U.S. FISH AND WILDLIFE SERVICE
SPECIES ASSESSMENT AND LISTING PRIORITY ASSIGNMENT FORM

SCIENTIFIC NAME: *Hypomesus transpacificus*

COMMON NAME: Delta smelt

LEAD REGION: Region 8

DATE INFORMATION CURRENT AS OF: June 28, 2022

STATUS/ACTION:

____Species assessment – determined either we do not have sufficient information on threats or the information on the threats does not support a proposal to list the species and, therefore, it was not elevated to Candidate status

_X_ Listed species petitioned for uplisting for which we have made a warranted-but-precluded finding for uplisting (this is part of the annual resubmitted petition finding)

____Candidate that received funding for a proposed listing determination, assessment not updated

____New candidate

____Continuing candidate

____Listing priority number change
Former LPN: ____
New LPN: ____

____Candidate removal: Former LPN: ____
- ____A – Taxon is more abundant or widespread than previously believed or not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status.
- ____U – Taxon not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status due, in part or totally, to conservation efforts that remove or reduce the threats to the species.
- ____F – Range is no longer a U.S. territory.
- ____I – Insufficient information exists on biological vulnerability and threats to support listing.
- ____M – Taxon mistakenly included in past notice of review.
- ____N – Taxon does not meet the Act’s definition of “species.”
- ____X – Taxon believed to be extinct.

Date when the species first became a Candidate (as currently defined): April 7, 2010

Petition Information:
___Non-petitioned
_X_ Petitioned: Date petition received: March 8, 2006
90-day substantial finding FR publication date: July 10, 2008
12-month warranted but precluded finding FR publication date: April 7, 2010

FOR PETITIONED CANDIDATE SPECIES:
a. Is listing warranted (if yes, see summary of threats below)? Yes
b. To date, has publication of a proposal to list been precluded by other higher priority listing actions? Yes
c. Why is listing precluded? Higher priority listing actions, including court-approved settlements, court-ordered and statutory deadlines for petition findings and listing determinations, emergency listing determinations, and responses to litigation, continue to preclude the proposed and final listing rules for this species. We continue to monitor populations and will change its status or implement an emergency listing if necessary. The "Progress on Revising the Lists" section of the current CNOR (*http://endangered.fws.gov/*) provides information on listing actions taken during the last 12 months.

ANIMAL/PLANT GROUP AND FAMILY: Fish (Osteichthys), Osmeridae

HISTORICAL STATES/TERRITORIES/COUNTRIES OF OCCURRENCE: Contra Costa, Napa, Sacramento, San Joaquin, Solano, Sonoma, and Yolo Counties in the State of California.

CURRENT STATES/COUNTIES/TERRITORIES/COUNTRIES OF OCCURRENCE: Contra Costa, Sacramento, San Joaquin, Solano, Napa, and Yolo Counties in the State of California.

LAND OWNERSHIP: This species occurs in open waters. There are no known land locked populations. The statutory Delta totals 738,000 acres including approximately 538,000 acres of agricultural land uses, 60,000 acres of open water, and 64,000 acres of urban land uses. The remainder of the region presently consists of open space and wildlife habitat.

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LEAD FIELD OFFICE CONTACT: Bay-Delta FWO, Steven Detwiler, 916-761-4912, steven_detwiler@fws.gov

In this document, we use several different terms to describe the various portions of the Delta. These terms are Bay, Delta, Bay-Delta, and San Francisco Estuary. We define these terms as follows. The "Delta" represents the legal delta encompassing all waters east of Chipps Island. The "Bay" encompasses all waters west of Chipps Island where the legal delta ends. The "Bay-Delta" encompasses both the Bay and the Delta. The "San Francisco Estuary" encompasses all tidally-influenced waters within the Bay-Delta.

BIOLOGICAL INFORMATION:

Species Description

Delta smelt are slender-bodied fish, generally about 60 to 70 millimeters (mm) (2 to 3 inches (in)) long (Figure 1), although they may once have reached lengths of up to 120 mm (4.7 in) (Moyle 2002, p. 227). Delta smelt are in the Osmeridae family (northern smelts) (Stanley *et al.* 1995, p. 390). Live fish are nearly translucent and have a steely blue sheen to their sides (Moyle 2002, p. 227). Delta smelt are also identifiable by their relatively large ratio of their eye diameter to head length. The eye can occupy approximately 25–30 percent of their head length (Moyle 2002, p. 227). 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, p. 227).

Figure 1: Delta smelt

Taxonomy

We have carefully reviewed the available taxonomic information to reach the conclusion that the delta smelt (*Hypomesus transpacificus)* is a valid taxon. The delta smelt is one of six species currently recognized in the *Hypomesus* genus (Ilves and Taylor 2008, p. 8). Within the genus, delta smelt is most closely related to surf smelt (*H. pretiosis*), a species common along the western coast of North America (Ilves and Taylor 2008, p. 8). In contrast, delta smelt is a comparatively distant relation to the wakasagi (*H. nipponensis*), which was introduced into

Central Valley reservoirs in 1959 (Trenham *et al.* 1998, p. 417), and is sympatric with delta smelt in the estuary. Delta smelt and Wakasagi hybrids as well as Delta smelt and longfin smelt hybrids have been observed in the Bay-Delta (California Department of Fish and Game (CDFG) (later referred to as the California Department of Fish and Wildlife (CDFW)) (2001, p. 473). However, allozyme studies have demonstrated that all three species are genetically distinct and derived from different marine ancestors (Stanley *et al.* 1995, p. 394).

Habitat/Life History

Delta smelt are a euryhaline (tolerate a wide range of salinities) species (Moyle 2002, pp. 228–229). In captivity, some delta smelt can survive in seawater for extended periods (Komoroske *et al.* 2014, p. 6), however, in the wild they rarely occur in water with more than 10–14 salinity (about one-third seawater) (Bennett 2005, p. 11; Moyle 1992, p. 73). In the Practical Salinity Scale, salinity is defined as a pure ratio, and has no dimensions or units. Feyrer *et al.* (2007, p. 728) found that relative abundance of delta smelt was related to fall specific conductance (a surrogate for salinity) and water transparency. Delta smelt probably evolved within the naturally turbid (silt and particulate-laden) environment of the estuary's "low salinity zone" (LSZ) where the salinity ranges from approximately 0.5 to 6 (Kimmerer 1998, p.1; Moyle 2002, p. 228) and likely rely on certain levels of background turbidity at different life stages and for certain behaviors. Juvenile and sub adult delta smelt are most common within the LSZ at salinity of less than 1 to about 5 (Bennett 2005, p. 10, Sommer *et al.* 2011a, p. 8).

Between December and March (Grimaldo *et al.* 2009, p.1263; Sommer *et al.* 2011, p. 12), delta smelt begin to disperse back into freshwater areas where most spawning occurs (Hobbs et al. 2019, p. 5; Murphy and Hamilton 2013, p. 7-13). This movement is thought to be triggered by the first seasonal high outflow event in the Delta (Grimaldo 2009, p. 1259) although the specific cues for this movement are still unresolved. Bennett and Burau (2015, p. 9) found that delta smelt change their movements in response to tides, but could not distinguish the relative importance of turbidity versus changing tidal direction as cues for moving laterally or longitudinally (up- or downstream). In captivity, some delta smelt can survive to age two (Bennett 2005, p. 16, Figure 9). In the wild, most delta smelt die after spawning at age one, but a small contingent of adults may survive to spawn in their second year (Bennett 2005, p. 22). Fecundity is correlated with size. In captivity, age one females spawn between 1,000 to 4,000 eggs while age two females can spawn up to 12,000 eggs (Bennett 2005, p. 15). Adult females can produce multiple egg batches per spawning period if water temperatures stay cool long enough and the fish get enough food to support the development of multiple clutches of eggs (Damon et al. 2017, p. 198).

Spawning can begin in late January and may continue until water temperatures reach about 20 °C (68 °F), which usually occurs in May or June (Bennett 2005, p. 13). Spawning likely occurs mainly at night with several males attending females that broadcast eggs onto bottom substrate (Bennett 2005, p. 13). Although the full range of usable spawning substrate is unknown, spawning habits of its closest relative, the surf smelt, suggest that sandy substrate may be best (Bennett 2005, p. 17; Sommer *et al.* 2013, p. 13). In laboratory conditions, eggs typically hatch after 9 to 14 days and larvae begin feeding 5 to 6 days later (Mager *et al.* 2004, p. 172, Table 1). Larvae are generally most abundant in the Delta from mid-April through May (Bennett 2005, p.

13). Some delta smelt, have been observed spending their entire life cycle in freshwater within the Cache Slough region, including Liberty Island (Sommer *et al.* 2011, p. 9; Hobbs et al. 2019, p. 5) showing that an alternative life history strategy is possible if habitat parameters are favorable for delta smelt.

After several weeks of development, larval surveys indicate that many larvae move downstream until they reach nursery habitat in the LSZ, in part to reach cooler waters (Kimmerer 1998, p. 1; Moyle 2002, p. 228; Dege and Brown 2004, pp. 57–58). Juvenile smelt rear and grow in the LSZ and adjacent fresher water habitats for several months, where they are found in open waters (free of vegetation) (Dege and Brown 2004, pp. 56–58). By the summer, delta smelt exert greater control over their distribution to maintain an association with suitable habitat conditions (Kimmerer 2008, p. 18). Juvenile fish reach 40–50 mm (1.6–2 in) by early August (Erkkila *et al.* 1950; Ganssle 1966, p.78; Radtke 1966, p.118). Delta smelt reach adult size, 55–70 mm (2.2 – 2.8 in) standard length in 7–9 months (Moyle 2002, p. 228). The abrupt change from a single-age, adult cohort during spawning in spring to a population dominated by juveniles in summer strongly suggests that most adults die shortly after they spawn. Juvenile growth during September to November slows down considerably with a total length increase of only 3–9 mm (0.1 – 0.4 in) over these three months (Moyle 2002, p. 228). During this time period, less food is being produced in the estuary today than was produced historically at the same temperatures. Delta smelt are now 5-10 mm smaller at a given age than they were historically (Sweetnam 1999, p. 25).

Delta smelt feed primarily on small planktonic (free-floating) crustaceans, and occasionally on insect larvae (Moyle 2002, p. 228). Historically, the main prey of delta smelt was the copepod *Eurytemora affinis* and the mysid shrimp *Neomysis mercedis* (Moyle *et al.* 1992, p. 70, Table 1). The copepod *Pseudodiaptomus forbesi* has replaced *E. affinis* as a major prey source of delta smelt since its introduction into the San Francisco Bay-Delta (Baxter *et al.* 2008, p. 22). Larval smelt primarily consume the two copepods, *Eurytemora affinis* and *Pseudodiaptomus forbesi*, but freshwater copepods of the family Cyclopidae, can also be common prey (Nobriga 2002, p. 156; Slater and Baxter 2014, p. 8). The diversity of prey eaten by delta smelt increases as they grow, adult diets are dominated by adult copepods and somewhat larger crustaceans like amphipods, though many other invertebrates and larval fishes have been observed occasionally in stomach contents (Lott 1998, p. 19).

Water temperature also affects delta smelt distribution. Swanson *et al*. (2000, p. 386) reported a minimum temperature tolerance for juvenile delta smelt of 7.5 °C (45.5 °F) (p. 386). The approximate maximum temperature tolerances in captivity by life stage are as follows: larvae: 30 °C (86 °F), late larvae: 29 °C (84.2 °F), juvenile: 29 °C (84.2 °F), adult: 28.2 °C (82.8 °F), post spawned adult: 27.1 °C (Komoroske *et al.* 2014, p. 7). Tolerance limits are typically measured at the point that delta smelt lose their equilibrium or balance. In the wild, delta smelt are seldom collected from water that approach their physiological tolerance limits (Nobriga *et al.* 2008, p. 7, Fig 4; Komoroske *et al.* 2014, p. 9), probably because warm water increases energetic demands (Rose *et al.* 2013a, p. 1245), which has been shown to cause behavioral impairment and lowered competitive ability in other fishes.

Currently available information indicates that delta smelt habitat is most suitable for the fish when low-salinity water is near 20 °C (68 °F), highly turbid, oxygen saturated, low in contaminants, and containing high densities of calanoid copepods (e.g., Moyle 2002, p. 228; Nobriga 2002, pp. 160–163, Feyrer *et al.* 2007 pp. 728–732). Almost every component listed above has been degraded over time (see five factor analysis).

