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:
08FBDT00-2013-F-0015

MAY 03 2013

Raymond I. Carruthers, PhD
Lead Research Scientist
United States Department of Agriculture
Agricultural Research Service
800 Buchanan Street
Albany, CA 94710

Subject: Formal Consultation on the 2013-2017 *Egeria densa* Control Program in the Sacramento-San Joaquin Delta, California

Dear Dr. Carruthers:

This letter is in response to the U.S. Department of Agriculture's Agriculture Research Services (USDA-ARS) January 17, 2013, request for formal consultation with the U.S. Fish and Wildlife Service (Service) on the proposed California Department of Boating and Waterways (CDBW) 2013-2017 *Egeria densa* Control Program (EDCP) in the Sacramento-San Joaquin Delta and its tributaries. The EDCP falls within San Joaquin, Yolo, Alameda, Sacramento, Solano, and Contra Costa counties. Your request was received in our office on January 22, 2013. USDA-ARS has determined the project may affect, but is not likely adversely affect the threatened valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) (VELB) and giant garter snake (*Thamnophis gigas*) (GGS), and may adversely affect the threatened 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 VELB and its critical habitat and GGS. The CDBW proposes to implement Conservation Measures, as described in the Project Description below, to avoid adverse effects to VELB and its critical habitat and GGS. 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 EDCP conservation measures and 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 EDCP does not conduct operations within the area and therefore we concur that the project is not likely to adversely affect VELB critical habitat.

On June 1, 2001, the Service issued a biological opinion for the EDCP (Service File No. 1-1-00-F-0234). This biological opinion was subsequently amended three times (Service File No.'s 1-1-02-F-0158, 1-1-03-F-0061, and 1-1-04-F-0125). A more recent biological opinion for the EDCP was completed by the Service and issued on May 28, 2004 (Service File No. 1-1-04-F-0148) after USDA-ARS reinitiated consultation due to newer herbicide information obtained from toxicology studies required by the Service's June 1, 2001, biological opinion. This biological opinion replaces the Service's previous biological opinions and amendments for this project.

This biological opinion is based on the following information: 1) the December 31, 2012, *USDA-CDBW Egeria densa Control Program Biological Assessment* and January 7, 2013, *Supplemental Materials Binder*; 2) the Service's May 28, 2004, biological opinion for the EDCP (Service File No. 1-1-04-F-0148); 3) the California Department of Fish and Wildlife's (CDFW) 2004 study, *Acute Toxicities of Herbicides Used to Control Water Hyacinth and Brazilian Elodea on Larval Delta Smelt and Sacramento Spilttail*; 4) electronic mails (email), phone conversations, and meetings between the CDBW, USDA-ARS, National Marine Fisheries Service (NMFS) and the Service in 2012 and 2013; and 5) other information available to the Service.

CONSULTATION HISTORY

June 1, 2001	The Service issued a biological opinion for the EDCP (Service File No. 1-1-00-F-0234).
May 3, 2002	The Service issued a biological opinion for the EDCP amending the June 1, 2001 biological opinion (Service File No. 1-1-02-F-0158).
January 23, 2003	The Service issued a biological opinion for the EDCP amending the June 1, 2001 biological opinion (Service File No. 1-1-03-F-0061).
March 12, 2004	The Service issued a biological opinion for the EDCP amending the June 1, 2001 biological opinion (Service File No. 1-1-04-F-0125).
May 28, 2004	The Service issued a biological opinion for the EDCP (Service File No. 1-1-04-F-0148)
January 2, 2013	The Service received a December 31, 2012, formal consultation initiation letter for the 2013-2017 EDCP from the USDA-ARS.

January 16, 2013	The Service, NMFS, CDBW, and USDA-ARS met to discuss the proposed project.
January 22, 2013	The Service received a revised, January 17, 2013, consultation initiation letter and the project's December 31, 2012, *USDA-CDBW Egeria densa Control Program Biological Assessment* and the January 7, 2013, *Supplemental Materials Binder* from the USDA-ARS.
March 8, 2013	The Service, USDA-ARS and CDBW met to discuss the project description and the inclusion of additional conservation measures.
March 7 to March 22, 2013	The Service, CDBW and USDA-ARS exchange additional email and telephone communications clarifying information in the project description.

BIOLOGICAL OPINION

Description of the Proposed Action

The CDBW has proposed to control the spread of *Egeria densa* from 2013 to 2017 using chemical and physical control methods. The EDCP treats approximately 5,000 acres of Sacramento-San Joaquin Delta waterways within 350 treatment sites, in six counties. The treatment sites average one and two miles in length. Between 2007 and 2012, the CDBW chemically treated an approximate total of 3,200 acres of Delta waterways for *E. densa*. The number of acres treated each year depends on the intensity of *E. densa* infestation, CDBW staffing availability and budgetary allocations. The 2013-2017 EDCP is an adaptive program where control methods and treatment sites are reduced as the *E. densa* density is effectively reduced. The EDCP is designed to control the spread and growth of *E. densa* and to maintain navigation in certain waterways. Should treatment sites or methods need to change, the USDA-ARS will reinitiate consultation with the Service on behalf of the CDBW.

Background

Egeria densa, also known as Brazilian elodea, is a non-native, submerged aquatic macrophyte, commonly used as an aquarium plant for its assumed oxygenating properties. *E. densa* may grow in waters 1-3 meters deep and displays vigorous growth resulting in large, nearly pure stands (Cook and Urmi-Konig 1984). It is able to reproduce and establish new plants when plant material is cut or fragmented. Plant fragmentation allows *E. densa* to spread and establish into new areas. Because of its growth in shallower waters, it tends to be easily fragmented by boat traffic in the Delta. The rapid growth and thickness of *E. densa*-patches result in a navigation hazard. In addition, fragments of *E. densa* impede agricultural water diversions throughout the Delta. This invasive, exotic plant may also displace native vegetation. The thick *E. densa* stands are utilized by non-native, fish predators (Grimaldo and Hymanson 1999).

Aquatic plants often play a beneficial role in the function and "health" of waterbodies in a variety of ways such as: producing dissolved oxygen (DO), cycling nutrients, dampening wave action and currents, lowering water turbidity, and providing habitat for fish and wildlife. However, the excessive growth of aquatic vegetation (from exotic weed species such as Eurasian water milfoil, Brazillian elodia, hydrilla, and water hyacinth, etc.) can result in undesirable impacts to aquatic ecosystems. For instance, the normal nighttime respiration of an overabundance of submersed vegetation can severely deplete DO levels, particularly during summer months or other periods of elevated water temperatures. In addition, thick plant stands reduce light penetration and restrict water circulation patterns to the point of producing extreme temperature, pH and nutrient stratification in the affected water column. These major and other more subtle consequences of excessive plants can have deleterious effects on the full range of aquatic organisms, such as fish, invertebrates, and native plants. Egeria densa negatively impacts delta smelt by reducing turbidity and overwhelming littoral (near shore) habitats. The result is often a reduction in the biodiversity of waterbodies (US Army Corps of Engineers 1998; USFWS 2008).

Project Action Area

The action area of the 2013-2017 EDCP covers approximately 5,000 acres of the Sacramento-San Joaquin Delta waterways within six counties. The 350 EDCP treatment sites are within the range of the GGS, VELB, delta smelt and its critical habitat. None of the treatment sites is within the valley elderberry longhorn beetle's designated critical habitat. The general boundaries for the 2013-2017 EDCP treatment area include the legal Delta and its tributaries (see maps in Appendix A) are as follows:

- West up to, and including, Sherman Island, at the confluence of the Sacramento and San Joaquin Rivers;
- North to the northern confluence of the Sacramento River and Sacramento River Deep Water Ship Channel;
- South from Clifton Court along Old River to Mossdale, and continuing along the San Joaquin River to Mendota, just east of Fresno;
- East along the San Joaquin River to the City of Stockton. continuing 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.

Chemical Control Methods

In any given year, the EDCP will treat a selected number of treatment sites, typically ranging from three to twenty-five different treatment sites. The number of treatment sites in a given year may increase and will depend on the extent of *E. densa* invasion and available resources. Within a given treatment site, EDCP will treat only a carefully defined treatment polygon. The treatment polygon represents the area of the infestation and is often a small proportion of the overall treatment site. The EDCP proposes to treat *E. densa* using four different herbicides in conjunction with the hydrology of the area to maximize control efficacy. The four herbicides are fluridone (Sonar®), penoxsulam (Galleon®), imazamox (Clearcast®), and diquat (Reward®). Other chemicals with the same active ingredients may be substituted for the above name-brand chemicals in the EDCP by the CDBW.

Penoxsulam (Galleon®) and imazamox (Clearcast®) have not yet been used for treating *E. densa* in the complex, tidal, Delta environment. The EDCP will begin evaluating their efficacy and impacts at selected sites, and may increase use over time, depending on initial results. Diquat may be used in limited situations when more rapid efficacy would benefit the overall treatment approach. The CDBW will utilize different formulations of fluridone including: (1) Sonar PR Granular, (2) Sonar Q Pellets, (3) Sonar AS Aqueous, Sonar* SRP, and (4) SonarOne®. These products contain the same herbicide active ingredient, but allow for differing release times. Treatment crews will use injection hoses to apply aqueous herbicide into treatment areas, and a broadcast method to apply pellets or granules. Pellets and granules will be applied on the water surface, but sink rapidly to the sediment.

Prior to the start of each treatment season, CDBW and USDA-ARS will prioritize treatment sites and methods. The prioritization process will be based on results of pre-season field surveys combined with the experience and knowledge of the program environmental scientists, herbicide management experts, field supervisor, and program managers. During the pre-season, EDCP staff and management will conduct one or more field surveys. During these surveys, teams will visit potential treatment sites, conduct rake surveys, and evaluate the extent of *E. densa* infestation and site conditions at each location. The team will also evaluate the extent of *E. densa* coverage at sites treated in previous years to determine whether these sites need to be re-treated.

Chemical treatments in selected sites will likely begin in March, with the majority of treatments beginning by April 1st. Treatments will continue for up to sixteen weeks, once or twice per week, depending on the particular herbicide protocol. Treatment crews use injection hoses to apply aqueous herbicide into treatment areas, and a broadcast method to apply pellets. Both methods are applied from airboats or outboard motor workboats. Prior to the start of the treatment season, EDCP will design a treatment protocol for each selected site that is designed to maintain a pre-determined concentration of herbicide in the water column during the treatment period. Treatment crews will follow specific requirements to account for wind, dissolved oxygen, pH, drinking water intakes, agricultural intakes, and total acres treated. Treatment crews will follow all label requirements.

The EDCP may conduct additional treatments in the fall during the late-season growth spurt characteristic of *E. densa*. These fall treatments will be completed by November 30th. The amount of herbicide applied in the project area to treat *E. densa* can be minimized by treating plants early in the growing season. Early treatment will also minimize the negative ecosystem impacts of this invasive species.

In 2007 and 2008, CDBW focused all EDCP treatments within three treatment sites in Franks Tract, a known *Egeria densa* nursery area. This focused treatment approach was highly effective, and after two years of treatment, boats could again navigate within Franks Tract. Due to the success of the Franks Tract treatment regime, CDBW continued the focused treatment approach, expanding to new areas in 2009, 2010, 2011, and 2012 (Table 1).

Table 1: EDCP Areas Treated, Net Acres, and Pounds Herbicide Active Ingredient (Fluridone)

Site Name	Site Number(s)	2007	2008	2009	2010	2011	2012
1. Franks Tract	173, 174, 175	x	x		x	x	x
2. White Slough	36, 37, 39			x	x		x
3. Disappointment Slough	32			x	x		x
4. Bishop Cut	34			x			x
5. Honker Cut	38						x
6. Fourteen Mile Slough	26			x			x
7. Whiskey Slough	62						x
8. Old River	79						x
5. Pipers Slough (Bethel Island)	107					x	x
6. Taylor Slough (Bethel Island)	110					x	x
7. Sandmound Slough (Bethel Island)	108, 109, 111, 112					x	x
8. Discovery Bay	93					x	x
9. Sycamore Slough	203						x
10. Snug Harbor	252						x
Net Acres	**Average: 1,978**	2,571	2,571	228	641	3,195	2,663
Pounds Active Ingredient	**Average: 5,077**	7,479	4,977	562	1,974	8,113	7,357

Proposed Herbicides for the EDCP

Reward® (the active ingredient is Diquat):

The herbicide active ingredient diquat dibromide was first approved by the USEPA for aquatic use in 1962, and again in 2000 (Washington DOE 2012). CDPR approved the use of diquat for aquatic uses in California in 2002. Diquat has been part of the EDCP since 2002, but has not been utilized by CDBW since 2005. There are several different diquat products, with a liquid formulation, Reward®, used most recently by EDCP.

Reward®, a non-selective contact herbicide, needs direct contact with the plant tissue to effectively control the plant's growth. Diquat dibromide, which is the active ingredient in Reward®, kills the plant tissue by destroying the plant's membranes. Diquat is fast acting and quickly absorbed into the plant tissue. However, diquat easily binds with organic particles and therefore its effectiveness is diminished in turbid waters. Because it quickly binds to particles and becomes biologically unavailable, its persistence in the waters of the Delta is limited.

Studies on the erosion of diquat-treated soils near bodies of water indicate that diquat dibromide stays bound to soil particles, remaining biologically inactive in surface waters, such as lakes, rivers, and ponds (Gillett 1970). When diquat dibromide is applied to open water, it disappears rapidly because it binds to suspended particles in the water (Gillett 1970). Diquat dibromide's half-life is less than 48 hours in the water column, and may be on the order of 160 days in sediments due to its low bioavailability (EXTOXNET 1993). Microbial degradation and sunlight play roles in the breakdown of the compound (EXTOXNET 1993). Hosea (2005) found diquat in Delta sediments following EDCP treatments in 2002 and 2005, but not at levels of concern.

If diquat is used, it will be applied below the water surface using weighted hoses. There is little concern regarding air drift because liquid diquat is applied below the surface. The herbicide label recommends applying diquat in water at a rate of 0.5 to 2.0 gallons per surface acre per four foot water depth (Syngenta 2005). The higher level is recommended for severe weed infestations. For deeper treatment sites, this is equivalent to an additional 0.25 to 0.50 gallons per acre- foot. The maximum concentrations of diquat used by the EDCP would be approximately 0.37mg/L, with lesser concentrations reaching the water column. For best results, the label recommends re-treating, as necessary, on 14 to 21 day intervals. Because diquat is fast-acting, there is potential for reductions in dissolved oxygen levels following treatment. To avoid low DO impact the label recommends treating only 1/3 to ½ of the water body area at one time, and to wait fourteen days between diquat treatments. The tidal flow in the Delta and limited diquat utilization will reduce potential for low DO.

