt swimming performance occur at contaminant concentrations lower than levels that cause mortality.

Summary of Delta Smelt Status and Environmental Baseline

In summary, delta smelt's LSZ ecosystem has been changing and has changed very rapidly on several occasions during the past several decades. First, suitable land area was reduced, then water diversions increased, then the temporal overlap of low-salinity water with the best

remaining landscape was reduced, then the food web began dramatically changing, then the turbidity delta smelt are assumed to use to see their food as larvae (Baskerville-Bridges et al. 2004) and use to hide from predators at later life stages (sensu Gregory and Levings 1998) lessened. Water temperatures are expected to rise (Dettinger 2005), which can only generate greater areas of stressful or even lethal temperature conditions for longer periods. Modeled future conditions suggest difficult conservation challenges and choices lie ahead (Feyrer et al. 2011; Brown et al. unpublished data 2011).

Status of the Delta Smelt Critical Habitat

The Status of Critical Habitat and Environmental Baseline sections are combined into one section in this document. The Service designated critical habitat for the delta smelt on December 19, 1994 (Service 1994). The geographic area encompassed by the designation includes all water and all submerged lands below ordinary high water and the entire water column bounded by and contained in Suisun Bay (including the contiguous Grizzly and Honker Bays); the length of Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma sloughs; and the existing contiguous waters contained within the legal Delta (as defined in section 12220 of the California Water Code) (Service 1994).

Conservation Role of Delta Smelt Critical Habitat

The Service's primary objective in designating critical habitat was to identify the key components of delta smelt habitat that support successful spawning, larval and juvenile transport, rearing, and adult migration. Delta smelt are endemic to the Bay-Delta and the vast majority only live one year. Thus, regardless of annual hydrology, the Delta must provide suitable habitat all year, every year. Different regions of the Delta provide different habitat conditions for different life stages, but those habitat conditions must be present when needed, and have sufficient connectivity to provide migratory pathways and the flow of energy, materials and organisms among the habitat components. The entire Delta and Suisun Bay are designated as critical habitat; over the course of a year, the entire habitat is occupied.

Description of the Primary Constituent Elements

In designating critical habitat for the delta smelt, the Service identified the following primary constituent elements essential to the conservation of the species:

Primary Constituent Element 1: Physical habitat" is defined as the structural components of habitat. Because delta smelt is a pelagic fish, spawning substrate is the only known important structural component of habitat. It is possible that depth variation is an important structural characteristic of pelagic habitat that helps fish maintain position within the estuary's LSZ (Bennett et al. 2002; Hobbs et al. 2006).

Primary Constituent Element 2: "Water" is defined as water of suitable quality to support various delta smelt life stages with the abiotic elements that allow for survival and reproduction. Delta smelt inhabit open waters of the Delta and Suisun Bay. Certain conditions of temperature, turbidity, and food availability characterize suitable pelagic habitat for delta smelt and are discussed in detail in the Status of the Species/Environmental Baseline section, above. Factors such as high entrainment risk and contaminant exposure can degrade this PCE even when the basic water quality is consistent with suitable habitat.

Primary Constituent Element 3: "River flow" is defined as transport flow to facilitate spawning migrations and transport of offspring to LSZ rearing habitats. River flow includes both inflow to and outflow from the Delta, both of which influence the movement of migrating adult, larval, and juvenile delta smelt. Inflow, outflow, and Old and Middle Rivers flow influence the vulnerability of delta smelt larvae, juveniles, and adults to entrainment at Banks and Jones (refer to Status of the Species/Environmental Baseline section, above). River flow interacts with the fourth primary constituent element, salinity, by influencing the extent and location of the highly productive LSZ where delta smelt rear.

Primary Constituent Element 4: "Salinity" is defined as the LSZ nursery habitat. The LSZ is where freshwater transitions into brackish water; the LSZ is defined as 0.5-6.0 psu (parts per thousand salinity; (Kimmerer 2004). The 2 psu isohaline is a specific point within the LSZ where the average daily salinity at the bottom of the water is 2 psu (Jassby et al. 1995). By local convention the location of the LSZ is described in terms of the distance from the 2 psu isohaline to the Golden Gate Bridge (X2); X2 is an indicator of habitat suitability for many San Francisco Estuary organisms and is associated with variance in abundance of diverse components of the ecosystem (Jassby et al. 1995; Kimmerer 2002). The LSZ expands and moves downstream when river flows into the estuary are high. Similarly, it contracts and moves upstream when river flows are low. During the past 40 years, monthly average X2 has varied from as far downstream as San Pablo Bay (45 km) to as far upstream as Rio Vista on the Sacramento River (95 km). At all times of year, the location of X2 influences both the area and quality of habitat available for delta smelt to successfully complete their life cycle. In general, delta smelt habitat quality and surface area are greater when X2 is located in Suisun Bay. Both habitat quality and quantity diminish the more frequently and further the LSZ moves upstream, toward the confluence.

Overview of Delta Smelt Habitat and the Primary Constituent Elements

As previously described in the Status of the Species/Environmental Baseline section, delta smelt live their entire lives in the tidally-influenced fresh- and brackish waters of the San Francisco Estuary (Moyle 2002). Delta smelt are an open-water, or pelagic, species. They do not associate strongly with structure. They may use nearshore habitats for spawning (PCE #1), but free-swimming life stages mainly occupy offshore waters (PCE #2). Thus, the distribution of the population is strongly influenced by river flows through the estuary (PCE #3) because the quantity of fresh water flowing through the estuary changes the amount and location of suitable low-salinity, open-water habitat (PCE #4). This is true for all life stages. During periods of high river flow into the estuary, delta smelt distribution can transiently extend as far west as the Napa

River and San Pablo Bay. Delta smelt distribution is highly constricted near the Sacramento-San Joaquin river confluence during periods of low river flow into the estuary (Feyrer et al. 2007). In the 1994 designation of critical habitat, the best available science held that the delta smelt population was responding to variation in spring X2. In the intervening 14 years, the scientific understanding of delta smelt habitat has improved. The current understanding is that X2 and the combined water flows of the Old River and Middle River both must be considered to manage entrainment and that X2 indexes important habitat characteristics throughout the year.

Alterations to Estuarine Bathymetry PCE # 1 (~ 1850-present)

The first major change in the LSZ was the conversion of the landscape over which tides oscillate and river flows vary (Nichols et al. 1986). The ancestral Delta was a large tidal marsh-floodplain habitat totaling approximately 300,000 acres. Most of the wetlands were diked and reclaimed for agriculture or other human use by the 1920s. The physical habitat modifications of the Delta and Suisun Bay were mostly due to land reclamation and urbanization. Water conveyance projects and river channelization have had some influence on the regional physical habitat by armoring levees with riprap, building conveyance channels like the Delta Cross Channel, storage reservoirs like Clifton Court Forebay, and by building and operating temporary barriers in the south Delta and permanent gates and water distribution systems in Suisun Marsh.

In the 1930s to 1960s, the shipping channels were dredged deeper (~12 m) to accommodate shipping traffic from the Pacific Ocean and San Francisco Bay to ports in Sacramento and Stockton. These changes left Suisun Bay and the Sacramento-San Joaquin river confluence region as the largest and most bathymetrically variable places in the LSZ. This region remained a highly productive nursery for many decades (Stevens and Miller 1983; Moyle et al. 1992; Jassby et al. 1995). However, the deeper landscape created to support shipping and flood control requires more freshwater outflow to maintain the LSZ in the large Suisun Bay/river confluence region than was once required (Gartrell 2010).

Seasonal salinity intrusion reduces the temporal overlap of the LSZ (indexed by X2) with the Suisun Bay region, especially in the fall (Feyrer et al. 2007, 2010). Thus, the second major change has been in the frequency with which the LSZ is maintained in Suisun Bay for any given amount of precipitation (DFG 2010). This metric showed a step-decline in 1977 from which it has never recovered for more than a few years at a time. Based on model forecasts of climate change and water demand, this trend is expected to continue (Feyrer et al. 2011). As such this alteration of PCE # 1 also affects the other PCEs, particularly PCE # 4. The major landscape factor affecting this interaction was the dredging of shipping channels.

Spawning delta smelt require all four PCEs, but spawners and embryos are the life stage that is believed to most require a specific structural component of habitat. Spawning delta smelt require sandy or small gravel substrates for egg deposition (Bennett 2005). The major invasive species effect on physical habitat is the dense growth of submerged aquatic vegetation in the Delta (described in more detail below). These plants carpet large areas in parts of the Delta such as Frank's Tract. The vegetation beds act as mechanical filters removing turbidity and possibly

other water quality components as the tides and river flows move water over them (Hestir 2010). Thus, the proliferation of submerged aquatic plants has likely also reduced the area of nearshore habitat suitable for delta smelt spawning.

Alterations to Water (PCE # 2)

PCE # 2 is primarily referring to a few key water quality components (other than salinity) that influence spawning and rearing habitat suitability for delta smelt. Research to date indicates that water quality conditions are more important than physical habitat conditions for predicting where delta smelt occur (Feyrer et al. 2007; Nobriga et al. 2008) – probably because delta smelt is a pelagic fish except during its egg/embryo stage. However, the interaction of water quality and bathymetry is thought to generally affect estuarine habitat suitability (Peterson 2003) and there is evidence that delta smelt habitat is optimized when appropriate water quality conditions overlap the Suisun Bay region (Moyle et al. 1992; Hobbs et al. 2006; Feyrer et al. 2011). This is discussed further in the section about PCE # 4 (salinity).

Reduced turbidity (1999-present)

The next major change was a change in estuarine turbidity that culminated in an estuary-wide step-decline in 1999 (Schoellhamer 2011). For decades, the turbidity of the modified estuary had been sustained by very large sediment deposits resulting mainly from gold mining in the latter 19th century. The sediments continued to accumulate into the mid-20th century, keeping the water relatively turbid even as sediment loads from the Sacramento River basin declined due to dam and levee construction (Wright and Schoellhamer 2004). The flushing of the sediment deposits may also have made the estuary deeper overall and thus a less suitable nursery from the 'static' bathymetric perspective (Schroeter 2008). Delta smelt larvae require turbidity to initiate feeding (Baskerville-Bridges et al. 2004), and as explained above, older fish are thought to use turbidity as cover from predators. Thus, turbidity is an aspect of PCE # 2 which is a necessary water quality aspect of delta smelt's critical habitat.