POPULATION STATUS

Historical Range/Distribution

Delta smelt are endemic to the San Francisco Bay-Delta in California. Expansions and contractions to the range are discussed below.

Current Range/Distribution

Delta smelt are endemic to the upper San Francisco Bay-Delta estuary (Figure 2). The reported range of the Delta smelt has at times extended from Berkeley in the San Francisco Bay to the City of Napa on the Napa River, throughout Suisun Bay and the Delta, along the axis of the Sacramento River to Knight's Landing and along the axis of the San Joaquin River to the City of Lathrop (Merz *et al.* 2011, p. 181-182; Vincik and Julienne 2012, p. 173). At all life stages, the western limit of Delta smelt distribution is strongly influenced by the position of the LSZ (Moyle *et al.* 1992, p. 72; Dege and Brown 2004, p. 56; Sommer *et al.* 2011, p. 7; Sommer and Mejia 2013, p. 8), although delta smelt commonly use tidal habitats where salinity is lower than 0.5 so their eastern distribution limit is less affected by salinity. Delta smelt of all life stages have been most frequently encountered in an area called the 'North Delta Arc' (see Figure 2 inset). Given the current very low abundance of delta smelt (see *Population Indices* below), recent information indicates its distribution may be more restricted than what was historically observed. The exceptionally low spring outflow due to the current drought is interacting with low abundance to limit the species' distribution.

Population Indices

Monitoring surveys that have historically collected delta smelt have been conducted by California Department of Fish and Wildlife since as far back as 1959. Most of the ongoing studies are currently conducted under the auspices of the Interagency Ecological Program (IEP), an entity made up of State, Federal and non-government agencies that work collaboratively to oversee data collection and scientific analysis in the Bay-Delta. Several of the IEP's field investigations provide delta smelt distribution and relative abundance information, including the Spring Kodiak Trawl (SKT), the 20-mm survey (20-mm survey), the Summer Townet Survey (STN), and the Fall Midwater Trawl (FMWT). These surveys generate time series of abundance indices. The index numbers are not numbers of fish in the Bay-Delta. Rather they tell us whether years are better or worse in relation to one another. The Service has recently developed statistical methods to put all four indices on the same numeric scale (Polansky et al. 2019, p. 717, Table 2).

Figure 2: Waterways colored in purple depict the delta smelt distribution described by Merz *et al.* (2011). The Service has used newer information to expand the transient range of delta smelt further up the Napa and Sacramento rivers than indicated by Merz *et al.* (2011). The red polygon depicts the boundary of delta smelt's designated critical habitat. The inset map shows the region known as the North Delta Arc shaded light green.

The SKT is a surface trawl targeting spawning adult delta smelt at up to 40 stations from the Napa River landward throughout the Delta. Sampling occurs monthly from January to May. The SKT has been conducted every year since 2002, but the full sampling effort first occurred in 2004. The 20-mm survey provides information on larval and post-larval delta smelt. The 20-mm survey has been conducted every year since 1995. The survey samples twice per month and most sampling has occurred from March-June. The STN 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, but sampling effort has varied over time. The FMWT has been conducted nearly every year since 1967. This survey also targets age-0 striped bass, but collects delta smelt > 40 mm in length. The FMWT samples monthly, September through December. The relative abundance index data and maps of the sampling stations used in these surveys are available from the California Department of Fish and Wildlife (CDFW) at http://www.dfg.ca.gov/delta/.

FMWT-derived data are generally accepted as the better of the longest-term time series available for detecting and roughly scaling inter-annual trends in the relative abundance of delta smelt. From 1969–1981, the mean of delta smelt FMWT indices was 894. From 1982–1992, the mean FMWT index dropped to 272. Both the FMWT and STN indices suggest the delta smelt population declined abruptly in the early 1980s (Moyle *et al.* 1992, pp. 71–72). The population rebounded somewhat in the mid–1990s (Sweetnam 1999, p. 24) when the mean of the FMWT indices was 529 (1993–2002). From 2003–2012, the FMWT indices averaged 83.3. Delta smelt numbers have trended precipitously downward since the early 2000s (Thomson *et al.* 2010, p. 1439, Figure 3). In the wet water year of 2011, the FMWT index for delta smelt increased to 343, which is the highest index recorded since 2001. It immediately declined again in 2012 to 42 and continued to decline in 2013 and 2014 when the index was 18 and 9, respectively. For the years 2018, 2019, 2020, and 2021, the FMWT and STN indices have been zero (Table 1). The SKT survey for that same period were 2.1, 0.4, 0.3, and 0 respectively.

In December 2021, the Service, along with CDFW, DWR, and Reclamation, began experimentally releasing captively produced delta smelt into the Sacramento-San Joaquin River Delta in an experiment intended to help inform future supplementation of the species in the wild. A total of five releases totaling 55,733 brood year 2021 marked (adipose fin clip or Visible Implant Elastomer (VIE)) delta smelt from UC Davis' Fish Conservation and Culture Laboratory. The first release of 12,800 delta smelt occurred over December 14 and 15, 2021 in Rio Vista. The second release of 12,800 delta smelt occurred over January 11 and 12, 2022 in Rio Vista. The third release of 6,400 delta smelt occurred on February 3, 2022 in the Sacramento Deep Water Ship Channel. The fourth release of 12,800 delta smelt occurred over February 9 and 10, 2022 in Suisun Marsh. The fifth release of 10,933 delta smelt occurred over February 16 and 17 in the Sacramento Deep Water Ship Channel. A subsample of those marked fish have been recaptured in the Deepwater Shipping Channel, central Delta, south Delta, and Suisun March by EDSM, Chipps Island Trawl, SKT, Bay Study, and at the CVP salvage facility.

Table 1. Summary of delta smelt survey monitoring indices for various life stages since 2010 (source CDFW https://www.dfg.ca.gov/delta/data/).

Year	Spring Kodiak Trawl (SKT)	20-mm Survey	Summer Townet Survey (STN)	Fall Midwater Trawl (FMWT)
Life Stage sampled	***Spawning adults***	***Post-larval and juvenile smelt***	***Juvenile smelt***	***Juvenile and sub-adults***
2010	27.4	3.8	0.8	29
2011	18.8	8.0	2.2	343
2012	130.2	11.1	0.9	42
2013	20.4	7.8	0.7	18
2014	30.1	1.1	0.5	9
2015	13.8	0.3	0	7
2016	1.8	0.7	0	8
2017	3.8	1.5	0.2	2
2018	2.1	Not calculated	0	0
2019	0.4	0.1	0	0
2020	0.3	Not calculated	0	0
2021	0	0	0	0
2022	TBD	TBD	TBD	TBD

A delta smelt abundance estimation procedure based on SKT data has been developed by the Service. Though technically still a set of abundance indices, the Service indices are as close to abundance numbers as can currently be achieved with available information. Estimates of historical delta smelt abundances for the months of January and February based on SKT data are provided in Table 2. The estimates and 95% confidence intervals are listed below. For example, the 2020 population estimate is 5,213 individuals with 95% confidence intervals ranging between 1,241 and 14,710 individuals.

Table 2. Spring Kodiak Trawl (SKT) survey abundance estimates and related statistics and data summaries. The Year-to-Year Ratio column shows the population growth rate from one year to the next, calculated as the ratio of abundances from consecutive years. *Data from only February was used because SKT sampling did not take place in January.

			95% Confidence Interval		**Total delta smelt caught (total tows) by the SKT survey**		
Year	Abundance Estimate	Standard Error	Lower Bound	Upper Bound	January	February	Year-to-Year Ratio
2002	1,093,244	195,329	760,332	1,523,294	262 (35)	394 (39)	NA
2003*	996,055	261,205	581,197	1,597,198	NA (0)	232 (39)	0.91
2004	966,981	262,190	553,729	1,573,002	380 (39)	300 (34)	0.97
2005	715,858	147,190	470,572	1,044,828	220 (39)	218 (40)	0.74
2006	272,327	42,400	198,681	364,438	44 (40)	84 (40)	0.38
2007	449,466	128,731	249,216	749,168	109 (40)	107 (39)	1.65
2008	509,428	188,396	236,859	963,839	132 (40)	36 (39)	1.13
2009	1,166,145	523,856	459,083	2,464,804	579 (40)	61 (42)	2.29
2010	251,863	54,580	161,753	374,582	88 (41)	57 (41)	0.22
2011	461,599	202,547	185,712	962,088	177 (42)	128 (40)	1.83
2012	1,177,201	328,682	662,728	1,939,836	320 (42)	287 (42)	2.55
2013	333,682	89,809	191,886	541,064	100 (41)	125 (41)	0.28
2014	308,972	91,474	167,858	522,884	148 (40)	55 (40)	0.93
2015	213,345	76,639	101,434	397,439	21 (39)	68 (39)	0.69
2016	25,445	9,584	11,661	48,622	7 (40)	6 (39)	0.12
2017	73,331	23,342	38,010	128,459	18 (38)	8 (41)	2.88
2018	26,649	21,397	5,215	82,805	10 (40)	4 (41)	0.36
2019	5,610	4,395	1,138	17,135	1 (40)	1 (39)	0.21
2020	5,213	3,644	1,241	14,710	1 (39)	1 (40)	0.93
2021	0		Not Defined		0 (39)	0 (36)	0
2022	12,679	9,033	2,942	36,250	0 (36)	5 (40)	NA

Beginning in 2017, the Service initiated the Enhanced Delta Smelt Monitoring (EDSM) survey (Table 3). The EDSM differs from the CDFW fish surveys in its use of a stratified random sampling design instead of fixed sampling stations, its use of higher numbers of repeat tows when necessary, and its stopping rules to avoid excessive take. EDSM was designed to estimate the proportion of the delta smelt population that experience mortality due to entrainment from water operations in near real-time, but has proven most useful for documenting the continued existence of delta smelt in the wild as CDFW surveys have returned zero catch with increasing frequency. The EDSM conducts high-frequency sampling year-round using a Kodiak Trawl from July through the following March and 20-mm plankton nets during April-June. Sampling occurs weekly.

Table 3. Enhanced Delta Smelt Monitoring (EDSM) Survey abundance estimates.

			95% Confidence Interval		**Total delta smelt caught (total tows) by the EDSM survey**		
Year	Abundance Estimate	Standard Error	Lower Bound	Upper Bound	January	February	Year-to-Year Ratio
2017	83,878	20,070	28,770	193,146	63 (477)	33 (684)	NA
2018	6,821	2,778	1,664	19,123	10 (772)	3 (610)	0.08
2019	4,482	1,062	1,546	10,288	18 (730)	7 (518)	0.66
2020	1,027	520	209	3,134	3 (691)	2 (606)	0.23
2021	267	189	41	928	2 (327)	0 (466)	0.26
2022	4,909	2,232	1,911	10,450	6 (468)	12 (484)	18.39

The point estimates of delta smelt abundance generated by EDSM (Table 3) differ from the SKT point estimates (Table 2), however, the estimates from both programs often fall within each other's confidence intervals. Ultimately, they show similar trends in declining abundance with both surveys indicating a sequence of declining abundance each year from 2017-2021. This year's estimates of the adult spawning stock size were 12, 679 for the SKT and 4,909 for the EDSM. These increases in abundance estimates over last year are due to recaptures of cultured delta smelt that were experimentally released in late 2021-early 2022.

THREATS: FIVE FACTOR ANALYSIS

Introduction of Threats

Section 4 of the Act (16 U.S.C. 1533) and implementing regulations (50 CFR part 424) set forth procedures for adding species to, removing species from, or reclassifying species on the Federal Lists of Endangered and Threatened Wildlife and Plants. Under section 4(a)(1) of the Act, a species may be determined to be endangered or threatened based on any of the following five factors:

(A) The present or threatened destruction, modification, or curtailment of its habitat or range,

(B) Overutilization for commercial, recreational, scientific, or educational purposes,

(C) Disease or predation,

(D) The inadequacy of existing regulatory mechanisms, or,

(E) Other natural or manmade factors affecting its continued existence.

In making these findings, information pertaining to each species in relation to the five factors provided in section 4(a)(1) of the Act is discussed below. The threat is significant if it drives or contributes to the risk of extinction of the species such that the species warrants listing as endangered or threatened as those terms are defined by the Act.