The EDCP will utilize diquat only in certain cases where more rapid efficacy is required, and when listed fish species are not likely to be present. Diquat will augment fluridone treatment protocols, providing a different and faster mode of action. Longer- acting herbicides such as fluridone, penoxsulam and imazamox will be the primary control methods.

Sonar® (the active ingredient is fluridone):

Fluridone was approved by the USEPA in 1986 and by the CDPR for use in California as an aquatic herbicide in 1996. There are a variety of different formulations of the herbicide, including liquid and pellets. The EDCP will utilize fluridone formulations such as: Sonar* AS (liquid), Sonar® PR (granular) and two pellet formulations, SonarOne®, Sonar® Q. The pellet and granular formulations provide different release profiles due to the characteristics of the inert clay ingredients. All formulations have the same mode of action and concentration limitations. SePRO developed the release profile for SonarOne based on the characteristics of the Delta.

Sonar®, a systemic herbicide, needs to be absorbed by both plant shoots and root systems to effectively control the plant. Fluridone, which is the active ingredient in Sonar®, kills the plant's roots and shoots by inhibiting the formation of carotene. Carotene is the enzyme which protects the plant's chlorophyll from the sun's radiation and without it the plant will be unable to produce chlorophyll. Because it is a systemic herbicide, use of Sonar® results in a longer lasting control of *E. densa*. Sonar® requires uptake through the leaves, stems, root systems to be effective and needs to be in contact with the plant for a longer time. Therefore its use is limited to use in slow moving and stagnant waters. The effectiveness of Sonar® is limited in the tidal Delta.

Photolysis is one of the major degradation pathways of fluridone, breaking down the herbicide into naturally occurring elements. A study summarizing field dissipation data for fluridone formulations found an average half-life of 20 days in pond water (ranging from 5 days to 60 days) and 3 months in pond hydrosoil (West *et al.* 1983). Fluridone half-life in lakes is shorter due to dispersal of fluridone, with an average half-life of less than one week. In tidal situations such as the Delta, movement of herbicide will likely be the greatest factor affecting half-life.

The effectiveness of fluridone depends on the degree to which the herbicide maintains contact with the target plant. Fluridone treatment programs will typically last from 8 to 16 (or12) weeks based upon site conditions (weed growth, flow patterns and agriculture irrigation intake considerations). In some instances, the treatment program may last less than 8 weeks. Some sites might require an extended treatment protocol to meet specific site conditions. Fluridone formulations will be applied at rates of five (5) to thirty (30) ppb per application, lower than the 10 to 40 ppb or 16 to 75 ppb listed on Sonar labels. The intent will be to maintain a fluridone concentration in the water column of the treatment site of between one (1) and ten (10) ppb, most often in the one (1) to three (3) ppb range. This is more than two orders of magnitude below the National Pollution Discharge Elimination System (NPDES) receiving water limit of 560 ppb. As specified on the herbicide label, there is no seasonal application maximum for fluridone applied in a flowing water system, such as the Delta (which is classified as a riverine system). For waters such as the Delta, the label specifies that the application technique should maintain a concentration of 10 ppb to 40 ppb in the applied area for a minimum of 45 days. As noted, EDCP protocols typically apply lower concentrations for longer time periods.

Liquid fluridone will be applied below the water surface and the pellets or granules will be applied with broadcast spreaders that are attached to the boat. There is little concern regarding air drifting because liquid fluridone will be applied below the water surface via weighted hoses (not over the surface), and the pelleted/granular formulations are heavy enough that the wind speeds in which CDBW will be treating will not cause them to drift. Once on the water surface, the pellets or granules sink to the bottom rapidly (within seconds).

Fluridone is not to be applied at a rate of greater than 20 ppb within ¼ mile of active potable water intake. However, the labels specify that Sonar PR, Sonar Q, and SonarOne may be applied at between 8 to 20 ppb where functioning water intakes are present. Sonar AS may be applied at between 6 to 20 ppb where functioning water intakes are present. The EDCP will follow the maximum 20 ppb requirement in those sites with functioning potable water intakes.

Galleon® (the active ingredient is penoxsulam)

The herbicide active ingredient penoxsulam received US Environmental Protection Agency (USEPA) approval through the reduced risk program for use on aquatic weeds from the USEPA in 2007 and from the CDPR in 2009. Penoxsulam was initially approved for use on rice crops by USEPA in 2004. The EDCP currently plans to utilize the penoxsulam product Galleon®SC in a liquid formulation, and may eventually add other formulations, such as a granular formulation, Galleon 2.7G, which is currently in the USEPA registration process. 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). Langeland et. al. (2009) identified penoxsulam as providing good control for *E. densa* in Florida.

Because of the Delta's unique characteristics, EDCP will evaluate penoxsulam application protocols to determine the most effective treatment approach and treatment period for *E. densa*. Based on herbicide characteristics, it is likely that *E. densa* treatment will require an eight to twelve week treatment protocol, similar to the approach for treating *E. densa* with fluridone. EDCP also expects that the concentration of penoxsulam in the water column following treatment will be similar to that of fluridone, with actual water concentrations following treatment likely tobe less than one-half of the application rate.

Liquid penoxsulam will be applied below the water surface and when available, granular forms will be applied with broadcast spreaders that are attached to the boat. There is little concern regarding air drifting because liquid penoxsulam will be applied below the water surface via weighted hoses (not over the surface), and the granular formulations will be heavy enough that the wind speeds in which CDBW will be treating will not cause them to drift. Once on the water surface, granules sink to the bottom rapidly (within seconds). There are no label restrictions for penoxsulam regarding dissolved oxygen, as the slow-acting nature of this herbicide should have minimal impact on dissolved oxygen levels (Washington DOE 2012).

As penoxsulam will be a new EDCP herbicide. There are no prior program data regarding actual herbicide concentrations following *E. densa* treatment. The EDCP will conduct monitoring at the initial penoxsulam treatment sites to develop a baseline for expected herbicide concentrations in treatment sites and receiving waters following treatment. For example, one treatment protocol might be to start with a 50 ppb application, followed by weekly 10 ppb applications, for a maximum of ten additional weeks. Another treatment protocol might be to start with a 30 ppb application, followed by weekly 15 ppb or less applications, until the maximum 150 ppb application and/or efficacy is achieved. Prior to the start of each treatment season, EDCP will provide the Service and NMFS with the penoxsulam treatment plan. CDBW will assume a conservative figure of 50 ppb, which would likely be the maximum application rate.

Clearcast® (the active ingredient is imazamox)

Imazamox is a relatively new aquatic herbicide active ingredient. The aquatic formulation of imazamox, Clearcast®, received USEPA approval through the reduced risk program in 2008 (SERA 2010). The CDPR approved Clearcast in liquid form for aquatic uses in California on August 7, 2012. The USEPA has also approved a fast release granular imazamox formulation for aquatic use, Clearcast® 2.7G. The EDCP will incorporate this imazamox formulation once it is approved in California. The manufacturer may also develop a slow-release imazamox formulation that would be particularly appropriate for Delta water conditions.

The EDCP will utilize available formulations of this active ingredient. Imazamox was approved for terrestrial use by the USEPA in 1997, and by the CDPR in 2002. 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.

Imazamox is highly soluble in water, and is mobile to highly mobile in soil (Washington DOE 2012; USEPA 2008). Volatization of imazamox is not significant (USEPA 1997). Imazamox has a low potential for bioaccumulation. The primary method of degradation of imazamox in surface water is photolytic (Washington DOE 2012).

Because of the Delta's unique characteristics, EDCP will evaluate imazamox application protocols to determine the most effective treatment approach and treatment period for *E. densa*. Based on herbicide characteristics, it is likely that *E. densa* treatment will require two to four week treatment protocol, much shorter than the current approach for treating Egeria densa with fluridone. EDCP also expects that the concentration of imazamox in the water column following treatment will be similar to that of fluridone, with actual water concentrations following treatment likely to be less than one-half of the application rate. The concentration of any single application or sum of all applications per annual growing cycle may not exceed 500 ppb.

Liquid imazamox will be applied below the water surface and the granular formulations, when available, will be applied with broadcast spreaders that are attached to the boat. There is little concern regarding air drifting because liquid fluridone will be applied below the water surface via weighted hoses (not over the surface), and the granular formulations will be heavy enough that the wind speeds in which CDBW will be treating will not cause them to drift. Once on the water surface, the granules sink to the bottom rapidly (within seconds).

There are no label restrictions regarding dissolved oxygen; however, CDBW will follow the same application approaches as for other herbicides to minimize 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 hours period after treatment to irrigate from still and quiescent waters.

Physical Control Methods

In addition to herbicide treatments, EDCP proposes, in selected situations, to utilize handpicking and suction harvesting (by SCUBA divers), and benthic barrier. Evaluation of biological control methods is currently experimental and will not be utilized for the 2013-2017 EDCP. Handpicking and suction harvesting by SCUBA divers will primarily be utilized to reduce plant biomass in sensitive sites where chemical treatments cannot be utilized due to possible negative effects to protected plants (e.g. *Sambucus* spp.) growing on waterway shorelines. Use of benthic barriers will be evaluated in select approved sites.

Diver Assisted Handpicking

This method involves handpicking *E. densa*, with the use of a small rake or hand- tool when needed, to ensure that the plant is completely removed. It will be necessary to utilize contracted SCUBA divers for this work because *E. densa* is rooted in the sediment, typically in an average of five to ten feet water depth. Divers will place the harvested *E. densa* in net bags, making sure to collect all plant fragments. Because *E. densa* reproduces vegetatively, plant fragments can be a source of new infestations if not removed from the water. Collected plants will be disposed of in approved locations away from the water's edge and sensitive habitats, typically on nearby farm fields.

Diver-Operated Suction Harvesting

This method is essentially equivalent to vacuuming the plants, which are then removed to a basket on a boat, barge, or nearby dock. SCUBA divers hold a 3 to 5 inch-wide hose attached to a high pressure water pump located on the boat, barge, or dock. The hose extends about 50 feet from the pump (USACE 2005). The pump creates a venturi effect, creating suction to pull the plant through the hose and into the collection basket. Water and any sediment is drained back into the waterbody, and the plant mass is disposed of at an approved site away from the shore. Divers may use small rakes or tools to ensure that the plant is removed at the root, and then guide the plant into the hose. This method can be highly selective, as trained divers can literally pick and choose which plants to remove.

Benthic Barriers

The EDCP will incorporate benthic barriers in isolated instances. This method, which is well-established, will be new to EDCP operations. Benthic barriers consist of a physical cover over aquatic weeds, preventing sunlight from reaching the plants. Without the ability to photosynthesize, plants typically die back within approximately four to eight weeks (New York DEC 2005, Madsen 2000). The EDCP will utilize benthic barriers in selected locations where they are likely to be most effective, including relatively small areas (2 acres or less), and high-intensity use areas such as docks, boat launch areas, and swimming areas. Benthic barriers can be an important tool in removing new infestations in these areas (Madsen 2000), and may be especially effective in high-water flow areas of the Delta where herbicide treatments will not be effective.

Benthic barriers are non-selective, killing all plants underneath the barrier. Depending on the material, benthic barriers may also kill macroinvertebrates that are under the mat, although some newer materials do not result in effects to macroinvertebrates (Derma-Safe pers. comm.). Benthic barriers can be made from a variety of different materials, including textiles (burlap, jute), plastic, woven synthetics, or screens (Washington DOE 2012). According to Washington DOE, an ideal benthic barrier should be durable, heavier than water, reduce or block light, prevent plants from growing into and under the fabric, be easy to install and maintain, and should readily allow gases produced by rotting weeds to escape without buoying the fabric upwards. To avoid potential issues with gas production under the mats, Gunnison and Barko (1992) recommend deploying barriers early in the year when the standing crop is low, and under cooler temperature conditions when microbial decomposition rates are low.

Proposed Schedules of Treatment Activities

The EDCP regularly consults several state and federal fish surveys to monitor presence of listed fish species. CDBW environmental scientists compare results from fish surveys with scheduled treatment sites to determine likely presence of listed fish species. If these surveys indicate that threatened or endangered fish are likely to be present in the treatment site, EDCP will delay treatment. These surveys include the following:

- Service "DatCall" data (juvenile fish monitoring program through the Interagency Ecology Program (IEP)). This survey includes three trawls and various beach seines at locations throughout the Delta. Reports are sent on a weekly basis to report data from the previous week (http://www.fws.gov/stockton/jfmp).

- CDFW surveys and studies (also through IEP). These surveys include the 20mm Survey, Smelt Larva Survey, and Spring Kodiak Survey in the Delta, Suisun Bay, and San Francisco Bay. Results are posted on the CDFW website within 72 hours of data collection on interactive maps (http://www.dfg.ca.gov/delta/data/).

- Department of Water Resources (DWR) and USBR (through CDFW) fish salvage data. These daily and weekly reports provide salvage data collected at the state and federal fish salvage facilities (http://www.dfg.ca.gov/ delta/apps/salvage/Default.aspx and http://www.water.ca.gov/swp/operation scontrol/calfed/calfedmonitoring.cfm).

- FishBio San Joaquin Basin Update reports on surveys in the San Joaquin Basin, including Calaveras River, Stanislaus River, Tuolumne River and Mokelumne River. Report frequencies vary, and will be used to supplement the regular surveys listed above. CDBW subscribes to the FISHBIO newsletter (http://fishbio.com/fisheries/industry-news/regional-fisheries-news).

- CDFW Knights Landing Rotary Screw Trap (RST) data provides weekly reports (via email newsletter) of fish presence on the Sacramento River at Knights Landing. This

location is outside of EDCP program area, but migration of fish at Knights Landing can indicate movement toward the Delta.

Table 2 provides a schedule of EDCP treatment activities as they were prescribed in 2012 and that will be generally followed for the 2013-2017 EDCP. Timing of various treatment components, particularly chemical treatments, have historically been limited by the Service's and NMFS previous biological opinions in order to avoid potential exposure of listed species, particularly juveniles, to herbicides.

Table 2: Schedule of EDCP treatment activities

Activity	2012											
	JAN	FEB	MAR[a]	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Environmental Surveys												
Surveyor Training												
Coverage Surveys												
Fluridone Treatment												
Penoxsulam Treatment[b]												
Imazamox Treatment[c]												
Diquat Treatment[d]												
Herbicide Monitoring												
Diver Handpicking and Suction Harvesting												
Benthic Barriers												
Reporting												

[a] The March start date for herbicide treatment would be dependent on temperature and fish surveys.

