



United States Department of the Interior



FISH AND WILDLIFE SERVICE
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In reply refer to:
2023-0004507-S7-001

March 10, 2023

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Sacramento District
1325 J Street
Sacramento, California 95814-2922

Subject: Formal Consultation on the South Delta Temporary Barriers Project for 2023-2027, San Joaquin County, California (U.S. Army Corps of Engineers File Number SPK-2001-00121)

Dear Ms. Pascus:

This letter is in response to the U.S. Army Corps of Engineers' (Corps) October 12, 2022, letter to the U.S. Fish and Wildlife Service (Service) requesting initiation of formal consultation on the California Department of Water Resources' South Delta Temporary Barriers Project (proposed project) in San Joaquin County, California. The Service received the email transmittal on October 13, 2022. The Corps has determined the proposed project may affect and is likely to adversely affect the federally threatened delta smelt (*Hypomesus transpacificus*) and its critical habitat. This response is in accordance with section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*) (Act) and in accordance with the implementing regulations pertaining to interagency cooperation (50 CFR 402).

The Federal action on which we are consulting is the Corps' issuance of a permit under Section 404 of the Clean Water Act of 1972, as amended, 33 U.S.C. § 1344 *et seq.*, and Section 10 of the Rivers and Harbors Act of 1899, as amended, 33 U.S.C. § 403 *et seq.*, to work within navigable waters and the discharge of dredged or fill material within approximately 1.48 acres of waters of the U.S.

In reviewing this request, the Service has relied upon: (1) the Corps' October 12, 2022, initiation letter; (2) the July 2022 *Programmatic Biological Assessment of Potential Effects on Listed Fishes from the 2023–2027 Temporary Barriers Project* and January 2023 revision; and (3) other information available to the Service.

Consultation History

The proposed project under consultation is an on-going annual installation and removal project with its operation under a separation consultation for the Central Valley Project (CVP) and State Water Project (SWP) operations. The Consultation History below is specific to this current consultation and does not include the history of previous consultations.

- March 7, 2018 The Service issued the biological opinion for the *California Department of Water Resources' 2018-2022 Temporary Barriers Project, San Joaquin County, California* (Corps File Numbers SPK-2000-00696 and SPK-2001-00121). The 2018-2022 proposed project consisted of annual construction and removal of the Middle River, Old River near Tracy, and Grant Line Canal agricultural barriers, and the spring and fall Head of Old River barriers.
- October 13, 2022 The Service received the Corps' request for consultation for this proposed project. The proposed 2023–2027 iteration of the temporary barriers project would consist of annual construction and removal of the Middle River, Old River near Tracy, and Grant Line Canal barriers.
- January 4, 2023 The Service requested clarification regarding the biological assessment's reference to *Conservation Measures* from previous consultations.
- January 27, 2023 The Service received an email and a revised biological assessment removing reference to *Conservation Measures* from previous consultations from the California Department of Water Resources.
- January 30, 2023 The Service received an email from the Corps following up the January 27, 2023 email.

BIOLOGICAL OPINION

Description of the Proposed Action

Background

The California Department of Water Resources (DWR) initiated the South Delta Temporary Barriers Project (TBP) in 1991 and has continued implementation in compliance with Section 3406(b)(15) of the Central Valley Project Improvement Act. The TBP is currently permitted by the Corps under permit number SPK-2001-00121. The principal purpose of the TBP is to maintain channel water levels to meet the reasonable and beneficial needs of water users in the south Delta. The TBP involves the seasonal installation of three rock barriers in Middle River near Victoria Canal (MR), Old River near Tracy (ORT), and Grant Line Canal near Tracy Boulevard Bridge (GLC). These rock barriers are designed to act as flow control structures, “trapping” tidal waters behind them following a high tide. These barriers raise water levels and

improve water circulation to benefit south Delta farmers and are collectively referred to as agricultural barriers (ag barriers).

The TBP was initiated with the intention that it would be a temporary program implemented only until permanent operable gates could be installed. However, because the timing of implementation of permanent operable gates is uncertain, the TBP is proposed to continue until the permanent operable gates are constructed.

Proposed Project

The proposed 2023–2027 TBP would consist of annual construction and removal of the MR, ORT, and GLC ag barriers. Construction activities for all of the barriers would begin as early as May 1 and removal would be completed no later than November 30 of each year. Any rock barrier operating on or after September 15 would be notched by September 15 to allow for passage of adult salmon. At GLC, flashboards would be removed at the southern end to create the notch in the barrier. Barriers cannot be constructed when ambient flows in the San Joaquin River are more than 5,000 cubic feet per second (cfs), as measured at the Vernalis monitoring station, because flows of more than 5,000 cfs create extremely hazardous working conditions and cause rocks to move as they are placed.