The primary known threats cited in the 2010 delta smelt uplisting document are: entrainment by State and Federal water export facilities (Factor E), summer and fall increases in salinity due to reductions in freshwater flow and summer and fall increases in water clarity (Factor A), and effects from introduced species, primarily the overbite clam and invasive aquatic weeds particularly, *Egeria densa* (Factor E). Additional threats included predation (Factor C), entrainment into power plants (Factor E), contaminants (Factor E), and small population size (Factor E). Since the 2010 warranted 12-month finding, we have identified climate change as a threat in the 2012 Candidate Notice of Review. Climate change was not analyzed in the 2010 12-month finding document. Since the 2010 uplisting document, one of the two power plants within the range of the delta smelt using water for cooling has shut down and power plants are no longer thought to be a threat to the population as a whole. We have identified a number of existing regulatory mechanisms that provide protective measures that affect the stressors acting on the delta smelt. Despite these existing regulatory mechanisms and other conservations efforts, some stressors continue to act on the species such that it is warranted for uplisting under the Act.

A. The present or threatened destruction, modification, or curtailment of its habitat or range.

Increased Salinity due to Reduced Freshwater Flow

As California's population has grown, demands for reliable water supplies and flood protection have increased. In response, local, state, and federal agencies have built dams and canals, and captured water in reservoirs, to increase capacity for water storage and conveyance, resulting in one of the largest manmade water systems in the world (Nichols et al. 1986, p. 569). Operation of this system has altered the seasonal pattern of freshwater flows in the Bay-Delta. Storage in the upper watershed of peak runoff and release of the captured water for irrigation and urban needs during subsequent low flow periods result in a broader, flatter hydrograph with less seasonal variability in freshwater flows into the estuary (Kimmerer 2004, p. 15).

Two of the key hydrodynamic variables used in resource management of the Bay-Delta are Delta inflow (from the rivers into the Delta) and Delta outflow (from the Delta into the bays, tidally-averaged flow at Chipps Island). Due to high flow events, these variables are closely correlated, but they are not interchangeable. In the Bay-Delta, the location where salinity is equal to 2 parts per thousand is called X2. X2 is indexed as distance in kilometers from the Golden Gate Bridge. X2, as a measure of the low salinity zone (LSZ), is important to delta smelt because it has been shown to affect a variety of factors that contribute to delta smelt survival, making it a useful indicator of habitat conditions (Jassby *et al.* 1995, p. 282; Dege and Brown 2004, pp. 56–58). Delta outflow is the variable that most directly affects the location of X2 (Jassby *et al.* 1995, p. 284). The location of X2 is influenced by precipitation in the watershed (i.e., wetter, or drier seasonal weather patterns), tides, and by water operations, both upstream at the dams and riverine diversions and in the Delta at the water export facilities (Jassby *et al.* 1995, all; Kimmerer 2004, p. 18).

In addition to the system of dams and canals built throughout the Sacramento and San Joaquin River basins, the Bay-Delta is unique in having the largest water diversion system on the west coast. The State Water Project (SWP) and Central Valley Project (CVP) each operate water export facilities in the Delta (Kimmerer and Nobriga 2008, p. 2). Project operation is dependent upon upstream water supply and export area demands, both of which are strongly affected by the interannual variability in Delta hydrology caused by variability in precipitation. From 1956 to the 1990s, water exports increased from approximately 5% of the Delta inflow to approximately 30% of the average annual Delta inflow (Cloern and Jassby 2012, p. 7). In total, an estimated 39% of the estuary's unimpaired flow (runoff that would hypothetically occur if upstream dams and diversions were not in existence) is consumed upstream or diverted from the estuary (Cloern and Jassby 2012, p. 8). Annual inflow from the watershed to the Delta is strongly correlated to unimpaired flow, mainly due to the effects of high-flow events (Kimmerer 2004, p. 15). Water operations of the CVP and SWP are regulated in part by the California State Water Resources Control Board (SWRCB) according to the Water Quality Control Plan (WQCP) (SWRCB 2000, all). The WQCP sets several salinity standards the projects must meet and limits Delta water exports in relation to Delta inflow (the Export/Inflow, or E/I ratio). Operations are also regulated by both the Service's and NMFS's current Biological Opinions (BiOps) (USFWS 2019, NMFS 2019) and DWR's operation is regulated by CDFW's 2020 Incidental Take Permit (CDFW 2020).

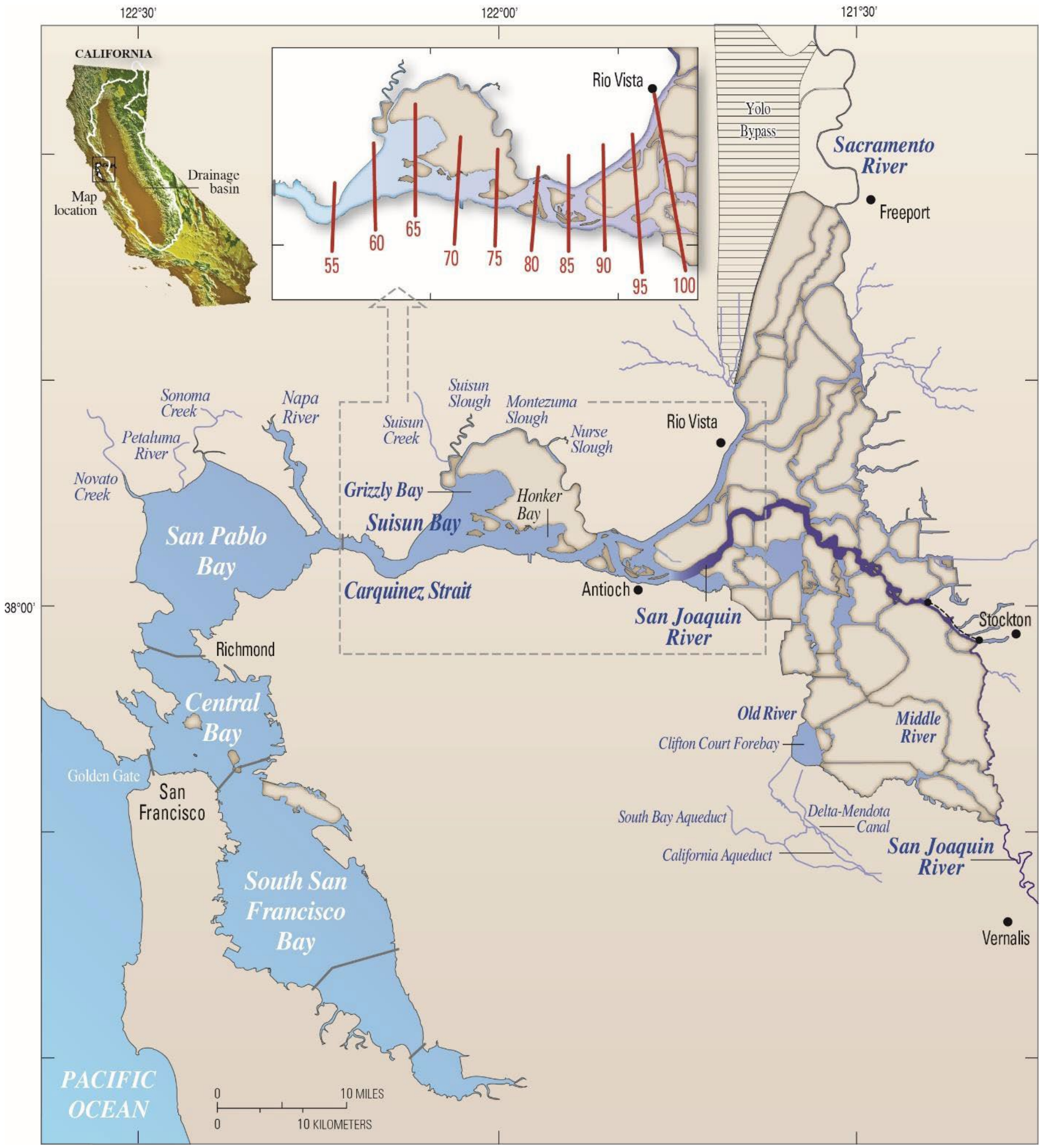

Figure 3: Delta Map showing various locations of X2 as listed by kilometers from Golden Gate Bridge. Credit: Jeanne DiLeo, USGS

The close association of delta smelt with the San Francisco Estuary's LSZ and X2 has been known for many years (Stevens and Miller 1983; Moyle *et al.* 1992). There have been documented changes to the delta smelt's LSZ habitat that have led to degraded present-day habitat conditions. Reduced Delta outflow causes the X2 and the rest of the LSZ to contract and move upstream which results in reduced habitat quality for the delta smelt (Bennett 2005, pp. 11, 20; Figure 6.). Abundance of delta smelt in the fall has been linked to fall habitat conditions (Feyrer *et al.* 2011, p. 123).

The seasonal distribution of the delta smelt population is strongly influenced by river flows because the quantity of fresh water flowing through the estuary changes the amount and location of suitable turbid, low-salinity, open-water habitat (Feyrer *et al.* 2007 pp. 728–732; Feyrer *et al.* 2011, p. 124, Fig 2). From late spring through fall and early winter, most delta smelt occur in the LSZ, which varies by geographic location with Delta outflow (Dege and Brown 2004, pp. 56–58; USFWS 2019, pp. 77; Hobbs et al. 2019, p. 7). Higher Delta outflow moves the LSZ westward into Suisun Bay and sometimes even San Pablo Bay, and lower Delta outflow allows the LSZ to encroach eastward into the Delta (Kimmerer *et al.* 2013, pp. 6–8). Delta outflow lower than ~ 11,400 cfs (amount of flow needed to keep X2 at Chipps Island) concentrates delta smelt in the Delta's channelized waterways where habitat variability is lower, the availability of shoals is lower, and entrainment risk is higher (SWRCB 1995, p. 26, Moyle 2002, p. 230, Bennett 2005, pp. 11, 20). Low outflow is associated with greater water clarity, which as discussed above can have consequences for delta smelt survival. Additionally, overbite clam abundance in Suisun Bay tends to increase when the LSZ shifts upstream (See Factor E: Introduced Species for detailed analysis). The location of the LSZ during spring has also been shown to affect delta smelt larval abundance in recent years (Baxter *et al.* 2015, p. 47). Delta outflow varies naturally within and among years due to variation in precipitation and snowmelt. However, present-day Delta outflow is lower than historical outflows in winter and spring, and is much less variable than historical outflows due to the storage and diversion of water throughout the Sierra-Nevada and Central Valley. Recent declines in Delta outflow are closely linked to water exports at the State and Federal diversion facilities (Cloern and Jassby 2012, p. 6–8).

The State of California recently went through a multi-year drought and is presently in another. Droughts in the Central Valley further decrease freshwater flows. The severity of California's drought was exacerbated by record warm temperatures and below normal precipitation in 2015, resulting in a severely reduced snowpack, a pattern observed again in 2021. The Governor responded to these droughts by signing emergency drought relief funding for critical water infrastructure projects and emergency drought actions. From 2012 to 2015, Federal and State governments (U.S. Bureau of Reclamation [USBR] and California Department of Water Resources [DWR]) took actions to ensure that reduced water quality and supply did not reach a level of concern for human health and safety, while complying with biological opinions. The actions taken included the 2015 placement of a salinity rock barrier on West False River and numerous Temporary Urgency Change Orders (TUCP) from the California SWRCB to DWR and Reclamation in 2014 and 2015 that modified requirements under Decision 1641 to meet certain water quality objectives, reduced reservoir releases, reduced outflow objectives, and modified temperature objectives. With the return of drought conditions in 2020, a TUCP was again approved in the spring of 2021 and the placement of a salinity rock barrier occurred again in June in the West False River between Jersey and Bradford Islands. The TUCPs allow the CVP and SWP operators to reduce freshwater outflow to the San Francisco Estuary. The CDFW and Service fish surveys indicate that the relative abundance of delta smelt in recent years is currently the lowest on record and is at the precipice of falling below detection thresholds of even the most efficient sampling programs. Detailed results of these surveys were presented above under population indices. The low index numbers represent in part the cumulative impact of drought to the delta smelt and its habitat (Mahardja et al. 2021, p. 12).

Climate Change

Climate change is likely already impacting the delta smelt. Climate change is discussed here under Factor A because, although it may affect the delta smelt directly by creating physiological stress, the primary impacts of climate change on the species are expected to be through changes in the availability and distribution of delta smelt habitat and its population resilience (Mahardja et al. 2021, p. 12).