Dams and armored levees have contributed to the long-term decline in sediment load to the estuary (Wright and Schoellhamer 2004) and to the clearing of estuary water. This is a long-term effect that stemmed from building and maintaining infrastructure. Opportunities to substantively address this change are limited due to the extreme Central Valley flood and water supply risks that would result from decommissioning dams or removing levees.

Alterations of River Flows PCE # 3

This PCE refers to the transport flows that help guide young delta smelt from spawning habitats to rearing habitats, and to flows that guide adult delta smelt from rearing habitats to spawning habitats. Delta outflow also has some influence on delta smelt's supporting food web (Jassby et al. 2002; Kimmerer 2002) and it affects abiotic habitat suitability as well (Feyrer et al. 2007; 2011). The latter is expanded upon in the discussion of PCE # 4. The environmental driver with the strongest influence on PCE # 3 is highly dependent on the time-scale being considered. The

tide has the largest influence on flow velocities and directions in delta smelt's critical habitat at very short timescales (minutes to days), whereas interannual variation in precipitation and runoff has the largest influence on flows into and through the Delta at very long timescales (years to decades), and sometimes at shorter time scales (days to weeks) during major storm events. Changes to flow regimes can have the largest influence on PCE #3 at timescales of weeks to seasons. This is particularly true during periods of low natural inflow, for instance during the fall and during droughts, and in the south Delta where Old and Middle River flows are often managed using changes in export flow rates.

Salinity PCE # 4

The core delta smelt habitat, is the LSZ (Moyle et al. 1992; Bennett 2005). The LSZ is where freshwater transitions into brackish water, and is defined as the area of the estuary where salinity ranges from 0.5-6.0 psu (parts per thousand salinity; Kimmerer 2004). This area is always moving due to tidal and river flow variation. Larval delta smelt tend to reside somewhat landward (upstream) of X2 (Dege and Brown 2004), but the center of juvenile distribution tends to be very near X2 until the fish start making spawning migrations in the winter (Feyrer et al. 2011; Sommer et al. 2011). Because of this association between the distribution of salinity in the estuary and the distribution of the delta smelt population, the tidal and river flows that comprise

PCE # 3 affect PCE # 4.

The expansion and contraction of the LSZ affects the areal extent of abiotic habitat for delta smelt, both during spring (Kimmerer et al. 2009) and fall (Feyrer et al. 2007, 2011). In the spring, most delta smelt are larvae or young juveniles and the LSZ is typically maintained over the expansive Suisun Bay region. Thus, abiotic habitat "limitation" is unlikely and no consistent influence of spring X2 variation on later stage abundance estimates has been reported to date (Jassby et al. 1995; Bennett 2005; Kimmerer et al. 2009). Historical maxima in juvenile abundance according to CDFW's TNS occurred in low outflow years when abiotic habitat area was comparatively low (Kimmerer 2002; Kimmerer et al. 2009).

In contrast, during fall delta smelt are late stage juveniles and for the past decade or more, the LSZ has been persistently constricted by low Delta outflow. Fall habitat conditions affect delta smelt distribution and the concurrent FMWT abundance index (Feyrer et al. 2007, 2011). However, the quantitative life cycle models developed to date have not found evidence for a year over year effect of fall LSZ location on delta smelt population dynamics (Mac Nally et al. 2010; Thompson et al. 2010; Deriso 2011).

It is now recognized that some delta smelt occur year-around in the Cache Slough region including the Sacramento River Deep Water Shipping Channel and Liberty Island (Kimmerer 2011; Miller 2011; Sommer et al. 2011). The latter has been a consistently available habitat only since 1997. This region is often lower in salinity than 0.6 psu – the lower formal limit of the LSZ as defined by Kimmerer (2004). Delta smelt likely use it because it is one of the most turbid habitats remaining in the Delta (Nobriga et al. 2005). A recent population genetic study found no

evidence that delta smelt inhabiting this region are unique compared to delta smelt using the LSZ-proper (Fisch et al. 2011), therefore it is likely that individual delta smelt migrate between the LSZ and the Cache Slough region. This is consistent with the high summer water temperatures observed there, which might compel individual delta smelt to seek out cooler habitats within and outside the Cache Slough region.

Cumulative Effects

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

Within the action area, non-Federal diversions of water (e.g., municipal and industrial uses, as well as diversions through intakes serving numerous small, private agricultural lands) are on-going and likely to continue into the foreseeable future. These non-federal diversions are not likely to entrain very many delta smelt based on the results of a study by Nobriga et al. (2004). Nobriga et al. (2004) reasoned that the littoral location and low-flow operational characteristics of these diversions reduced their risk of entraining delta smelt. A study of the Morrow Island Distribution System by DWR produced similar results, with one demersal species and one species that associates with structural environmental features together accounting for 97-98 percent of entrainment; only one delta smelt was observed to be entrained during the two years of the study (DWR 2007). Although these non-federal diversions do not appear to entrain large numbers of delta smelt, they are a source of entrainment for delta smelt.

State or local levee maintenance may also destroy or adversely affect delta smelt spawning or rearing habitat and interfere with natural, long term spawning habitat-maintaining processes. Operation of flow-through cooling systems on the Mirant electrical power generating plants that draw water from and discharge into the action area may also adversely affect delta smelt in the form of entrainment and locally increased water temperatures.

Adverse effects to delta smelt and its critical habitat may result from point and non-point source chemical contaminant discharges within the action area. These contaminants include, but are not limited to ammonia and free ammonium ion, numerous pesticides and herbicides, and oil and gasoline product discharges. Oil and gasoline product discharges may be introduced into Delta waterways from shipping and boating activities and from urban activities and runoff. Implicated as potential stressors of delta smelt, these contaminants may adversely affect fish reproductive success and survival rates.

Other future, non-Federal actions within the action area that are likely to occur and may adversely affect delta smelt and its critical habitat include: the dumping of domestic and industrial garbage that decreases water quality; construction and maintenance of golf courses that reduce habitat and introduce pesticides and herbicides into the aquatic environment; oil and gas development and production that may affect aquatic habitat and may introduce pollutants into the

water; agricultural activities, including burning or removal of vegetation on levees that reduce riparian and wetland habitats that contribute to the quality of habitat used by delta smelt; and livestock grazing activities that may degrade or reduce riparian and wetland habitats that contribute to the quantity and quality of habitat used by delta smelt.

Climate Change

The global average temperature has risen by approximately 0.6 degrees centigrade during the 20th Century (International Panel on Climate Change 2001, 2007; Adger et al 2007). There is an international scientific consensus that most of the warming observed has been caused by human activities (International Panel on Climate Change 2001, 2007; Adger et al. 2007), and that it is "very likely" that it is largely due to increasing concentrations of greenhouse gases (carbon dioxide, methane, nitrous oxide, and others) in the global atmosphere from burning fossil fuels and other human activities (Cayan et al. 2005, EPA Global Warming webpage http://yosemite.epa.gov; Adger et al. 2007). Eleven of the twelve years between 1995 and 2006 rank among the twelve warmest years since global temperatures began in 1850 (Adger et al. 2007). The warming trend over the last fifty years is nearly twice that for the last 100 years (Adger et al. 2007). Under a high emissions scenario, the International Panel on Climate Change estimates that global temperatures will rise another four degrees centigrade by the end of this Century; even under a low emissions growth scenario, the International Panel on Climate Change estimates that the global temperature will go up another 1.8 degrees centigrade (International Panel on Climate Change 2001). The increase in global average temperatures affects certain areas more than others. The western United States, in general, is experiencing more warming than the rest of the Nation, with the 11 western states averaging 1.7 degrees Fahrenheit warmer temperatures than this region's average over the 20th Century (Saunders et al. 2008). California, in particular, will suffer significant consequences as a result of global warming (California Climate Action Team 2006).

In California, reduced snowpack will cause more winter flooding and summer drought, as well as higher temperatures in lakes and coastal areas. The incidence of wildfires in California will also increase and the amount of increase is highly dependent upon the extent of global warming. No less certain than the fact of global warming itself is the fact that global warming, unchecked, will harm biodiversity generally and cause the extinction of large numbers of species. If the global mean temperatures exceed a warming of two to three degrees centigrade above pre-industrial levels, twenty to thirty percent of plant and animal species will face an increasingly high risk of extinction (International Panel on Climate Change 2001, 2007).

The mechanisms by which global warming may push already imperiled species closer or over the edge of extinction are multiple. Global warming increases the frequency of extreme weather events, such as heat waves, droughts, and storms (International Panel on Climate Change 2001, 2007; California Climate Action Team 2006; Lenihan et al. 2003). Extreme weather events may cause mortality of individuals and significantly influence which species will remain extant or occur in natural habitats. Where populations are isolated, a changing climate may result in local extinctions, with range shifts precluded by lack of habitats.

The delta smelt is an obligate, aquatic species and its population could be negatively affected by climate change. Through the use of models and evidence of planetary warming due to greenhouse gasses, science can predict the possible ecological changes that might occur in the San Francisco Bay-Delta ecosystem in future years (Cloern et al. 2011). Dramatic weather changes could result in an increased frequency of drought within the legal Delta, increased air temperatures, reduced suitable aquatic habitat (Cloern et al. 2011) and also reduced native prey populations. Reductions in freshwater outflow can shift X2 upstream, where habitat conditions are less suitable. Shifts in X2 may have negative consequences for delta smelt breeding and survival. Conversely, climate change may lead to years where heavy rainfall and snow melt is common, causing more frequent flood events and sea level rise that may lead to drastic changes in water salinity levels appropriate for delta smelt survival.

There is currently no quantitative analysis of how ongoing climate change is currently affecting delta smelt and the Delta ecosystem. Climate change could have caused shifts in the timing of flows and water temperatures in the Delta which could lead to a change in the timing of migration of adult and juvenile delta smelt.

Effects of the Proposed Action

CDBW proposes to continue to utilize 2,4-D and Glyphosate along with the adjuvant Agri-dex during the 2013-2017 WHCP. Application of the adjuvant and these herbicides onto water hyacinth mats in the Delta may pose direct and indirect effects to delta smelt and its critical habitat. Although, based on toxicological studies conducted, it is anticipated that any direct effects to delta smelt are likely to be low.

CDBW proposes to begin utilizing penoxsulam and imazamox and the adjuvant Competitor only in Areas 3 and 4 between March 1 and November 30 for the 2013-2017 WHCP. Application of the adjuvant and the herbicides onto water hyacinth mats within the Delta may pose direct and indirect effects to delta smelt and its critical habitat. In Areas 3 and 4 it is anticipated that any direct effects to delta smelt are likely to be low because the herbicides will be applied where delta smelt habitat is considered to be of poor quality and the occurrence of delta smelt in those areas is low.