Relative to previous implementation of the TBP, the following activities are proposed for the 2023– 2027 TBP permit period.

- Sediment removal at the three barrier sites may be conducted as necessary during the project term to prepare for barrier construction, barrier removal, or culvert replacement. The removal of sediment would be limited to the minimum amount necessary to allow for barrier installation, barrier removal, or culvert replacement, and would not extend beyond 200 feet in any direction from the barrier footprint. Sediment removal may include removal of deposits adjacent to barriers that could impact installation or mobilize downstream upon barrier or culvert removal. Sediment removal would take no longer than 21 days and will be conducted during the barrier construction period (as early as May 1 of each year and may take place as late as August 1); and before or during barrier removal (mid-October to November 30). Sediment removal would take place only as needed in the event that sediment is deposited within or near the barrier footprint by high flow events. Sediment removal is not expected to occur in most years. The quantity of sediment to be removed would not be determined until site conditions are checked prior to construction each year.
- Sediment removal would be completed using a clamshell, a dragline, or an excavator. No suction dredging would be used. All removed sediment would be deposited and retained in an upland area that has no connection to waters of the U.S., and activities would comply with all conditions from the Clean Water Act Section 401 Water Quality Certification that are pertinent to sediment removal.
- The locations for disposal of dredged spoils from the barriers is as follows: sediments would be deposited at the U.S. Bureau of Reclamation (Reclamation) land at the western

end of Fabian Tract, approximately 1 mile west of the ORT barrier on Finck Road along the levee crown would provide access to the site.

- The stockpiled GLC barrier material may be relocated to the land side of the levee crown on the north abutment of the barrier to reduce truck trips.

The TBP has three locations in the south Delta (Figures 1 and 2):

- MR near Victoria Canal, San Joaquin County. Latitude 37.8857 N, Longitude 121.4822 W, Section 36, Township 1N, Range 4E, U.S. Geological Survey (USGS) map Holt, Assessor's Parcel Numbers 189-250-22 and 131-120-04.
 - Dimensions: 270 feet × 50 feet.
 - Rock is stockpiled onsite, on the water side of the levee crown at the south end of the barrier.
- ORT near the city of Tracy, San Joaquin County. Latitude 37.8103 N, Longitude 121.5428 W, Section 28, Township 1S, Range 4E, USGS map Clifton Court Forebay, Assessor's Parcel Numbers 258-041-01 and 189-050-43.
 - Dimensions: 250 feet × 60 feet.
 - Rock is stockpiled approximately 0.5 mile upstream on the land side of the levee crown in an agricultural equipment yard.
- GLC near the Tracy Boulevard Bridge in San Joaquin County. Latitude 37.8199 N, Longitude 121.4483 W, Section 29, Township 1S, Range 5E, USGS map Union Island, Assessor's Parcel Numbers 189-240-20 and 189-170-07.
 - Dimensions: 300 feet × 100 feet.
 - Rock is stockpiled at an equipment storage yard 2 miles north on the corner of Howard Road and Tracy Boulevard. Depending on property acquisition, stockpile may be moved closer to the barrier in an existing agricultural equipment storage yard on the land side of the levee north of the barrier.