Our analyses under the Act include consideration of ongoing and projected changes in climate. The terms "climate" and "climate change" are defined by the Intergovernmental Panel on Climate Change (IPCC). The term "climate" refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements (IPCC 2013a, p. 1450). The term "climate change" thus refers to a change in the mean or variability of one or more measures of climate (for example, temperature or precipitation) that persists for an extended period, whether the change is due to natural variability or human activity (IPCC 2013a, p. 1450).

Scientific measurements spanning several decades demonstrate that changes in climate are occurring, and that the rate of change has increased since the 1950s. Examples include warming of the global climate system, and substantial increases in precipitation in some regions of the world and decreases in other regions (for these and other examples, see Solomon *et al*. 2007, pp. 35–54, 82–85; IPCC 2013b, pp. 3–29; IPCC 2014, pp. 1–32). Results of scientific analyses presented by the IPCC show that most of the observed increase in global average temperature since the mid-20th century cannot be explained by natural variability in climate and is "very likely" (defined by the IPCC as 90 percent or higher probability) due to the observed increase in greenhouse gas (GHG) concentrations in the atmosphere as a result of human activities, particularly carbon dioxide emissions from use of fossil fuels (Solomon *et al*. 2007, pp. 21–35; IPCC 2013b, pp. 11–12 and figures SPM.4 and SPM.5). Further confirmation of the role of GHGs comes from analyses by Huber and Knutti (2011, p. 4), who concluded it is extremely likely that approximately 75 percent of global warming since 1950 has been caused by human activities.

Scientists use a variety of climate models, which include consideration of natural processes and variability, as well as various scenarios of potential levels and timing of GHG emissions, to evaluate the causes of changes already observed and to project future changes in temperature and other climate conditions (Meehl *et al*. 2007, all; Ganguly *et al*. 2009, pp. 11555, 15558; Prinn *et al*. 2011, pp. 527, 529). All combinations of models and emissions scenarios yield very similar projections of increases in the most common measure of climate change, average global surface temperature until about 2030. Although projections of the magnitude and rate of warming differ after about 2030, the overall trajectory of all the projections is one of increasing global warming through the end of this century, even for the projections based on scenarios that assume that GHG emissions will stabilize or decline. Thus, there is strong scientific support for projections that warming will continue through the 21st century, and that the magnitude and rate of change will be influenced substantially by the extent of GHG emissions (Meehl *et al*. 2007, pp. 760–764, 797–811; Ganguly *et al*. 2009, pp. 15555–15558; Prinn *et al*. 2011, pp. 527, 529; IPCC 2013b, pp. 19–23). See IPCC 2013b (all), for a summary of other global projections of climate-related changes, such as frequency of heat waves and changes in precipitation.

Various changes in climate may have direct or indirect effects on species. These effects may be positive, neutral, or negative, and they may change over time, depending on the species and other relevant considerations, such as threats in combination and interactions of climate with other variables (for example, habitat fragmentation) (IPCC 2014, pp. 4–11). Identifying likely effects often involves aspects of climate change vulnerability analysis. Vulnerability refers to the degree to which a species (or system) is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the type, magnitude, and rate of climate change and variation to which a species is exposed, its sensitivity, and its adaptive capacity (Glick *et al*. 2011, pp. 19–22; IPCC 2014, p. 5). There is no single method for conducting such analyses that applies to all situations (Glick *et al*. 2011, p. 3). We use our expert judgment and appropriate analytical approaches to weigh relevant information, including uncertainty, in our consideration of the best scientific information available regarding various aspects of climate change.

Global climate projections are informative, and, in some cases, the only or the best scientific information available for us to use. However, projected changes in climate and related impacts can vary across and within different regions of the world (IPCC 2013b, pp. 15–16). Therefore, we use “downscaled” projections when they are available and have been developed through appropriate scientific procedures, because such projections provide higher resolution information that is more relevant to spatial scales used for analyses of a given species (see Glick *et al*. 2011, pp. 58–61, for a discussion of downscaling). With regard to our analysis for the delta smelt and overall Bay-Delta, downscaled projections are available (e.g., Dettinger 2005, p. 295–299) and they have been applied to forecasting delta smelt habitat conditions (Feyrer *et al.* 2011; Cloern *et al.* 2011; Brown *et al.* 2013).

San Francisco Bay-Delta Climate Change

The effects of climate change do not act in isolation; they are anticipated to exacerbate existing threats to delta smelt. We considered the potential effects of climate change on the delta smelt based on projections derived from various modeling scenarios. A series of publications (Feyrer *et al.* 2011; Cloern *et al.* 2011; Brown *et al.* 2013; Brown *et al*. 2016) have modeled future impacts of climate change in the delta and projected how this will affect delta smelt. These models used the B1 and A2 scenarios from the 2007 IPCC report. Each scenario included both a warmer-wetter and warmer-dryer sub scenario. Modeled predictions presented in these publications are based on current baseline conditions (no increased outflow, no breaching of levees) which may or may not change in the future. Temperature increases are likely to lead to a continued rise in sea level, further increasing salinity which will increasingly restrict delta smelt’s already limited geographic range (Feyrer *et al.* 2011, p. 124; Cloern *et al.* 2011, p. 7; Brown *et al.* 2013, p. 761). Higher air temperatures will reduce snowpack, melt snow earlier in the winter or spring, and increase water temperatures. These changes will likely alter freshwater flows, possibly shifting and condensing the timing and location of delta smelt reproduction (Brown *et al.* 2013, p. 765, Brown *et al*. 2016, p. 14).

Projections indicate that temperature and precipitation changes will diminish snowpack, changing the availability of natural water supplies (USBR 2011, p. 143; Knowles *et al.* 2018, p. 7641). 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 with an associated decrease in runoff for the remainder of the year (USBR 2011, p. 147; Knowles *et al.* 2018, p. 7646). Sacramento Valley Ecoregion projections include a 27 percent decrease in annual freshwater flows and earlier snowmelts, with increased freshwater flows in January and February but lower flows throughout the rest of the year (PRBO 2011, p. 27). 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 may result in increased drought frequency and severity (Rieman and Isaak 2010, p. 6). Thus overall, these changes may lead to increased frequency of flood and drought cycles during the 21st century (USBR 2011, p. 149).

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 (Practical Salinity Unit) by the end of the century (Cloern *et al.* 2011, p. 7). Elevated salinity could push the position of the LSZ, as indicated by the position of X2, farther up the estuary if outflows are not increased or landscape changes made to compensate for it. 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, p. 765). This increase in the position of X2 in the fall is expected to result in a decrease in suitable physical habitat (Brown *et al.* 2013, p. 765) if current levees and channel structures are maintained. A decrease in spring habitat due to the movement of X2 upstream due to sea level rise is also expected to result from climate change.

We expect warmer estuary temperatures to be yet another significant conservation challenge for delta smelt based on climate change models. Mean annual water temperatures within the Delta are expected to increase steadily during the second half of this century (Cloern *et al.* 2011, p. 7). Warmer water temperatures could reduce delta smelt growth, increase delta smelt mortality and constrict suitable habitat within the estuary during the summer months. Due to warming temperatures, delta smelt are projected to spawn an average of ten to twenty-five days earlier in the season depending on the location (Brown *et al.* 2013, p. 765). Also due to expected temperature increases, total number of high mortality days (cumulative number of days of daily average water temperature >25 °C (77 °F)) is expected to increase for all IPCC climate change scenarios (Brown *et al.* 2013*,* p. 765). The number of stress days (cumulative number of days of daily average water temperature >20 °C (68 °F)) 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, p. 766). More recent research suggests that delta smelt will face a shorter maturation window and significant thermal habitat constriction. A shorter maturation window will likely have effects on reproduction success (Brown *et al*. 2016, p. 14). Growth rates have been shown to slow as water temperatures increase, requiring delta smelt to consume more food to match growth rates that are normal at lower water temperatures (Rose *et al.* 2013a, p. 1252). Delta smelt are already often smaller than they used to be (Sweetnam 1999, p. 23; Bennett 2005, p. 46), and expected temperature increases due to climate change will likely further slow growth rates.

Warmer water will tend to move the spawning season earlier in the year (Brown *et al.* 2013, p. 769). This means the fish will have to grow faster to compensate for the shorter growing season to produce as many eggs as they do now. This may already be a serious limitation on their population fecundity (Rose *et al.* 2013b, p. 1268). Higher temperatures may restrict delta smelt distribution into the fall, limiting their presence in Suisun Bay for more than just salinity reasons and forcing greater inhabitation of cooler, high salinity waters (Brown *et al.* 2013, p. 769). Water temperatures are already presently above 20 °C (68 °F) for most of the summer in core habitat areas, sometimes even exceeding 25 °C (77 °F) for short periods.

The delta smelt is currently at the southern limit of the inland distribution of the family Osmeridae along the Pacific coast of North America. That indicates that this region was historically already about as warm as fish in the Osmeridae family could handle. Increased temperatures associated with climate change may result in a habitat in the Bay-Delta that is outside of the delta smelt's ecological tolerance limits.

Reduced Turbidity

Turbid conditions throughout the estuary attenuate light in the water column and limit phytoplankton growth rate, and thereby productivity (Cloern 1987, p. 1375–1378; Jassby 2008, p. 14). This is one reason why eutrophication has not presented a major problem in the estuary, despite high nutrient concentrations. Increasing water clarity could allow for higher productivity and, eventually, eutrophication. In addition to its role in regulating primary productivity, turbidity is an important component of fish habitat in the Bay-Delta and elsewhere and delta smelt are strongly associated with turbid water (Feyrer et al. 2007, p. 728; Nobriga et al. 2008, p. 7; Feyrer et al. 2011, p. 123). Turbidity has been shown to be important for successful feeding and predator avoidance in multiple species (Pangle *et al*. 2012, all).

First-feeding delta smelt larvae require relatively turbid waters to capture prey (Baskerville-Bridges *et al.* 2004, p. 223). Hasenbein et al. (2016, p. 9) placed 60 day post-hatched delta smelt in waters with turbidities of 5, 12, 25, 35, 50, 80, 120 and 250 nephelometric turbidity units (NTU) to test feeding rates at these turbidities. Turbidities of 25 to 80 NTU were determined to be the optimal range in the tested conditions as evident from the highest survival, feeding and changes in gene expression compared with other treatments. Delta smelt may also use turbidity as cover from predators. This was hypothesized based on long-term monitoring of the distribution of fish in the wild (e.g., Feyrer *et al.* 2007, p. 731) and more recently supported by a laboratory experiment (Ferrari *et al.* 2014, p. 87, Fig 4). From the 1950's to the present, the Delta has experienced a decline in turbidity (Wright and Schoellhamer 2004, p. 12) that culminated in an estuary-wide step-decline in population commencing in 1999 (Schoellhamer 2011, p. 897).

The increased water clarity in delta smelt rearing habitat in recent decades is attributed to the interruption of sediment transport by upstream dams (Arthur and Ball 1979, p. 157; Wright and Schoellhamer 2004, pp. 7, 10) and the spread of the exotic introduced water plants, mainly *Egeria densa* (Brazilian waterweed), which trap suspended sediments (Hestir *et al*. 2016, p. 7-8). 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, p. 728). This is consistent with behavioral observations of captive delta smelt (Nobriga and Herbold 2008, p.11). Few daylight trawls catch delta smelt at Secchi depths over one half meter and capture probabilities of delta smelt are highest at 0.40 m depth or less.

Channel Disturbance, Dredging, Sand-mining

The placement of riprap bank protection has led to the loss of riparian habitat, large woody debris, shallow water habitat, and natural channel migration. Bank stabilization and riprapping has been shown to: 1) change natural river processes, 2) reduce channel meandering, which reduces habitat complexity, 3) create a smooth, hydraulically enhanced surface that is not conducive to the habitat requirements of fish, 4) stop erosion, which stops woody vegetation from entering the river and reduces the long-term recruitment of large woody debris, 5) inhibit plant growth through thick rock at the waterline, which causes vegetation to grow further from the shoreline and a subsequent reduction in outside food sources for aquatic invertebrates, and 6) decrease near-shore roughness, which contributes to increased stream velocities and a decrease in available refuge for fish (USFWS 2000, pp. 6–12). Bank protection along the Sacramento River has thereby contributed to habitat fragmentation. More than half of the river's banks in the lower 194 miles have been riprapped, mostly under the Army Corps of Engineers Sacramento River Bank Protection Project (SRBPP). The historical condition of the Sacramento River was free-flowing, without restrictions brought about by diversions and dams. Late summer flows were low compared to today's summer flows, but high flows during spring caused overbank flooding into areas that contained riparian forests (USFWS 2000, p. 7). Bank erosion and river meander were natural ecological processes. Today, most of the riparian forests and wetlands have been removed, and much of the historical habitat has been lost from all the Delta tributaries.