However, because of the timing and location of its use, it is anticipated that any direct effects to delta smelt are likely to be low.

No permanent effects to delta smelt critical habitat are likely to occur as a result of WHCP operations. Temporary effects to critical habitat include habitat loss caused by decreased DO levels (due to decaying water hyacinth), and decreases in the abundance of aquatic invertebrates that form the prey base of the delta smelt. Decreased DO below 5 mg/L could result in behavioral avoidance or physiological stress by adult delta smelt, or egg/larval mortality.

2,4-D and Glyphosate

Acute toxicological studies conducted on delta smelt were performed by CDFW-Aquatic Toxicology Laboratory. The results demonstrated that the environmental concentrations which would result from WHCP activities were less than toxicity thresholds for larval delta smelt (DFG 2004). Toxicological data and field studies suggest that 2,4-D, glyphosate, and Agri-Dex present low mortality risk to delta smelt.

Xie (2005) conducted monitoring of 2,4-D in a field application setting on juvenile rainbow trout which are used as surrogates for delta smelt because they are an established cold-water fish used for toxicity testing. The study observed no acute toxicity to juvenile rainbow trout but observed vitellogenin-induction levels higher than controls in laboratory exposures. The increased production of vitellogenin, an egg yolk precursor, indicates that 2,4-D could cause endocrine disruption at EPA-permitted application rates (Xie 2005). The estrogenic activity of 2,4-D is concerning as the metabolic consequences of increase in unneeded egg yolk precursor production in females or the production of any egg yolk precursors in males is unknown. Endocrine disruption could alter the development, growth or reproduction of delta smelt. No additional studies have further linked 2,4-D to endocrine disruption in aquatic species since Xie (2005). The extent to which individual delta smelt may be affected by 2, 4-D in this manner or whether such effects would have population level consequences cannot be determined with currently available scientific information.

Indirect ecosystem level effects from broad spectrum herbicide application include; decreased productivity for food web production within lower tropic levels, increased areas with low DO, and multiple chemical exposures to delta smelt at low doses. Although studies of 2,4-D, glyphosate, and Agri-Dex have not shown individual pronounced toxicological effects on delta smelt, or their eggs or larvae, it is not clear how these herbicides will interact when combined with other contaminants present within the delta. In the spring and summer months, there are several sources of pesticides within the Delta including external and within-delta inputs (Kuivilia and Moon 2004). Interactions between pesticides, herbicides, and other contaminants within the Delta may cause harm to delta smelt and/or their food web. Zooplankton is a key food source for delta smelt. Richards *et al.* (2004) linked reduced zooplankton diversity within the Delta to increased contaminants, which could be an important factor in the decrease of delta smelt populations (Kuivila and Foe 1995).

Most delta smelt spawning occurs from April through mid-May (Moyle 2002) with larvae development coinciding with the proposed April 1 start date of WHCP herbicide treatments within the delta. Contaminants and physiochemical stressors (i.e. low DO levels or high carbon dioxide levels) can deteriorate the health of delta smelt leaving them more vulnerable to harm and/or harassment caused by predation and disease, particularly during their development, as larval and juvenile smelt are more sensitive to environmental stressors than adult delta smelt (Teh 2007). Environmental stressors such as decreased levels of DO caused by decaying water hyacinth following herbicide treatment, can particularly affect delta smelt eggs and larvae. Delta

smelt larvae are semi-buoyant and subject to hydrology and could be directed by river flows into areas of low DO which could cause direct mortality, harm and/or harassment to the larvae.

Penoxsulam and Imazamox

The newly proposed herbicides penoxsulam and imazamox included for the 2013-2017 WHCP program have only recently been registered in California. Because the herbicides are newly registered, little or no independent toxicity data is available other than that generally produced during the registration process. Due to recent registration, very little additional toxicological data is available. Longer aqueous half-lives and increased mobility for penoxsulam and imazamox as compared to 2,4-D and glyphosate suggest the potential for increased aquatic environmental risk. Immunofuction and endocrine effects from exposures are also unknown. Concerns about potential risks may be addressed by bioassays on delta smelt. Proposed future toxicity tests will clarify the risk of penoxsulam and imazamox on larval and adult delta smelt from their use. Prior to the proposed future toxicity tests being conducted on delta smelt, the WHCP is proposing to only utilize penoxsulam and imazamox in Areas 3 and 4 from March 1 to November 30 when delta smelt are unlikely to be present in the area to further reduce any possible risks to delta smelt.

Acute toxicology data for the newly registered penoxsulam and imazamox are available only from the EPA pesticide registration process and thus very few peer reviewed studies are available. Toxicity tests on other fishes showed penoxsulam and imazamox to be practically nontoxic with LC50's above 100 mg/L. Penoxsulam and imazamox have bluegill EC50's of >103 and >120 mg/L which are lower in comparison to 2,4-D and Glyphosate, 2600 and >1000 mg/L respectively, indicative of higher toxicity (Fairchild 2011). Despite higher toxicities, the reduced environmental risk of penoxsulam and imazamox comes from the reduced application volume required during treatment. The EPA's Ecological Risk Assessment for penoxsulam found that for two fish species, risk did not exceed concern levels for aquatic organisms or endangered species (USEPA 2007). No EPA Ecological Risk Assessment has been conducted for imazamox. Acute or chronic data on the effects of exposures of penoxsulam or imazamox on delta smelt are not yet available.

The registration toxicity data for standard toxicity when testing fish species suggests that environmental concentrations from the WHCP activities with the proposed chemicals would be less than the toxicity thresholds. Although toxicity thresholds for these two herbicides are lower than for 2,4-D or glyphosate (implying they are more toxic), risk from their use is reduced because the WHCP proposes to apply them at lower concentrations than the existing program herbicides. This available data suggest that there would be no effect on delta smelt from their use.

Adjuvants: Agri-Dex and Competitor

Acute toxicity studies by the Washington State University have indicated that Agri-Dex® (the active ingredients are Paraffin Base Petroleum Oil/Polyoxyethylate Polyol Fatty Acid Esters)

is practically non-toxic and is significantly less toxic to rainbow trout than the previously used adjuvant R-11® (Smith et al. 2004). Competitor®, a vegetable oil-based adjuvant, is slightly toxic with a rainbow trout LC50 of 95 mg/L (WSDA 2005) as compared to >1000 mg/L for Agridex with similar application rates.

Conclusion

After reviewing the current status of the delta smelt and its critical habitat, the environmental baseline for the project action area, the effects of the proposed project, the applicant's proposed conservation measures, and cumulative effects, it is the Service's opinion that the WHCP, as proposed, is not likely to jeopardize the continued existence of the delta smelt or result in the destruction or adverse modification of its critical habitat. This determination was based on the temporary nature of the effects proposed, WHCP treatment restrictions, the applicant's proposed conservation measures, and the non-toxicity of 2,4-D, glyphosate and Agri-dex® at the levels used in the 2013-2017 WHCP.

INCIDENTAL TAKE STATEMENT

Section 9 of the Act and Federal regulation pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harass is defined by the Service as an intentional or negligent act or omission which creates the likelihood of injury to a listed species by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding or sheltering. Harm is defined by the Service to include significant habitat modification or degradation that results in death or injury to listed species by impairing behavioral patterns including breeding, 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 incidental to and not intended as part of the agency action is not considered to be prohibited taking under the Act, provided that such taking is in compliance with this Incidental Take Statement.

The measures described below are nondiscretionary for listed species in this biological opinion and must be implemented by USDA-ARS so they become binding conditions of any grant or permit issued to the applicant, as appropriate, in order for the exemption in section 7(o)(2) to apply. USDA-ARS has a continuing duty to regulate the activity that is covered by this incidental take statement. If the Federal agency (1) fails to require the applicant to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, and/or (2) fails to retain oversight to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse.

Amount or Extent of Take

Delta Smelt

The Service anticipates that incidental take of delta smelt in the form of harassment, harm, and mortality may occur. However, take is expected to be low. The Service anticipates difficulty in detecting take and cannot provide precise numbers of delta smelt that could be harassed, harmed, or killed by 2013-2017 WHCP operations. Delta smelt have a relatively small body size and they are relatively cryptic. Their presence in the Delta coincides with relatively turbid conditions, and their presence in aquatic vegetation makes them difficult to detect. Accordingly, the Service is quantifying take incidental to the project as all delta smelt located within the acres of water where hyacinth mats are being treated within the Delta and upland tributaries.

The Service anticipates that annually from March 1 to November 30 during the years of 2014 to 2017 as much as 3,500 acres (5,000 acres for the 2013 treatment season only) of water hyacinth mats located within the Delta which is designated as delta smelt critical habitat could be temporarily impacted as a result of chemical control of water hyacinth. Delta smelt distribution will shift throughout the year, depending on timing and life stage. As such, it can be assumed that not all of the 3,500 acres of water hyacinth mats within the Delta will have delta smelt occurring within the area during the time of application. Numerous sites within the WHCP treatment area are situated outside of delta smelt range (Areas 3 and 4) and/or are in areas that do not contain essential PCE's of delta smelt critical habitat. Additional sites are located outside of areas where delta smelt are likely to be found or in areas considered low quality delta smelt habitat due to low flow and/or low DO levels. The Service anticipates that in 2013 from March 1 to November 30, as much as 5,000 acres of water hyacinth mats located within the Delta which is designated as delta smelt critical habitat could be temporarily impacted as a result of chemical control of the water hyacinth.

The Service concludes that all delta smelt inhabiting areas surrounding up to 5,000 acres of water hyacinth mats in 2013, and as much as 3,500 acres of water hyacinth mats annually from 2014 to 2017, within delta smelt habitat may be harassed, harmed or killed by the temporary modification and degradation of habitat as a result of WHCP operations. This is the maximum acreage of water hyacinth mats that could potentially be treated through the proposed action. However, the Service believes that the actual acres of water hyacinth mats within habitat that could support delta smelt subject to WHCP operational activities will be less than the maximum acreage estimated above and that actual take in the form of harassment, harm or mortality will be minimal.

The Service has made this determination based on the applicant's proposed Conservation Measures, the number of treatment areas that do not contain essential PCE's for delta smelt or are considered to be of low quality habitat to delta smelt (caused by existing DO levels and slow or no flow, or are outside of delta smelt range), and delta smelt's varied distribution throughout the year which reduces the probability they would occur near or within the area at the time of treatment.

Upon implementation of the following reasonable and prudent measures, incidental take associated with WHCP operations in the form of harm, harassment, the USDA-ARS and CDBW will become exempt from the prohibitions described under section 9 of the Act.