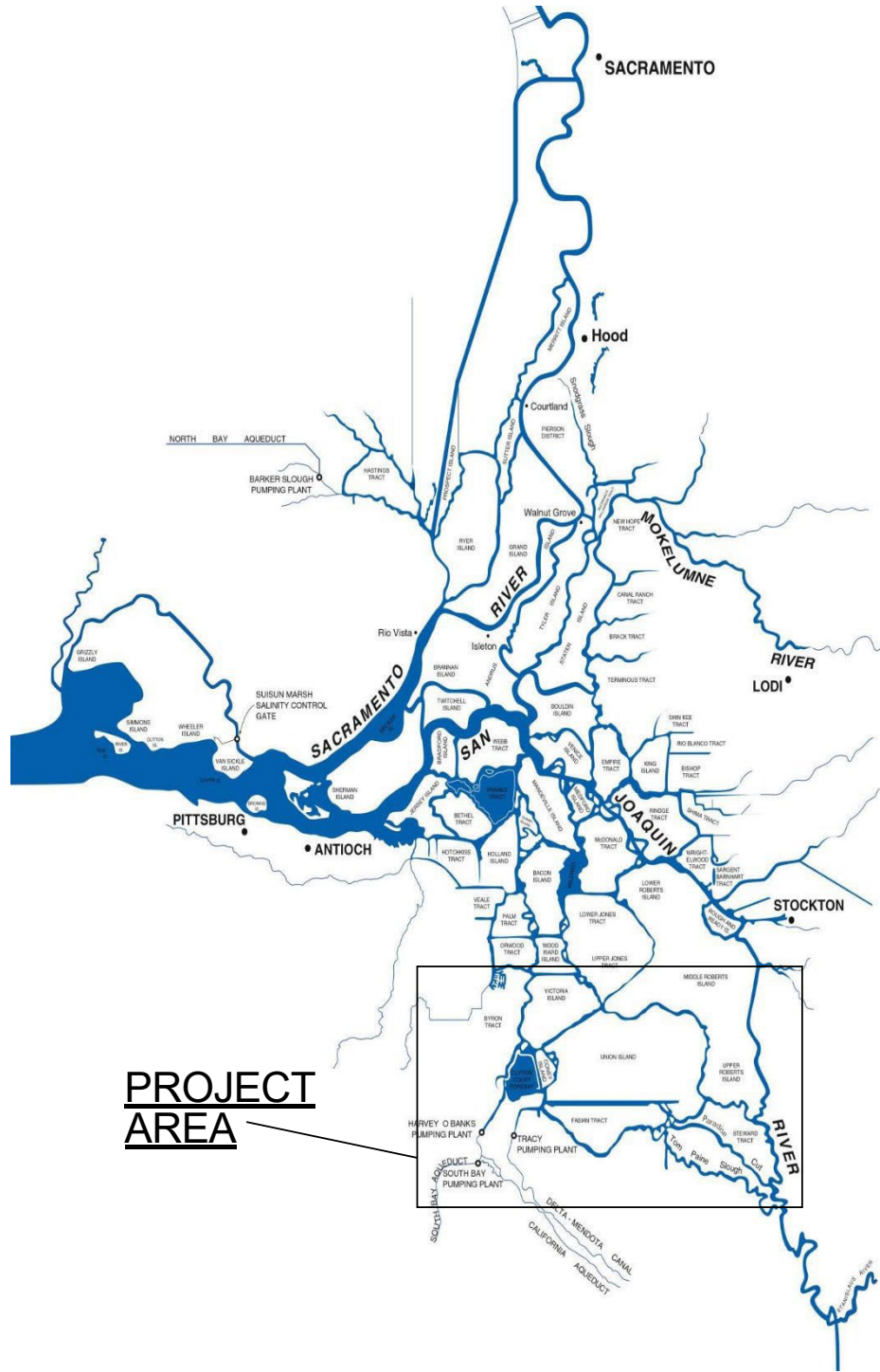


Figure 1. Project Area in the South Delta Region



Figure 2. Location of Temporary Barriers in South Delta (Middle River barrier; Grant Line Canal barrier; Old River at Tracy barrier)

Construction

Construction of the ag barriers entails the placement of rock barriers within the channels of the Middle River, Old River, and Grant Line Canal. Each spring, heavy construction equipment is mobilized to move stockpiled rock from storage locations into the channel to form the barriers. Large front-end loaders, dump trucks, off-road haulers, cranes, long reach excavators, and drag lines are used to move and place the materials and to remove sediment. The land-based equipment accesses each site using existing roads or levee crowns that do not support vegetation or other sensitive biological resources. No new roads would be constructed.

Each ag barrier would be installed in a similar manner. The rock for the barriers would be transported to the barrier site by haul trucks and dumped. An excavator would place the rock in the river, creating the body of the barrier. As the barrier installation progresses across the river, the haul trucks would back onto the barrier to dump the rock near the excavator that is placing the rock into the river channel. At Middle River, the rock is stored along the levee bank. From the levee bank, the rock would be picked up by a track loader and delivered to the excavator working in the river building the barrier.

Middle River Barrier

The MR barrier is located about 0.5 mile south of the confluence of Middle River, Trapper Slough, and North Canal (Figure 2). The MR barrier is a rock barrier constructed with a center weir section that allows tidal flows to enter the Middle River upstream of the barrier by overtopping the weir crest and flowing through submerged culverts that have tidally operated

flap-gates on their upstream end (Figure 3). The barrier elevation and the closure of the flap-gates partially retain the tidal flow behind the barrier during the ebb tide. By maintaining a minimum water elevation of 2.6 feet North American Vertical Datum of 1988 (NAVD88) measured at the Howard Road Bridge station, the barrier allows agricultural water diverters to operate their pumps throughout each tidal cycle.