Ongoing maintenance dredging regularly occurs in the Sacramento and San Joaquin Deep Water Ship Channels of the Delta. Dredging can change the light transmittance, dissolved oxygen and nutrient concentrations, salinity, temperature, and pH of the water (Windom and Stickney 1976). Dredging will also re-suspend contaminants if they are present in the surface sediments (Levine-Fricke 2004, p. 44). However, these effects are localized and the plumes do not last long once dredging stops (Schoellhamer 2002, p. 491). Dredging can result in mortality, and injury or displacement (particularly in marinas) of delta smelt (Levine-Fricke 2004, p. 67–72).

Sand mining is another form of dredging that is most likely to affect delta smelt at the egg and larval life stages. There are a number of measures in place to minimize the effects of sand mining in the estuary. Applicants are required to install fish screens in compliance with CDFW and NMFS criteria over sand mining vent pipes to exclude juvenile and adult fish from entrainment during sand mining events. In addition, a work window of December 1 through June 30 is in place, and during this time sand mining operations are restricted to areas that are 20 ft. or greater in depth. Delta smelt are thought to spawn in water 15 ft. or less. This restriction will avoid spawning habitat in shallower depths for delta smelt. Sand mining volume percentages during the spawning period of delta smelt are also reduced. Because spawning substrate is not known to be limited for the species (Hobbs *et al.* 2007, all), restrictions are in place to protect delta smelt, and sand is a dominant substrate in the estuary, sand mining is not expected to limit spawning.

Summary for Factor A

Based on a review of the best scientific and commercial information available, we find that destruction, modification, or curtailment of habitat poses a threat to delta smelt due to a suite of factors. The operation of upstream reservoirs, water export facilities, and other water diversions has altered the magnitude, duration, and frequency of Delta outflows and the location and extent of the LSZ and has reduced habitat that the delta smelt uses. Lower turbidity reduces larval foraging efficiency and increases predation risk. Forecasted warmer water temperatures and higher salinity in the Delta due to climate change will likely further impair delta smelt habitat in the future. Channel disturbance, dredging and sand mining do not rise to the level of a threat that is currently acting on the species at the population level. Although channel modification and levee construction have altered the Delta and resulted in habitat fragmentation and depletion for the delta smelt, this is a historical, and not a current, threat.

B. Overutilization for commercial, recreational, scientific, or educational purposes.

Delta smelt monitoring surveys are conducted throughout the year, and sampling effort has generally increased over time as new programs have been added. The majority of surveys in the Delta are conducted by the Interagency Ecological Program (IEP). The mission of the IEP is, in collaboration with others, to provide ecological information and scientific leadership for use in management of the San Francisco Estuary. The goals of IEP are to: describe the status and trends of aquatic ecological factors of interest in the estuary, develop an understanding of environmental factors that influence observed aquatic ecological status and trends, use knowledge of the above information in a collaboration process to support natural resource planning, management, and regulatory activities in the estuary, continually reassess and enhance long-term monitoring and research activities that demonstrate scientific excellence, and to provide scientific information about the estuary that is accurate, accessible, reliable, and timely. The IEP studies benefit the delta smelt by providing information that helps with the conservation of the species.

Because of low abundance and a high level of sampling mortality, some survey methods have been modified to limit incidental catches of delta smelt when delta smelt is not the target species.

Because take includes the act of catching and handling the fish, any individual that is captured is counted in the take total and it is expected that a substantial fraction of fish sampled by trawling results in lethal take of delta smelt. Over the past few years the Service worked with all parties engaged in the scientific monitoring and take of delta smelt to reduce overall take, avoid and minimize lethal take, and ensure that maximum information is gathered from such studies to aid in scientific understanding and management of the species.

Based on the low water volumes sampled by fish surveys relative to the amount of water in sampled areas, the number of delta smelt collected in sampling surveys relative to the total population is unlikely to be very high. Further, the benefits monitoring can have in improving scientific understanding leading to more effective management actions have been important historically. Therefore, we find the amount of take expected to occur from sampling surveys does not reach a level substantial enough to be considered a threat (USFWS 1997, p. 31). There is no evidence of use of the species for other commercial, recreational, scientific, or educational purposes.

C. Disease or predation.

Disease

Studies have not found evidence of significant disease infestations in wild delta smelt (Teh 2007, p. 8; Baxter *et al.* 2008, p. 14) (See contaminants discussion in Factor E for more information). Based on the best scientific and commercial information available, we conclude that disease is not a threat to the delta smelt.

Predation

There are numerous fish species that have been confirmed to be delta smelt predators either through visual analysis of their stomach contents or by detection of delta smelt DNA in their digestive tracts. It seems likely that delta smelt are also occasionally consumed by piscivorous birds that forage in their habitat but we are unaware of any data available to confirm this hypothesis. The following paragraphs focus on three predators that the local scientific community has concentrated their research efforts upon for their potential to affect delta smelt viability.

The delta smelt predator with the highest historical documentation is striped bass (*Morone saxatilis*; Nobriga and Smith 2020, pp 8-9, Table 1). Striped bass were confirmed to prey on both juvenile and adult delta smelt. Striped bass are widely distributed in pelagic areas of the San Francisco Bay-Delta and parts of its watershed, and thus striped bass distribution fully encompasses the distribution of delta smelt juveniles and adults (Nobriga and Smith 2020, p. 12 and Table 5). Thus, striped bass are likely to be the most significant predator of post-larval delta smelt (Nobriga and Feyrer 2007, p. 9; Nobriga and Smith 2020 all). Although the relative rarity of delta smelt in the estuary food web would presumably make them solely an incidental prey item for striped bass, it is possible that striped bass abundance and demand for prey are always high enough to limit delta smelt population growth rate (Nobriga *et al.* 2013, p. 1574). However, focused studies of this predator-prey linkage would be required to determine whether predation by striped bass is significant enough to be of concern for delta smelt populations.

In contrast to the situation for striped bass, several researchers have found inverse correlations between the relative abundance of largemouth bass or multi-species indices that included largemouth bass and the relative abundance of delta smelt (Mac Nally *et al.* 2010, p. 1425, Fig 3b; Thomson *et al.* 2010, p. 1439, Fig 3c; Maunder and Deriso 2011, p. 1297, Table 6). At this time, however, there is no way to determine whether these correlations are causative (predation by largemouth bass caused delta smelt to decline) or not (delta smelt simply use different habitats than largemouth bass and delta smelt habitat has decreased while largemouth bass habitat has increased). Largemouth bass are freshwater fish that prefer clear waters along shorelines (littoral habitat) with relatively dense water plants (Nobriga and Feyrer 2007, pp. 4, 8; Brown and Michniuk 2007, p. 196; Baxter *et al.* 2008, p. 17). This is a suite of habitat characteristics that is distinctly different from those described above for delta smelt. Thus, unlike delta smelt and striped bass, delta smelt and largemouth bass have different habitat requirements (e.g., Nobriga *et al.* 2005, p. 783) and their distributions do not strongly overlap. There has been a major increase in the Delta's largemouth bass population since the early 1990s that is believed to have been facilitated by the spread of introduced plants such as *Egeria densa*, which provides rearing habitat for the bass (Baxter *et al.* 2008, p. 17). Despite increases in largemouth bass populations and habitat, Nobriga and Feyrer (2007, p 6) did not find delta smelt as largemouth bass prey. Nor have more recent and extensive surveys of largemouth bass stomach contents (Baxter *et al.* 2015, p. 65; Weinersmith et al. 2019, p. 10). In captivity however, even young juvenile largemouth bass will attempt to consume delta smelt (Ferrari *et al.* 2014, p. 87) so they presumably represent a predation threat when the species closely co-occur in the wild.

Due to their size, juvenile and adult delta smelt are mainly vulnerable to larger predatory fishes. However, delta smelt eggs and larvae are very small (eggs are ~ 1 mm in diameter and larvae hatch at ~ 5–6 mm in length). Thus, these early life stages of delta smelt are potentially available prey to a much greater number of predators (Schreier *et al*. 2016, p. 729). One of these is the nonnative Mississippi silverside (*Menidia audens*), which like delta smelt, is an annual fish with a maximum length near 100 mm (4 in.). Mississippi silversides were first introduced to the San Francisco Bay-Delta in the mid-1970s, and have increased dramatically in numbers since the mid-1980s (Mahardja *et al*. 2016, p. 2). Mississippi silversides may be both predators and competitors of delta smelt (Bennett 2005, pp. 49, 50). They forage in schools around shoreline habitats and tidal marsh channels of the San Francisco Bay-Delta, where they are abundant. Silversides have been confirmed to be predators of larval delta smelt based on evaluation of DNA in their stomach contents (Baerwald *et al.* 2012, p. 1606; Schreier *et al*. 2016, all).

Although generally inverse relative abundance trends between delta smelt and Mississippi silverside have been recognized for several decades (Bennett and Moyle 1996, p. 530; Bennett 2005, p. 50), two recent statistical evaluations of delta smelt relative abundance trends both concluded that Mississippi silverside densities did not significantly correlate with the delta smelt trends when other factors were considered (Mac Nally *et al.* 2010, p. 1422; Thomson *et al.* 2010, p. 1441; Polansky *et al*. 2021, Web Appendix C).

Summary for Factor C

Based on a review of the best scientific information available, we find that disease is not a threat to the delta smelt. We conclude that predation is an additional threat to delta smelt. Although predation is a naturally occurring mechanism, non-native fishes that have been introduced into the delta have likely increased the risk of predation to delta smelt (Schreier et al. 2016, all; Nobriga and Smith 2020, all). Current and historical evidence of delta smelt in stomachs of the relatively small number of non-native fishes sampled compared to overall non-native population numbers shows that predation from non-native fishes is likely having some effect on overall population numbers of delta smelt. We believe that the lack of positive data confirming predation as a population driver is an artifact of the underlying data (Nobriga and Smith 2020, p. 4, Fig. 2). Delta smelt is a rare fish and has been a rare fish (compared to other species) for many decades. Therefore, it is not surprising that studies are inconclusive on the extent of population level effects.

D. The inadequacy of existing regulatory mechanisms.

State Laws

California Endangered Species Act: The delta smelt was listed as threatened under the California Endangered Species Act (CESA) in 1993 (CDFW 2014b), and was reclassified as endangered under the CESA in 2010 (14 CCR 670.5). The CESA prohibits unpermitted possession, purchase, sale, or take of listed species. However, the CESA definition of take does not include harm, which under the Federal Endangered Species Act can include modification or degradation of habitat that actually kills or injures wildlife by significantly impairing essential behavioral patterns (50 CFR 17.3). The CESA requires consultation between the CDFW and other State agencies to ensure that activities of State agencies will not jeopardize the continued existence of State-listed species (CDFW 2014c). The SWP is currently operating to an incidental take permit for delta smelt issued on March 31, 2020.

Porter Cologne Water Quality Control Act: The Porter-Cologne Water Quality Control Act (California Water Code 13000 *et seq*.) is a California State law that established the SWRCB and nine Regional Water Quality Control Boards that are responsible for the regulation of activities and factors that could degrade California water quality and for the allocation of surface water rights (California Water Code Division 7). In 1995, the SWRCB developed the Bay-Delta Water Quality Control Plan which expanded water quality objectives for the Delta. This plan was updated in 2006, and is currently implemented by Water Rights Decision 1641, which imposes flow and water quality standards on the State and Federal water export facilities to assure protection of beneficial uses in the Delta (SWRCB 2000, p. 43). The various flow and salinity objectives can constrain export pumping and were designed, in part, to protect fisheries. These objectives include specific freshwater flow requirements throughout the year, specific water export restraints from February-June, and water export limits based on a percentage of estuary inflow throughout the year. The water quality objectives were designed to protect agricultural, municipal, industrial, and fishery uses; they vary throughout the year and by hydrology. In addition to regulating flow requirements, the Porter Cologne Water Quality Control Act also regulates contaminants released into the Delta (see Clean Water Act). The SWRCB last updated the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary in 2017, although during drought, emergency petitions to deviate from water quality standards have been granted, resulting in a reduction in suitable rearing habitat for delta smelt.