Effect of the Take

The Service has determined that this level of anticipated take is not likely to result in jeopardy to the delta smelt. We base this determination on the temporary nature of the effects, proposed WHCP treatment restrictions, and the non-toxicity of 2,4-D, Glyphosate, and Agri-dex® at the levels used in habitat containing PCE's of delta smelt (within Areas 1 and 2) of the WHCP. Areas 3 and 4 are considered to be located outside of delta smelt range and the habitat does not contain PCE's for delta smelt. Therefore the WHCP treatment in areas 3 and 4 is not expected to have effect on delta smelt. Delta smelt critical habitat will not be adversely modified or destroyed by the proposed action.

Reasonable and Prudent Measures

The following reasonable and prudent measures are necessary and appropriate to minimize the effects of the WHCP project to the delta smelt:

1. The USDA-ARS shall ensure CDBW complies with this biological opinion.

2. The USDA-ARS shall ensure CDBW minimizes effects to delta smelt and its critical habitat.

Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the Act, the USDA-ARS shall ensure CDBW complies with the following terms and conditions, which implement the reasonable and prudent measures described above. These terms and conditions are non-discretionary.

1) The following terms and conditions implement Reasonable and Prudent Measure Number One (1) and Two (2):

    a. The USDA-ARS shall ensure CDBW implements the Conservation Measures proposed by CDBW and as described in the Project Description (page 21) of this biological opinion.

Reporting Requirements

The Service is to be notified immediately of the finding of any listed species or any unanticipated take or suspected take of species addressed in this opinion. Injured delta smelt must be cared for by a qualified person such as the Service-approved biologist. Dead individuals of this species

shall be placed in a zip-lock® plastic bag or jar with appropriate preservative solution containing a piece of paper with the date, time, location where the animal was found, and who found it written in permanent ink. The plastic bag should be placed in a freezer in a secure location. The Service and CDFW must be notified within twenty-four (24) hours of discovery of death or injury to delta smelt or GGS that occurs due to project related activities or is observed at the project site. The notification must include the date, time, and location of the incident or of the finding of a dead or injured animal and be clearly indicated on a USGS 7.5 minute quadrangle and other maps at a finer scale. The Service contacts are Kim S. Turner, Assistant Field Supervisor, at telephone (916) 930-5604 and Dan Crum, Resident Agent-in-Charge of the Service's Law Enforcement Division, at telephone (916) 414-6660. The CDFW contact person is Andrea Boertien, Environmental Scientist, at telephone (209) 942-6070.

The USDA-ARS and the CDBW will submit to the Service an annual project review and monitoring report by January 31st annually. The annual report will detail the following:

a. The date, time and number of times an individual site was treated;
b. Amount and type of chemical used at each site;
c. Treatment methods utilized throughout the year;
d. Whether listed species or its habitat were present;
e. All environmental scientist and treatment crew monitoring results; and
f. Results of the 2013 DO Monitoring Study.

The USDA-ARS and the CDBW will submit to the Service weekly field surveys beginning in late February to identify re-growing water hyacinth compared with the location of the most recent state and Federal fish monitoring data.

In addition, upon completion of toxicological testing of the herbicides imazamox and penoxsulam on delta smelt, all reporting, methodologies, and results will be provided to the Service.

Unless new information reveals effects of the proposed action may affect listed species to an extent not considered in this document or a new species or critical habitat is designated that may be affected by the proposed action, no further action pursuant to the Act is necessary. Any actions or proposed actions that are modified in a manner that causes an effect to listed species or critical habitat that was not considered in this consultation will require re-initiation.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities that can be implemented to further the purposes of the Act, such as preservation of endangered species habitat, implementation of recovery actions, or development of information and data bases.

1. The Service recommends CDBW and USDA-ARS work to increase public awareness of potential threats to proper ecosystem function by exotic species introductions such as water hyacinth and increase public awareness of the importance of native flora and fauna of the Delta and its tributaries.

2. The Service recommends CDBW and USDA-ARS work to assist the Service in implementing recovery actions identified in the recovery plans for the valley elderberry longhorn beetle, GGS, and Sacramento-San Joaquin Delta native fishes.

To be kept informed of actions minimizing or avoiding adverse effects or benefiting listed and proposed species or their habitats, the Service requests notification of the implementation of any conservation recommendations.

REINITIATION - CLOSING STATEMENT

This concludes formal consultation with USDA-ARS for the proposed 2013-2017WHCP. As provided in 50 CFR 402.16, re-initiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been maintained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the proposed action may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to listed species or critical habitat that was not considered in this opinion; or (4) a new species or critical habitat is designated that may be affected by the proposed action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease pending re-initiation.

Please address any questions or concerns regarding this response to Tiffany Heitz, Fish and Wildlife Biologist, at Tiffany_Heitz@fws.gov or (916) 930-5627. Please refer to Service file number 81410-2013-F-0005 in any future correspondence regarding this project.

Sincerely,

Michael Chotkowski
Field Supervisor

cc: NMFS, Garwin Yip
DFW, Jim Starr
CDBW, Director

Literature Cited

Adger, N., P. Aggarwal, S. Agrawala, J. Alcamo, A. Allali, O. Anisimov, N. Arnell, M. Boko, O. Canziani, T. Carter, G. Casassa, U. Confalonieri, R. V. Cruz, E. de Alba Alcaraz, W. Easterling, C. Field, A. Fischlin, B. B. Fitzharris, C. G. Carcia, C. Hanson, H. Harasawa, K. Hennessy, S. Huq, R. Jones, L. K. Bogataj, D. Karoly, R. Klein, Z. Kundzewicz, M. Lal, R. Lasco, G. Love, X. Lu, G. Magrin, L.J. Mata, R. McLean, B. Menne, G. Midgley, M.Q. Mizra, J. Moreno, L. Mortsch, I. Niang-Diop, R. Nicholls, B. Novaky, L. Nurse, A. Nyong, M. Oppneheimer, J. Palutikof, M. Parry, A. Patwardhan, P. R. Lankao, C. Rosenzweig, S. Schneider, S. Semenov, J. Smith J. Stone, J. van Ypersele, D. Vaughan, C. Vogel, T. Wilbanks, P.P. Wong, S. Wu, and G. Yohe. 2007. Working Group II Contribution to the Intergovernmental Panel on Climate Change 4th Assessment Report. Climate Change 2007: Climate change, impacts, adaptation, and vulnerability. Brussels, Belgium.

Amweg, E.L., D.P. Weston, & N.M. Ureda. 2005. Use and toxicity of pyrethroid pesticides in the Central Valley, California, USA. Environmental Toxicology and Chemistry 24: 966–972.

Arthur, J.F., M. D. Ball, and S.Y. Baughman. 1996. Summary of federal and State water project impacts in the San Francisco Bay-Delta estuary, California. Pages 445-495 in J. T. Hollibaugh (editor) San Francisco Bay: the ecosystem. AAAS, San Francisco, CA.

Atwater B.F, S.G. Conard, J.N. Dowden, C.W. Hedel, R.L. MacDonald, and W. Savage. 1979. History, landforms, and vegetation of the estuary's tidal marshes. Pages 347-386 in San Francisco Bay: The Urbanized Estuary – Investigations into the Natural History of San Francisco Bay and Delta With Reference to the Influence of Man. Pacific Division of the American Association for the Advancement of Science. San Francisco, CA.

Bailey, H. C., C. Alexander, C. DiGiorgio, M. Miller, S. I. Doroshov, and D. E. Hinton. 1994. The effect of agricultural discharge on striped bass (Morone saxatilis) in California's Sacramento-San Joaquin drainage. Ecotoxicology 3: 123-142.

Baskerville-Bridges, B., J.C. Lindberg, J.V. Eenennaam and S. Doroshov. 2000. Contributed Paper to the IEP: Progress and development of delta smelt culture: Year-end report 2000. IEP Newsletter, Winter 2001, 14(1): 24-30. Available at < http://www.water.ca.gov/iep/newsletters/2001/IEPNewsletterWinter2001.pdf#page=24>.

Baskerville-Bridges, B., J. C. Lindberg, and S.I. Doroshov. 2004. The effect of light intensity, alga concentration, and prey density on the feeding behavior of delta smelt larvae. Pages 219-228 *in* F. Feyrer, L.R. Brown, R.L. Brown and J.J. Orsi, eds. Early fife history of fishes in the San Francisco Estuary and watershed. Am. Fish. Soc. Symp. 39, Bethesda, MD, USA.

Baxter, R., R. Breuer, L. Brown, M. Chotkowski, F. Feyrer, M. Gingras, B. Herbold, A. Mueller-Solger, M. Nobriga, T. Sommer, and K. Souza. 2008. Pelagic organism decline progress report: 2007 synthesis of results. Available at: <http://www/science.calwater.ca.gov/pdf/workshops/POD/IEP_POD_2007_synthesis_report_031408.pdf>.

Bennett, W.A. and P.B. Moyle. 1996. Where have all the fishes gone? Interactive factors producing fish declines. Pages 519-541 in Hollibaugh, JT, editor. San Francisco Bay: the ecosystem. Pacific Division of the American Association for the Advancement of Science. San Francisco, CA.

Bennett, W.A., W.J. Kimmerer, and J.R. Burau. 2002. Plasticity in vertical migration by native and exotic fishes in a dynamic low-salinity zone. Limnology and Oceanography 47:1496-1507.

Bennett, W.A. 2005. Critical assessment of the delta smelt population in the San Francisco Estuary, California. San Francisco Estuary and Watershed Science Available at <http://repositories.cdlib.org/jmie/sfews/vol3/iss2/art1>.

Bennett, W.A., J.A. Hobbs, and S. Teh. 2008. Interplay of environmental forcing and growth-selective mortality in the poor year-class success of delta smelt in 2005. Final Report to the Interagency Ecological Program.

Brandes, Patricia L. and J.S. McLain. 2001. Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. Contributions to the biology of Central Valley salmonids. Fish Bulletin 179(2). 100 pp.

Brown, R.L. and W.J. Kimmerer. 2002. Delta smelt and CALFED's Environmental Water Account: A summary of the 2002 delta smelt workshop. Prepared for the CALFED Science Program, October 2002.

Brown, L.R. and D. Michniuk. 2007. Littoral fish assemblages of the alien-dominated Sacramento-San Joaquin Delta, California, 1980-1983 and 2001-2003. Estuaries and Coasts 30:186-200.