Figure 3. Middle River Barrier Weir (central weir not visible due to overtopping)

The rock materials for MR barrier are stockpiled adjacent to the barrier site on the water side of the levee crown. Each year, the MR barrier weir section is reconstructed by placing approximately 2,300 cubic yards (cy) of rock between the two previously constructed abutments that are left in place year-round. Each abutment has three, 48-inch-diameter culverts with tidally operated flap-gates that are also left in place. Placement of rock completes a barrier that is 270 feet long and 50 feet wide. The portion of the barrier installed seasonally within waters of the U.S. is approximately 0.10 acre. The rock weir section is 140 feet long and 18 feet wide at its crest. By September 15, a 10-foot-wide notch (fall notch) is constructed in the weir for salmon passage. The notch allows a minimum depth of 6 inches of water to pass over the barrier during low-high tide events. The notch remains in place until the barrier is removed.

Raising the MR barrier raises water levels within Middle River, benefiting agricultural diverters. The raised MR barrier weir elevation is 1 foot higher than the GLC weir and allows water to flow upstream and then down Grant Line Canal. However, water from the Middle River would be prevented from flowing to Grant Line Canal during the peak irrigation season because agricultural pumping on Middle River diverts any upstream flow that may occur, causing water in the reach to converge at the point of diversion. DWR retains the option to raise the height of the MR barrier as needed during peak irrigation months and after delta smelt concerns have passed. The height of the weir may be increased from 3.3 feet (typical) to 4.3 feet NAVD88.

Raising the barrier height 1 foot requires an additional 100 cy of rock and reduces the width of the crest to 15 feet. However, there is no change in the footprint of the MR barrier and no significant changes in the disturbance to the riverbed or channel from the original design. The

fall notch in the MR barrier remains at the same elevation regardless of the 1-foot increase in weir height. When the weir is raised to 4.3 feet, the notch is 10 feet wide and at an elevation of 2.6 feet NAVD88. The MR barrier is raised only when risks to delta smelt have passed and full barrier operations are allowed by the Service.

DWR proposes to continue optionally raising the MR barrier weir for the following reasons:

- Provide additional water level protection for diverters on Middle River.
- Increase the circulation upstream of the barriers, thereby improving water quality and supply to agricultural diversions for crops.
- Reduce null zones where stagnant water creates low dissolved oxygen (DO) levels and algae blooms.

The center weir section of the MR barrier is removed during the non-irrigation season (December through April). The flap-gates are tied open when the center weir section is removed. Although the culverts are left in place for most years, culverts are replaced every 10 to 15 years to ensure their functionality. No culvert replacement is planned at MR barrier during the 2023–2027 period.

Old River near Tracy Barrier

The ORT barrier is located near the CVP's Tracy fish screen facility on Old River, approximately 0.5 mile east of the CVP's inlet (Figures 2 and 4). The ORT barrier allows tidal flows to enter the channel upstream of the barrier by overtopping the weir crest and flowing through the submerged culverts. The barrier elevation and the closure of tidal flap-gates on the upstream side of each culvert partially retain the tidal flow upstream of the barrier.



Figure 4. Old River near Tracy Barrier

Each year, construction of the ORT barrier begins with placement of a rock and gravel pad followed by the placement of three metal culvert frames, each containing three 48-inch-diameter culverts (nine culverts total) with flap-gates, on the prepared pad. The culverts are then covered with approximately 5,000 cy of rock to form a 250-foot-long berm that is 60 feet wide at its base. The portion of the barrier installed seasonally within waters of the U.S. is approximately 0.54 acre. The center of the barrier has a 75-foot-wide weir with a crest elevation of 4.4 feet NAVD88. For the ORT barrier, quarry rock is stockpiled approximately 0.5 mile upstream of the barrier site on the land side of the levee crown. Beneath the weir are the nine culverts, 60 feet long and 1 foot apart, with tidally operated flap-gates on the upstream ends. During summer months, some of the flap-gates may be tied to the open position to improve circulation in this area. Tying the flap-gates open in conjunction with the Middle River raise provided by the MR barrier is intended to increase net downstream flow and reduce stagnant zones in Old River. A temporary boat ramp is constructed on the north end of the barrier footprint with a riprap base, which is then covered by crushed rock and topped with articulated concrete mats. Because much of the boat ramp structure is underwater, divers aid in the positioning of the concrete mats. As at the MR barrier, a 10-foot-wide notch is constructed by September 15 to allow adult salmon passage.