[b] Penoxsulam (Galleon)was approved by California Department Pesticide Regulation (CDPR) for aquatic use in 2009, but has not been utilized in EDCP as of 2012.

[c] Imazamox (Clearcast) was approved by CDPR for aquatic use on August 7, 2012, but has not been utilized in EDCP as of 2012.

[d] Diquat was used between 2001 and 2005; diquat will be utilized in limited applications to support treatments with the other herbicides.

For 2013 and beyond, EDCP proposes a start-date approach that utilizes a combination of calendar-dates, field surveys of *E. densa*, Delta water temperatures, and IEP and CDFW fish surveys to determine presence of special status fish species. The objective of this approach is to improve EDCP chemical treatment efficacy without negatively impacting special status fish species. Seasonal temperature fluctuations in the Delta impact both *E. densa* growth and migratory fish activity. These weather fluctuations can become relatively extreme. While *E. densa* grows to some extent year-round in the Delta, it experiences a fall growth spurt, typically when water temperatures fall back to around 20°C (68°F), and day-length is shortening (Scott Shuler pers. comm.). Ideally, fall treatments should start in September and October. Table 3 summarizes the proposed treatment start dates.

Table 3. Summary of treatment start dates.

Proposed EDCP Treatment Dates (2013-2017)		Comments
Beginning between late February to April 1, for up to 12 weeks	Specific approved high priority nursery sites, and warm-water sites, TBD	Length of treatment period depends on herbicide
Beginning April 1 to May 15, for up to 12 weeks	Other EDCP treatment sites where listed fish are assumednot to be present	Length of treatment period depends on herbicide
Beginning mid- September for up to 8 weeks, and ending by November 30	Selected fall EDCP treatment sites where listed fish are not present	Length of treatment period depends on herbicide

The EDCP start-dates will be determined as follows:

1. EDCP will monitor daily Delta water temperatures at several key DWR monitoring stations near EDCP treatment sites, such as Bethel Island, Steamboat Slough, and Middle River at Tracy Road Bridge. In addition, EDCP crews and environmental scientists will monitor *E. densa* infestations during the winter period to determine the extent of growth and health of the weed;

2. When water temperatures at these sites consistently reach 10°C (50°F), and/or there are signs of plant fragmentation, EDCP will evaluate the need for early season treatments, report these locations to Service and NMFS, and consult with IEP/CDFW databases to determine whether listed fish species are present. If listed fish species are not present, and Service and NMFS concur, treatments will start in these specific sites, potentially as early as late-February, but likely by early March;

3. EDCP will continue to monitor water temperatures and conduct field surveys in other sites with *Egeria* infestations between mid-February and March 31st. As water temperatures reach the 12°C to 14°C range (53.6°F to 57.2°F), EDCP will report these locations to Service and NMFS, and consult with IEP to determine whether listed fish species are present. If listed fish species are not present, and Service and NMFS concur, treatments will start in these specific sites;

4. The EDCP will maintain the historical April start date in any remaining *E. densa* treatment sites where treatments did not begin earlier based on water temperatures and surveys;

5. Following completion of the first treatment phase, which will last up to sixteen weeks from treatment start date depending on the herbicide used, EDCP will monitor treatment effectiveness and survey for new infestations. EDCP will identify potential sites for fall treatments, depending on the extent of *Egeria* infestations, efficacy of spring treatments, and amount of herbicide used (so as to not exceed any applicable seasonal application rates). EDCP will inform the Service and NMFS of proposed fall treatment sites. Fall treatments will typically start in mid-September, or when water temperature drops to

approximately 20°C, and will last approximately 8 weeks, to be completed by November 30.

EDCP Monitoring Program

The 2013-2017 EDCP will follow an Operations Management Plan that specifies a pre-application planning protocol, an Application/ Monitoring Coordination Protocol, "Best Maintenance Practices" for Handling Herbicides, Equipment Maintenance and Calibration, and an Herbicide Spill Contingency Plan. The Operations Management Plan includes specification requirements related to avoiding threatened or endangered species, conducting habitat evaluation, dissolved oxygen measurement, and other program monitoring requirements. The CDBW is currently updating the Operations Management Plan, and will provide a copy to NMFS and the Service when the plan is finalized.

Based on NPDES permit requirements, EDCP will follow a monitoring protocol. This protocol has historically fulfilled requirements of the Regional Water Quality Control Board, NOAA Fisheries, and the Service. At each monitoring site, EDCP's environmental scientists will take the initial samples within 24 hours of the treatment start (upstream and adjacent to the *Egeria densa* mat). Post-application monitoring (downstream of the treatment area) will begin after the treatment period is over, and continue until all sampling locations show non- detectable herbicide levels. 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 EDCP will select monitoring sites for all herbicides used, and different habitat types. The EDCP will revise the monitoring approach to comply with the new NPDES General Permit, as described below.

At each monitoring site, EDCP environmental scientists will monitor and report pre- and post-treatment dissolved oxygen, turbidity, pH, 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 EDCP will conduct additional monitoring to ensure that herbicide levels are maintained, and to ensure that herbicide residues do not exceed manufacturer's acceptable levels for crops being grown in nearby fields. For these tests, EDCP will utilize FasTEST, an immunoassay test that can rapidly determine fluridone and penoxsulam concentrations, typically providing results within 48 hours of the time the sample was taken.

EDCP Conservation Measures

The 2013-2017 EDCP will implement a number of conservation measures to avoid and minimize potential impacts of the program to federally-listed species and their critical habitats. These measures have been developed over time, working with the Service, NMFS, the State Water Resources Control Board, and local Agricultural Commissioners. The following EDCP measures are ones that EDCP regularly implements to reduce or eliminate potential effects of the EDCP:

1. Avoid herbicide application, diver-assisted removal, and use of benthic barriers near special status species, and sensitive riparian and wetland habitat; and other biologically important resources. Each year, prior to the start of the treatment season, EDCP will conduct field crew environmental awareness training. This training will be conducted by a Service-approved biologist prior to all chemical applications and physical harvesting activities.

    a. Under this training, crews will be informed about the presence and life histories of delta smelt, GGS and VELB; habitats associated with species; critical habitats and wetlands; the Terms and Conditions of the program's biological opinions; incidental take procedures; and that unlawful take of an animal or destruction of its habitat is a violation of the Act. EDCP also will provide crews with a field guide (Species Identification Deck) for easy identification of special status species on-site.

    b. A survey of treatment sites will be conducted by the CDBW and a map identifying the location of elderberry shrubs and GGS occurrences utilizing the California Natural Diversity Database and will be provided to field crews prior to any treatment operation. Prior to treating a site, crews will conduct a visual survey to determine whether special status plants, animals, or sensitive habitats are present. Crews will complete an Environmental Observations Checklist for each site to document the presence or absence of special status species. If any special status species or sensitive habits are present at the site, the field crew will not perform any treatment.

    c. Provide treatment crews with electronic mapping that identifies previously surveyed areas for giant garter snake habitat. EDCP application crews will use this map as a tool for performing pre-application visual inspections for the presence of GGS. If GGS are present, treatment crews will not treat at that location.

2. Require treatment crews to participate in training on herbicide and heat hazards EDCP will provide training to ensure that treatment crews have the knowledge and tools necessary to conduct the program in a safe manner. Training will include reading, understanding, and following herbicide label requirements; purpose and proper use of Personal Protective Equipment; symptoms of herbicide poisoning and minimization of exposure; avoidance, symptoms, and treatment of heat exposure; and emergency medical procedures.

3. Follow best management practices to minimize the risk of spill and to minimize the impact of a spill, should one occur. The EDCP best management practices include several provisions to reduce the potential for spill, such as: fastening herbicide containers securely in boats in original, watertight containers; carrying a marker buoy and anchor line to mark any spills in water; reporting spills immediately to appropriate State and local agencies; immediately stopping movement of land spills using absorbing materials; marking and monitoring spills in water for herbicide residues and environmental impacts, if appropriate. Treatment crews will include at least one person with a Qualified Applicators Certificate (QAC), and all crew members will participate in annual training on herbicide handling procedures.

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

1. To minimize take of delta smelt, the herbicide Reward® (the active ingredient is Diquat) can only be used from August 1 through November 30 of each year and limited to a total of 50 treatment acres in the Delta per year. Diquat will be utilized as part of the EDCP under emergency conditions only. Emergency conditions are such that *E. densa* growth completely impedes navigation of Delta waters, such as a completely blocked slough that would impair movement of emergency response vessels. The CDBW will review the latest CDFW fish survey information to determine the potential occurrence of delta smelt nearest the proposed diquat treatment site and will contact the Service as soon as practicable about their treatment plan before chemical treatment is initiated.

2. The CDBW will review the latest CDFW fish survey information to determine the potential occurrence of delta smelt nearest to a potential treatment site and will contact the Service as soon as practicable but before chemical treatment.

3. 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 adults, larvae, and eggs. The study will be approved by the Service and completed prior to the utilization of these herbicides in treatment Areas 1 and 2 as defined in the CDBW's Water Hyacinth Control Program (See Appendix B).

4. To minimize sediment disturbance, the EDCP will monitor turbidity levels during and immediately after diver-operated suction harvesting activities. If turbidity levels are greater than 50 NTUs (NPDES threshold) in the Central Delta and 250 NTUs in the remaining Delta, the EDCP will not suction harvest *E. densa* to maintain turbidity levels below the NPDES threshold. The EDCP will utilize sediment curtains to localize turbidity effects.

5. Collect plant fragments during and immediately following treatment. To maximize containment of plant fragments, EDCP crews will collect *E. densa* fragments. Crews will also be trained on the importance of minimizing fragment escape.

6. Operate program vessels in a manner that causes the least amount of disturbance to the habitat. Operational procedures for EDCP vessels will minimize boat wakes and propeller wash. These procedures will be particularly important in shallow water, or other sensitive habitats.

7. Implement temporal and spatial limitations and restrictions on herbicide treatments and other removal methods to minimize treatments during times, and at locations, where larval and/or migratory fish are likely to be present. The specific locations and times followed in the EDCP have been guided by the prior biological opinions. In the future, EDCP will implement a survey-based approach to conducting treatments that allows for early season treatments in areas with *E. densa* infestations when listed fish species are not likely to be present. In addition, EDCP will follow calendar year treatment dates when listed fish species may be present (although treatments will not be conducted in sites where IEP data shows listed fish are present). These treatment time restrictions minimize potential exposure of migratory salmonids and sensitive juvenile fish to EDCP herbicides.

8. Implement an adaptive management approach to minimize the use of herbicides. Under an adaptive management approach, EDCP will seek to improve efficacy and reduce environmental impacts over time as new and better information is available. Specifically, EDCP will evaluate the need for control measures on a site by site, month- to-month, basis; select appropriate indicators for pre-treatment monitoring; monitor indicators following treatment and evaluate data to determine program efficacy and environmental impacts; support ongoing research to explore impacts of the EDCP and alternative control methodologies; report findings to regulatory agencies; and adjust program actions, as necessary, in response to recommendations and evaluations by USDA-ARS, CDBW staff, regulatory agencies and stakeholders. In addition to this adaptive management approach, EDCP will follow maintenance control practices that from a program standpoint seek to reduce the number of acres of *E. densa* to be treated each year, until treatment acreage reaches a minimal level. This will reduce the volume of herbicide utilized by the EDCP.

9. Monitor herbicide levels to ensure that EDCP does not result in potentially toxic concentrations of chemicals in Delta waters. The EDCP will conduct comprehensive monitoring that is in compliance with the general NPDES permit. The EDCP will collect a pre-treatment sample no more than 24 hours prior the start of treatment, and collect post-treatment samples, continuing until the sampling location shows non-detectable herbicide levels. The EDCP will conduct water quality monitoring as required by the NPDES General Permit for each pesticide, and water body type. Water samples will be submitted to a certified analytical laboratory to measure fluridone, penoxsulam, imazamox, and diquat, as appropriate. The limits set by the SWQCB for imazamox and penoxulam will be presented to the Service as soon as those are determined and known by CDBW. Should these levels exceed allowable limits, EDCP will take immediate measures to reduce chemical levels at future treatment sites.

EDCP will conduct additional FasTEST monitoring for fluridone and penoxsulam applications to more closely track herbicide levels.

10. Monitor dissolved oxygen levels pre- and post-treatment for all EDCP treatments, and at selected locations in the Delta over time. Based on the pre-treatment DO levels, the EDCP application crew will determine whether to conduct treatment at that site. No treatment will be performed when dissolved oxygen levels are between 3 ppm (the level below which DO is considered to be detrimental to fish species) and the basin plan limits established by the Regional Water Quality Control Board. The basin plan limits depend on location and time of year, and range from 5 ppm to 8 ppm. CDBW will maintain written and map summaries of specific DO numeric limits. When pre-treatment levels are below 3 ppm, fish species are not likely to be present due to the extremely low oxygen levels. When pre-treatment levels are above the basin plan limit, EDCP treatments, following label guidelines and mitigation measures, are not expected to adversely affect special status fish, resident native or migratory fish, or sensitive riparian or wetland habitats. The EDCP 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.

11. To avoid DO effects, the herbicide label specifies that no more than one-third to one-half of a water body should be treated at diquat at one time, with a waiting period of 14 days for follow-up treatment of the remaining area. The EDCP will follow diquat label requirements to reduce the potential for DO impacts. Because diquat will only be used for limited spot treatments within EDCP, the actual area treated is likely to be much smaller than the label limitation. EDCP field crews will take dissolved oxygen readings prior to treatments and will not initiate a treatment if measured dissolved oxygen levels are between 3.0 and 5.0 mg/L (current Basin Plan standards). EDCP environmental scientists will continue to measure post- treatment dissolved oxygen levels, and adjust treatment protocols, if necessary, should DO levels decline to levels unsafe for fish. The EDCP will also implement long-term DO monitoring to better understand the natural diurnal fluctuations in DO in *E. densa* areas.

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

1. Provide a 100 foot buffer between treatment sites and shoreline elderberry shrubs (*Sambucus* spp.), the host plant for the VELB. EDCP will conduct a survey of treatment sites to prepare a map that identifies locations of elderberry shrubs, and

provide this map to field crews. EDCP crews will maintain the 100 foot buffer zone for herbicide treatments when elderberry shrubs are present. Crews will also conduct treatments downwind of elderberry shrubs. In addition, EDCP environmental scientists will survey a sample of elderberry shrubs which could be potentially impacted by application activities at the beginning of the treatment season, and at the end of the treatment season. Environmental scientists will compare the health of elderberry shrubs at control sites (i.e. not adjacent to treatments) with elderberry shrubs located adjacent to treated sites. If elderberry shrubs located near treated sites show signs of adverse effects from treatment, EDCP will develop additional mitigation measures to protect elderberry shrubs (for example, increasing the size of the buffer zone).

