

DELTA SMELT

Hypomesus transpacificus

USFWS: Threatened

CDFG: Threatened

Species Account

Status and Description. The delta smelt was listed as a threatened species by the Department of Fish and Game on December 9, 1993 and the U.S. Fish and Wildlife Service on March 5, 1993. The delta smelt originally was classified as the same species as the pond smelt (*Hypomesus olidus*), but Hamada (1961) and Moyle (1976, 1980) recognized the delta smelt as a distinct species (Federal Register 1993). The delta smelt is the only smelt endemic to California and the only true native estuarine species found in the Sacramento-San Joaquin Estuary (known as the Delta) (Moyle *et al.* 1989, Stevens *et al.* 1990, Wang 1986).

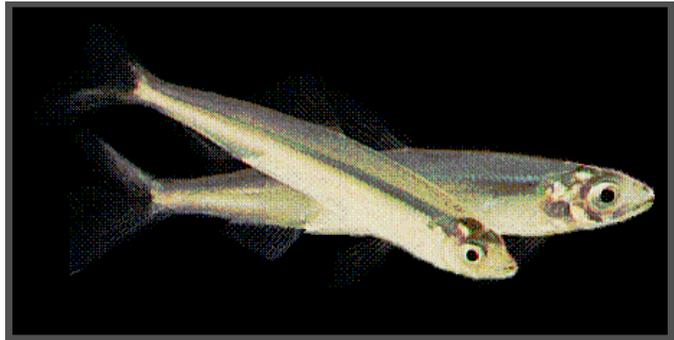


Photo courtesy of California Dept of Fish and Game

Adult delta smelt are slender-bodied fish from the Osmeridae family (smelts). They were described by Moyle (2002) as being about 60-70 millimeters (2.36-2.76 inches) in standard length, but may grow as large as 120 millimeters (4.73 inches). They have a steely-blue sheen on the sides that gives them a translucent appearance. Occasionally one chromatophore may lie between the mandibles, but usually none is present. Its mouth is small, with a maxilla that does not extend past the mid-point of the eye. The eyes are relatively large, with the orbit width contained about 3.5-4 times in the head length. The upper and lower jaws have small, pointed teeth. The first gill arch has 27-33 gill rakers. Delta smelt have 7 branchiostegal rays, 9-10 dorsal fin rays, 8 pelvic fin rays, 10-12 pectoral fin rays, and 15-17 anal fin rays. The lateral line is incomplete and has 53-60 scales along it. Delta smelt have 4-5 pyloric caeca (Moyle *et al.* 1989).

Range, Populations and Activity. Historically, the delta smelt occurred from Suisun Bay upstream to the city of Sacramento on the Sacramento River and Mossdale on the San Joaquin River (Moyle *et al.* 1992), and was one of the most common species in the Sacramento-San Joaquin Estuary (also known as the Delta) (CDFG 2000a). It was also one of the most common and abundant pelagic fish caught by California Department of Fish and Game trawl surveys in the Delta during the early 1970s (Stevens and Miller 1983, Moyle *et al.* 1989, Stevens *et al.* 1990). Delta smelt historically congregated in upper Suisun Bay and Montezuma Slough (mainly during March to mid-June) when the Sacramento and San Joaquin river flows were high (Federal Register 1993). Erkkila *et al.* (1950) collected young delta smelt near Sherman Island, at the confluence of the Sacramento and San Joaquin Rivers, in July and August of 1948. Delta smelt have been observed in the upper Suisun Bay and the lower reaches of the Delta in the fall and collected by otter trawl near New York Slough and the Antioch Bridge during the fall and winter (Moyle 1976). During high river outflows delta smelt may wash into San Pablo Bay, but the higher salinities do not permit populations to become established (Federal Register 1993).