As previously discussed, the culverts and abutments for the MR barrier remain in place year-round. However, the ORT barrier culverts are reinstalled each year. For culvert installation, the underwater culvert pads would be constructed using a dragline. The work boats would first take soundings, and then a riprap pad would be placed and leveled. The riprap pad would then be capped with crushed rock to prevent puncture of the culverts. The frame, including culverts, would then be set on the underwater pad and covered with rock to form the barrier.

Grant Line Canal Barrier

The GLC barrier is located on Grant Line Canal east of Tracy Boulevard and approximately 4 miles north of the city of Tracy (Figure 2 & 5).



Figure 5. Grant Line Canal Barrier

Each year, the GLC barrier is constructed with approximately 12,600 cy of rock that is placed between the existing south abutment and the north canal bank to create a 300-foot-long barrier that is up to 100 feet wide at its base. The portion of the barrier installed seasonally within waters of the U.S. is approximately 0.57 acre. The center of the barrier has a weir section with a crest at 3.3 feet elevation that is 125 feet long and 24 feet wide. Rock for the GLC barrier is stockpiled offsite at the Howard Road storage area located 2.0 miles north of the barrier at the intersection of Tracy Boulevard and Howard Road. The Howard Road staging yard would be accessed by taking Tracy Boulevard north to Howard Road. Alternatively, all or a portion of the stockpile may be relocated to the land side of the levee on the north abutment of the GLC barrier in a farm equipment storage yard. The existing south abutment contains six 48-inch-diameter, 60-foot-long culverts with tidally operated flap-gates on the upstream ends. Each culvert has a catwalk structure affixed to its top that allows access to each flap-gate, which is operated with a winch and hand crank. A 10-foot-wide flashboard structure is also built at the south abutment. The flashboard can be adjusted to allow delta smelt passage during spring and salmon passage during the fall. As at the ORT barrier, a ramped boat portage facility is provided at the north levee. The boat ramp is constructed with a riprap base, which is covered with crushed rock and topped with articulated concrete mats. Because much of the boat ramp structure is underwater, divers aid in the positioning of the concrete mats.

Although the culverts are left in place for most years, culverts are replaced every 10 to 15 years to ensure their functionality. Culvert replacement is planned at the GLC barrier during the 2023–2027 period.

Removal

The ag barriers are removed during the fall when the installation procedure is reversed. An excavator removes the majority of the rock down to the underwater pad of the culvert frames. Because the culvert pad is longer and wider than the “reach” of the excavator, a dragline with a

bucket removes the remainder of the underwater rock associated with the barriers. The removed rock is stockpiled outside of the waterway at the locations previously described until used again. The rock is screened prior to subsequent use in order to remove any fines that may have accumulated. At the barrier sites, the channel bottom is restored to pre-project conditions after the barriers are removed. Confirmation that the channel bottom has been restored to pre-project conditions is accomplished via bathymetric surveys, which are conducted each year before construction (pre-project) and after barrier removal. The barrier culverts and abutments at the MR barrier remain in place throughout the year, as do the culverts and south barrier abutment at the GLC barrier. Barrier removal, including in-water work, and associated construction activities, such as mobilization and site clean-up, typically take approximately 5 working days for the MR barrier, 20 working days for the ORT barrier and 21 working days for the GLC barrier.

Schedule

Construction activities for all of the barriers would begin as early as May 1 and removal would be completed no later than November 30 of each year. Any rock barrier operating on or after September 15 would be notched beginning September 15 to allow for passage of adult salmon. At the GLC barrier, flashboards would be removed to create the notch in the barrier. The ag barriers cannot be constructed when ambient flows in the San Joaquin River are more than 5,000 cfs, as measured at the Vernalis monitoring station. Barriers would be constructed and removed during daylight hours.

The ag barriers would be installed and operated based on the schedule in Table 1. Intermediate operation is defined as when all but one flap gate at all barriers are untied. Full operation is defined as when the remaining flap gates at all barriers are untied. Untying or releasing the flap gates will set the culverts to tidal operation. Water operations for the CVP and SWP that affect water levels and in the south Delta are described and analyzed in the most recent long term operations consultation.