2. *E. densa* harvesting and disposal will not be allowed in sensitive riparian and wetland habitat typically associated with GGS or VELB. Sensitive areas will have been marked on a GIS map by the Service-approved biologist for the EDCP crews.

3. Disturbance of upland GGS habitat (e.g. harvested *E. densa* placement) will be limited to May 1 to October 1. This is the active period for the snake and they are less likely to estivate during these times and more likely to avoid human presence and activities by moving away on their own.

4. Identify and utilize disposal areas for diver-harvested *E. densa* that have no and/or low habitat value for GGS. EDCP will provide crews electronic mapping that identifies previously surveyed areas for GGS habitat. Crews also will conduct surveys to ensure there are no other special-status plants or animal species located within 100 feet of disposal sites. Harvested *E. densa* will be disposed of only in pre-approved disposal sites.

5. Identify and utilize disposal areas for diver-harvested *E. densa* that are at least 100 feet away from elderberry shrubs (*Sambucus* ssp.) and 100 feet away from aquatic giant garter snake habitat. EDCP disposal will not occur near elderberry shrubs, which are potential habitat for the federally threatened VELB. EDCP disposal will not occur near aquatic giant garter snake habitat. Diver-harvested *E. densa* will be disposed of only in pre-approved disposal sites.

CDBW proposes additional avoidance and minimization measures to reduce possible effects to water quality in the project areas:

1. Minimize public exposure to herbicide treated water. Prior to treatments, EDCP will release a public notice announcing the program. EDCP treatments generally take place in heavily infested waterways, which are usually unsuitable for water recreation. If recreationists are present when treatment occurs, treatments crews will inform recreationists about the treatment, asking them to move to a different location, or crews will move treatments to a different location.

2. Follow the Memorandum of Understanding (MOU) protocol for herbicide applications within one (1) mile of Contra Costa Water District (CCWD) drinking

water intake facilities. The MOU is an agreement between CCWD and CDBW. No applications shall occur within Rock Slough, or within one mile of the confluence of Rock Slough and Old River, or within one mile of CCWD's Old River or Mallard Slough intake pumps without consensual agreement between CCWD and CDBW. Herbicide applications within one mile of CCWD's water intakes may only occur with prior consent of CCWD. In order to treat within one mile of an intake, EDCP must notify CCWD at least two weeks in advance, and make every reasonable attempt to schedule applications during periods when CCWD's intakes are shut down for environmental or maintenance reasons, allowing at least two complete tidal cycles between application and restart. This measure is primarily aimed at reducing the potential for drinking water contamination from the EDCP.

3. Notify County Agricultural Commissioners about EDCP activities. Before an application may occur, EDCP shall file Pesticide Use Recommendations (PUR) and a Notice of Intent (NOI) with the appropriate County Agricultural Commissioner (CAC) office, when required for restricted material or as requested by each county. Each NOI will include the site number, spray dates, locations, and herbicides and adjuvants to be used. NOIs will be submitted before the upcoming treatment week. Based on information in the NOIs, CAC's could inform land owners of particular periods of time during which irrigation should not occur. If necessary, EDCP shall also obtain a Restricted Use Permit (RUP) from all appropriate CACs.

Status of Delta Smelt and Environmental Baseline

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

Adult-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 Wildlife 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 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 Fall Midwater Trawl (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 2002; 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 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 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.CDFW.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 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.

One published exception to the multi-factor hypothesis was proposed by Glibert (2010), who posited that nutrient pollution was the root cause of all the food web and fish assemblage changes that caused the decline of delta smelt and other pelagic fishes. However, the statistical approach she used to support her hypothesis was not appropriate and the untransformed data sets do not support this hypothesized chain of consequences stemming solely from wastewater inputs to the Delta (Jassby and others in press). 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 2002; 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

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.

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 IEP 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 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; 2011; Maunder and Deriso 2011).

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 2002). 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 and Bennett 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 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.* 2013). 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 (see effects section).

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 1996; 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-1980's, 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 (> 20^0C) 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 1988). 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.* 2009b).

E. 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 algae, *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 CALFED Science Conference). 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 dissolved oxygen to lethal levels for fish (Saiki *et al.* 1998), although delta smelt do not strongly overlap the densest *Microcystis* concentrations, so dissolved oxygen 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 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 *et al.* 1992).

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 (Ameg *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). The Sacramento Regional Wastewater Treatment Plant was identified as the largest source of pyrethroids to the Delta (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.* (2010b) 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.* (2010b) 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 *et al.* 2006). 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 *et al.* 2006). 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.

Climate Change: At present, quantitative analysis of how ongoing climate change is specifically affecting delta smelt and the Delta ecosystem does not exist. 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.

Status of the Delta Smelt Critical Habitat

The action area for this consultation is within portions of designated 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 (PCEs) 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 low-salinity zone (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 Requirements 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.

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; 2011). 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 (CDFW 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).

Changing predation pressure (1879 to present): Nothing is known about the historical predators of delta smelt or their possible influence on delta smelt. Fish eggs and larvae can be opportunistically preyed upon by many invertebrate and vertebrate animals so there has always been a very long list of potential predators of delta smelt's eggs and larvae. 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: a habitat that is not known to have had an equivalent predator prior to the establishment of striped bass (Moyle 2002). This 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. 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 also not known mainly because quantitative descriptions of predator impacts on rare prey are extremely difficult to generate. 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 observed 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 observed in delta smelt population dynamics (Bennett 2005; Maunder and Deriso 2011). Because it is generally true for fishes, the vulnerability of delta smelt to predators is influenced primarily by habitat conditions. Turbidity may be a key mediator of delta smelt's vulnerability to predators (Nobriga *et al.* 2005; 2008). Growth rates, an interactive outcome of feeding success and water temperature, are also well known to affect fishes' cumulative vulnerability to predation (Sogard 1997). Thus, predation rate is best characterized as an aspect food web function linked to PCE # 2.

Food web alterations attributable to the overbite clam (1987-present): The next major change to PCE # 2 occurred following the invasion of the estuary by overbite clam (*Corbula amurensis*). The overbite clam was first detected in 1986 and from 1987-1990 its influence on the ecosystem became evident. Since 1987, there has been a step-decline in phytoplankton biomass (Alpine and Cloern 1992; Jassby *et al.* 2002). Phytoplankton in the LSZ is an important component of the pelagic food web that delta smelt are a part of because a key part of the diet of delta smelt's prey is phytoplankton. Not only does the overbite clam reduce food for delta smelt's prey, it can also graze directly on the larval stages of the copepods eaten by delta smelt (e.g., Kimmerer *et al.* 1994). The grazing pressure applied by the overbite clam rippled through the historical zooplankton community that fueled fishery production in the LSZ (Kimmerer *et al.* 1996; Orsi and Mecum 1996; Kimmerer 2002b; Feyrer *et al.* 2003). This major change in the way energy moved through the ecosystem has likely facilitated the numerous invasions of the estuary by suppressing the production of historically dominant zooplankton, which increases the opportunity for invasion by other species that are less dependent on high densities of LSZ phytoplankton.

The distribution and abundance of several LSZ fishes have changed since 1987 (Kimmerer 2002b; Kimmerer 2006; Rosenfield and Baxter 2007; Mac Nally *et al.* 2010). Surprisingly, the changes in phytoplankton and zooplankton production have not been as evident for delta smelt as for other organisms (Kimmerer 2002b; Kimmerer 2006; Sommer *et al.* 2007; Mac Nally *et al.* 2010). Nonetheless, delta smelt collected in the FMWT have been persistently smaller since the overbite clam invasion (Sweetnam 1999; Bennett 2005). This is evidence for reduced growth rates that could have been caused by food web changes stemming from overbite clam grazing. The Service considers the prey density aspect of the estuarine food web to be a component of PCE # 3 ("Water"). The Central Valley Project and State Water Project entrain some food web production (about 4.5% on a daily average basis was attributed to all water diversions in the Delta; Jassby *et al.* 2002). However, prey densities have been most strongly affected by clam grazing (Kimmerer *et al.* 1994; Jassby *et al.* 2002). Urban wastewater input, *Microcystis* blooms, and pesticide loads may also impair the production of zooplankton eaten by delta smelt

or eaten by delta smelt's prey (Wilkerson *et al.* 2006; Dugdale *et al.* 2007; Jassby 2008; Ger *et al.* 2009; Werner *et al.* 2010).

Proliferation of submerged aquatic vegetation (1980s to present): For many decades, the Delta's waterways were turbid and the 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 *E. densa*, a fast-growing aquarium plant that has taken hold in many shallow habitats (Brown and Michnuik 2007; Hestir 2010). *E. 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 (> 20^0C) 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, dense SAV promotes 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, including largemouth bass, which now dominate many shallow habitats of the Delta and displace native fishes (Nobriga *et al.* 2005; Brown and Michniuk 2007). Finally, SAV colonization over the last three decades has led to a shift in the dominant freshwater food web pathways that fuel fish production (Grimaldo *et al.* 2009b). It is noteworthy that SAV-dominated habitats are comparatively productive (Nobriga *et al.* 2005; Grimaldo *et al.* 2009b), but most of the productivity they generate remains in the nearshore environment and therefore does not contribute much to pelagic fish production (Grimaldo *et al.* 2009b).

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.

Changing water temperature (present through long-term climate forecasts): Delta smelt is already subjected to thermally stressful temperatures every summer in the Delta. 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.

All available regional climate change projections predict central California will be warmer still in the coming decades (Dettinger 2005). It is expected that warmer estuary temperatures will be yet another significant conservation challenge (Brown *et al.* 2013; Cloern *et al.* 2011). This is true because they will limit abiotic habitat suitability further than indicated by flow-based projections (e.g., Feyrer *et al.* 2011). In addition, warmer water temperatures mean that higher prey densities will be required just to maintain present-day growth rates, which are already lower than they once were (Sweetnam 1999; Bennett 2005). Water temperature is mainly affected by climate variation, both as air temperature and as flood and drought scale flow variation (Kimmerer 2004; Wagner *et al.* 2010).

Sensitivities to contaminants (ongoing): Delta smelt's spawning migration coincides with early winter rains (Sommer *et al.* 2011). This 'first-flush' of inflow to the Delta brings sediment-bound pesticides with it (Bergamaschi *et al.* 2001), and peak densities of larvae and juveniles can co-occur with numerous pesticides (Kuivila and Moon 2004). Bennett (2005) reported that about 10% of the delta smelt analyzed for histopathological anomalies in 1999-2000 showed evidence of deleterious contaminant exposure, but this was low compared to the 30%-60% of these fish that appeared to be food-limited.

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). 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. Climatic scale flow variation (e.g., flood versus drought scale variation) affects the amount of methyl mercury (Darryl Slotton presentation) entering the ecosystem and may have some influence on the meaningful dilution of ammonium from urban wastewater inputs (Dick Dugdale presentation).

Invasive species may also affect PCE # 2 by changing contaminant dynamics. For instance, *Microcystis* blooms generate toxic compounds that can kill delta smelt prey (Ger *et al.* 2009) and accumulate in the estuarine food web (Lehman *et al.* 2010). A second example is the biomagnification of selenium in the food web by *Corbula* (Stewart *et al.* 2004). This has been considered a potential issue for the clam's predators – namely sturgeon, splittail, and diving ducks (Richman and Lovvorn 2004; Stewart *et al.* 2004). However, it is not known whether this change in selenium dynamics negatively affects delta smelt and other fishes that do not directly prey on the clams.

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 Rriver flows are often managed using changes in export flow rates.

Entrainment into water export diversions (1951 to present): The amount of water diverted from the estuary has generally increased over time, and most of the increase during the 1950s and 1960s was due to Central Valley Project exports and since the latter 1960s, State Water Project exports. There are two basic potential fishery impacts that result from water diversion from the Delta: ecosystemic impacts and direct entrainment. From the ecosystemic perspective, water diversions are unnatural 'predators' because they 'consume' organisms at every trophic level in the ecosystem from phytoplankton (Jassby *et al.* 2002) to fish (Kimmerer 2008). Unlike natural predators which typically shift their prey use over time in association with changes in prey fish density (Nobriga and Feyrer 2008), fractional entrainment losses of fishes to diversions are functions of water demand (e.g., Grimaldo *et al.* 2009). Thus, water diversions not only elevate 'predation' mortality in an aquatic system, but they can do so in an atypical, density-independent manner. Diversions and fish collection facilities in the south Delta are very large structures which attract large aggregations of actual predatory fish that prey on smaller species like delta smelt before they reach the fish salvage facilities and within these facilities (Gingras 1997).

Estimated entrainment losses of delta smelt to Project diversions can be substantial in some years (Kimmerer 2008). Given the delta smelt's current density-independent population dynamics, even a statistically indiscernable entrainment effect on the population is likely to cause the species to continue to decline (Kimmerer 2011). The entrainment losses of delta smelt are not generally observed until they reach the early juvenile stage (~ 20-30 mm in length), but combinations of 20mm Survey distribution data and hydrodynamic modeling provide evidence that their risk of entrainment into the Project diversions can be described by any of several indices that integrate Delta inflow and export flow (Kimmerer and Nobriga 2008; Kimmerer 2008; Service 2008; Grimaldo *et al.* 2009).

Delta smelt entrainment losses estimated from survey data and hydrodynamics can also be substantial in some years (Kimmerer 2008), though it is possible that Kimmerer may have overestimated them (Miller 2011). Nonetheless, increasingly higher outflow (or lower X2) moves the bulk of the larval population increasingly west, which results in fewer larvae distributed in the south Delta where they are at highest risk of entrainment. At the same time, indices like the export to inflow ratio or Old and Middle River flow are useful metrics for gauging the effect of exports on the south Delta.

The risk of delta smelt entrainment into smaller agricultural irrigation diversions used mainly to irrigate crops within the Delta is also related to flow conditions. These in-Delta irrigation diversions generally have mean flow rates less than 1 cubic meter per second (Nobriga *et al.* 2004). The lower the Delta outflow, the higher the proportion of the young delta smelt population that overlaps the array of irrigation diversions in the Delta (Kimmerer and Nobriga 2008). However, the irrigation diversions are not currently considered to represent a substantial source of mortality because they individually draw small quantities of water relative to channel volumes (Nobriga *et al.* 2004).