Currently, delta smelt are only found from the Suisun Bay upstream through the Delta in Contra Costa, Sacramento, San Joaquin, Solano, and Yolo Counties. Because of substantial human-caused changes in the relative ratios of seasonal freshwater outflows in the years since 1981, the highest densities of delta smelt has shifted to the Sacramento River channel in the Delta (Moyle *et al.* 1992). In the Delta, delta smelt have been known to spawn in the Sacramento River and in Barker, Lindsey, Cache, Georgiana, Prospect, Beaver, Hog, and Sycamore sloughs (Wang 1991, Federal Register 1994). Delta smelt also spawn north of Suisun Bay in Montezuma and Suisun sloughs and their tributaries (Federal Register 1994). Newly hatched larvae have been observed in Montezuma Slough and throughout the Delta as far as the lower Sacramento River and the San Joaquin River near the Tracy Pumping Station (Wang 1986). In Suisun Bay and the Delta, small juveniles (approximately 30 millimeters total length) have been collected in plankton tows, while larger juveniles and adults have been abundant in the trawl and trap net catches during spring and summer (Wang 1986). Large schools of delta smelt have been observed on the intake screens of the Pittsburg and Contra Costa power plants (Wang 1986). In studies conducted in the spring and summer of 1989 and 1990 by the California Department of Fish and Game, California Department of Water Resources, and the Bureau of Land Management, larval and juvenile delta smelt were collected from Roe Island in Suisun Bay north to the confluence of the Sacramento and Feather Rivers and east to Medford Island on the San Joaquin River (Wang 1991). In 1990, young delta smelt were taken at the Tracy Pumping Plant at the end of February (Wang 1991).

Over the last 20 years, populations of delta smelt have declined by ten-fold, and since 1982, have remained at extremely low levels (Federal Register 1994). Between 1982 and 1992, populations were consistently very low (Moyle *et al.* 1992, Sweetnam 1999). From 1992 to 2000 numbers of delta smelt were low, but were within historical (pre-1980) levels for five of seven years, although lower than the historical average (Rockriver 2001). From 1993 to 1999, the size of the delta smelt population varied, with extremely low levels observed in 1994 and 1996 and moderate levels observed in 1993 and 1995 (CDFG 2000a). The 1997 population appeared to be only slightly larger than in 1996, while the 1998 population was relatively low during summer tow net surveys and slightly higher during fall midwater trawls. The 1999 delta smelt population was similar to previous years with average densities similar to 1996 and 1997 and lower than in 1995 and 1998. The status in 1999 of the delta smelt was stable to declining (CDFG 2000a). The 2000 spring Midwater Trawl Survey and summer Towntnet Survey indicate a slight decrease in the population of the species, but the 1999-2000 two-year average indices were high compared to recent years and still much lower than indices calculated from the 1970s (Rockriver 2001). In 2000, salvaged delta smelt from the State Water Project and Central Valley Project decreased from 152,000 in 1999 to 113,000 fish (Rockriver 2001). State Water Project delta smelt salvage during the 1970s (when populations were higher) was 564,146 ∇ 389,226 delta smelt per year (Rockriver 2001). The true number of delta smelt is unknown and difficult to estimate because handling a smelt is likely to kill it (Moyle 2002). Recent population abundance indices confirm that the species has not shown any significant signs of recovery (Moyle and Herbold 1989, Moyle *et al.* 1989, Stevens *et al.* 1990, Moyle *et al.* 1992, Sweetnam 1992).

The spawning season of delta smelt varies from year to year and may occur from December to August (Federal Register 1994). Moyle (1976) collected gravid adults from December to April, although ripe delta smelt were most common in February and March. In 1989 and 1990, Wang (1991) estimated that spawning had taken place from mid-February to late June or early July, with the peak spawning period occurring in late April and early May. In 1993, a wet year, spawning may have occurred as

early as January and extended into June, with peak spawning occurring in April (Federal Register 1994). In 1994, a critically dry year, peak spawning occurred at the end of April, and may have begun as early as late February (Federal Register 1994).

Delta smelt spawn in shallow, fresh or slightly brackish water upstream from the brackish-water habitat associated with the mixing zone (Wang 1991), mostly in tidally-influenced backwater, dead-end sloughs and channel edge-waters in the western Delta (Radtke 1966, Moyle 1976, Moyle 2002, Wang 1986, Wang 1991, Moyle *et al.* 1992). Spawning also has been recorded in Montezuma Slough near Suisun Bay and far upstream in the Sacramento River near Rio Vista (Radtke 1966, Wang 1986).

Delta smelt have a low fecundity compared to other California species of Osmeridae and produce only 1,247-2,590 eggs per female as opposed to 5,000-25,000 eggs (Moyle 1976, Moyle *et al.* 1992). Although delta smelt spawning behavior has not been observed in the wild (Moyle *et al.* 1992), the adhesive eggs are thought to attach to substrates such as cattails and tules, tree roots, and submerged branches (Moyle 1976, Wang 1991). Based on data for a closely related species, delta smelt eggs probably hatch in 12-14 days (Federal Register 1993). In the laboratory, delta smelt eggs hatch in 10-14 days (Federal Register 1994). Laboratory studies indicate that delta smelt spawn in a current, usually at night, distributing their eggs over a local area (Lindberg 1992, Mager 1993). After hatching, larvae float near the surface of the water column in both inshore and channel areas (Wang 1986), and are transported downstream toward the mixing zone where they are retained by the vertical circulation of fresh and salt waters (Stevens *et al.* 1990). When the mixing zone is located in a broad geographic area with extensive shallow-water habitat less than 4 meters deep, high densities of phytoplankton and zooplankton are produced (Arthur and Ball 1978, 1979, 1980), and larval and juvenile delta smelt grow rapidly (Moyle *et al.* 1992, Sweetnam and Stevens 1993).