Table 1. Agricultural Barrier Installation and Operation Schedule

Schedule	MR Barrier	ORT Barrier	GLC Barrier
May 1	Installation may begin.	Installation may begin.	Installation may begin.
May 15 to May 31	Intermediate operation may occur if: •the need for MR barrier full operation is clearly demonstrated by DWR through forecasting water levels by Delta modeling and by actual stage data collected in the field. Such data shall be provided to California Department of Fish and Wildlife (CDFW),	Intermediate operation may occur if: •the need for ORT barrier full operation is clearly demonstrated by DWR through forecasting water levels by Delta modeling and by actual stage data collected in the field. Such data shall be provided to CDFW, NMFS, and	Intermediate operation may occur if: •the need for GLC barrier full operation is clearly demonstrated by DWR through forecasting water levels by Delta modeling and by actual stage data collected in the field. Such data shall be provided to CDFW, NMFS, and Service 1 week in advance of

	<p>National Marine Fisheries Service (NMFS), and Service 1 week in advance of closing the flap-gates.</p> <p>Full operation may occur if:</p> <ul style="list-style-type: none"> •the daily mean water temperatures at Mossdale Station (MSD) have reached and consistently registered for three consecutive days at or above 71.6 deg-Fahrenheit (22 deg-Celsius) 	<p>Service 1 week in advance of closing the flap-gates.</p> <p>Full operation may occur if:</p> <ul style="list-style-type: none"> •the daily mean water temperatures at MSD have reached and consistently registered for three consecutive days at or above 71.6 deg-Fahrenheit (22 deg-Celsius) 	<p>closing the flap-gates and center sections of the barrier.</p> <p>And:</p> <ul style="list-style-type: none"> •the incidental take concern level for delta smelt at the SWP/CVP facilities has not been reached. •If the incidental take concern limit is reached at the SWP/CVP facilities and if reductions in SWP/CVP exports are determined to be inadequate to protect delta smelt, CDFW, NMFS, and USFWS may require the flap-gates to be tied in the open position and the center section of the barrier to be removed. <p>Full operation may occur if:</p> <ul style="list-style-type: none"> •the daily mean water temperatures at MSD have reached and consistently registered for three consecutive days at or above 71.6 deg-Fahrenheit (22 deg-Celsius)
June 1 to November 30	<p>Full operation may occur.</p> <p>Barrier elevation can be raised from 3.3 feet NAVD88 to 4.3 feet NAVD88 with Service approval.</p>	<p>Full operation may occur.</p>	<p>Full operation may occur.</p> <p>If the incidental take concern limit is reached at the SWP/CVP facilities and if reductions in SWP/CVP exports are determined to be inadequate to protect delta smelt, CDFW, NMFS, and Service may require the flap-gates to be tied in the open position and the center section of the barrier to be removed.</p>
September 15	<p>Barrier must be notched to allow passage of adult salmon.</p>	<p>Barrier must be notched to allow passage of adult salmon.</p>	<p>Barrier must have enough flashboards removed to allow passage of adult salmon.</p>
November 30	<p>Barrier must be completely removed from the channel.</p>	<p>Barrier must be completely removed from the channel.</p>	<p>Barrier must be completely removed from the channel.</p>

Conservation Measures

1. In accordance with requirements issued in the 2022 California Endangered Species Act (CESA) Incidental Take Permit (ITP) (ITP # 2081-2021-079-03), DWR will purchase or secure 3.8 acres of shallow water habitat credits for the TBP. DWR will utilize a credit of 1.6 acres remaining from previous mitigation purchases and an additional 2.2 acres of shallow water habitat credits will be purchased to secure the 3.8 acres required to fully mitigate for project impacts in the 2023-2027 permit period. DWR has also purchased 3.0 acres of Swainson's hawk (*Buteo swainsoni*) foraging habitat to mitigate impacts on Swainson's hawk.
2. *Conduct a Worker Environmental Awareness Program.* Construction workers will participate in a worker environmental awareness program that addresses species under the jurisdiction of the permitting agencies (CDFW, Service, and NMFS). Workers will be informed that listed and other protected species, and their habitats may be present, and that unlawful take of these species or destruction of their habitat is a violation of the federal Act, CESA, and/or Migratory Bird Treaty Act. Before the start of construction, a qualified biologist approved by the permitting agencies will instruct all construction workers about the life histories of the protected species and the terms and conditions of the applicable biological opinions, CESA ITP, and other regulatory permits that include biological resource protection measures. Proof of this instruction will be submitted to the permitting agencies.
3. *Prepare and Implement an Erosion Control Plan.* An erosion control plan will be prepared before the start of ground-disturbing construction activities. The plan will be developed with site-specific measures to control erosion, prevent spills, and control sedimentation and runoff. The measures in this plan will be implemented throughout construction to minimize the potential for erosion and sedimentation during barrier construction and removal.