In Suisun Marsh, water diversions are largely made to support waterfowl production. Some Suisun Marsh diversions are larger for the size of channels they are in than most of the agricultural irrigation diversions in the Delta. Based on hydrodynamic simulations, proximity to water diversions in the marsh is expected to correlate strongly with entrainment (Culberson *et al.* 2004), and substantial delta smelt losses have been reported when these diversions are not screened (Pickard 1982). Entrainment risk for delta smelt in western Suisun Marsh is considered low because the habitat surrounding the diversions is often too saline (Enos *et al.* 2007).

Salinity PCE # 4

The core delta smelt habitat is the LSZ (Moyle *et al.* 1992; Bennett 2005). The low-salinity zone is where freshwater transitions into brackish water; the LSZ 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. The 2 psu isohaline is a specific location within the LSZ where the average daily salinity at the bottom of the water is 2 psu (Jassby and others 1995). By local convention, changes in the location of the LSZ are described in terms of the distance from the Golden Gate Bridge to the 2 psu isohaline (X2); X2 is an indicator of habitat suitability for many of the estuary's organisms and it is associated with variance in abundance of diverse components of the ecosystem (Jassby and others 1995; Kimmerer 2002b; Kimmerer and others 2009). The LSZ expands and moves downstream when river flows into the estuary are high (Kimmerer *et al.* 2009). 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).

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). In fact, 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 Fall Midwater Trawl 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.

Effects of the Proposed Action to Delta Smelt and its Critical Habitat

Temporary effects due to chemical treatments include critical habitat loss caused by decreased DO levels due to biomasses of decaying *E. densa*, decreased abundance of aquatic invertebrates that form the prey base of the delta smelt, and possible physiological and endocrine stresses to delta smelt eggs, larvae and adults. Decreased DO levels below 5 mg/L could result in behavioral avoidance or physiological stress by adult and juvenile delta smelt, or egg/larval mortality. 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. It is not clear how the proposed EDCP 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 larval development coinciding with the proposed spring EDCP 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 *E. densa* 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.

Although delta smelt are not thought to frequent *E. densa* beds, the potential exists for suction harvesting and benthic mats to kill delta smelt that seek refuge in and amongst the exotic aquatic plants. Suction harvesting may disturb feeding, breeding, and sheltering activities of the fish as the suction harvester destroys aquatic vegetation. CDBW treatment boats alter the hydrostatic pressure and equilibrium of the water resulting in physiological and sensory stressors for fish.

Fluridone

Acute toxicology studies performed by CDFW-Aquatic Toxicology Laboratory (Riley and Finlayson 2004) determined that Sonar® (active ingredient is fluridone) are non-toxic to larval delta smelt at the levels used by the EDCP. The CDBW will apply fluridone concentrations to the water column between one to ten ppb (0.001 ppm to 0.01ppm) for the 2013-2017 EDCP. This range is below the 96-hour, LC50 concentration of 6.1ppm that results in lethal effects to delta smelt (Riley and Finlayson 2004). Anderson (2004b) evaluated the dilution of Sonar AS in two Delta locations and found that maximum concentration levels were maintained for only one to 1.5 hours. Maximum levels began decreasing by 2 hours, and at 24 hours were minimal. Anderson also found lower fluridone concentrations in deeper waters as compared to the top few feet of water. Hosea (2005) found that fluridone did remain in Delta sediment following treatment, but not at levels of concern.

Diquat

CDBW will utilize diquat for the 2013-2017 EDCP but with temporal restrictions and limited treatment acres. Application of this herbicide into the Delta may pose direct and indirect effects to all delta smelt life stages, its food sources, and its critical habitat. Acute toxicology studies performed by CDFW-Aquatic Toxicology Laboratory in 2004, determined that Reward® is toxic to larval delta smelt at the application concentrations (maximum concentration 0.47 mg/L) used in previous years by the EDCP and its use would result in delta smelt mortality if used when larval delta smelt are present (Riley and Finlayson 2004). The 2013-2017 EDCP proposes to apply diquat at a maximum concentration of 0.34 mg/L. Further, a 2010 toxicology risk assessment conducted by the US Environmental Protection Agency also concluded acute toxic effects and oxygen deficiency by diquat to all life stages of delta smelt individuals and adverse modification of its critical habitat due to acute risk quotients (RQ) exceeding the level of concern (LOC) for direct water applications (USEPA 2010). Acute RQ exceeded the LOC's for 11 out of 21 scenarios for effects to aquatic prey items, aquatic habitat and/or primary productivity (USEPA 2010). Diquat is persistent in the environment and binds to sediment and terrestrial soils. Therefore the use of Reward® when delta smelt are present could result in the harm, harassment and mortality of delta smelt and modification of its critical habitat. The effects of diquat will be minimized by the EDCP treatment restrictions that limit CDBW's use of it toonly

50 treatment acres per year and during the delta smelt work-window of August 1 to November 30. Diquat effects to delta smelt can be further minimized by substituting its use with Reward® if the nearest CDFW and IEP delta smelt survey sampling stations did not capture delta smelt in the infested EDCP treatment sites.

Penoxsulam and Imazamox

The newly proposed herbicides penoxsulam and imazamox included for the 2013-2017 EDCP 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. 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 conducted by CDBW 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, under the WHCP, the CDBW is proposing to only utilize penoxsulam and imazamox in Areas 3 and 4 (see Appendix B) from March 1 to November 30 when delta smelt are less likely to be present in the area to further reduce any possible risks to delta smelt.

Injection of the herbicides onto *E. densa* beds within the Delta may pose direct and indirect effects to delta smelt and its critical habitat. The EDCP will also treat in WHCP Areas 3 and 4 (see Appendix B) and it's 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. Additionally, because of the timing and location of penoxsulam and imazamox use, it is anticipated that any direct effects to delta smelt are likely to be low.

Acute toxicology data for the newly registered penoxsulam and imazamox are available only from the USEPA 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 96-hour, LC50 values above 101 mg/L. Penoxsulam and imazamox LC50 values for rainbow trout (*Oncorhynchus mykiss*) range from >102 and >122 mg/L which are lower in comparison to diquat 10 mg/L, indicative of higher toxicity (Washington DOE 2002). The reduced environmental risk of penoxsulam and imazamox comes from the reduced application volume required during treatment. The USEPA'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 USEPA 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 EDCP activities with the proposed chemicals would be less than the toxicity thresholds. Risk from their use is reduced because the CDBW 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.

Other Effects

The EDCP will have a number of positive effects for delta smelt. Recovery Tasks # 1121 (Develop Delta habitat and vegetation zones) and #132 (Eliminate loss of shallow water habitat) of the *Delta Native Fishes Recovery Plan* (Recovery Plan) (Service 1996), will be addressed by reducing competitive exclusion of native aquatic vegetation by a non-native aquatic macrophyte.

A benefit of the removal of *Egeria densa* is the likely density reduction of non-native predatory fish within shallow water areas, and may provide additional benefits to delta smelt if waterways are re-colonized by native vegetation. In locations where *E. densa* stands are reduced by the EDCP, foraging habitat may be enhanced for delta smelt. Grimaldo *et al.* (2000) have shown that although predation risk is higher in open water, foraging success is higher as well. Delta smelt, like salmonids, are primarily visual foragers and may have difficulty foraging in dense beds of *E. densa* where access to prey items can be restricted. Dense stands of *E. densa* form a wall throughout much of the subtidal zone forcing delta smelt into deeper water or channels where prey densities may be lower and predation risk may be higher (Grimaldo *et al.* 2000).

Shallow vegetated areas function as nurseries for small fish, providing relatively abundant food and shelter from predators. However, the use of dense aquatic vegetation, such as *E. densa*, by native fish is not well documented. Although some studies report that dense beds of *E. densa* provide habitat for certain fish, other studies suggest that depressed oxygen levels and reduced temperatures characteristic of beds are limiting to certain species (Cook and Urmi-Konig 1984).

McGowan (1998) found that *E. densa* beds were populated by predominantly non-native fish species. No delta smelt were collected. McGowan's findings are similar to those of Grimaldo and Hymanson (1999), who report that introduced fish species and crabs were most abundant in *E. densa* stands, as opposed to other submerged macrophyte habitat types. These findings of suggest that *E. densa* is not typically used by native fish species or specifically any threatened, endangered, or special status species as habitat or as a migration corridor.

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 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% 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 Nrg 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.

Contaminants

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.

Ammonia loading in the Bay-Delta has increased significantly in the last 25 years (Jasby 2008). Effects of elevated ammonia levels on fish range from irritation of skin, gills, and eyes to reduced swimming ability and mortality (Wicks *et al.* 2002). Delta smelt have shown direct sensitivity to ammonia at the larval and juvenile stages (Werner *et al.* 2008). Connon *et al.* (2011) investigated the sublethal effects of ammonia exposure on the genes of juvenile delta smelt and found that ammonia altered gene transcription including specific genes related to cell membrane integrity, energy metabolism, and cellular responses to environmental stimuli. The study supports the possibility of ammonia exposure-induced cell membrane destabilization that would affect membrane permeability and thus enhance the uptake of other contaminants. Ammonia also can be toxic to several species of copepods important to larval and juvenile fishes (Werner *et al.* 2010; Teh *et al.* 2011).

Climate Change

Effects of climate change could be particularly profound for aquatic ecosystems and include increased water temperatures and altered hydrology, along with changes in the extent, frequency, and magnitude of extreme events such as droughts, floods, and wildfires (Reiman and Isaak 2010). Numerous climate models predict changes in precipitation frequency and pattern in the western United States (IPCC 2007b). Projections indicate that temperature and precipitation changes will diminish snowpack, changing the availability of natural water supplies (USBR 2011). Warming may result in more precipitation falling as rain and less storage as snow. This would result in increased rain on snow events and increase winter runoff as spring runoff decreases (USBR 2011). Earlier seasonal warming increases the likelihood of rain-on-snow events, which are associated with mid-winter floods. Smaller snowpacks that melt earlier in the year result in increased drought frequency and severity (Rieman and Isaak 2010). These changes may lead to increased flood and drought risk during the 21st century (USBR 2011).

It is uncertain how a change in the timing and duration of freshwater flows will affect delta smelt. The melting of the snowpack earlier in the year could result in higher flows in January and February, ahead of peak spawning and hatching months for delta smelt. This could alter the timing or magnitude of migration and spawning cues, and potentially result in decreased spawning success. As the freshwater boundary moves farther inland into the Delta with increasing sea level (see below) and reduced flows, adults will need to migrate farther into the Delta to spawn, increasing the risk of predation and the potential for entrainment into water export facilities and diversions for both themselves and their progeny.

The National Academy of Sciences (NAS) projected that sea levels along the California coast south of Cape Mendocino will rise 4–30 centimeters (cm) (2–12 inches (in)) by 2030, 12–61 cm (5–24 in) by 2050, and 42–167 cm (16–66 in) by 2100 (NAS 2012) compared to 2000 sea levels. Research indicates that the coastal land area south of Cape Mendocino is sinking at an average rate of about 1 millimeter (mm) (.04 in) per year, although Global Positioning System (GPS)-measured rates vary widely (-3.7–0.6 mm per year) (NAS 2012). The NAS committee used output from global ocean models under an IPCC (2007) mid-range greenhouse gas emission scenario (NAS 2012, p. 5). However, carbon dioxide emissions from fossil fuels for the past decade have been at the high end of IPCC scenarios owing to rapid economic growth in developing countries (Le Qu´er´e *et al.* 2009). Because emissions for the last decade have been on the high end of the IPCC scenarios, a maximum rise of 5.48 feet (ft) (167 cm) by 2100 is appropriate for analyzing the impact of sea level rise on delta smelt.

Even if emissions could be halted today, the oceans would continue to rise and expand for centuries due to their capacity to store heat (CEC 2009). In the Bay-Delta, higher tides combined with more severe drought and flooding events are likely to increase the likelihood of levee failure, possibly resulting in major alterations of the environmental conditions (Moyle 2008). It is reasonable to conclude that more severe drought and flooding events will also occur in other estuaries where the Delta smelt occurs. Sea level rise is likely to increase the frequency and range of saltwater intrusion. Salinity within the northern San Francisco Bay is projected to rise by 4.5 psu by the end of the century (Cloern *et al.* 2011). Elevated salinity levels could push the position of X2 farther up the estuary and could result in increased distances that delta smelt must migrate to reach spawning habitats. Fall X2 mean values are projected to increase by a mean of about 7 km to the area of Antioch for a distance of approximately 90 km from the golden gate bridge by 2100 (Brown *et al.* 2013). This increase in the position of X2 is expected to result in a decrease in suitable physical habitat (Brown *et al.* 2013). Elevated sea levels could result in greater sedimentation, erosion, coastal flooding, and permanent inundation of low-lying natural ecosystems (CDFG 2009).

We expect warmer estuary temperatures to be yet another significant conservation challenge based on climate change models. Typically, the bulk of delta smelt spawning occurs at water temperatures between 7 and 15 °C (44.6 and 59 °F), although spawning has been observed at both lower and higher temperatures (Wang 1986, Moyle 2002). Mean annual water temperatures within the upper Sacramento River portion of the Bay-Delta estuary are expected to approach or exceed 14 °C (57.2 °F) during the second half of this century (Cloern *et al.* 2011). Warmer water

temperatures could increase delta smelt mortality and constrict suitable habitat throughout the Delta during the summer months. Due to warming temperatures, Delta smelt are projected to spawn between ten and twenty-five days earlier in the season depending on the location (Brown *et al.* 2013). Also due to expected temperature increases, total number of high mortality days is expected to increase for all IPCC climate change scenerios (Brown *et al.* 2013). The number of stress days is expected to be stable or decrease partly because many stress days will become high mortality days. This could lead to delta smelt being forced to grow under highly stressful conditions during summer and fall with less time to mature because of advanced spawning (Brown *et al.* 2013). 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.* 2013). Water temperatures are presently above 20°C (68 °F) for most of the summer in core habitat areas, sometimes even exceeding the nominal lethal limit of 25 °C (77 °F) for short periods.

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.

Conclusion

After reviewing the current status of the delta smelt and its critical habitat, the environmental baseline, the effects of the proposed EDCP, and the cumulative effects, it is the Service's biological opinion that the proposed EDCP is not likely to jeopardize the continued existence of the delta smelt, or result in the destruction or adverse modification of delta smelt critical habitat. We base this determination on the temporary nature of the effects, proposed EDCP treatment restrictions and conservation measures, the limited use of diquat, and the non-acute toxicity of fluridone at the levels used in the EDCP.

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

The Service anticipates that incidental take of delta smelt in the form of harassment, harm, injury 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 the proposed 2013-2017 EDCP operations. Delta smelt have a relatively small body size and 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 within the acreage of Delta and upland tributaries under treatment for *E. densa*.