Juvenile delta smelt are 40-50 millimeters (1.58-1.97 inches) fork length by early August (Federal Register 1993). They reach sexual maturity as adults when they are 55-70 millimeters (2.17-2.76 inches) fork length (Federal Register 1993). By June, delta smelt are rarely longer than 50 millimeters (1.97 inches) fork length (Federal Register 1993), indicating that adult delta smelt have a 1-year life span and usually die after spawning (Erkkila *et al.* 1950, Moyle 1976, Moyle *et al.* 1992), although 2-year old smelt have been found (CDFG 2000b).

The primary food for all life stages of the delta smelt are the nauplius, copepodite, copepodid, and adult stages of copepod (Federal Register 1993). Adult smelt ate almost solely the euryhaline copepod (*Eurytemora affinis*) (Herbold 1987), until the 1980s when the native *Eurytemora affinis* were displaced by the introduced copepod *Pseudodiaptomus forbsii* and their diet shifted to the non-native copepod (Sommer and Herbold 2000). Adult smelt will also prey on opossum shrimp (*Neomysis mercedis*) as a secondary food source, and on cladocerans (*Daphnia* spp., *Bosmina* spp.) as a seasonal food source (Federal Register 1993). The pelagic larvae of delta smelt feed on phytoplankton until they are four days old, then begin to feed on rotifers on the sixth day and *Artemis nauplii* on the 14th day (Mager 1993). Within the mixing zone, the pelagic larvae are zooplanktivores and feed on rotifers, copepods, cladocerans, and amphipods (Federal Register 1993). Juvenile delta smelt primarily eat planktonic crustaceans, small insect larvae, and mysid shrimp (Moyle 1976). Smelts feed together in schools (USFWS 2002).

Habitat Use. Delta smelt are a euryhaline species (species adapted to living in fresh and brackish water) that occupies estuarine areas with salinities below 2 grams per liter (2 parts per thousand). They rarely occur in estuarine waters with more than 10-12 parts per thousand salinity (about one-third sea water) (Ganssle 1966, Moyle 1976, Moyle *et al.* 1992, Sweetnam and Stevens 1993), but have been collected from estuarine waters up to 14 parts per thousand salinity. For a large part of their one-year life span, delta smelt live along the freshwater edge of the mixing zone (saltwater-freshwater interface), where the salinity is approximately 2 parts per thousand (USFWS 2002). The best survival and growth of smelt larvae occurs when the mixing zone occupies a large geographic area, including extensive shoal regions that provide suitable spawning substrates at depths less than 4 meters (Federal Register 1993). Sixty-two percent of delta smelt collected in Suisun Bay occurred at 3 sampling stations at these depths; the remaining 38 percent were caught at 6 deeper stations (Federal Register 1993). Using midwater trawl data, Obrebski (1993) found delta smelt distribution peaking upstream of the mixing zone, but distribution can be fairly broad, especially in years when abundance levels are high (CDWR and USBR 1993). Besides salinity, the distribution of delta smelt has also been shown to be related to prey abundance; in 1993 and 1994, delta smelt were found in Suisun Bay despite the fact that ideal salinity conditions were located upstream, however, high levels of copepod *Eurytemora* were present (CDWR and USBR 1994).

Delta smelt spawn in shallow, fresh or slightly brackish water upstream of the mixing zone (Wang 1991), mostly in tidally-influenced backwater sloughs and channel edge-waters where solid substrate (cattails, tules, tree roots, and submerged branches) are present for the attachment of eggs (Moyle 1976, Wang 1986, Wang 1991, Moyle *et al.* 1992, Sommer and Herbold 2000). They spawn in freshwater at temperatures from about 45-59 degrees Fahrenheit (7-15 degrees Celsius) (Federal Register 1993).