If applicable, tightly woven fiber netting (mesh size less than 0.25 inch) or similar material will be used at the barrier sites for erosion control and other purposes, including to reduce the likelihood of wildlife becoming trapped or entangled in the erosion control material. Coconut coir matting is acceptable, but no plastic monofilament matting will be used for erosion control. Where feasible, the edge of the material will be buried in the ground to prevent wildlife from crawling underneath the material.

4. *Prepare and Implement a Spill Prevention and Control Program.* A spill prevention and control program will be prepared before the start of construction to minimize the potential for a release of hazardous, toxic, or petroleum substances into the project area during construction and operation. The program will be implemented during construction. In addition, DWR will place sandbags, biologs, or other containment features around the areas used for fueling or other uses of hazardous materials to ensure that these materials do not accidentally leak into the river. DWR will adhere to the standard construction best management practices described in the current California Department of Transportation *Construction Site Best Management Practices Manual* (the biological assessment cites

the 2003 manual but the most recent manual is dated 2017, California Department of Transportation 2017).

5. *Prepare and Implement a Hazardous Materials Management Program.* A hazardous materials management program (HMMP) will be prepared and implemented to identify the hazardous materials to be used during construction; describe measures to prevent, control, and minimize the spillage of hazardous substances; describe transport, storage, and disposal procedures for these substances; and outline procedures to be followed in case of a spill of a hazardous material. The HMMP will require that hazardous and potentially hazardous substances being stored onsite be kept in securely closed containers located away from drainage courses, storm drains, and areas where stormwater is allowed to infiltrate. It will also stipulate procedures to minimize hazards during onsite fueling and servicing of construction equipment. Finally, the HMMP will require that adjacent land users be notified immediately of any substantial spill or release.
6. *Conduct Biological Monitoring.* A qualified biologist or biologists approved by the permitting agencies will be onsite during daytime construction to conduct compliance inspections and monitoring during barrier installation and removal. The qualifications of the biologist(s) will be presented to the permitting agencies for review and approval before construction activities begin at the project sites. The complete set of permitting documents will be available onsite during construction. The biologist(s) will be given the authority to stop work that may result in, or if there is, take of listed species in excess of the limits provided by the permitting agencies in any permitting document (biological opinions, CESA ITP). Should the biologist(s) exercise this authority, the permitting agencies will be notified by telephone and electronic mail within 1 working day. A report of daily records from monitoring activities and observations will be prepared and provided to the permitting agencies upon completion of project activities.
7. *Implement Turbidity Monitoring during Construction/Removal and Adjust Construction Activities Accordingly.* DWR will monitor turbidity levels during barrier construction and removal. Monitoring will be conducted by measuring upstream and downstream of the disturbance area to ensure compliance with *The Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins* (the biological assessment cites the 4th edition 2011 Basin Plan but the most recent Basin Plan is the 5th addition dated 2019, Central Valley Regional Water Quality Control Board 2019). For Delta waters, the general objectives for turbidity apply, except during periods of stormwater runoff; the turbidity of Delta waters shall not exceed 50 Nephelometric Turbidity Units (NTU) in the waters of the Central Delta or 150 NTU in other Delta waters. Exceptions to the Delta-specific objectives are considered when a dredging operation can cause an increase in turbidity. In the case of dredging, an allowable zone of dilution within which turbidity exceeding the limits can be tolerated will be defined for the operation and prescribed in a discharge permit.

DWR contractors will slow or adjust work to ensure that turbidity levels do not exceed those conditions described in the Clean Water Act Section 401 Water Quality Certification issued by the Central Valley Regional Water Quality Control Board

(CVRWQCB) or conditions prescribed by the permitting agencies (NMFS, Service, and CDFW). If slowing or adjusting work to lower turbidity levels is not practical or if thresholds cannot be met, DWR will consult with the CVRWQCB and permitting agencies to determine the most appropriate measures to minimize turbidity impacts to the maximum extent feasible.

8. *Stockpile Materials in Designated Construction Staging Areas.* Stockpiling of construction materials such as rocks, gravel, flexible cement matting, portable equipment, vehicles, and supplies, including chemicals and chemical containers, shall be restricted to designated construction staging areas and exclusive of the riparian areas.

Action Area

The Action Area is defined in 50 CFR § 402.02, as “all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action.” For the purposes of the effects analysis, the Action Area generally comprises the lands and waterways of the southern Sacramento-San Joaquin Delta southwest of the city of Stockton. Major waterways within the south Delta include the San Joaquin River, Old River, Middle River, Woodward and North Victoria canals, Grant Line and Fabian canals, Italian Slough, Tom Paine Slough, and the adjoining canals of the CVP and SWP. However, because of the anticipated effects of the TBP, the Action Area for this consultation not only encompasses the lands and waterways described above (indicated generally as the “Project Area” in Figure 1) but also includes lands and waterways of the central Delta including the lower San Joaquin River downstream of Old River, Columbia Cut, and Turner Cut, and all reaches of Middle River and Old River and adjoining sloughs and canals (Figure 1).