From 2007 to 2012, the EDCP treated 200 to 3,500 acres of waterways for *E. densa* infestations in the Delta. The Service anticipates that annually from March 1 to November 30 during the years of 2013 to 2017, as much as 3,500 acres, possibly up to 5,000 acres, of Delta waterways that are designated as delta smelt critical habitat, could be temporarily affected as a result of chemical control of *E. densa*. Delta smelt distribution will shift throughout the year, depending on timing and life stage. As such, it can be assumed that not all potential 5,000 acres of the *E. densa* treatment sites within the Delta will have delta smelt occurring within the area during the time of application. Numerous sites within the EDCP project are situated outside of delta smelt range or are in areas that do not contain essential PCE's of delta smelt critical habitat. Sites may be outside of areas where delta smelt are likely to be found or in areas not considered quality delta smelt habitat due to low water flow and/or low DO levels.

The Service concludes that any delta smelt inhabiting up to 5,000 acres of delta smelt habitat may be harassed, harmed or killed by the temporary modification and degradation of habitat as a result of EDCP operations. Five thousand acres is the maximum acreage that could potentially be treated in the Delta for the 2013-2017 proposed action. However, the Service believes that the actual acres of habitat that could support delta smelt subject to EDCP operational activities in a given calendar year, will be less than the maximum acreage estimated above and that actual take in the form of harassment, harm or mortality will be substantially lower than the number of delta smelt that may inhabit the potential maximum of 5,000 acres treated in the Delta.

The Service has made this determination based on CDBW's proposed Treatment Restrictions and Conservation Measures, the number of treatment areas that do not contain essential PCE's for delta smelt or are considered to be of little or no habitat value to delta smelt (caused by existing DO levels and slow or no water flow, or are outside of delta smelt range and designated critical habitat), and that delta smelt's varied distribution throughout the year 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 EDCP operations in the form of harm, harassment, injury, or mortality to delta smelt, 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, the proposed EDCP conservation measures for minimizing project effects to delta smelt and its critical habitat, the limited use of Reward© only when there are emergency conditions, and the non-toxicity of Sonar® at the levels used in habitat containing PCE's of 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 EDCP project to the delta smelt and its critical habitat:

1. The USDA-ARS shall ensure CDBW implements the *Conservation Measures* (page 16) as described in the *Project Description* of this biological opinion.

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

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

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):

a. The USDA-ARS through CDBW shall educate and inform all and any contractors involved in the project as to the *Conservation Measures* and *Terms and Conditions* in this biological opinion.

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

a. USDA-ARS will devise toxicity studies for imazamox and penoxulam to determine the effects of both herbicides on delta smelt. This study proposal will be submitted to the Service and CDFW for review.

b. Should CDBW determine that an *Egeria densa* infestation in the Delta constitutes an emergency situation and Reward® is to be utilized, the USDA-ARS and CDBW will contact the Assistant Field Supervisor of the BDFWO's ESA-Regulatory Division at (916) 930-5603, prior to the application of Reward® and provide the Service with the proposed treatment plan for review. The utilization of Reward® by CDBW for a given year, in Delta waterway(s) shall be at the Service's discretion.

3) The following terms and conditions implement Reasonable and Prudent Measure Number Three (3):

a. Should any events in the project action area hinder CDBW's ability to conduct the EDCP as described in *Project Description*, CDBW and the USDA-ARS will notify the Service of any modifications to project activities and/or equipment used via e-mail or telephone, as soon as possible prior to enacting any altered phase of the project. The Service's ESA-Regulatory Division can be reached at (916) 930-5603.

b. If requested before, during, or upon completion of EDCP, the applicant shall allow access by the Service to the project site to review effects to the delta smelt, and its critical habitat.

c. The USDA-ARS and CDBW shall comply with all the reporting requirements (below).

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 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 ESA-Regulatory Division, 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 by the CDBW.

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 enhance and restore aquatic and wetland habitat in the Sacramento-San Joaquin River estuary.

2. The Service recommends CDBW and USDA-ARS work to increase public awareness of potential threats to proper ecosystem function by exotic plant species introductions

and increase public awareness of the importance of native flora and fauna of the Delta and its tributaries.

3. The Service recommends CDBW and USDA-ARS work to assist the Service in implementing recovery actions identified in the recovery plan for the 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 2013-2017 EDCP. 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 Ms. Maral Kasparian, Senior Fish and Wildlife Biologist, at Maral_Kasparian@fws.gov or (916) 930-3715. Please refer to Service File Number 08FBDT00-2013-F-0015 for any future correspondence regarding this project.

Sincerely,

FOR Michael Chotkowski
Field Supervisor

cc:
Sylvia Ortega-Hunter, California Department of Boating and Waterways, Sacramento, California
Garwin Yip, National Marine Fisheries Service, Sacramento, California
Crystal Spurr, California Department of Fish and Wildlife, Stockton, California

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.

Alpine, A. E. and J.E. Cloern. 1992. Tropic interactions and direct physical effects control on phytoplankton biomass and production in an estuary. Limnology and Oceanography, 37(5): 946-955.

Anderson, Lars W.J. 2004b. Fluridone (4AS) dissipation during typical applications of Sonar (4AS). USDA-ARS. Davis, CA.

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.

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 on the internet 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(editors), Early life history of fishes in the San Francisco Estuary and watershed. American Fisheries Society Symposium 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 on the internet 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 J. T. Hollibaugh(editors), San Francisco Bay:

the ecosystem. Pacific Division of the American Association for the Advancement of Science. San Francisco, CA.

Bennett, W.A. 2005. Critical assessment of the delta smelt population in the San Francisco Estuary, California. San Francisco Estuary and Watershed Science 3(2).

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, L. R., W. A. Bennett, R. W. Wagner, T. Morgan-King, N. Knowles, F. Feyrer, D. H. Schoelhamer, M.T. Stacey, and M. Dettinger. 2013. Implications for future survival of delta smelt from four climate change scenarios for the Sacramento-San Joquin Delta, California. Estuaries and Coasts. DOI 10.1007/s12237-013-9585-4. Available on the internet at < http://link.springer.com/article/10.1007%2Fs12237-013-9585-4#>.

Brown, L. R., W. Kimmerer and R. Brown. 2008. Managing water to protect fish: a review of California's Environmental Water Account, 2001-2005. Environmental Management DOI 10.1007/s00267-008-9213-4. Availble on the internet at <http://www.springerlink.com/content/u4022223x2181287/fulltext.pdf>.

Brown, R.L. 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)1: 186–200.

Brown, R.L. and W.J. Kimmerer. 2001. Environmental and institutional background for CALFED's Environmental Water Account. CALFED Bay-Delta Program, Sacramento, California.

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 Wildlife (CDFW). 2013. Fall Midwater Trawl [database on the internet]. Available from http://www.delta.ca.gov/data/mwt99/index.html. Accessed on September 18, 2002.

_____. 2013. 20mm Survey [database on the internet]. Available from http://www.delta.ca.gov/data/20mm/2000/. Accessed on September 18, 2002.

_____. 2013. Summer Townet Survey [database on the internet]. Available from http://www.delta.CDFW.ca.gov/data/skt/skt2002/index.html. Accessed on September 18, 2002.

_____. 2004. Comment Letter on the Five Year Status Review of the Delta Smelt. 2 pp.

_____. 2011. California Natural Diversity Data Base (CNDDB) RAREFIND. Natural Heritage Division, Sacramento, California.

_____. Fish Bulletin No. 133.

California Department of Pesticide Regulation. 2011. The top 100 sites by pounds of active ingredients statewide in 2009 (all pesticides combined). Available at <http://www.cdpr.ca.gov/docs/pur/purmain.htm>. Accessed March 28, 2011.

California Department of Water Resources and U.S. Bureau of Reclamation, Mid-Pacific Region. 1993. Effects of the Central Valley Project and State Water Project on delta smelt. Sacramento County, California. 134 pp.

California Department of Water Resources and U.S. Bureau of Reclamation, Mid-Pacific Region 1994. Effects of the Central Valley Project and State Water Project on delta smelt and Sacramento splittail. Sacramento, California. 230 pp.

California Regional Water Quality Control Board, Central Valley Region. 1992. Agricultural drainage contribution to water quality in the Grasslands Area of western Merced County, California: October 1990 to September 1991.

_____. 2010. Waste discharge requirements for the Sacramento Regional County Sanitation District, Sacramento Regional Wastewater Treatment Plant, Sacramento County, Order No. R5-2010-0114, NPDES No. CA0077682. December 9, 2010. Central Valley Region, Rancho Cordova, CA.

Castillo, G., Morinaka, J., Baskerville-Bridges, B., Lindberg, J., Fujimura, R., Dubois, J., Tigan, G. and V. Poage. 2008. Pilot Mark-Recapture Study to Estimate Delta Smelt Pre-screen Loss and Salvage Efficiency. 2008 CALFED Science Conference Presentation.

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.

Cayan, D., M. Dettinger, I. Stewart and N. Knowles. 2005. Recent changes toward earlier springs – Early signs of climate warming in western North America. Watershed Management Council Networker, 13, Spring. Pages 3-9. Available at http://www.watershed.org.

Central Valley Regional Water Quality Control Board. 1998. Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins. Fourth Edition. September 15, 1998. Sacramento, CA. Available: <http://www.swrcb.ca.gov/centralvalley/water_issues/basin_plans/sacsjr.pdf>. Accessed: October 21, 2010.

Cloern, J.E, N. Knowles L.R. Brown, D. Cayan, M.D. Dettinger, *et al.* 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, 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.

Cook, C.D.K. and K. Urmi-Konig. 1984. A revision of the genus *Egeria* (Hydrocharitaceae). Aquatic Botany, 19, pp. 73-96.

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 (editors) Early life history of fishes in the San Francisco Estuary and watershed. American Fisheries Society Symposium 39, Bethesda, MD, USA.

Davis J.A., M.D. May, G. Ichikawa, and D. Crane. 2000. Contaminant Concentrations from Fish in the Sacramento-San Joaquin Delta and Lower San Joaquin River, 1998. San Francisco Estuary Institute, Richmond, California.

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 (1)1. Available on the internet at <http://escholarship.org/uc/item/9fm1z1zb>.

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. American Fisheries Society 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. Available on the internet at <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.

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.

Edwards, G.W., K. Urquhart and T. Tillman. 1996. Adult salmon migration monitoring during the various operational phases of the Suisun Marsh Salinity Control Gates, September–November 1994. Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report 50. 27 p.

Enge, K.M. and K.N. Wood. 2002. A pedestrian road survey of an upland community in Florida. Southeastern Naturalist 1(4): 365-380.

Enos, C, Sutherland, J, Nobriga, M. 2007. Results of a two-year fish entrainment study at Morrow Island Distribution System in Suisun Marsh. Interagency Ecological Program Newsletter 20(1): 10-19.

Environmental Science Associates. 2003. Stockton Delta Water Supply Project. 25 pp.

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.

EXTOXNET. 1993. Diquat dibromide. Cornell University, Northeastern Integrated Pest Management Center. http://pmep.cce.cornell.edu. Accessed November 2, 2012.

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. 2010. 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. Scott 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.

Ger, K.A., S.J. The, D.V. Baxa, S. Lesmeister, and C.R. Goldman. 2009. The effects of dietary *Microcystis aeruginosa* and miscrocystin on the copepods of upper San Francisco Estuary. Freshwater Biology 55: 1548-1559, 12 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.

Gillett, J. W. 1970. The biological impact of pesticides in the environment. Environmental Health Sciences Series No. 1. Oregon State University, Corvallis, OR, 10-96.

Gingras, M. 1997. Mark/recapture experiments at Clifton Court Forebay to estimate pre-screening loss to entrained juvenile fishes, 1976-1993. Interagency Ecological Program Technical Report 55.

Grimaldo, L.F., A. R. Stewart and W. Kimmerer. 2009b. Dietary segregation of pelagic and littoral fish assemblages in a highly modified tidal freshwater estuary. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 1(1): 200-217.

Grimaldo, L.F., T. Sommer, N. Van Ark, G. Jones, E. Holland, P.B. Moyle, P. Smith and B. Herbold. 2009. Factors affecting fish entrainment into massive water diversions in a freshwater tidal estuary: can fish losses be managed? North American Journal of Fisheries Management 29(5) 1253-1270. First published online on: 09 January 2011 (iFirst).

Grimaldo, L. and Z. Hymanson. 1999. What is the Impact of the Introduced Brazilian Waterweed Egeria densa to the Delta Ecosystem? Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter, Vol. 12, No. 1, Winter 1999, 43 p.

Gunnison, D., and J.W. Barko. 1992. Factors influencing gas evolution beneath a benthic barrier. Journal of Aquatic Plant Management 30: 23-28.

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. alifornia 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.E. Burton. 2006. Assessing nursery habitat quality for native smelts (*Osmeridae*) in the low-salinity zone of the San Francisco estuary. Journal of Fish Biology 96(3): 907-922.

Hobbs, J.A., Bennett, W.A., Burton, J. 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(2): 518-527.

Horppila, J., A. Liljendahl-Nurminen, and T. Malinen. 2004. Effects of Clay Turbidity and light on the predatory-prey interaction between smelts and Chaoborids. Canadian Journal of Fisheries and Aquatic Sciences 61: 1862-1870.

Hosea, R.C. 2005. Residue of Fluridone and Diquat Dibromide in Sediment from the Sacramento- San Joaquin Delta, California, 2002-2005. California Department of Fish and Game.

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

Interagency Ecological Program (IEP) for the San Francisco Bay. 2010. IEP Newsletter 23:1. 25 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/>.

_____. 2007b. Summary for Policymakers. Pp. 1–18. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY. 996 pp.

_____. 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. Ecological Applications 5(1): 272-289.

Jassby, A.D., Cloern, J.E. 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.

Jassby, A.D., A.B. Mueller-Solger and M. Vaysierres. 2005. Subregions of the Sacramento-San Joaquin Delta: identification and use. Interagency Ecological Program Newsletter 18(2): 46-56.

Jassby, A.D. 2008. Phytoplankton in the upper San Francisco estuary: recent biomass trends, their causes and their trophic significance. San Francisco Estuary and Watershed Science, Vol. 6, Issue 1 (February 2008), Article 2.

Johnson, W. W. and Finley, M. T. 1980. Handbook of Acute Toxicity of Chemicals to Fish and Aquatic Invertebrates, Resource Publication 137. U.S. Department of Interior, Fish and Wildlife Service, Washington, DC, 7-38.

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., Denton, R.A., 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. 2002. 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>.