Population Levels and Occurrence in Plan Area. Delta smelt are mainly associated with the open water portions of the Coastal Marsh vegetation types within the plan area Coastal Marsh Natural Community. The species can also be found in open water areas of Freshwater Marsh and Streams/Sloughs within the Riparian, Streams, and Freshwater Marsh Natural Community. There are 11 records of delta smelt reported from Solano County. They have been known to spawn in the Sacramento River and in Barker, Lindsey, and Cache sloughs (Wang 1991, Federal Register 1994). Delta smelt also spawn north of Suisun Bay in Montezuma and Suisun sloughs and their tributaries (Federal Register 1994).

Dispersal. Shortly before spawning, adult delta smelt migrate upstream from the brackish-water habitat associated with the mixing zone and disperse widely into river channels and tidally-influenced backwater sloughs (Radtke 1966, Moyle 2002, Wang 1991).

The seasonal movement of juvenile delta smelt occurs within a short section of the upper estuary. Juvenile smelt move downstream (Radtke 1966, Moyle 1976) to San Pablo Bay and Carquinez Strait (Ganssle 1966) before turning back to Suisun Bay for spawning in late June and early July (Wang 1991). When the mixing zone is contained within Suisun Bay, juveniles are dispersed widely throughout shallow-water and marsh habitat (Federal Register 1994). Dispersal in areas downstream from the State and Federal water pumps and in-Delta agricultural diversions protects juveniles from entrainment and distributes them among the extensive, protective, and highly productive shoal regions of Suisun Bay (Federal Register 1994). The mixing zone, when located upstream, becomes confined in the deep river channels, which are smaller in total surface area, contain fewer shoal areas,

have swifter, more turbulent water currents, and lack high zooplankton productivity (Federal Register 1994).

Threats to the Species. Delta smelt are considered environmentally sensitive because they live only one year, have a limited diet, have a low fecundity for a fish with planktonic larvae, are poor swimmers, are easily stressed, and reside primarily in the interface between salt and freshwater (CDFG 2000a). The delta smelt has declined nearly 90 percent over the last 20 years, and is primarily threatened by large freshwater exports from the Sacramento River and San Joaquin River diversions for agriculture and urban use (Federal Register 1993). Other threats include drought, agricultural and industrial chemicals, introduced non-native aquatic species, and reduction in abundance of key food organisms (Federal Register 1993).

The principal concern for this species has been the diversion/reduction of freshwater into the Delta. Since 1983, the proportion of water exported from the Delta during October through March has increased (Moyle *et al.* 1992). Federal and State water diversion projects in the southern Delta export mostly Sacramento River water with some San Joaquin River water (Federal Register 1993). During periods of high export pumping and low to moderate river outflows, reaches of the San Joaquin River reverse direction and flow to the pumping plants located in the southern Delta (Federal Register 1993). A relationship has been found between the number of juvenile delta smelt salvaged at the State and Federal pumps and both the percent of inflow diverted and total Delta outflow (CDWR and USBR 1994). When total diversion rates are high relative to Delta outflow and the lower San Joaquin River and other channels have a net upstream (i.e., reverse or negative) flow, out-migrating larval and juvenile fish become disoriented. Mortalities occur as a result of entrainment and predation by striped bass at the various pumping plants and other water diversion sites. Delta smelt larvae require net positive riverine flows and estuarine outflows of sufficient magnitude in order to be carried downstream into the upper end of the mixing zone of the estuary rather than upstream to the pumping plants (Federal Register 1993).

All size classes of delta smelt suffer near total loss when they are entrained by the pumping plants and diversions in the south Delta (Federal Register 1993). Very few delta smelt are effectively salvaged at the State and Federal pumping plant screens and the few that are transported into water project reservoirs or canals fail to reproduce. The smelt's embryonic, larval, and post-larval mortality rates also become higher as reduced western Delta flows allow increases in the salinity level and relocation of the mixing zone (Federal Register 1993).

During periods of drought and increased water diversions, the mixing zone and associated smelt populations shifted farther upstream in the Delta. Prior to 1984, the mixing zone was usually located in Suisun Bay during October through March, while from April through September, the mixing zone usually was found upstream in the channels of the rivers (Federal Register 1993). From 1984 to 1993, with the exception of the record flood outflows of 1986, the mixing zone had been located primarily in the river channels during the entire year because of increased water exports and diversions (Federal Register 1993). When located upstream, the mixing zone becomes confined to the deep river channels, becomes smaller in total surface area, contains very few shoal areas of suitable spawning substrates, may have swifter, more turbulent water currents, and lacks high zooplankton productivity (Federal Register 1993). Delta smelt reproduction is likely affected because the mixing zone is located in the main channels of the Delta, east of Suisun Bay (Moyle *et al.* 1992). In 1982, the delta smelt population declined significantly because of the shifted location of the mixing

zone to the less favorable narrow, deep, and less productive channels in the lower rivers (Federal Register 1993).