Brown, L. R., W. A. Bennett, R. W. Wagner, T. Morgan-King, N. Knowles, F. Feyrer, D. H. Schoellhamer, M.T. Stacey, and M. Dettinger. 2011. Implications for future survival of delta smelt from four climate change scenarios for the Sacramento-San Joaquin Delta, California, unpublished data.

Burns, Bo. 2009. Clearcase herbicide technical information (presentation). BASF Chemical Corporation.

CALFED Bay Delta Program. 2000. Ecosystem Restoration Program (ERP Volume 1. Sacramento, California: Prepared for the CALFED Bay Delta Program. CD-ROM Version.

California Climate Action Team. 2006. Climate action team report to Governor Schwarzenegger and the legislature. California Environmental Protection Agency, Sacramento, California.

California Department of Fish and Game. 2011a. http://www.delta.dfg.ca.gov/data/20mm/

California Department of Fish and Game. 2011b. Spring Kodiak Trawl Survey. http://www.delta.dfg.ca.gov/data/skt/

California Department of Fish and Game. 2011c. Summer Tow Net Survey. http://www.delta.dfg.ca.gov/data/townet/

Cayan, D. 2005. Northern hemisphere spring warming during the past five decades: links to snow cover losses. Presented at the 16th conference on climate variability and change. Scripps Institute of Oceanography, University of California, San Diego, January 13, 2005.

Cloern, J.E, N. Knowles L.R. Brown, D. Cayan, and M.D. Dettinger. 2011. Projected evolution of California's San Francisco Bay-Delta-River System in a century of climate change. PLoS ONE 6(9): e24465.

Connon, R. E., L.A. Deanovic, E.B. Fritsch, L.S. D'Abronzo, and I.Werner. 2011. Sublethal responses to ammonia exposure in the endangered delta smelt; *Hypomesus transpacificus* (Fam. Osmeridae). Aquatic Toxicology 105: 369-377.

Connon, R. E., J. Geist, J. Pfeiff, A.V. Loguinov, L.S. D'Abronzo, H. Wintz, C.D. Vulpe, and I. Werner. 2009. Linking mechanistic and behavioral responses to sublethal esfenvalerate exposure in the endangered delta smelt; *Hypomesus transpacificus* (Fam. Osmeridae). BMC Genomics 10: 608. 18 pp.

Culberson, S.D., C.B. Harrison., C. Enright, and M.L. Nobriga. 2004. Sensitivity of larval fish transport to location, timing, and behavior using a particle tracking model in Suisun Marsh, California. Pages 257-267 *in* F. Feyrer, L.R. Brown, R.L. Brown and J.J. Orsi, eds. Early life history of fishes in the San Francisco Estuary and watershed. Am. Fish. Soc. Symp. 39, Bethesda, MD, USA.

Davis, J.A., D. Yee, J.N. Collins, S.E. Schwarzbach, and S.N. Luoma. 2003. Potential for Increased Mercury Accumulation in the Estuary Food Web. San Francisco Estuary and Watershed Science. Vol. 1.

Dege, M. and L.R. Brown. 2004. Effect of outflow on spring and summertime distribution and abundance of larval and juvenile fishes in the upper San Francisco Estuary. Am. Fish. Soc. Symposium 39: 49-65.

Dettinger, M.D. 2005. From climate-change spaghetti to climate-change distributions for 21st Century California. San Francisco Estuary and Watershed Science 3: http://repositories.cdlib.org/jmie/sfews/vol3/iss1/art4.

Dugdale, R.C., F.P. Wilkerson, V.E. Hogue, and A. Marchi. 2007. The role of ammonium and nitrate in spring bloom development in San Francisco Bay. Estuarine, Coastal, and Shelf Science 73:17-29.

Dow Chemical Company. 2008. Product safety assessment, penoxsulam. 233-00438-MM-0908.

DWR Delta Overview. http://baydeltaoffice.water.ca.gov/sdbtbp/deltaoverview/delta_overview.pdf

DWR and Reclamation (California Department of Water Resources and U.S. Bureau of Reclamation). 1994. Biological Assessment - Effects of the Central Valley Project and State Water Project on Delta Smelt and Sacramento Splittail. Prepared for U.S. Fish and Wildlife Service, Sacramento, CA. 230 pp.

DWR 2007. Morrow Island Distribution System fish entrainment study. Interim data summary report, Division of Environmental Services, Sacramento, CA.

Edmunds, J.L., K.M. Kuivila, B.E. Cole, and J.E. Cloern. 1999. Do herbicides impair phytoplankton primary production in the Sacramento-San Joaquin River Delta? In: USGS Toxic Substances Hydrology Program Technical Meeting Proceedings, Charleston, SC, March 8-12, 1999.

Emerine, Sherrie E., R.J. Richardson, S.L. True, A.M. West, and R.L. Roten. 2010. Greenhouse response of six aquatic invasive weeds to imazamox. J. Aquat. Plant. Management. 48.105-111.

Erkkila, L.F., J.F. Moffett, O.B. Cope, B.R. Smith, and R.S. Nelson. 1950. Sacramento-San Joaquin Delta fishery resources: effects of Tracy pumping plant and delta cross channel. U.S. Fish and Wildlife Services Special Report. Fisheries 56. 109 pp.

ESA/Madrone. 1984. Environmental data report, Water hyacinth control plan for the Sacramento-San Joaquin Delta. Sacramento, California. Prepared for the U.S. Army Corps of Engineers.

Feyrer, F, B. Herbold, S.A. Matern, and P.B. Moyle. 2003. Dietary shifts in a stressed fish assemblage: consequences of a bivalve invasion in the San Francisco Estuary. Environmental Biology of Fishes 67:277-288.

Feyrer, F., M.L. Nobriga, and T.R. Sommer. 2007. Multi-decadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. Canadian Journal of Fisheries and Aquatic Sciences 64:723-734.

Feyrer, F., K. Newman, M.L. Nobriga and T.R. Sommer. 2011. Modeling the effects of future outflow on the abiotic habitat of an imperiled estuarine fish. Estuaries and Coasts: 34(1):120-128.

Fisch, K. M., J.M. Henderson, R.S. Burton and B. May. 2011. Population genetics and conservation implications for the endangered delta smelt in the San Francisco Bay-Delta. Conservation Genetics. Published online 1 July 2011.

Foott, J. S. and J. Bigelow. 2010. Pathogen survey, gill Na-K-ATPase activity, and leukocyte profile of adult delta smelt. California Department of Fish and Game 96(4): 223-231.

Foott, J. S. and R. Stone. 2007. Histological Evaluation and Viral Survey of Juvenile Longfin Smelt (*Spirinchus thaleichthys*) and Threadfin Shad (*Dorosoma petenense*) collected from the Sacramento-San Joaquin River Delta. U.S. Fish and Wildlife Service, California Nevada Fish Health Center FY 2007 Investigational Report. April-November 2007. 16 pp.

Ganssle, D. 1966. Fishes and decapods of San Pablo and Suisun bays. Pages 64-94 in D.W. Kelley (editors) Ecological studies of the Sacramento-San Joaquin Estuary, Part 1.

Gartrell, G. 2010. Delta Flow Criteria informational proceeding. State Water Resources Control Board, Contra Costa Water District. 14 pp.

Giddings, J.M., L.W. Hall, Jr, and K.R. Solomon. 2000. Ecological risks of diazinon from agricultural use in the Sacramento - San Joaquin River Basins, California. Risk Analysis 20:545–572.

Grimaldo, L.F., A. R. Stewart, and W. Kimmerer. 2009. Dietary segregation of pelagic and littoral fish assemblages in a highly modified tidal freshwater estuary. In review Marine and Coastal Fisheries.

Hallock, R.J. and W. Van Woert. 1959. A survey of anadromous fish losses in irrigation diversions from the Sacramento and San Joaquin rivers. California Fish and Game 45: 227-521.

Hay, D. 2007. Spawning biology of eulachons, longfins and some other smelt species Sacramento, November 15, 2007, Powerpoint presentation. Available on the internet at <http://www.science.calwater.ca.gov/pdf/workshops/workshop_smelt_presentation_Hay_111508.pdf>.

Herbold, B. 1994. Habitat requirements of delta smelt. Interagency Ecological Studies Program Newsletter, Winter 1994. California Department of Water Resources, Sacramento, California.

Hestir, E. 2010. Trends in estuarine water quality and submerged aquatic vegetation invasion. PhD dissertation, University of California, Davis.

Hobbs, J.A., W.A. Bennett, and J. Burton. 2006. Assessing nursery habitat quality for native smelts (Osmeridae) in the low-salinity zone of the San Francisco Estuary. Journal of Fish Biology 69: 907-922.

Hobbs, J.A, W.A. Bennett, J. Burton, and M. Gras. 2007. Classification of larval and adult delta smelt to nursery areas by use of trace elemental fingerprinting. Transactions of the American Fisheries Society 136:518-527.

Houde, E.D. 1987. Subtleties and episodes in the early life of fishes. Journal of Fish Biology 35 (Suppl A): 29-38.

Horpilla, J., A. Liljendahl-Nurminen, and T. Malinen. 2004. Effects of clay turbidity and light on the predator–prey interaction between smelts and chaoborids. Canadian Journal of Fisheries and Aquatic Sciences. 61: 1862-1870.

Howard, P. H., Ed. 1991. Handbook of Environmental Fate and Exposure Data for Organic Chemicals. Vol. III: Pesticides. Lewis Publishers, Chelsea, MI,7-21, 10-10.

Greenfield, B.K. and T.P. McNabb. 2005. Chapter 2: Control costs, operation, and permitting issues for non-chemical plant control: case studies in the San Francisco Bay-Delta region, California. Journal of Aquatic Plant Management. In: Aquatic Pesticide Monitoring Program Nonchemical Alternatives Year 3 Report. Oakland, California. San Francisco Estuary Institute. 15-24.

Greenfield, Ben K., Geoffrey S. Siemering, Joy C. Andrews, Michael Rajan, Stephen P. Andrews Jr., and David F. Spencer. 2007. Mechanical shredding of water hyacinth *(Eichhornia crassipes)*: effects on water quality in the Sacramento-San Joaquin River Delta, California. Estuaries and Coasts. 30(4):627-640.

Gren, G.G. 1983. Office report. Jacksonville, Florida. United States Army Corps of Engineers. August 3, 1983.

HSBD. 2001. U.S. National Library of Medicine. 2001. Hazardous Substances Databank. Bethesda, MD, 10-9 pp.