Kimmerer, W., and M. Nobriga. 2005. Development of bootstrapped confidence intervals for the IEP fish abundance indices. Interagency Ecological Program Newsletter 18(2): 68-75.

Kimmerer, W.J. 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., and M.L. Nobriga. 2008. Investigating particle transport and fate in the Sacramento-San Joaquin Delta using a particle tracking model. San Francisco Estuary and Watershed Science, 6:2 (4). Available on the internet at <http://repositories.cdlib.org/jmie/sfews/vol6/iss1/art4>.

Kimmerer, W.J., and B. Bennett. 2008. Research plan to determine the mechanisms underlying the "Fish-X2" relationships. Report to the CALFED Ecosystem Restoration Program, Contract ERP-02-P19. Submitted June 12, 2008. Available on the internet at

Kimmerer, W.J., E.S. Gross, 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(1). San Francisco Estuary and Watershed Science, John Muir Institute of the Environment, UC Davis. Available on the internet at <http://escholarship.org/uc/item/0rd2n5vb>.

Knowles, N. 2002. atural 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, A.C., Jr. and J.J. Orsi. 1983. Factors regulating abundance and distribution of the shrimp *Neomysis mercedis* in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 112:476-485.

Kuivila, K.M. & 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.

Le Qu´er´e C., Raupach M.R., Canadell J.G., Marland G., Bopp L., et al. 2009. Trends in the sources and sinks of carbon dioxide. Nature Geoscience 2:831–36.

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.

Lehman, P.W., Teh, S.J., Boyer, G.L., Nobriga, M.L, Bass, E., Hogle, C. 2010. Initial impacts of Microystis aeruginosa blooms on the aquatic food web in the San Francisco Estuary. Hydrobiologia 637: 229-248.

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, Joan 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, Regina 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 on the internet 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. nalysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling (MAR). Ecological Applications 20(5): 1417–1430.

Madsen, J. D. 2000. Advantages and disadvantages of aquatic plant management techniques. US Army Engineer Research and Development Center Environmental Laboratory. Originally in North America Lake Management Society, LakeLine. 20 (1):22-34. Available at: <http://www.aquatics.org/pubs/madsen2.htm>.

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(editors), Early life history of fishes in the San Francisco Estuary and watershed. American Fisheries Society Symposium 39, Bethesda, MD, USA.

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). San Francisco Estuary and Watershed Science, John Muir Institute of the Environment, UC Davis. Available on the internet at <http://escholarship.org/uc/item/5941x1h8>.

Miller, W.J. 2007. Declaration of William J. (B.J.) Miller, Ph.D. Regarding Interim Injunctive Relief, July 23, 2007, Proceedings of Natural Resources Defense Council, et al. v. Kempthorne, et al., Case No. 05 CV-01207 OWW (E.D. Cal.).

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 Delta. San Francisco Estuary and Watershed Science (5(3). Available on the internet at < http://escholarship.org/uc/item/04822861

Moyle, P.B. 1976. Inland Fishes of California. University of California Press, Berkeley, California. 405 pp.

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

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

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), Limnology and Oceanography 47(5): 1468-1476.

National Academy of Sciences. 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. Committee on Sea Level Rise in California, Oregon, and Washington Board on Earth Sciences and Resources and Ocean Studies Board
Division on Earth and Life Studies. National Academies Press, Washington, D.C. 250 pp. Available on the internet at <www.national-academies.org>.

New York State Department of Environmental Conservation. April 2005. A Primer on Aquatic Plant Management in New York State, Chapter 6, Local/Shoreline Management Activities. New York State. Available at: <www.dec.ny.gov/docs/water_pdf/ch6p2.pdf>.

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., Z. Hymanson and R. Oltmann. 2000. Environmental factors influencing the distribution and salvage of young delta smelt: a comparison of factors occurring in 1996 and 1999. Interagency Ecological Program Newsletter 13(2):55-65. Available on the internet at <http://www.iep.ca.gov/report/newsletter/2000spring/IEPNewsletter_Spring2000.pdf>.

Nobriga, M. L., 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 on the internet at <http://www.iep.ca.gov/report/newsletter>.

Nobriga, M. L., and F. Feyrer. In press. Diet composition of San Francisco Estuary striped bass: does trophic adaptability have its limits? Environmental Biology of Fishes.

Nobriga, M.L. 2002. Larval delta smelt diet composition and feeding incidence: environmental and ontogenetic influences. California Department of Fish and Wildlife 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 on the internet at <http://repositories.cdlib.org/jmie/sfews/vol5/iss2/art4>.

Nobriga, M.L., 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 on the internet at < http://escholarship.org/uc/item/5xd3q8tx>.

Oros, D.R. & 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. 1986. Zooplankton distribution and abundance in the Sacramento-San Joaquin Delta in relation to certain environmental factors. Estuaries 9(4B):326-339.

Ostrach, D., J. M. Low-Marchelli, K. J. Eder, S. J. Whiteman, and J. G. Zinkl. 2008. Maternal transfer of xenobiotics and effects on larval striped bass in the San Francisco Estuary*PNAS 2008 105:19354-19359; published online before print November 24, 2008, doi:10.1073/pnas.0802616105*

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

Pickard, A, Baracco, A, Kano, R. 1982. Occurrence, abundance, and size of fish at the Roaring River Slough intake, Suisun Marsh, California, during the 1980-81 and the 1981-82 diversion seasons. Interagency Ecological Program Technical Report 3. California Department of Water Resources, Sacramento, CA.

Radtke, L. D. 1966. Distribution of smelt, juvenile sturgeon, and starry flounder in the Sacramento-San Joaquin Delta. Pages 115-119 in J. L. Turner and D. W. Kelley(editors), Ecological studies of the Sacramento-San Joaquin Estuary, Part 2. California Department of Fish and Game Fish Bulletin No. 136.

Rieman, Bruce E.; Isaak, Daniel J. 2010. Climate change, aquatic ecosystems, and fishes in the Rocky Mountain West: implications and alternatives for management. Gen. Tech. Rep. RMRS-GTR-250. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 46 p. Available on the internet at < http://www.arlis.org/docs/vol1/C/706819292.pdf>.

Richards, S., C.Wilson, D. Johnson, D. Castle, M. Lam, S. Mabury, P.Sibley, and K.Solomon. 2004. Effects of pharmaceutical mixtures in aquatic microcosms. Environ Toxicol Chem 23: 31-48.

Rose, K.A. 2000. Why are quantitative relationships between environmental quality and fish populations so elusive? Ecological Applications 10:367-385.

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.

F. Ryley and S. Finlayson. 2004. Acute toxicologies of herbicides used in to control water hyacinth and Brazilian elodea on larval delta smelt and SacramentoSplittail. CDFW Aquatic Toxicology Laboratory. Sacramento County, California. 14 pp + appendices.

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.

Saunders, S., C. Montgomery, and T. Easley. 2008. Hotter and drier, the west's changing climate. Rocky Mountain Climate Organization. Denver, Colorado.

Schoellhamer, David 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.

Shaffer, M.L. 1981. Minimum populations sizes for species conservation. Bioscience 31: 131-134.

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

Sommer, T., 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).

Stanley, S., 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, California. Copeia 2: 390-396.

Stevens, D.E. and S.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.

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.

Stewart, A.R., S.N. Luoma, C.E. Schlekat, M.A. Doblin, and K.A. Hieb. 2004. Foodweb pathway determines how selenium affects aquatic ecosystems: a San Francisco Bay case study. Environmental Science and Technology 38:4519-4526.

Swanson, C. And J.J. Cech, Jr. 1995. Environmental tolerances and requirements of the delta smelt, *Hypomesus transpacificus*. Final Report. Davis, California. 77 pp.

Swanson, C., P.S. Young and J.J. Cech, Jr. 1998. Swimming performance of delta smelt: maximum performance, and behavioral and kinematic limitations on swimming at submaximal velocities. Journal of Experimental Biology 201:333-345.

Swanson, C., T. Reid, P.S. Young and 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. 1999. Status of delta smelt in the Sacramento-San Joaquin Estuary. California Fish and Game 85(1): 22-27.

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.

Syracuse Environmental Research Associates (SERA). 2008. Fluridone Human Health and Ecological Risk Assessment Final Report. For the USDA/Forest Service, Southern Region. Atlanta, Georgia.

_____. 2010. Imazamox Human Health and Ecological Risk Assessment Final Report. For the USDA/Forest Service, Southern Region. Atlanta, Georgia.

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., Flores, I., Kawaguchi, M., Lesmeister, S. and C. The. 2011. August 31, 2011, Final Report: Full Life-Cycle Bioassay Approach to Assess Chronic Exposure of *Pseudodiaptomus forbesi* to Ammonia/Ammonium . Aquatic Toxicology Program, UC Davis. 46 pp.Available on the internet at

<http://swrcb2.swrcb.ca.gov/centralvalley/water_issues/delta_water_quality/ambient_ammonia_concentrations/tehetal_ammonium_exposure2011.pdf>.

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

Thetmeyer. H., and U. Kils. 1995. To see and not be seen: the visibility of predator and prey with respect to feeding behaviour. Marine Ecology Progress Series 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. Transactions of the American Fisheries Society 127: 417-424.

Turner, J.L. and D.W. Kelly. 1966. Ecological studies of the Sacramento-San Joaquin Delta. Calif. Dept. of Fish and Game Bulletin No. 136.

U.S. Bureau of Reclamation. 2003. Notice of Initiation of Federal Feasibility Studies. Mid-Pacific Regional Office, Sacramento California.

_____. 2011. SECURE Water Act Section 9503(c) – Reclamation Climate Change and Water, Report to Congress, 2011Authors, Contributors, and Editors (in alphabetical order): Alexander, P., Brekke, L., Davis, G., Gangopadhyay, S., Grantz, K., Hennig, C., Jerla, C., Llewellyn, D., Miller, P., Pruitt, T., Raff, D., Scott, T., Tansey, M.,Turner, T.

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.

_____. January 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.

_____. August 2007. Appendix F: The Risk Quotient Method and Levels of Concern. Washington D.C. 3pp.

_____. February 2008. Effects of Climate Change on Aquatic Invasive Species and Implications for Management and Research. Office of Research and Development. Washington DC.

_____. December 2010. Risks of Diquat Dibromide use to the Federally Threatened Delta Smelt (*Hypomesus transpacificus*). Pesticide Effects Determinations. Environmental Fate and Effects Division. Office of Pesticide Programs, Washington DC. 95 pp. Available on the internet at <epa.gov/espp/litstatus/effects/redleg-frog/2010/diquat/analysis.pdf>.

_____. February 2011. Water Quality Challenges in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Unabridged Advanced Notice of Proposed Rulemaking. Region 9. San Francisco, California. 84pp.

_____. 2012. Risk Assessments. http://www.epa.gov/oppefed1/ecorisk_ders/toera_risk.htm. Accessed June 26, 2012.

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.

U.S. Fish and Wildlife Service.1993a (Service). 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. 5-year review of the delta smelt. Available on the internet at < http://www.fws.gov/sacramento/es/documents/DS%205-yr%20rev%203-31-04.pdf>. Accessed August 27, 2010.

_____. 2008. Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP), Service

File No. 81420-2008-F-1481-5. Available on the internet at <http://www.fws.gov/sfbaydelta/ocap/>.

_____. 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: 17667-17680.

USACE Engineer Research and Development Center. 2005. Diver dredge. Available at: <http://el.erdc.usace.army.mil/pmis/MechanicalControls/MechanicalControlInfo.aspx?mechID=4>.

U.S. Army Corps of Engineers. 1998. Appropriate Use of Aquatic Herbicides. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS Land and Water [Land Water], vol. 42, no. 4, pp. 44-48.

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 on the internet at < http://jeb.biologists.org/cgi/content/full/208/5/831>.

Wagner, W., M. Stacey, L. Brown and M. Dettinger. 2011. Statistical models of temperature in the Sacramento-San Joaquin Delta under climate-change scenarios and ecological implications. Estuaries and Coasts34(3): 544-556.

Wang, J.C.S. 1986. Fishes of the Sacramento-San Joaquin estuary and adjacent waters, California: A guide to the early life histories. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary. Sacramento, California. Technical Report 9.

_____.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 for the Sacramento-San Joaquin Estuary. Sacramento, California. Technical Report 28.

_____. 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 Ecology (DOE). 2002. Appendix A: Final Risk Assessment for Diquat Dibromide. Prepared by Kathleen Emmett, Washington DOE Water Quality Program. Olympia, Washington. 354pp.

_____. Accessed October 17, 2012. Aquatic plant management – bottom screens. Washington DOE. Available at: <www.ecy.wa.gov>.

_____. Accessed October 23, 2012. Aquatic plant management – diver dredging. Washington DOE. Available at: <www.ecy.wa.gov>.

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

Werner, I., L.A. Deanovic, V. Connor, V. DeVlaming, H.C. Bailey, and D.E. Hinton. 2000. Insecticide-caused toxicity to Ceriodaphnia dubia (Cladocera) in the Sacramento-San Joaquin River Delta, California, USA. Environmental Toxicology and Chemistry 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.

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

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.

White, D. K., C. Swanson, P. S. Young, J. J. Cech, Jr., Z.Q. Chen and M. L. Kavvas. 2007. Close encounters with a fish screen II: Delta smelt behavior before and during screen contact. Transactions of the American Fisheries Society 136:528-538.

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.

Wicks, B. J., Joensen, R., Tang, Q. and D. J. Randall. 2002. Swimming and ammonia toxicity in salmonids: the effect of sub lethal ammonia exposure on the swimming performance of coho salmon and the acute toxicity of ammonia in swimming and resting rainbow trout. Aquatic Toxicology 59: 55-69.

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.

Winder, M., A. D. Jassby, and R. Mac Nally. 2011. Synergies between climate anomalies and hydrological modifications facilitate estuarine biotic invasions. Ecology Letters: doi: 10.1111/j.1461-0248.2011.011635.x.

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

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 Reserach 41. Available on the internet at <http://sfbay.wr.usgs.gov/publications/pdf/wright_2005_River EstuarySedBudgets.pdf>.