Federal Laws

National Environmental Policy Act: The National Environmental Policy Act (NEPA) (42 U.S.C. 4321 *et seq.*) requires all Federal agencies to formally document, consider, and publicly disclose the environmental impacts of major Federal actions and management decisions significantly affecting the human environment. NEPA documentation is provided in an environmental impact statement, an environmental assessment, or a categorical exclusion, and may be subject to administrative or judicial appeal. However, the Federal agency is not required to select an alternative having the least significant environmental impacts, and may select an action that will adversely affect sensitive species provided that these effects are known and identified in a NEPA document. Therefore, we do not consider the NEPA process in itself to be a regulatory mechanism that is designed to provide significant protection for the delta smelt.

Endangered Species Act: The delta smelt is currently listed as a threatened species under the Endangered Species Act of 1973, as amended (Act). The Act defines a "threatened species" as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" (section 3(20) of the Act). An "endangered species" is "any species which is in danger of extinction throughout all or a significant portion of its range" (section 3(6) of the Act). Section 6 of the Act authorizes us to enter into conservation agreements with States, and to allocate funds for conservation programs to benefit threatened or endangered species. Section 7 of the act requires all Federal agencies, in consultation with and with the assistance of the Secretary (in this case the USFWS), to ensure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered or threatened species or result in destruction or adverse modification of their designated critical habitat.

The CVP, operated by the Bureau of Reclamation (Reclamation), and SWP, operated by the DWR, are currently operating under a Biological Opinion (BiOp) issued October 21, 2019 under section 7 of the Act (USFWS 2019, all) and a court authorized Interim Operations Plan. A BiOp includes an Incidental Take Statement (ITS) specifying reasonable and prudent measures necessary to minimize the incidental take of the species resulting from CVP and SWP operations.

Central Valley Project Improvement Act: The Central Valley Project Improvement Act (CVPIA) amends the previous CVP authorizations to include fish and wildlife protection, restoration, and mitigation as project purposes having equal priority with irrigation and domestic water uses, and fish and wildlife enhancement as having an equal priority with power generation. Included in CVPIA section 3406 (b)(2) was a provision to dedicate 800,000 acre-feet of Central Valley Project yield annually (referred to as "(b)(2) water") for fish, wildlife, and habitat restoration. Since 1993, (b)(2) water has been used and in some years supplemented with acquired environmental water pursuant to CVPIA section 3406 (b)(3) to increase stream flows and reduce Central Valley Project export pumping in the Delta. These management actions were taken to contribute to the CVPIA anadromous fish doubling goals but may have incidentally protected delta smelt and their habitat. As discussed above (under Biology and Factor A), increased freshwater flows and lower exports have been shown to be beneficial to delta smelt.

Clean Water Act: The Clean Water Act (CWA) provides the basis for the National Pollutant Discharge Elimination System (NPDES). The CWA gives the EPA the authority to set effluent limits and requires any entity discharging pollutants to obtain a NPDES permit. The EPA is authorized through the CWA to delegate the authority to issue NPDES Permits to State governments. In States that have been authorized to implement CWA programs, the EPA still retains oversight responsibilities (USEPA 2014). California is one of these States to which the EPA has delegated CWA authority. The Porter-Cologne Water Quality Control Act established the California SWRCB and nine Regional Water Quality Control Boards that are now responsible for issuing these NPDES permits, including permits for the discharge of effluents such as ammonia. The SWRCB is responsible for regulating activities and factors that could degrade California water quality (California Water Code Division 7, section 13370–13389).

The release of ammonia into the estuary has been shown to have detrimental effects on the Delta ecosystem by inhibiting the production of diatoms, a kind of phytoplankton (see Factor E, below). The release of ammonia is controlled primarily by the CWA (Federal law) and secondarily through the Porter-Cologne Water Quality Control Act (State law). In 2013, the EPA updated freshwater discharge criteria that included new more stringent limits on ammonia (USEPA 2013, pp. 1–3). This was done to limit the effects of ammonia on freshwater clams and snails in the Delta. In addition, an NPDES permit for the Sacramento Regional Wastewater Treatment Plant, a major discharger, was prepared by the California Central Valley Regional Water Quality Control Board in the fall of 2010, with new ammonia limitations intended to reduce loadings to the Delta. Reduced ammonia discharges to the Sacramento River were realized beginning in 2019 with the Sacramento Regional Wastewater Treatment Plant's Nitrifying Sidestream treatment process which reduced ammonia from 10-20%. The newly completed Biological Nitrogen Removal (BNR) facility was operational on April 19, 2021 and new ammonia nitrogen NPDES permit limits were in effect on May 10, 2021. The BNR facility removes almost all ammonia and approximately 65% of the total dissolved nitrogen from the wastewater effluent which is discharged into the Sacramento River. Planned U.S. Geological Survey science efforts and required Clean Water Act NPDES monitoring will track the performance of the BNR facility, effluent ammonia nitrogen permit compliance, and future Sacramento River water quality conditions downstream (CRWQCB 2021, Attachment E).

Summary for Factor D

We have identified a number of existing regulatory mechanisms that provide protective measures that affect the stressors acting on the delta smelt. Despite these existing regulatory mechanisms and other conservations efforts, some stressors continue to act on the species such that it is warranted for uplisting under the Act.

E. Other natural or manmade factors affecting its continued existence.

Other factors affecting the continued existence of the delta smelt include entrainment (fish drawn in and transported through the flow of water) into the South Delta by water diversions, introduced species, contaminants, and increased vulnerabilities of small populations.

Water Export Facilities: Operation of water export facilities directly affects fish by entraining them into the South Delta and if they survive long enough, the diversion facilities themselves. Delta smelt's risk of entrainment varies with the environmental and manmade effects on Delta hydrology and the habitats occupied by delta smelt when water is being diverted (Kimmerer and Nobriga 2008, pp. 19–20). The two largest water export facilities located in the South Delta, Jones Pumping Plant (CVP) and Banks Pumping Plant (SWP), exported between 4.31 and 7.74 km3 (3.49 and 6.28 million acre-feet) per year between water years (October 1–September 30) 1999 and 2008.

It is important that we differentiate "entrainment" from "salvage." Fish are considered "entrained" when they are moved into the south Delta, where they and their progeny are lost to the population. Fish are considered "salvaged" at the SWP when they are collected by the Skinner Fish Facility. At the CVP, fish are considered salvaged when they are collected by the federal fish facility. Entrainment of delta smelt varies within and among seasons and among years. Studies of entrainment at the State and Federal export facilities found that entrainment rates increased with reverse flows in the southern Delta, which are a function of export rates and Delta inflows (Kimmerer and Nobriga 2008 p. 17, Fig 16; Kimmerer 2008, p. 20–22). The entrainment of adult delta smelt at CVP and SWP occurs mainly during their upstream spawning movement between December and March (Grimaldo et al. 2009, p. 1257). The salvage of age zero delta smelt occurs from April–July with a peak in May–June (Grimaldo et al. 2009, p. 1257). Kimmerer (2008, p. 20, 22; 2011, p. 4) estimated that from 0 to 25 percent of the larval population and 1 to 38 percent of the adult population is entrained annually by the State and Federal export facilities, with average annual losses estimated at 10% of the population (Kimmerer 2008, p. 25, 2011). Rose extrapolated from this study to find annual losses varying between 1–23% of the adult population (Rose 2013, p. 1251). The majority of entrained delta smelt do not make it to the pumps to enter the fish facility to undergo the salvage process and instead are lost through predation or other mechanisms in the Clifton Court Forebay (Castillo 2012, p. 14). Due to continuing declines in smelt numbers, very few smelt are actually making it to the salvage facility.

In October 2019, the Service issued a BiOp on operations of the CVP and SWP which included measures to manage conditions that could result in entrainment of delta smelt. These tools include consideration of real-time information, Old and Middle River (OMR) flow limits to minimize the project's influence on delta smelt dispersal, turbidity bridge avoidance, and the Service's delta smelt life cycle model which was subsequently used to set OMR flow targets to minimize entrainment of larval and juvenile smelt.

Prior to the implementation of OMR flow limits in the Service's 2008 and 2019 BiOps, export of water by the CVP and SWP could limit the reproductive success of delta smelt spawned in the San Joaquin River by entraining most of the dispersing larvae (Kimmerer and Nobriga 2008, p. 11). Similarly, winter entrainment of delta smelt sometimes represented a substantial loss of pre-spawning adults and their reproductive potential (Sommer et al. 2007, p. 275). However, OMR flow rules in place since 2007 have reduced entrainment (Smith 2019 p. 17; Smith et al. 2020, p. 9, Fig. 5), which has reduced the overall magnitude of this threat on delta smelt as compared to other threats.

We do not consider entrainment in most small agricultural diversions to be a significant threat due to their nearshore location and tendency to divert at maximum rates during the summer when many delta smelt are not in channels adjacent to them. Entrainment into power plants appears to have had a significant impact on delta smelt in the past and was cited in the 2010 12-month finding document, however, operations have been modified and the generating stations in question are now fully air cooled, so the effects of operations have been eliminated and are no longer significant.

Introduced Species

The Bay-Delta zooplankton community has shifted in both the abundance and composition of species over the last several decades (Winder *et al.* 2011, p. 679; Kratina *et al.* 2014, p. 1070). Delta smelt feed primarily on small planktonic (free-floating) crustaceans, and occasionally on insect larvae (Moyle 2002, p. 228). The densities of these prey items depend upon a variety of factors that determine local productivity and the rate at which production from upstream sources is delivered. Historically, the main prey of delta smelt was the copepod *Eurytemora affinis* and the mysid shrimp *Neomysis mercedis*. The copepod *Pseudodiaptomus forbesi* has replaced *E. affinis* as a major prey source of delta smelt since its introduction into the San Francisco Bay-Delta. Two other copepod species, *Limnoithona tetraspina* and *Acartiella sinensis*, have become abundant since their introduction to the San Francisco Bay-Delta in the mid-1990s. *Limnoithona tetraspina* is now the most common copepod in the estuary and as of 2006 made up approximately 95% of the total adult copepods in the LSZ (Bouley and Kimmerer 2006, p. 219). Delta smelt eat these introduced copepods, but only *P. forbesi* is a dominant prey item (Slater and Baxter 2014, p. 8). It has been suggested that *L. tetraspina* may be an inferior food for pelagic fishes including delta smelt because of its small size and generally sedentary behavior (Bouley and Kimmerer 2006, pp. 220–227). Experimental studies addressing this issue have suggested that smelt larvae will attack *L. tetraspina* until they grow large enough to successfully capture larger copepods; also, growth rate of delta smelt fed *L. tetraspina* was lower than that of smelt fed the larger copepods (Sullivan *et al.*, 2016, p. 638-640). As mentioned previously, delta smelt are thought to require a turbid environment for efficient, successful foraging.

Copepods get most of their nutrition from phytoplankton and other direct consumers of phytoplankton. A major reason for the long-term phytoplankton reduction in the upper estuary is grazing by the introduced overbite clam (*Potamocorbula amurensis*), which became abundant by the late 1980s. The overbite clam precipitated major changes in the estuarine food web and has impaired pelagic fish production. Starting about 1987-1988, major step-declines were observed in the abundance of phytoplankton (Alpine and Cloern 1992, p. 949), mysid shrimp (Orsi and Mecum 1986, p. 331) and the copepod *Eurytemora affinis* due to grazing by the clam (Kimmerer *et al.* 1994, p. 86). The overbite clam incidentally consumes copepod nauplii as it filters phytoplankton and other small organisms from the water (Kimmerer *et al.* 1994, p. 87), therefore, it not only reduces phytoplankton biomass but also competes directly with delta smelt for food because copepod nauplii are the primary prey for delta smelt larvae.