International Panel on Climate Change (IPCC). 2001. Climate Change 2001: The scientific basis. Contribution of the Working Group I to the 3rd Assessment Report of the Intergovernmental Panel on Climate Change. Houghton, J. T., Ding, D. J., Griggs, M., Noguer, P. J., van der linden, X. Dai, K. Maskell and C. A. Johnson (editors). Cambridge University Press, Cambridge, United Kindgom and New York, New York. 881 pp. Available at <http;//www.ipcc.ch/>.

_____. 2007. Climate Change 2007: The scientific basis. Contribution of the Working Group I to the 4th Assessment Report of the Intergovernmental Panel on Climate Change. Alley, R., T. Bernsten, N. L. Bindoff, Z. Chen, A. Chidthaisong, P. Friedlingstein, J. Gregory, G. Hegerl, M. Heimann, B. Hewiston, B. Hoskins, F. Joos, J. Jouzel, V. Kattsov, U. Lohmann, M. Manning, T. Matsumo, M. Molina, N. Nicholls, J. Overpeck, D. Qin, G. Raga, V. Ramaswamy, J. Ren, M. Rusticucci, S. Solomon, R. Somerville, T. F. Socker, P. Stott, R. F. Souffer, P. Whetton, R. A. Wood, D. Wratt. 21 pp. Available at <http;//www.ipcc.ch/>.

Jassby, A.D., W.J. Kimmerer, S.G. Monismith, C. Armor, J.E. Cloern, T.M. Powell, J.R.Schubel, and T.J. Vendlinski. 1995. Isohaline position as a habitat indicator for estuarine populations. Ecol. Appl. 5(1): 272-289.

Jassby, A.D., J.E. Cloern, and B.E. Cole. 2002. Annual primary production: patterns and mechanisms of change in a nutrient-rich tidal ecosystem. Limnology and Oceanography 47:698-712.

Johnson, M. L., I. Werner, S. Teh, and F. Loge. 2010. Evaluation of chemical, toxicological, and histopathologic data to determine their role in the pelagic organism decline. University of California, Davis. Davis, California.

Kawakami, B.T., R.A. Denton, and G. Gartrell. 2008. Investigation of the Basis for Increases in Delta Fall Salinity. CALFED Science Conference Poster Presentation.

Kimmerer, W.J. and J.J. Orsi. 1996. Causes of long-term declines in zooplankton in the San Francisco Bay estuary since 1987. Pages 403-424 in J. T. Hollibaugh (editor) San Francisco Bay: the ecosystem. AAAS, San Francisco, CA.

Kimmerer, W.J. 2002a. Physical, biological and management responses to variable freshwater flow into the San Francisco Estuary. Estuaries 25: 1275-1290.

_____. 2002b. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages. Marine Ecology Progress Series 243:39-55.

_____. 2004. Open water processes of the San Francisco Estuary: from physical forcing to biological processes. San Francisco Estuary and Watershed Science. Available on the internet at <http://repositories.cdlib.org/jmie/sfews/vol2/iss1/art1>.

_____. 2008. Losses of Sacramento River Chinook salmon and delta smelt to entrainment in water diversions in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science 6:2 (2). Available on the internet at <http://repositories.cdlib.org/jmie/sfews/vol6/iss2/art2>.

Kimmerer, W.J., E.S. Gross, and M.L. MacWilliams. 2009. Is the response of estuarine nekton to freshwater flow in the San Francisco Estuary explained by variation in habitat volume? Estuaries and Coasts (32): 375-389.15 pp. DOI 10.1007/s12237-008-9124-x.

Kimmerer, W.J. 2011. Modeling delta smelt losses at the South Delta export facilities. San Francisco Estuary and Watershed Science 9: Issue 1 [April 2011], article 6.

Knowles, N. 2002. Natural and human influences on freshwater inflows and salinity in the San Francisco Estuary at monthly to interannual scales. Water Resources Research 38(12): 1289. Available on the internet at < http://sfbay.wr.usgs.gov/publications/pdf/knowles_2002_sf_estuary.pdf>

Knutson Jr., A.C. and J.J. Orsi. 1983. Factors regulating abundance and distribution of the shrimp *Neomysis mercedis* in the Sacramento-San Joaquin Estuary. T. Am. Fish. Soc. 112: 476-485.

Kuivila, K. M. and C. G. Foe. 1995. Concentrations, transport, and biological effects of dormant spray pesticides in the San Francisco Estuary, California. Environmental Toxicology and Chemistry 14: 1141-1150.

Kuivila, K.M. and G.E. Moon. 2004. Potential exposure of larval and juvenile delta smelt to dissolved pesticides in the Sacramento-San Joaquin Delta, California. American Fisheries Society Symposium 39:229-242.

Langeland, K., M. Netherland, and W. Haller. 2009. Efficacy of herbicide active ingredients against aquatic weeds. University of Florida IFAS Extension. SS-AGR-44.

Lehman, P.W., G. Boyer, C. Hall, S. Waller, and K. Gehrts. 2005. Distribution and toxicity of a new colonial *Microcystis aeruginosa* bloom in the San Francisco Bay Estuary, California. Hydrobiologia 541:87-99.

Lenihan, J. R., Drapek, D. Bachelet, and R. Neilson. 2003. Climate change effects on vegetation distribution, carbon and fire in California. Ecological Applications 13(6): 1667-1681.

Lindberg, J. C., B. Baskerville-Bridges, and S.I. Doroshov. 2003. "Two Reproductive Concerns Tested in Captive Delta Smelt, *Hypomesus transpacificus*, 2002: I. Effect of substrate and water velocity on spawning behavior.

Linville, R.G., S.N. Luoma, L. Cutter, and G.A. Cutter. 2002. Increased selenium threat as a result of invasion of the exotic bivalve *Potamocorbula amurensis* into the San Francisco Bay-Delta. Aquatic Toxicology 57: 51-64.

Lott, J. 1998. Feeding habits of juvenile and adult delta smelt from the Sacramento-San Joaquin River Estuary. Interagency Ecological Program Newsletter 11(1):14-19. Available at <http://iep.water.ca.gov/report/newsletter/>.

Mac Nally, R., Thomson, J.R., Kimmerer, W. J., Feyrer, F., Newman, K.B., Sih, A., Bennett, W.A., Brown, L., Fleishman, E., Culberson, S.D., and G. Castillo. 2010. Analysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling (MAR). Ecological Applications 20(5): 1417–1430.

Madsen. J.D., and R.M. Wersal. 2008. Herbicide formulations for managing free-floating aquatic plants. 2008 Proceedings, Southern Weed Science Society. 61:210.

Mager, R.C., S.I. Doroshov, J.P. Van Eenennaam, and R.L. Brown. 2004. Early life stages of delta smelt. Pages 169-180 *in* F. Feyrer, L.R. Brown, R.L. Brown and J.J. Orsi, eds. Early fife history of fishes in the San Francisco Estuary and watershed. Am. Fish. Soc. Symp. 39, Bethesda, MD, USA.

Malik, J., Barry, G. and Kishore, G. Minireview. 1989. The herbicide glyphosate. BioFactors. 2(1): 17 25, 10-100.

Marine, K.R. and J.J. Cech Jr. 2004. Effects of high water temperature on growth, smoltification, and predator avoidance in juvenile Sacramento River Chinook salmon. North American Journal of Fisheries Management: 24(1):198–210.

Maunder, M.N and R. B. Deriso. 2011. A state–space multistage life cycle model to evaluate population impacts in the presence of density dependence: illustrated with application to delta smelt (*Hypomesus transpacificus*). Can. J. Fish. Aquat. Sci. 68: 1285–1306.

Miller, W. J. 2011. Revisiting assumptions that underlie estimates of proportional entrainment of delta smelt by state and federal water diversions from the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science, 9(1). Available at <http://escholarship.org/uc/item/5941x1h8>.

Monson, N.E., J.E. Cloern, and J.R. Burau. 2007. Effects of flow diversion on water and habitat quality: examples from California's highly manipulated Sacramento-San Joaquin.

Moyle, P.B. 2002. Inland fishes of California. University of California Press, Berkeley and Los Angeles, Ca.

Moyle, P.B., B. Herbold, D.E. Stevens, and L.W. Miller. 1992. Life history and status of delta smelt in the Sacramento-San Joaquin Estuary, California. Transactions of the American Fisheries Society 121:67-77.

Mueller-Solger, A.B., A.D. Jassby, and D.C. Mueller-Navarra. 2002. Nutritional quality of food resources for zooplankton (Daphnia) in a tidal freshwater system (Sacramento?San Joaquin River Delta), Limnol. Oceanogr. 47(5), 2002, 1468-1476.

Newman K.B. 2008. Sample design-based methodology for estimating delta smelt abundance. San Francisco Estuary and Watershed Science 6(3): article 3.Available at: <http://repositories.cdlib.org/jmie/sfews/vol6/iss3/art3>.

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

Nobriga, M. and M. Chotkowski 2000. Recent historical evidence of centrarchid increases and tule perch decrease in the Delta. Interagency Ecological Program Newsletter 13(1):23-27. Available at <http://www.iep.ca.gov/report/newsletter>.

Nobriga, M.L. 2002. Larval delta smelt diet composition and feeding incidence: environmental and ontogenetic influences. California Fish and Game 88:149-164.

Nobriga, M. L., Z. Matica, and Z.P. Hymanson 2004. Evaluating Entrainment Vulnerability to Agricultural Irrigation Diversions: A Comparison among Open-Water Fishes. Pages 281-295 in F. Feyrer, L.R. Brown, R.L. Brown, and J.J. Orsi, editors. Early Life History of Fishes in the San Francisco Estuary and Watershed. American Fisheries Society, Symposium 39, Bethesda, Maryland.

Nobriga, M.L., F. Feyrer, R.D. Baxter, and M. Chotkowski. 2005. Fish community ecology in an altered river delta: spatial patterns in species composition, life history strategies and biomass. Estuaries 28:776-785.

Nobriga, M.L. and F. Feyrer. 2007. Shallow-water piscivore-prey dynamics in California's Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science 5: Available at <http://repositories.cdlib.org/jmie/sfews/vol5/iss2/art4>.

Nobriga, M. L. and F. Feyrer . 2008. Diet composition of San Francisco Estuary striped bass: does trophic adaptability have its limits? Environmental Biology of Fishes. 83: 495-503.

Nobriga, M. and B. Herbold. 2008. Conceptual model for delta smelt (*Hypomesus transpacificus*) for the Delta Regional Ecosystem Restoration and Implementation Plan (DRERIP).