The delta smelt is especially vulnerable during periods of long drought. Deleterious effects of the 1987-1992 drought would have been exacerbated if additional alterations in hydrology caused by reductions of freshwater inflows to the Delta altered the timing and/or duration of water exports (Federal Register 1993).

Agricultural chemicals and residues, chemicals from urban runoff, and heavy metal contaminants released from industrial and mining also threaten delta smelt. Nichols *et al.* (1986) found that all major rivers in the delta smelt's historic range had been exposed to large volumes of agricultural and industrial chemicals that are applied in the California Central Valley watersheds. Toxicology studies of rice field irrigation drain water of the Colusa Basin Drainage Canal documented significant toxicity of drain water to striped bass embryos and larvae, medaka larvae, and the major food organism of the striped bass larvae and juveniles, the opossum shrimp (*Neomysis mercedis*) (Federal Register 1993). Delta smelt could also be affected by run-off. Although the effects of heavy metal contaminating compounds on delta smelt larvae and their food resources are not well known, the compounds could potentially adversely affect delta smelt survival (Federal Register 1993).

Several introduced species adversely affect the delta smelt directly. The delta smelt population may become displaced by the wagasaki, or Japanese smelt (*Hypomesus nipponensis*), which was inadvertently introduced into reservoirs of the Sacramento River drainage by the California Department of Fish and Game (Moyle 1976). Non-native inland silversides have been known to prey on smelt larvae and may compete for similar prey such as copepods and cladocerans (Bennett 1995). An asian clam (*Potamocorbula amurensis*), discovered in Suisun Bay in 1986, could affect the phytoplankton dynamics in the estuary by decreasing phytoplankton biomass and by directly consuming the delta smelt's primary food, the nauplii of the copepod *Eurytemora affinis* (Federal Register 1993). Additionally, the introduced striped bass may have caused an increase in predation on all size classes of the delta smelt (Federal Register 1993). Three non-native species of euryhaline copepods (*Sinocalanus doerrii*, *Pseudodiaptomus forbesi*, and *Pseudodiaptomus marinus*) became established in the Delta between 1978 and 1987 (Carlton *et al.* 1990), while *Eurytemora affinis* populations, the native euryhaline copepod, have declined since 1980. These introduced copepod species are more efficient at avoiding the predation of larval delta smelt and exhibit a different swimming behavior that makes them less attractive to feeding delta smelt larvae. Because of reduced food availability or feeding efficiency, weakened delta smelt larvae are more vulnerable to starvation or predation (Federal Register 1993).

Critical Habitat. Critical habitat for the delta smelt was designated on December 19, 1994 (59FR65256). Critical habitat for the delta smelt is contained within Contra Costa, Sacramento, San Joaquin, Solano, and Yolo counties, California (Federal Register 1994). Designated critical habitat 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), Goodyear, Suisun, Cutoff, First Mallard (Spring Branch) and Montezuma sloughs, and the Sacramento/San Joaquin River Delta, as defined in Section 12220 of the California Water Code of 1969 (a complex of bays, dead-end sloughs, channels typically less than 4 meters deep, marshlands, etc.) as follows: bounded by a line beginning at the Carquinez Bridge which crosses the Carquinez Strait; thence, northeasterly along the western and northern shoreline of Suisun Bay, including

Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma Sloughs; thence, upstream to the intersection of Montezuma Slough with the western boundary of the Delta as delineated in section 12220 of the State of California's Water Code of 1969; thence, following the boundary and including all contiguous water bodies contained within the statutory definition of h)40*0*0* the Delta, to its intersection with the San Joaquin River at its confluence with Suisun Bay; thence, westerly along the south shore of Suisun Bay to the Carquinez Bridge (Federal Register 1994). Critical habitat for the delta smelt includes those areas possessing the primary constituent elements essential to the conservation of the delta smelt. These primary constituent elements are the physical habitat, water, river flow, and salinity concentrations required to maintain delta smelt habitat for: 1) spawning; 2) larval and juvenile transport; and 3) rearing; and 4) adult migration (Federal Register 1994).