Pelagic primary productivity in the upper San Francisco Estuary is currently low compared to other estuaries (Kimmerer *et al.* 2012, pp. 920–924) and low fish abundance may be expected as a consequence. Pelagic fishes responded to the food web changes brought on by the overbite clam in several ways. Northern anchovy, a marine fish, largely vacated the low-salinity zone, retreating to saltier water in San Francisco Bay (Kimmerer 2006, p. 211). Striped bass reduced their use of offshore habitats or suffered higher mortality in them giving the impression that they had moved increasingly toward inshore areas (Sommer *et al.* 2011, p. 1456). Many fish species reduced their use of mysids as prey (Feyrer *et al.* 2003, p. 281). The production per unit of flow of striped bass, longfin smelt, starry flounder, and Bay shrimp appears to have declined as a result of overbite clam grazing (Kimmerer 2002, p. 1281; Kimmerer *et al.* 2009, p. 6, Fig. 3). A recent evaluation of potential food limitation for delta smelt using an individual based life cycle model suggested that changes in the estuarine food web since the 1970s have contributed to a lower population growth rate (Kimmerer and Rose 2018, p. 231, Fig. 4).

Egeria densa and other non-native submerged and emergent aquatic vegetation (e.g., *Myriophyllum spicatum, Alternanthera philoxeroides, Eichhornia crassipes*) may affect delta smelt in direct and indirect ways. *Egeria* may infest as much as 15,000 surface water acres, or 22% of the Delta's approximately 68,000 acres (USDA ARS 2017, p. 3-12). Directly, submerged aquatic vegetation can overwhelm littoral habitats (inter-tidal shoals and beaches) where delta smelt may try to spawn, making them unsuitable for spawning or increasing the risk of predation for delta smelt or their eggs. Indirectly, submerged aquatic vegetation decreases turbidity by trapping suspended sediment, which has contributed to a decrease in both juvenile and adult smelt habitat quality and a contraction of delta smelt distribution in the upper estuary (Feyrer *et al.* 2007, p. 728; Nobriga *et al.* 2008, pp. 8–9). First-feeding delta smelt larvae require relatively turbid waters to capture prey (Baskerville-Bridges *et al.* 2004, p. 223). Clearer water may also make delta smelt more susceptible to predation (Ferrari *et al.* 2014, p. 86).

In summary, we find that the overbite clam and other introduced species have altered the Delta food web such that they cumulatively constitute a threat to delta smelt. It is likely that impacts to delta smelt from introduced species will continue to worsen.

Contaminants

In 2014, over 21 million pounds of pesticides were applied within the five-county Bay-Delta area, and Bay-Delta waters are listed under the Clean Water Act section 303(d) as impaired for several legacy and currently used pesticides (California Department of Pesticide Regulation 2016, p. 1). Concentrations of dissolved pesticides vary in the Delta both temporally and spatially (Kuivila 1999, all). Several areas of the Delta, particularly the San Joaquin River and its tributaries, are impaired due to elevated levels of diazinon and chlorpyrifos, which are toxic at low concentrations to some aquatic organisms (MacCoy *et al.* 1995, pp. 21–30). Several studies have demonstrated the acute and chronic toxicity of two common insecticides, diazinon and esfenvalerate, in fish species (Barry *et al.* 1995, p. 273; Goodman *et al.* 1979, p. 479; Holdway *et al.*; 1994, p. 169; Scholz *et al.* 2000, p. 1911; Tanner and Knuth 1996, p. 244). The effects to delta smelt can be direct or indirect (effects that reduce the food supply of the delta smelt).

Pyrethroid insecticides are of particular concern because of their widespread use and observed genotoxicity (DNA damaging) in fishes at environmentally-relevant concentrations (Campana *et al.* 1999, p. 159). The pyrethroid esfenvalerate is associated with delayed spawning and reduced larval survival of bluegill sunfish (*Lepomis macrochirus*) (Tanner and Knuth 1996, pp. 246–250) and increased susceptibility of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) to disease (Clifford *et al.* 2005, pp. 1770–1771). In addition, pyrethroids may interfere with nerve cell function, which could eventually result in paralysis (Bradbury and Coats 1989, pp. 377–378; Shafer and Meyer 2004, pp. 304–305).

Indirect effects to delta smelt through the food web have been documented. Weston and Lydy (2010, p. 1835) found the largest source of pyrethroids flowing into the Delta to be coming from the Sacramento Regional Wastewater Treatment Plant (SRWTP), where only secondary treatment occurs. Their data not only indicate the presence of these contaminants, but the concentrations found exceeded acute toxicity thresholds for the amphipod *Hyalella azteca*. Another study of storm events in five urban creeks in Suisun Marsh in February 2014 detected concentrations of bifenthrin (a pyrethroid) and fipronil outside of the primary agricultural pesticide season. Although the concentrations of these two insecticides were not high enough to cause mortality, they did result in paralysis of either the amphipod *Hyalella azteca*, or the larval midge *Chironomus dilutus* in 70% of the samples collected (Weston *et al.* 2015, pp. 20–25). Toxicity values for estuarine and marine invertebrates are not known for these insecticides but this study raises concerns about the effects to estuarine invertebrates from urban stream insecticide loading. This is of substantial concern because the use of insecticides in the urban environment had not before been considered the primary source of insecticides flowing into the Delta. Furthermore, this was not the case for the Stockton Wastewater Treatment facility, where tertiary treatment occurs, suggesting that different treatment methods may remove or retain pyrethroids differently (Baxter *et.al.* 2010, p. 33).

Ammonia loading in the Bay-Delta has increased significantly in the last 25 years (Jasby 2008, p. 15–16). 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, p. 67). Delta smelt have shown direct sensitivity to ammonia at the larval and juvenile stages (Werner *et al.* 2008, pp. 85–88). Connon *et al.* (2011, pp. 347–375) 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, pp. 78–79; Teh *et al.* 2011, pp. 25–27).

In addition to direct effects on fish, ammonia in the form of ammonium is thought to reduce primary production by diatoms, an important kind of phytoplankton, because ammonium inhibits the ability of diatoms to take nitrate out of the water. Diatoms grow faster using nitrate than ammonium. Ammonium in the estuary has been shown to suppress spring phytoplankton blooms in Suisun and Grizzly Bays by slowing down the growth rates of diatoms (Dugdale *et al.* 2007, pp. 26–28; Parker *et al.* 2012, pp. 6–8). However, Kimmerer et al. 2014 (p. 1214) found no direct evidence of ammonium effects on phytoplankton production within the LSZ from 2006-2008. A recent study conducted found no evidence that ammonium was inhibiting diatom production in Pacheco Slough in the fall (Esparza et al. 2014, p. 198). There were several differences between this recent research and past research. The Pacheco Slough study was conducted from August to October as opposed to the Wilkerson study that started in November, it measured biomass and not growth rates, and it took place in a slough rather than in open waters.

The role of ammonium nitrogen uptake inhibition in Sacramento River primary production is not fully understood. Parker *et al.* (2012, pp. 577–580) observed primary production in the Sacramento River decreased in the SRWTP region as compared to the upper river region during the months of March and April. However, a previous study found that declines in phytoplankton density above the SRWTP between the Tower Bridge in Sacramento and Garcia Bend are a possible cause of this decline in productivity (Foe *et al.* 2010, p. 13). General ecological principles would lead us to believe that decreased primary productivity, wherever it occurs in delta smelt habitat, is likely to lead to a decrease in copepods and other zooplankton that delta smelt rely upon for food. A link between primary productivity and productivity in higher trophic levels has been documented in various pelagic food webs (Nixon 1988, p. 1019; Sobczak *et al.* 2005, p. 133). At this time, we conclude that more science is needed to determine the role of ammonium in the food web. However, because ammonium may be affecting the food web as shown in research described above, we support future actions in the Bay-Delta that would reduce ammonium outputs. One of these actions, modification of the Sacramento Regional Wastewater Treatment Plant, is discussed above (see pp. 26).

Selenium, introduced into the estuary primarily from agricultural irrigation runoff via the San Joaquin River drainage and oil refineries in San Francisco Bay, has been implicated in toxic and reproductive effects in fish and wildlife (Linville *et al.* 2002, p. 52). Selenium exposure has been shown to have effects on some benthic foraging species—deformities typical of selenium exposure including lordosis (spinal deformities) have been observed in splittail collected from Suisun Bay (Stewart *et al*. 2004, p. 4524). However, there is no evidence to date that selenium exposure is contributing to the decline of delta smelt or other pelagic species in the Bay-Delta (Baxter *et al.* 2010, p. 28).

Complex mixtures of contaminants spanning many different classes can be common in regions heavily influenced by agricultural or urban environments. To date, a variety of studies have documented the impacts of complex chemical mixtures on aquatic organisms. Laetz *et al.* (2009, p. 351) exposed juvenile Coho salmon (*Oncorhynchus ktsutch*) to sub-lethal concentrations of five current-use pesticides and found the compounds were acting as synergists with each other. Nørgaard and Cedergreen (2010, p. 962) found that a mixture of fungicides and pyrethroids could produce a 12-fold increase in toxicity over what was expected using an additive model when looking at impacts to *Daphnia magna*. LeBlanc *et al.* (2012, p. 383) examined the sub-lethal effects of three pesticides: chlorpyrifos, dimethoate (both organophosphates) and imidacloprid (a neonicotinoid), and found a synergistic interaction when aquatic invertebrates (*Chironomus dilutus* larvae) were exposed to all three at once. Carvalho *et al.* (2014, pp. 225–228) produced two mixtures of 14 and 19 different compounds of concern, including metals, pesticides, pharmaceuticals, and hydrocarbons, all at concentrations below the Environmental Quality Standards. A host of sub-lethal impacts to many different aquatic organisms were detected including fish embryo toxicity, increased oxidative stress, and decreased invertebrate mobility.

Contaminants are suspected to be a stressor on delta smelt despite little direct evidence (Kuivila and Moon 2004, pp. 237–241; Brooks *et al.* 2012, pp. 611–614). A study of juvenile delta smelt in five different regions encompassing their range examined fish for signs of contaminants and food limitation. The histopathological analysis of 244 fish sampled in 2012 and 2013 found an 11-fold increase in gill and liver lesion scores in Cache Slough as compared to Suisun Marsh. Higher lesion scores indicate less healthy tissues and are indicative of contaminant-related stress (Hammock *et al.* 2015, p. 320).

Large blooms of toxic *Microcystis aeruginosa* (a species of cyanobacteria) were first documented in the Bay-Delta during the summer of 1999 (Lehman *et al.* 2005, p. 87). *M. aeruginosa* forms large colonies throughout most of the Delta and increasingly down into Suisun Bay (Lehman *et al.* 2005, p. 92; 2013, p. 150). Blooms typically occur when water temperatures are above 20 °C (68 °F) (Lehman *et al.* 2010, p. 238). It is unclear whether microcystins and other toxins produced by local blooms are acutely toxic to fishes at current concentrations; however, the toxins accumulate in fish and their prey. During summer 2005, Age-0 striped bass and Mississippi silversides that were co-occurring with the *Microcystis* bloom showed various forms of liver damage (Lehman *et al.* 2010, p. 241). When ingested with food, microcystins have been experimentally shown to cause substantial impairment of health in threadfin shad (Acuña *et* *al.* 2012, p. 1195). In addition, the copepods that delta smelt eat are particularly susceptible to these toxins (Ger 2008, pp. 12, 13; Ger *et al.* 2010, p. 1554). An investigation of food web effects and fish toxicity concluded that even at low abundances, *M. aeruginosa* may impact estuarine fish productivity through both direct toxicity and food web impacts (Lehman *et al.* 2010, p. 241–245). *M. aeruginosa* is most likely to affect juvenile delta smelt during summer blooms.

Vulnerability of Small Populations

Delta smelt are increasingly concentrated in their rearing habitat during all but the wettest years, making them vulnerable to environmental conditions such as droughts, contaminant spills, and predation. Small, isolated populations are more likely to lose genetic variability due to genetic drift, and to suffer inbreeding depression due to the fixation of deleterious alleles (gene variants) (Lande 1998, pp. 11–17). Populations at low densities are often subject to Allee effects, which involve decreases in the ratio of offspring to adults as the population density decreases (Dennis 2002, p. 389). It is unknown if small population size has contributed to delta smelt's decline, but it seems likely that it has. It was recently documented that delta smelt's genetic effective population size declined between 2003 and 2009 as the population declined (Fisch *et al.* 2011, p.7, Fig 2). This study estimated that the effective population size declined from about 4,000–12,000 fish in 2003 to 1,000–2,000 fish during 2007–2009. The effective population size is an estimate of the number of adult fish that produced offspring that survived to adulthood in any given year. It is thought that the population experienced a genetic bottleneck during the 2007-2009 time period. The effective size can only be lower now given the abundance declines discussed above in the abundance index section. This loss of genetic diversity in the population reduces the ability for fish to respond to changes and evolve, and acts as a threat to the delta smelt population. Staff from UC Davis have maintained genetic diversity in the captive refugial population consistent with what existed in the wild as of 2017 (Finger *et al*. 2018, p. 5). However, domestication of the captive stock was occurring and limiting its rate requires crosses with wild fish (Finger *et al*. 2018, p. 10), which have been hampered by the very low catches of wild fish over the past couple of years.