Nobriga, M.L., T.R. Sommer, F. Feyrer, and K. Fleming. 2008. Long-term trends in summertime habitat suitability for delta smelt, *Hypomesus transpacificus*. San Francisco Estuary and Watershed Science 6: Available at <http//repositories.cdlib.org/jmie/sfews/vol6/iss1/art1>.

Odum, W. E. 1988. Comparative ecology of tidal freshwater and salt marshes. Ann. Rev. Ecol. Syst. 19:147-176.

Oros, D.R. and I. Werner. 2005. Pyrethroid Insecticides: an analysis of use patterns, distributions, potential toxicity and fate in the Sacramento-San Joaquin Delta and Central Valley. White Paper for Interagency Ecological Program. SFEI Contribution 415. San Francisco Estuary Institute, Oakland, CA.

Orsi, J.J. and W. L. Mecum. 1996. Food limitation as the probable cause of a long-term decline in the abundance of Neomysis mercedis the oppossum shrimp in the Sacramento-San Joaquin estuary. Pages 375-401 in Hollibaugh, JT (ed), San Francisco Bay: the ecosystem. American Association for the Advancement of Science, San Francisco.

Ostrach, D. 2008. Multiple stressors and their effects on the striped bass population in the San Francisco estuary. Presented at Interagency Ecological Program 2008 Annual Workshop, Pacific Grove, CA, February 26-29, 2008.

Peterson, M. S., 2003. A conceptual view of environment-habitat-production linkages in Tidal Riverine Estuaries. Review in Fisheries Science 11(4): 291-313.

Powles, Stephen B. 2008. Evolved glyphosate-resistant weeds around the world: lessons to be learnt. Pest Management Science. 64(4)360-365.

Radtke, L.D. 1966. Distribution of smelt, juvenile sturgeon, and starry flounder in the Sacramento-San Joaquin Delta with observations on food of sturgeon, in Ecological studies of the Sacramento-San Joaquin Delta, Part II. In: S.L. Turner and D.W. Kelley (Eds.), Ecological Studies of the Sacramento–San Joaquin Estuary, pp. 115-129. California Department of Fish and Game Fish Bulletin 136.

Rast, W. and J. Sutton. 1989. Stable isotope analysis of striped bass food chain in Sacramento-San Joaquin Estuary, California, April-September, 1986. Water Resources Investigations Rept. 88-4164, U.S. Geological Survey, Sacramento, California. 62 pp.

Reclamation 2008. OCAP Biological Assessment on the Continued Long-term Operations of the Central Valley Project and the State Water Project.

Rose, K.A., J.H. Cowan, K.O. Winemiller, R.A. Myers, and R. Hilborn. 2001. Compensatory density-dependence in fish populations: importance, controversy, understanding, and prognosis. Fish and Fisheries 2: 293-327.

Ruhl, C.A., P.E. Smith, J.J. Simi, and J.R. Burau. 2006. The pelagic organism decline and long-term trends in Sacramento-San Joaquin Delta hydrodynamics. Presentation at the 4th Biennial 2006 CALFED Science Conference, October 23-25, 2006, Sacramento, California.

Saiki, M.K., M.R. Jennings, and R.H. Wiedmeyer. 1992. Toxicity of agricultural subsurface drainwater from the San Joaquin River, California, to juvenile Chinook salmon and striped bass. Transactions of the American Fisheries Society 121:78-93.

Saiki, M.K. 1998. An ecological assessment of the Grassland Bypass Project on fishes inhabiting the Grassland Water District, California. Final report submitted to U.S. Fish and Wildlife Service, Sacramento, CA. 72 pp.

San Francisco Estuary Institute (SFEI). 2004. *Syntheses of Scientific Knowledge for Maintaining and Improving Functioning of the South Bay Ecosystem and Restoring Tidal Salt Marsh and Associated Habitats over the Next 50 Years at Pond and Pond-Complex Scales.* Draft Final Report. Oakland, CA.

Schoellhamer, D. H. 2011. Sudden clearing of estuarine waters upon crossing the threshold from transport as an erodible sediment pool is depleted: San Francisco Bay, 1999. Estuaries and Coasts 34: 885-899.

Schroeter, RE. 2008. Biology and long-term trends of alien hydromedusae and striped bass in a brackish tidal marsh in the San Francisco Estuary. PhD dissertation, UC Davis.

Schuette, Jeff. 1998. Environmental fate of glyphosate. California Department of Pesticide Regulation. 13 pp.

SePRO 2010. Clearcast aquatic herbide label. SePRO Corporation. Indiana.

Slater, Steven. unpublished data California Department of Fish and Game.

Sogard, S. M. 1997. Size-selective mortality in the juvenile stage of teleost fishes: a review. Bulletin of Marine Science 60: 1129-1157.

Sobczak, W. V., J. E. Cloern, A. D. Jassby, and A. B. Muller-Solger. 2002. Bioavailability of organic matter in a highly disturbed estuary: The role of detrital and algal resources. Proceedings of the National Academy of Sciences 99, no. 12: 8101-8105.

Sommer, T.R., C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, B. Herbold, W. Kimmerer, A. Mueller-Solger, M. Nobriga, and K. Souza. 2007. The collapse of pelagic fishes in the upper San Francisco Estuary. Fisheries 32(6):270-277.

Sommer, T., F.H. Mejia, M.L. Nobriga, F. Feyrer, and L. Grimaldo. 2011. The Spawning Migration of Delta Smelt in the Upper San Francisco Estuary. San Francisco Estuary and Watershed Science 9(2)., 17 pages.

Spaar, S. 1994. Delta agricultural diversion evaluation1992 pilot study. California Department of Water Resources, Interagency Ecological Program Technical Report 3, Sacramento, California.

Spencer, D.F. and G.G. Ksander. 2005. Seasonal growth of water hyacinth in the Sacramento/San Joaquin Delta, California. Journal of Aquatic Plant Management. 43:91-94.

Stanley S.E., P.B. Moyle, and H.B. Shaffer. 1995. Allozyme analysis of delta smelt, *Hypomesus transpacificus*, and longfin smelt, *Spirinchus thaleichthys*, in the Sacramento-San Joaquin estuary. Copeia 1995:390–396.

Stevens, D.E. 1963. Food habits of striped bass, *Roccus saxatilis* (Walbaum), in the Sacramento-Rio Vista area of the Sacramento River. Master's Thesis. University of California, Davis.

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.

Sullivan et al., unpublished information.

Swanson, C. and J.J. Cech Jr. 1995. Environmental tolerances and requirements of the delta smelt, *Hypomesus transpacificus*. Final Report. California Department of Water Resources Contracts B-59499 and B-58959. Davis, California. July 20, 1995.

Swanson, C., T. Reid, P.S. Young, and J.J. Cech Jr. 2000. Comparative environmental tolerances of threatened delta smelt (*Hypomesus transpacificus*) and introduced wakasagi (*H. nipponensis*) in an altered California estuary. Oecologia 123: 384-390.

Sweetnam, D.A. and D.E. Stevens 1993. Report to the Fish and Game Commission: A status review of the delta smelt (*Hypomesus transpacificus*) in California. Candidate Species Status Report 93-DS. Sacramento, California. 98 pp plus appendices.

Sweetnam, D.A. 1999. Status of delta smelt in the Sacramento-San Joaquin Estuary. California Fish and Game 85:22-27.

Syracuse Environmental Research Associates, Inc. (SERA). 2010. Imazamox – Human Health and Ecological Risk Assessment Final Report. For USDA, Forest Service. New York. 158pp.

Taniguchi, Y., F.J. Rahel, D.C. Novinger, and K.G. Gerow.1998. Temperature mediation of competitive interactions among three fish species that replace each other along longitudinal stream gradients. Canadian Journal of Fisheries and Aquatic Sciences 55:1894-1901.

Teh, S. J. 2007. Final report of histopathological evaluation of starvation and/or toxic effects on pelagic fishes. UC Davis. 28 pages.

Thetmeyer. H. and U. Kils. 1995. To see and not be seen: the visibility of predator and prey with respect to feeding behaviour. Mar. Ecol. Prog. Ser. 126: 1-8.

Thomson, J.R., W.J. Kimmerer, L.R. Brown, K.M. Newman, Mac Nally, R., Bennett, W.A., Feyrer, F. and E. Fleishman. 2010. Bayesian change point analysis of abundance trends for pelagic fishes in the upper San Francisco Estuary. Ecological Applications 20(5): 1431–1448.

Trenham, P.C., H.B. Shaffer, and P.B. Moyle. 1998. Biochemical identification and assessment of population subdivision in morphometrically similar native and invading smelt species (*Hypomesus*) in the Sacramento-San Joaquin Estuary, California. T. Am. Fish. Soc. 127: 417-424.

Turner, J. L. and H. K. Chadwick 1972. Distribution and abundance of young-of-the-year striped bass, Morone saxatilis, in relation to river flow in the Sacramento-San Joaquin estuary. Transactions of the American Fisheries Society 101: 442-452.

Turner, J.L., Kelley, DW (editors). 1966. Ecological studies of the Sacramento-San Joaquin Delta, part II, fishes of the Delta. California Department of Fish and Game Fish Bulletin 136.

United States Environmental Protection Agency (USEPA). May 1997. Pesticide fact sheet, imazamox (Raptor herbicide). Office of Prevention, Pesticides, and Toxic Substances. Washington D.C..

_____2004. Ecological Risk Assessment for the Section 3 Registration of the New Chemical Penoxsulam for Uses on Rice. Environmental Fate and Effects Division (EFED). Washington DC. 55pp.

_____ 2005. Reregistration eligibility decision for 2,4-D. EPA 738-R-05-002. Prevention, Pesticides and Toxic Substance (7508C). 320 pp.

_____2007. Ecological Risk Assessment: Section 3, New Uses on Turf and for Control of Aquatic Vegetation in Aquatic Environments, Penoxsulam. Environmental Fate and Effects Division (EFED). Washington DC. 188pp.

USEPA Environmental Fate and Effects Division (EFED). September 2008. Ecological Risk Assessment Evaluating Imazamox for the Proposed New Use on Clearfield Rice. Washington DC. 85pp

United States Fish and Wildlife Service. 1991. Endangered and threatened wildlife and plants: Proposed threatened status for the delta smelt, October 3, 1991. Federal Register 56(192): 50075-50084.

_____. 1993. Endangered and threatened wildlife and plants: Determination of threatened status for the delta smelt. March 5, 1993. Federal Register 58(42):12854-12864.

_____. 1994a. Endangered and threatened wildlife and plants: Critical habitat determination for the delta smelt. December 19, 1994. Federal Register 59(242): 65256-65279.