The Final Rule (Federal Register 1994) for the determination of critical habitat for the delta smelt provides details on these constituent elements. The primary constituent elements are organized by habitat conditions required for each life stage. The specific geographic areas and seasons identified for each habitat condition represent the maximum possible range of each of these conditions. Depending on the water-year type (i.e., wet, above normal, normal, below normal, dry, critically dry), each of the habitat conditions specified below requires fluctuation (within-year and between-year) in the placement of the 2 parts per thousand isohaline (a line drawn to connect all points of equal salinity) around three historical reference points. These three historical reference points are the Sacramento-San Joaquin River confluence, the upstream limit of Suisun Bay at Chipps Island, and in the middle of Suisun Bay at Roe Island. The actual number of days that the 2 parts per thousand isohaline is maintained at the three points varies according to water-year type. Additionally, the number of days at each reference point must simulate a level of water project development equivalent to that which historically existed in 1968. The year, 1968, is a year in which delta smelt was abundant with appropriate hydrologic conditions to inhabit and which anadromous and resident fisheries were relatively healthy (Federal Register 1994).

To maintain suitable habitat conditions for recovery of the delta smelt, the naturally-occurring variability found in healthy estuarine ecosystems must be preserved for the following reasons: 1) temporal and spatial variability of the 2 parts per thousand isohaline will be the most effective deterrent to further invasion of newly introduced species and continued competition by those that are already established; 2) placement of the 2 parts per thousand isohaline in Suisun Bay will produce the high phytoplankton and zooplankton densities that characterize most healthy estuarine ecosystems; and 3) variability is needed to simulate natural processes and historical conditions (Federal Register 1994).

The primary constituent elements in the Final Rule (Federal Register 1994) for the delta smelt are defined as follows:

- **Spawning Habitat:** Delta smelt adults seek shallow, fresh, or slightly brackish backwater sloughs and edge-waters for spawning. To ensure egg hatching and larval viability, spawning areas also must provide suitable water quality (i.e., low concentrations of pollutants) and substrates for egg attachment (e.g., submerged tree roots and branches and emergent vegetation). Specific areas that have been identified as important delta smelt spawning habitat include Barker, Lindsey, Cache, Prospect, Georgiana, Beaver, Hog, and Sycamore sloughs and the Sacramento River in the

Delta, and tributaries of northern Suisun Bay. The spawning season may start as early as December and extend until July (Federal Register 1994).

- **Larval and Juvenile Transport:** To ensure that delta smelt larvae are transported from the area where they are hatched to shallow, productive rearing or nursery habitat, the Sacramento and San Joaquin Rivers and their tributary channels must be protected from physical disturbance (e.g., sand and gravel mining, diking, dredging, and levee or bank protection and maintenance) and flow disruption (e.g., water diversions that result in entrainment and in-channel barriers or tidal gates). Adequate river flow is necessary to transport larvae from upstream spawning areas to rearing habitat in Suisun Bay. Additionally, river flow must be adequate to prevent interception of larval transport by the State and Federal water projects and smaller agricultural diversions in the Delta. To ensure that suitable rearing habitat is available in Suisun Bay, the 2 parts per thousand isohaline must be located westward of the Sacramento-San Joaquin River confluence during the period when larvae or juveniles are being transported, according to the historical salinity conditions which vary according to water- year type. Reverse flows that maintain larvae upstream in deep-channel regions of low productivity and expose them to entrainment interfere with these transport requirements. Suitable water quality must be provided so that maturation is not impaired by pollutant concentrations. The specific geographic area important for larval transport is confined to waters contained within the legal boundary of the Delta, Suisun Bay, and Montezuma Slough and its tributaries. The specific season when habitat conditions identified above are important for successful larval transport varies from year to year, depending on when peak spawning occurs and on the water-year type. The Service identified situations in the biological opinion for the delta smelt (USFWS 1995) where additional flows might be required in the July-August period to protect delta smelt that were present in the south and central Delta from being entrained in the State and Federal project pumps, and to avoid jeopardy to the species. The long-term biological opinion on CVP-SWP operations (USFWS 1995) identifies situations where additional flows may be required after the February through June period identified by EPA for its water quality standards to protect delta smelt in the south and central Delta.
- **Rearing Habitat:** Maintenance of the 2 parts per thousand isohaline according to the historical salinity conditions described above and suitable water quality (low concentrations of pollutants) within the Estuary is necessary to provide delta smelt larvae and juveniles a shallow, protective, food-rich environment in which to mature to adulthood. This placement of the 2 parts per thousand isohaline also serves to protect larval, juvenile, and adult delta smelt from entrainment in the State and Federal water projects. An area extending eastward from Carquinez Strait, including Suisun Bay, Grizzly Bay, Honker Bay, Montezuma Slough and its tributary sloughs, up the Sacramento River to its confluence with Three Mile Slough, and south along the San Joaquin River including Big Break, defines the specific geographic area critical to the maintenance of suitable rearing habitat. Three Mile Slough represents the approximate location of the most upstream extent of tidal excursion when the historical salinity conditions described above are implemented. Protection of rearing habitat conditions may be required from the beginning of February through the summer.
- **Adult Migration:** Adult delta smelt must be provided unrestricted access to suitable spawning habitat in a period that may extend from December to July. Adequate flow and suitable water quality may need to be maintained to attract migrating adults in the Sacramento and San Joaquin River channels and their associated tributaries, including Cache and Montezuma sloughs and their