Summary for Factor E

Based on a review of the best scientific and commercial information available, we find that the following natural or manmade factors pose primary ongoing threats to the delta smelt: entrainment by the State and Federal water export facilities, and introduced species, primarily the overbite clam and invasion of aquatic weeds, particularly *Egeria densa*. Additional threats include contaminants and small population size. The threat to delta smelt from ammonia, in the form of ammonium, has been dramatically reduced by improved wastewater treatment in April, 2021.

CONSERVATION MEASURES PLANNED OR IMPLEMENTED

A variety of conservation measures have been proposed and/or undertaken in the estuary that benefit the delta smelt. Additional measures can be found above under the Factor D (Regulatory Mechanisms). The following list is not exhaustive.

The Delta Smelt Resiliency Strategy (Strategy) was proposed by the State of California in 2016. It proposes to address both immediate and longer term needs of the delta smelt, promote their resilience to drought as well as future variations in habitat conditions caused by climate change, future floods and droughts, CVP and SWP operations, and several other stressors. The proposed actions in the Strategy include habitat improvement projects like aquatic weed control, north Delta food web adaptive management projects, outflow augmentation, reoperation of the Suisun Marsh Salinity Control Gates, sediment supplementation in the low-salinity zone, spawning habitat augmentation, Roaring River distribution system food production, and coordinated managed wetland flood and drain operations in Suisun Marsh. It proposes a variety of other actions intended to improve the status of delta smelt including cessation of salvage of nonnative fishes in the summer and fall, planning for improved stormwater discharge management, building the Rio Vista Research Station and Fish Technology Center, accelerating tidal marsh habitat restoration, and exploring the feasibility of restoring Franks Tract into a tidal marsh. Several of these actions were incorporated into the proposed action permitted via the 2019 BiOp.

A subset of EcoRestore habitat restoration projects that overlap with the 8,000 acres of tidal marsh and associated subtidal habitat requirement previously described above and in the 2019 Service BiOp is also described in the Strategy.

Of the actions proposed, the following action has occurred:

North Delta Food Web Adaptive Management Projects

DWR augmented flow in the Yolo Bypass by closing Knights Landing Outfall Gates and routed water from Colusa Basin into Yolo Bypass in July 2016 to promote food production and export into areas where delta smelt are known to occur.

Suisun Marsh Habitat Management, Preservation and Restoration Plan: The Suisun Marsh Plan, signed in 2014, was developed to balance the goals and objectives of the Bay-Delta Program, Suisun Marsh Preservation Agreement and other management and restoration programs within Suisun Marsh. The Plan provides for simultaneous protection and enhancement of Pacific Flyway and existing wildlife values in managed wetlands, endangered species recovery, and water quality. The Plan addresses water quality, fisheries, wildlife, vegetation, special-status species, land use, land use development patterns, population, housing, economics, and public services (fire protection, vector control), cultural resources, air quality, noise, recreation, energy, visual impacts, and socioeconomic condition. (Suisun Marsh Habitat Restoration Plan 2011, all). The Suisun Marsh Plan will benefit the delta smelt by restoring areas that are key to the species habitat requirements.

Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California: This multi-species recovery plan, published in 2014, addresses conservation needs for the San Francisco Estuary, with a focus on the following listed plant and terrestrial species: *Cirsium hydrophilum var. hydrophilum* (Suisun thistle), *Cordylanthus mollis ssp. Mollis* (soft bird's beak), *Suaeda californica* (California sea-blite), California clapper rail (*Rallus longirostris obsoletus*), and salt marsh harvest mouse (*Reithrodontomys raviventris*). Restoration efforts from this plan are identified in the implementation table of this recovery plan. One of the actions in the plan is to restore 5,000 acres of high quality marsh habitat within the Suisun Bay Recovery Unit.

Restoration of this area is expected to help the delta smelt by increasing food web productivity and generally improving the habitat of the delta smelt.

Summary of Threats

This status review identified threats to the delta smelt attributable to Factors A, D, and E, as well as interactions between these threats. The primary known threats cited in the 2010 delta smelt uplisting document are: entrainment by State and Federal water export facilities (Factor E), reduction of suitable habitat through summer and fall increases in salinity due to reductions in freshwater flow and summer and fall increases in water clarity (Factor A), and effects from introduced species, primarily the overbite clam and the invasion of *Egeria densa* and other aquatic weeds (Factor E). Additional threats included predation (Factor C), contaminants (Factor E), and small population size (Factor E). Since the 2010 proposed up-listing, we identified climate change (Factor A) as a threat in the 2012 Candidate Notice of Review. Climate change was not analyzed in the 2010 up-listing document. Since the 2010 up-listing, one of the two power plants within the range of the delta smelt using water for cooling has shut down and power plants are no longer a threat to the population as a whole. We have identified a number of existing regulatory mechanisms that provide protective measures that affect the stressors acting on the delta smelt. Despite these existing regulatory mechanisms and other conservations efforts, the stressors continue to act on the species such that it is warranted for uplisting under the Act.

Upstream dams and water storage, exacerbated by water diversions, especially from the SWP and CVP water export facilities, result in reduced freshwater flows within the estuary, and these reductions in freshwater flows result in reduced habitat suitability for delta smelt by moving the location of LSZ in the estuary. First-feeding delta smelt larvae require relatively turbid waters to capture prey and delta smelt may also use turbidity as cover from predators. The increased water clarity in delta smelt rearing habitat in recent decades is attributed to the interruption of sediment transport by upstream dams and armored levees and the spread of the exotic introduced water plant *Egeria densa* (Brazilian waterweed), which traps suspended sediments. Increased water clarity is therefore a threat to delta smelt. Models indicate a steady log-linear decline in abundance of delta smelt since about the time of the invasion of the nonnative overbite clam in 1987 (Thomson et al. 2010, p. 1442; see Factor E: Introduced Species) in the Bay-Delta. Since the 1980s, the decline in abundance of delta smelt in the Bay-Delta has been partially attributed to reductions in food availability caused by establishment of the nonnative overbite clam in 1987 (Factor E) and possibly by ammonium concentrations (Factor E) and water diversions (Factor A).

Delta smelt is a rare fish and has been a rare fish (compared to other species) for many decades (Nobriga and Smith 2020, pp. 8-9, Fig. 2). Current and historical evidence of delta smelt in stomachs of non-native fishes shows that predation from non-native fishes is likely having some effect on overall population numbers of delta smelt. It is likely that the population is currently experiencing a genetic bottleneck with an adult population estimate of 267 fish for 2021. This loss of genetic diversity in the population reduces the ability for fish to respond to changes and evolve and acts as a threat to the delta smelt population.

The threats identified act together to contribute to the decline of the population (Rose *et al*. 2013b, p. 1266, Fig. 4). Reduced freshwater flows and changes to the food web have limited delta smelt's population growth rate (Kimmerer and Rose 2018, p. 231, Fig. 4). Climate change will likely exacerbate these threats. The combined effects of reduced freshwater flows, the invasive overbite clam (reduced levels of phytoplankton and zooplankton that are important to the Bay-Delta food web), entrainment, predation, small population size, and contaminants act to significantly degrade conditions for delta smelt.

The best scientific and commercial information available indicates that the threats facing the delta smelt are of sufficient imminence, intensity, and magnitude to endanger the continued existence of the species.

In 2010, we completed a 12-month finding for delta smelt in which we determined a change in status from threatened to endangered was warranted. The continuing and unabated downward trend in all delta smelt cohorts after 2011 supports that finding. The 2021 CDFW and Service adult abundance estimates are the lowest ever recorded. Although conservation measures are in place to protect the species including the 2019 Biological Opinion, these measures have not been sufficient to halt the decline of the species. Therefore, based on a review of the best scientific and commercial information available, we find that the delta smelt still meets the definition of an endangered species under the Act, and that it warrants reclassification from threatened to endangered. However, at this time, the promulgation of a formal rulemaking to reclassify delta smelt is precluded by higher priority actions.

Recommended Conservation Measures

Increasing Delta outflows so that they more closely approximate unimpaired flows in the watershed would address several needs of the delta smelt, likely improving its habitat quality and quantity and by extension its reproduction and survival. Furthermore, increased winter and spring flows may reduce water clarity, which would further increase habitat quality. Contaminant reduction within the Bay-Delta could improve primary and secondary productivity while at the same time limiting toxic exposure to delta smelt. The reduction of pesticides entering the Delta could also improve habitat conditions and fish health. Therefore, the Service recommends higher outflows and the reduction of contaminants entering the estuary. In the meantime, the Service and its partners are pursuing a supplementation effort pursuant to the 2019 BiOp. Supplementation may be needed to prevent imminent extirpation of the delta smelt.

LISTING PRIORITY

As a result of our analysis of the best available scientific and commercial information, we have assigned the delta smelt a Listing Priority Number of 2, based on high magnitude and immediacy of threats. While we conclude that reclassifying the species as endangered is still warranted, an immediate proposal to reclassify this species is precluded by other higher priority actions.

Magnitude	Immediacy	Taxonomy	Priority
High	**Imminent**	Monotypic genus	1

<table>
<tr><td rowspan="5"></td><td rowspan="2"></td><td>Species</td><td>2</td></tr>
<tr><td>Subspecies/Population</td><td>3</td></tr>
<tr><td rowspan="3">Non-imminent</td><td>Monotypic genus</td><td>4</td></tr>
<tr><td>Species</td><td>5</td></tr>
<tr><td>Subspecies/Population</td><td>6</td></tr>
<tr><td rowspan="6">Moderate to Low</td><td rowspan="3">Imminent</td><td>Monotype genus</td><td>7</td></tr>
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<tr><td rowspan="3">Non-Imminent</td><td>Monotype genus</td><td>10</td></tr>
<tr><td>Species</td><td>11</td></tr>
<tr><td>Subspecies/Population</td><td>12</td></tr>
</table>

Rationale for listing priority number:

Magnitude:

The magnitude of threats is high due to the number and severity of ongoing threats. These threats include a warming climate, low abundance and limited distribution, turbidity changes, entrainment and invasive species. The ecology and biology of the San Francisco Bay-Delta has changed drastically over the last 160 years. Although a number of conservation measures have been put in place to protect the delta smelt and its habitat, the population continues to decline. Changes in the position of the LSZ in the Bay-Delta and the turbidity of estuarine waters have altered foraging and breeding habitat. Delta smelt numbers have dwindled from a population estimate of over one million adult fish in 2012 to the 2021 CDFW's SKT survey in which zero delta smelt were caught (Table 2). Even the 2012 abundance likely represented a tiny fraction of adult numbers existing prior to major changes to the estuary's habitats and biota (Nobriga and Smith 2020, p. 4, Fig. 2). Stress from water storage and delivery operations and nonnative species is expected to continue into the future as water demands for the growing population in California continue to increase in the face of a warming and drying climate.

Imminence

The threats discussed above are ongoing and likely to continue into the future. We therefore consider threats to be imminent.

Have you promptly reviewed all of the information received regarding the species for the purpose of determining whether emergency listing is needed? Yes

Is Emergency Listing Warranted? No

COORDINATION WITH STATES

The Delta smelt is known only from California. Therefore, coordination is done with the State of California. Much of the coordination is done through the IEP and includes research and abundance surveys (See Description of Monitoring above). In addition, the Service coordinated with the State of California on the experimental release of cultured delta smelt that occurred in late 2021-early 2022. The Service coordinates with California on assessing and addressing the effects of water operations on delta smelt.

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All SAFs supporting 12-month findings or candidate notices of review will be signed by the Director. SAFs should continue to be surnamed by Regional and Headquarters staff and leadership.

Martha Williams, Director
U.S. Fish and Wildlife Service

June 20, 2023
Date