_____. 1994b. Formal consultation on the 1994 operation of the Central Valley Project and State Water Project: Effects on delta smelt. Sacramento, California. 34 pp., plus figures.

_____. 1995. Formal consultation and conference on the effects of long-term operation of the Central Valley Project and State Water Project on the threatened delta smelt, delta smelt critical habitat, and proposed threatened Sacramento splittail. Sacramento, California. 52 pages, plus figures and attachment.

_____. 1996. Sacramento-San Joaquin Delta Native Fishes Recovery Plan. Portland, Oregon.

_____. 2004. Five Year Status Review for the Delta Smelt. Sacramento, California. 50 pp.

_____.2010. Endangered and Threatened Wildlife and Plants; 12-Month Finding on a Petition to Reclassify the Delta Smelt From Threatened to Endangered Throughout its Range. Federal Register 75(66):17667-17680.

Utne-Palm, A.C., and J.E. Stiansen. 2005. Effect of larval ontogeny, turbulence and light on prey attack rate and swimming activity in herring larvae. Journal of Experimental Marine Biology and Ecology 268(2):147-170.Available at <http://jeb.biologists.org/cgi/content/full/208/5/831>.

Walters, C. 1997. Challenges in adaptive management of riparian and coastal ecosystems. Conservation Ecology [online]1(2):1. Available at: <http://www.consecol.org/vol1/iss2/art1/>.

Walters, J. 1999. Environmental fate of 2,4-Dichlorophenoxyacetic acid. Sacramento, California. Department of Pesticide Regulation, Environmental Monitoring Program. 12pp.

Wang, J.C.S. 1986. Fishes of the Sacramento-San Joaquin Estuary and adjacent waters, California: a guide to the early life stages. Interagency Ecological Studies Program Technical Report 9. Sacramento.

Wang, J.C.S. 1991. Early life stages and early life history of the delta smelt, *Hypomesus transpacificus*, in the Sacramento-San Joaquin Estuary, with comparison of early life stages of the longfin smelt, *Spirinchus thaleichthys*. Interagency Ecological Studies Program Technical Report 28, August 1991.

Wang, J.C.S. 2007. Spawning, early life stages, and early life histories of the Osmerids found in the Sacramento-San Joaquin Delta of California. Tracy Fish Facilities Studies California Volume 38. U.S. Bureau of Reclamation, Mid-Pacific Region.

Washington Department of Agriculture. 2009. Summary of aquatic acute toxicity data for spray adjuvants allowed for use on aquatic sites in Washington. Pesticide Management Division.

Washington Department of Ecology (DOE). January 2012. Environmental impact statement for penoxsulam, imazamox, bispyribac-sodium, flumioxazin, & carfentrazone-ethy. State of Washington. Publiciation no. 00-10-04-Addendum1. 98pp.

Wauchope, R. D., Buttler, T. M., Hornsby A. G. , Augustijn Beckers, P. W. M. and Burt, J. P. 1992. SCS/ARS/CES Pesticide properties database for environmental decision making. Rev. Environ. Contam. Toxicol. 123: 1-157, 7-22

Weed Science Society of America. 1994. Herbicide Handbook, 7th Edition. Champaign, IL. 59pp.

Werner, I., L.A. Deanovic, V. Conner, V. de Vlaming, H.C. Bailey, and D.E. Hinton. 2000. Insecticide-caused toxicity to *Ceriodaphnia dubia* (Cladocera) in the Sacramento-San Joaquin River Delta, California, USA. Environ. Tox. Chem. 19(1): 215-227.

Werner, I, L. Deanovic, D. Markiewicz, M. Stillway, N. Offer, R. Connon, and S. Brander. 2008. Pelagic organism decline (POD): Acute and chronic invertebrate and fish toxicity testing in the Sacramento-San Joaquin Delta, 2006-2007. Final report to the Interagency Ecological Program, April 30, 2008.

Werner, I., D. Markiewicz, L. Deanovic, R. Connon, S. Beggel, S. Teh, M. Stillway, C. Reece. 2010. Pelagic organism decline (POD): Acute and chronic invertebrate and fish toxicity testing in the Sacramento-San Joaquin Delta, 2008-2010. Final Report. U.C. Davis-Aquatic Toxicology Laboratory, Davis, California.

Weston, D.P., J. You, and M.J. Lydy. 2004. Distribution and toxicity of sediment-associated pesticides in agriculture-dominated water bodies of California's Central Valley. Environmental Science and Technology 38: 2752-2759.

Weston, D.P, R.W. Holmes, J. You, and M.J. Lydy. 2005. Aquatic toxicity due to residential use of pyrethroid insecticides. Environmental Science and Technology 39: 9778-9784.

Weston, B.P. and M.J. Lydy. 2010. Urban and agricultural sources of pyrethroid insecticides to the Sacramento-San Joaquin Delta of California. Environmental Science and Technology 44:1833-1840.

Whitehead, A., K.M. Kuivila, J.L. Orlando, S. Kotelevtsev, and S.L. Anderson. 2004. Genotoxicity in native fish associated with agricultural runoff events. Environmental Toxicology and Chemistry: 23:2868–2877.

Wilkerson, F.P., R.C. Dugdale, V.E. Hogue, and A. Marchi. 2006. Phytoplankton blooms and nitrogen productivity in San Francisco Bay. Estuaries and Coasts 29:401-416.

Winemiller, K.O. and Rose, K.A. 1992. Patterns of life-history diversification in North American fishes: implications for population regulation. Canadian Journal of Fisheries and Aquatic Sciences 49:2196-2218.

Wisconsin Department of Natural Resources. 2012. Penoxsulam Chemical Fact Sheet. Madison, WI. DNR PUB-WT-977 2012.

Wright, S. A., and D.H. Schoellhamer. 2005. Estimating sediment budgets at the interface between rivers and estuaries with application to the Sacramento–San Joaquin River Delta. Water Resources Research 41. Available on the internet at <http://sfbay.wr.usgs.gov/publications/pdf/wright_2005_River EstuarySedBudgets.pdf>.

Personal Communications

Adib-Samii 2008. Personal communication via e-mail with Victoria Poage, USFWS, re: water temperature thresholds for collection of delta smelt in routine survey sampling, October 8, 2008

Ali-Ger 2008 Personal communication during the CALFED Science Conference

Lindberg, Joan. 2011. Personal communication during a meeting conducted by Brian Hansen, USFWS. 2011.

Appendix 1

Calculated* Maximum Concentrations of 2,4-D, Immediately Following WHCP Treatment

Concentration of:	**2,4-D** *(Active Ingredient)*
1.Chemical directly out of spray nozzle	2,300 ppm
2.Chemical in 1 meter deep water, @ 100% water contact	0.43 ppm
3.Chemical in 2 meter deep water, @ 100% water contact	0.21 ppm
4.Chemical in 1 meter deep water, @ 20% water contact	85 ppb
5.Chemical in 2 meter deep water, @ 20% water contact	43 ppb

*The concentrations above are based on the pounds of active ingredient in maximum specified application rate per acre, and an appropriate dilution factor based on the volume of water in the tank mix, or within one or two meter-acres.

Calculated* Maximum Concentrations of Glyphosate Immediately Following WHCP Treatment

Concentration of:	**Glyphosate***(Active Ingredient)*
1.Chemical directly out of spray nozzle	3,600 ppm
2.Chemical in 1 meter deep water, @ 100% water contact	0.34 ppm
3.Chemical in 2 meter deep water, @ 100% water contact	0.17 ppm
4.Chemical in 1 meter deep water, @ 20% water contact	67 ppb
5.Chemical in 2 meter deep water, @ 20% water contact	34 ppb

*The concentrations above are based on the pounds of active ingredient in maximum specified application rate per acre, and an appropriate dilution factor based on the volume of water in the tank mix, or within one or two meter-acres.

Calculated* Maximum Concentrations of Penoxsulam Immediately Following WHCP Treatment

Concentration of:	**Penoxsulam***(Active Ingredient)*
1.Chemical directly out of spray nozzle	105 ppm
2.Chemical in 1 meter deep water, @ 100% water contact	9.8 ppb
3.Chemical in 2 meter deep water, @ 100% water contact	4.9 ppb
4.Chemical in 1 meter deep water, @ 20% water contact	2 ppb
5.Chemical in 2 meter deep water, @ 20% water contact	1 ppb

*The concentrations above are based on the pounds of active ingredient in maximum specified application rate per acre, and an appropriate dilution factor based on the volume of water in the tank mix, or within one or two meter-acres.

Calculated* Maximum Concentrations of Imazamox Immediately Following WHCP Treatment

Concentration of:	**Imazamox***(Active Ingredient)*
1.Chemical directly out of spray nozzle	600 ppm
2.Chemical in 1 meter deep water, @ 100% water contact	56 ppb
3.Chemical in 2 meter deep water, @ 100% water contact	28 ppb
4.Chemical in 1 meter deep water, @ 20% water contact	11.2 ppb
5.Chemical in 2 meter deep water, @ 20% water contact	5.6 ppb

*The concentrations above are based on the pounds of active ingredient in maximum specified application rate per acre, and an appropriate dilution factor based on the volume of water in the tank mix, or within one or two meter-acres.

Calculated* Maximum Concentrations of Agridex Immediately Following WHCP Treatment

Concentration of:	**Agridex** *(Active Ingredient)*
1.Chemical directly out of spray nozzle	5,000 ppm
2.Chemical in 1 meter deep water, @ 100% water contact	1.24 ppb
3.Chemical in 2 meter deep water, @ 100% water contact	0.62 ppb
4.Chemical in 1 meter deep water, @ 20% water contact	0.25 ppb
5.Chemical in 2 meter deep water, @ 20% water contact	0.12 ppb

*The concentrations above are based on the pounds of active ingredient in maximum specified application rate per acre, and an appropriate dilution factor based on the volume of water in the tank mix, or within one or two meter-acres.

Calculated* Maximum Concentrations of Competitor Immediately Following WHCP Treatment

Concentration of:	**Competitor** *(Active Ingredient)*
1.Chemical directly out of spray nozzle	5,000 ppm
2.Chemical in 1 meter deep water, @ 100% water contact	1.24 ppb
3.Chemical in 2 meter deep water, @ 100% water contact	0.62 ppb
4.Chemical in 1 meter deep water, @ 20% water contact	0.25 ppb
5.Chemical in 2 meter deep water, @ 20% water contact	0.12 ppb

*The concentrations above are based on the pounds of active ingredient in maximum specified application rate per acre, and an appropriate dilution factor based on the volume of water in the tank mix, or within one or two meter-acres.