tributaries. These areas also should be protected from physical disturbance and flow disruption during migratory periods.

Conservation Issues. The covered activities of the Solano Habitat Conservation Plan have little direct effect on the Delta smelt or its critical habitat. The primary population/habitat areas lie outside of the Plan Area boundaries or occur in areas with substantial existing regulatory protection (i.e., Suisun Marsh). The primary issues are primarily associated with the effects on water quality from urban runoff into the Delta and Suisun Marsh. The primary concerns related to water export and the effects of pumping in the Delta are not activities associated with the covered activities of the Solano Habitat Conservation Plan.

References and Literature Cited

Arthur, J.F. and M.D. Ball. 1978. Entrapment of suspended materials in the San Francisco Bay-Delta Estuary. U.S. Dept. Interior, Bureau of Reclamation, Sacramento, California.

_____. 1979. Factors influencing the entrapment of suspended material in the San Francisco Bay-Delta Estuary. Pages 143-174 In T.J. Conomos (ed.). Pacific Division, Amer. Assoc. Advance. Sci., San Francisco, California.

_____. 1980. The significance of the entrapment zone location to the phytoplankton standing crop in the San Francisco Bay-Delta Estuary. U.S. Dept. Interior, Water and Power Resources Service.

Bennett, W.A. 1995. Potential effects of exotic inland silversides on delta smelt. Interagency Program Newsletter. Winter 1995: 4-6.

Carlton, J.T., J.K. Thompson, L.E. Schemel, and F.H. Nichols. 1990. Remarkable invasion of San Francisco Bay (California, USA) by the asian clam *Potamocorbula amurensis*. I. Introduction and dispersal. Mar. Ecol. Prog. Ser. 66:81-94.

CDFG (California Department of Fish and Game). 2000a. The status of rare, threatened, and endangered animals and plants of California, delta smelt. Habitat Conservation Planning Branch. Available on the Internet at:
http://www.dfg.ca.gov/hcpb/species/jsp/ssc_result.jsp?specy=fish&query=Hypomesus%20transpacificus.

_____. 2000b. Wildlife photo gallery, anadromous resources, delta smelt. California Department of Fish and Game, Central Valley Bay-Delta Branch, Stockton, California. Available on the Internet at:
<http://www.delta.dfg.ca.gov/gallery/dsmelt.html>.

California Department of Fish and Game (CDFG). 2011. *California Natural Diversity Data Base (CNDDB)*. Sacramento, California.

CDWR and USBR (California Department of Water Resources and U.S. Bureau of Reclamation). 1993. Biological Assessment. Effects of the Central Valley Project and State Water Project on Delta

smelt. Prepared by the California Department of Water Resources and U.S. Bureau of Reclamation for the U.S. Fish and Wildlife Service. October 1993. 134 pp.

_____. 1994. Biological Assessment. Effects of the Central Valley Project and State Water Project on Delta Smelt and Sacramento Splittail. Prepared by the California Department of Water Resources and U.S. Bureau of Reclamation for the U.S. Fish and Wildlife Service. August 1994. 230 pp.

Erkkila, L.F., J.W. Moffet, O.B. Cope, B.R. Smith, and R.S. Smith. 1950. Sacramento-San Joaquin Delta fishery resources: Effects of Tracy Pumping Plant and the Delta Cross Channel. U.S. Fish and Wildlife Service Special Scientific Rept. 56:1-109.

Federal Register. 1993. Final rule: determination of threatened status for the Delta smelt. U.S. Fish and Wildlife Service, Division of Endangered Species, Sacramento, California. Friday, March 5, 1993. Available on the Internet at: <http://ecos.fws.gov/tess/frdocs/1993/93-5085.html>.