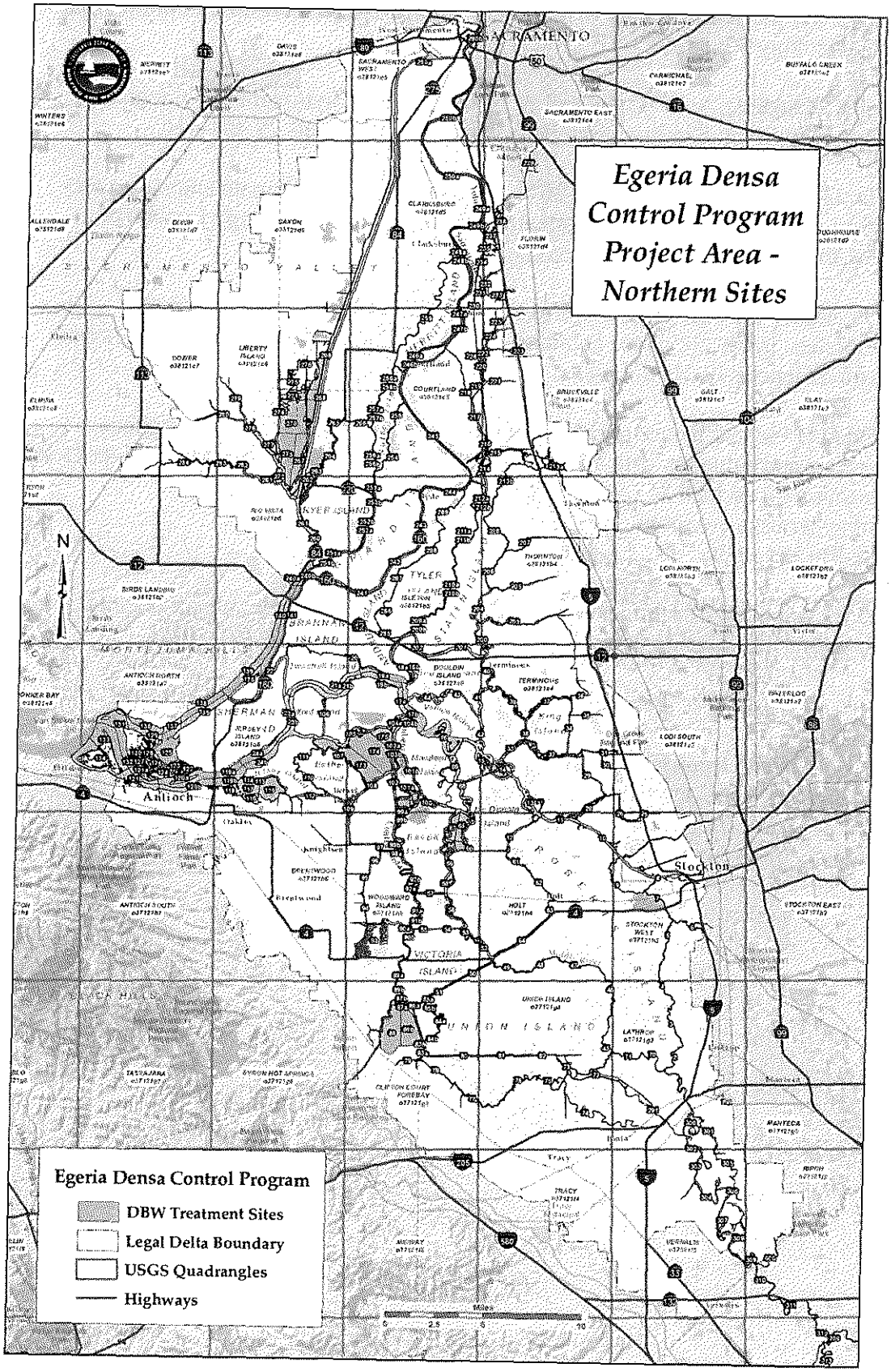
Xie, L. et al. 2005. Evaluation of estrogenic activities of aquatic herbicides and surfactants using an rainbow trout vitellogenin assay. Toxicological Sciences 87(2): 391-398.

Personal Communications

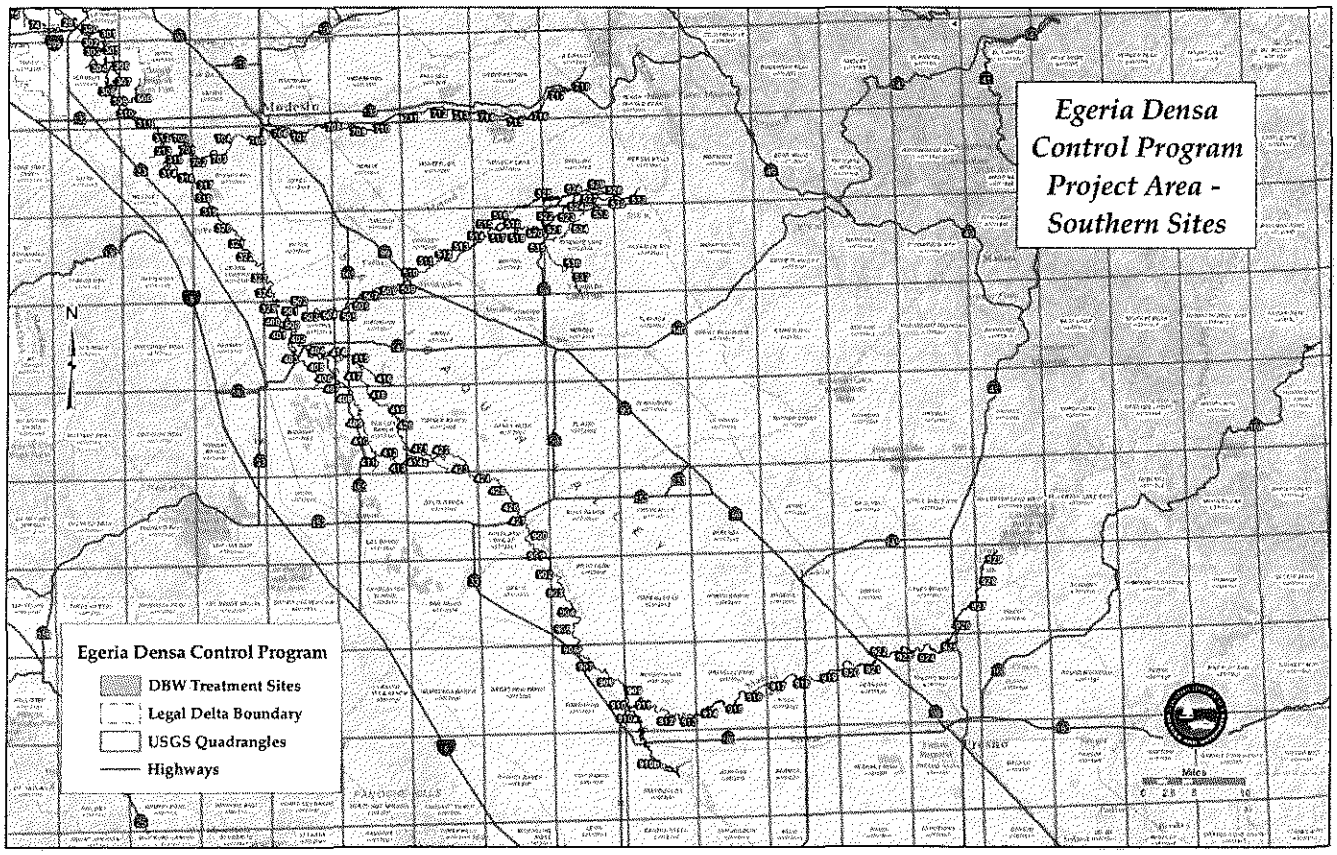
Lehman, Peggy. California Department of Water Resources, pers comm with USFWS
Lindberg, Joan. University of California, Davis, pers comm with USFWS
Scott Schuler. SePRO, pers comm with Wendy Pratt of Newpoint Group
Derma-Safe Company, pers comm with Wendy Pratt of Newpoint Group

APPENDIX A

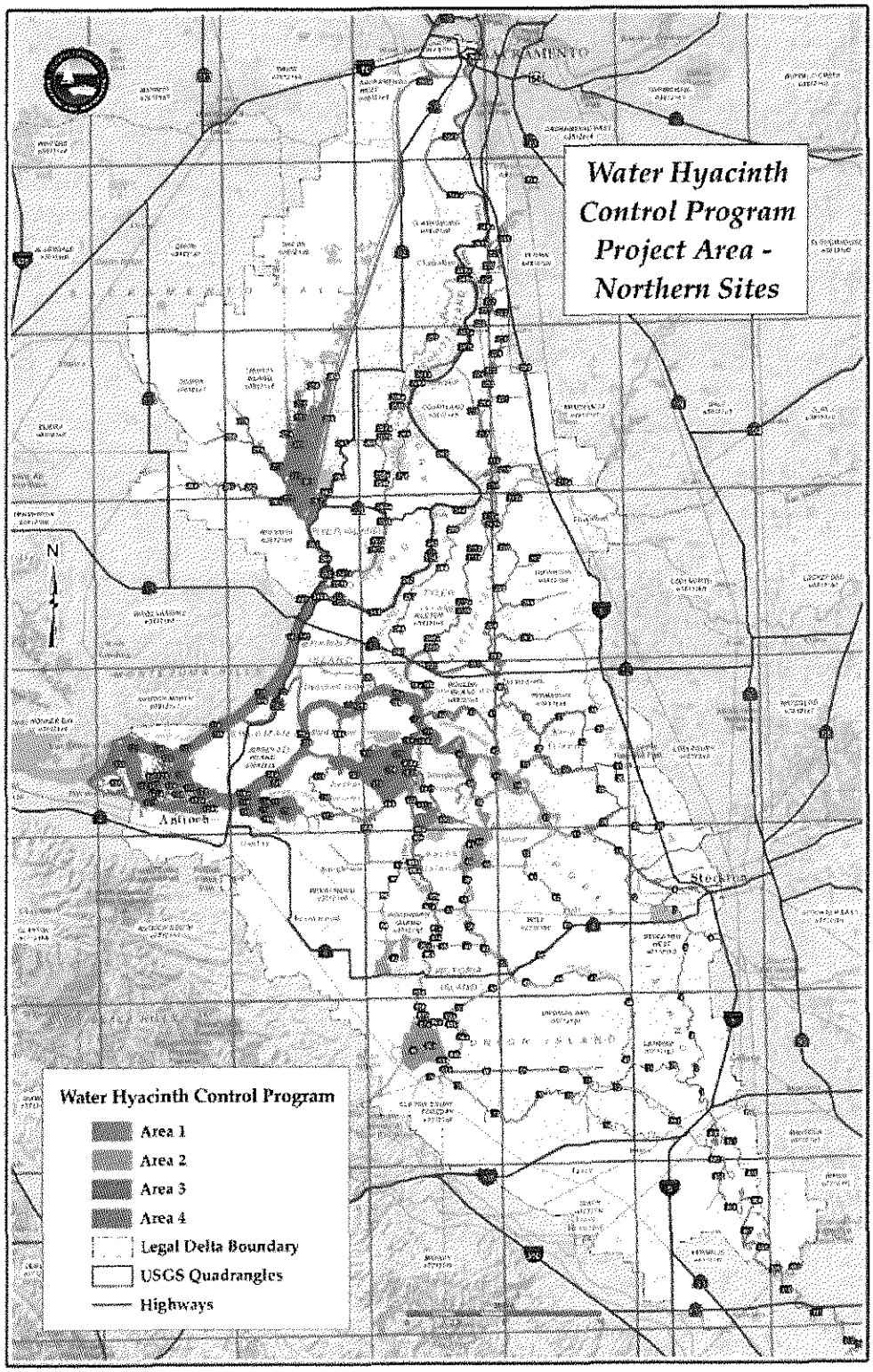
Egeria Densa Control Program Project Area - Northern Sites

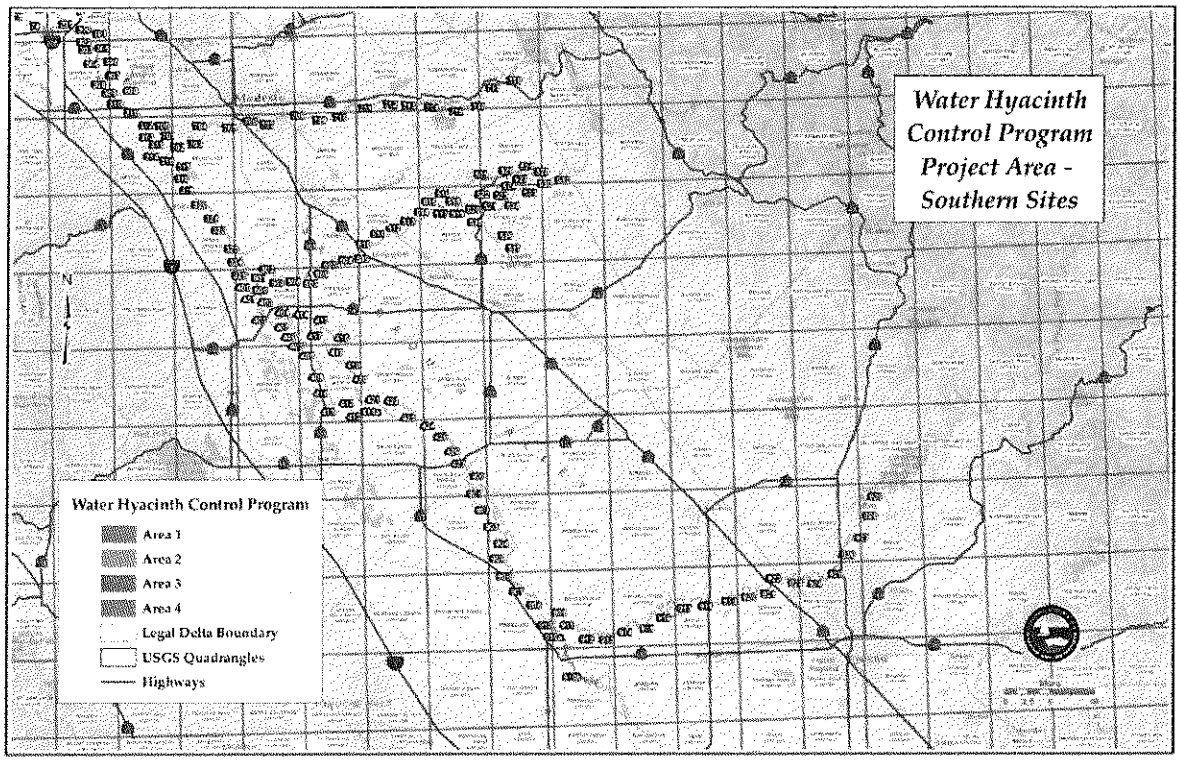


Egeria Densa Control Program Project Area - Southern Sites



APPENDIX B
Water Hyacinth Control Program Project Treatment Areas # 1, 2, 3, and a portion of 4



APPENDIX B

Water Hyacinth Control Program Project Treatment Area: a portion of #3 and #4