_____. 1994. Final rule: endangered and threatened wildlife and plants; critical habitat determination for the Delta smelt. U.S. Fish and Wildlife Service, 59 FR 65256, Rules and Regulations. December 19, 1994.

Ganssle, D. 1966. Fishes and decapods of San Pablo and Suisun bays. Pages 64-94 In D.W. Kelley, (ed.). Ecological studies of the Sacramento-San Joaquin estuary, Part 1. Calif. Dept. Fish and Game, Fish Bulletin No. 133.

Hamada, K. 1961. Taxonomic and ecological studies of the genus *Hypomesus* of Japan. Mem. Fac. Fish Hokkaido Univ. 9(1):1-56 (as cited by Moyle 1976, 1980).

Herbold, B. 1987. Patterns of co-occurrence and resource use in a non-coevolved assemblage of fishes. Ph.D. dissertation. Univ. of California, Davis. Vii+81 pp.

Lindberg, J.C. 1992. Development of delta smelt culture techniques. Report prepared by Biosystems Analysis, Inc. for the Department of Water Resources. 22 pp.

Mager, R. 1993. Delta smelt culturing. Pages 2-3 In W. Kimmerer Minutes of the March 1993 Food Chain Group Meeting. Department of Water Resources. April 22, 1993, memo. 8 pp.

Moyle, P.B. 1976. Inland fishes of California. University of California Press, Berkeley, California. 408 pp.

_____. 2002. Inland fishes of California: revised and expanded. University of California Press, Berkeley, California. 502 pp.

_____. 1980. *Hypomesus transpacificus* (McAllister), Delta smelt, Page 123 In D.S. Lee *et al.*, (eds.). Atlas of North American freshwater fishes. North Carolina State Mus. Nat. Hist., Raleigh, North Carolina. 854 pp.

Moyle, P.B. and B. Herbold. 1989. Status of the delta smelt, Hypomesus transpacificus. Unpublished final report prepared for U.S. Fish and Wildlife Service, Sacramento Field Office, Habitat Conservation Division, Sacramento, California. 42 pp.

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

Moyle, P.B., J.E. Williams, and E.D. Wikramanayake. 1989. Fish species of special concern of California. Final report prepared for State of California, Department of Fish and Game, Inland Fisheries Division, Rancho Cordova, California. 222 pp.

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

Obrebski, S. 1993. Relationships between Delta smelt abundance and the entrapment zone position. Draft report for the Department of Water Resources. 29 pp.

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 (eds.). Ecological studies of the Sacramento-San Joaquin estuary, Part 2. California Department of Fish and Game Fish Bulletin No. 136.

Rockriver, A. 2001. Delta smelt. Interagency Ecological Program Newsletter 14(2):19-21.

Sommer, T.R. and B. Herbold. 2000. Delta smelt. Pages 104-108 In P.R. Olofson (ed.). Goals Project. Baylands Ecosystem Species and Community Profiles: Life histories and environmental requirements of key plants, fish and wildlife. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. San Francisco Bay Regional Water Quality Control Board, Oakland, California.

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

Stevens, D.E., L.W. Miller, and B.C. Bolster. 1990. Report to the Fish and Game Commission: A status review of the delta smelt (Hypomesus transpacificus) in California. California Department of Fish and Game Candidate Species Status Report 90-2. 149 pp.

Sweetnam, D. 1992. Delta Smelt Project Update, October 1992. Unpublished report prepared by California Department of Fish and Game, Bay-Delta and Special Water Projects Division, Stockton, California. 7 pp.

_____. 1999. Status of delta smelt in the Sacramento-San Joaquin Estuary. California Department of Fish and Game 85:22-27.

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. Calif. Dept. Fish and Game Candidate Species Status Report 93-DS.

USFWS (U.S. Fish and Wildlife Service). 1995. Bay/Delta protection plan: making every drop count biological opinion. March 6, 1995.

_____. 1996. Sacramento-San Joaquin Delta Native Fisheries Recovery Plan. Portland, Oregon. November 29, 1996. Available on the Internet at:
http://ecos.fws.gov/recovery_plan/pdf_files/1996/961126.pdf.

_____. 2002. Threatened and endangered fish, delta smelt. Endangered Species Division, Sacramento Fish and Wildlife Service Office, Sacramento, California. Available on the Internet at:
http://sacramento.fws.gov/es/animal_spp_acct/delta_smelt.htm.

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, Tech. Rept. 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. Tech. Rept. 28.