Analytical Framework for the Jeopardy Determination

Section 7(a)(2) of the Act requires that Federal agencies ensure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of listed species.

“Jeopardize the continued existence of” means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species (50 CFR § 402.02).

The jeopardy analysis in this biological opinion considers the effects of the proposed Federal action, and any cumulative effects, on the rangewide survival and recovery of the listed species. It relies on four components: (1) the *Status of the Species*, which describes the current rangewide condition of the species, the factors responsible for that condition, and its survival and recovery needs; (2) the *Environmental Baseline*, which analyzes the current condition of the species in the Action Area without the consequences to the listed species caused by the proposed action, the factors responsible for that condition, and the relationship of the Action Area to the survival and recovery of the species; (3) the *Effects of the Action*, which includes all effects that are caused by the proposed Federal action; and (4) the *Cumulative Effects*, which evaluates the effects of future, non-Federal activities in the Action Area on the species. The *Effects of the Action* and *Cumulative Effects* are added to the *Environmental Baseline* and in light of the status

of the species, the Service formulates its opinion as to whether the proposed action is likely to jeopardize the continued existence of listed species.

Analytical Framework for the Adverse Modification Determination

Section 7(a)(2) of the Act requires that Federal agencies ensure that any action they authorize, fund, or carry out is not likely to destroy or to adversely modify designated critical habitat. A final rule revising the regulatory definition of “destruction or adverse modification” (DAM) was published on August 27, 2019 (84 FR 44976). The final rule became effective on October 28, 2019. The revised definition states:

“*Destruction or adverse modification* means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species.”

The DAM analysis in this biological opinion relies on four components: (1) the *Status of Critical Habitat*, which describes the current range-wide condition of the critical habitat in terms of the key components (i.e., essential habitat features, primary constituent elements, or physical and biological features) that provide for the conservation of the listed species, the factors responsible for that condition, and the intended value of the critical habitat overall for the conservation/recovery of the listed species; (2) the *Environmental Baseline*, which analyzes the current condition of the critical habitat in the Action Area without the consequences to designated critical habitat caused by the proposed action, the factors responsible for that condition, and the value of the critical habitat in the Action Area for the conservation/recovery of the listed species; (3) the *Effects of the Action*, which determines all consequences to designated critical habitat that are caused by the proposed Federal action on the key components of critical habitat that provide for the conservation of the listed species, and how those impacts are likely to influence the conservation value of the affected critical habitat; and (4) *Cumulative Effects*, which evaluate the effects of future non-Federal activities that are reasonably certain to occur in the Action Area on the key components of critical habitat that provide for the conservation of the listed species and how those impacts are likely to influence the conservation value of the affected critical habitat. The *Effects of the Action* and *Cumulative Effects* are added to the *Environmental Baseline* and in light of the status of critical habitat, the Service formulates its opinion as to whether the action is likely to destroy or adversely modify designated critical habitat. The Service’s opinion evaluates whether the action is likely to impair or preclude the capacity of critical habitat in the Action Area to serve its intended conservation function to an extent that appreciably diminishes the rangewide value of critical habitat for the conservation of the listed species. The key to making that finding is understanding the value (i.e., the role) of the critical habitat in the Action Area for the conservation/recovery of the listed species based on the *Environmental Baseline* analysis.

Status of the Species and Critical Habitat

Delta Smelt

Species Legal Status and Life Cycle Summary

The Service proposed to list the delta smelt as threatened with proposed critical habitat on October 3, 1991 (Service 1991). The Service listed the delta smelt as threatened on March 5, 1993 (Service 1993), and designated critical habitat for the species on December 19, 1994 (Service 1994). The delta smelt was one of eight fish species addressed in the *Recovery Plan for the Sacramento–San Joaquin Delta Native Fishes* (Service 1996). A 5-year status review of the delta smelt was completed on March 31, 2004 (Service 2004). The review concluded that delta smelt remained a threatened species. A subsequent 5-year status review recommended uplisting delta smelt from threatened to endangered (Service 2010a). A 12-month finding on a petition to reclassify the delta smelt as an endangered species was completed on April 7, 2010 (Service 2010b). After reviewing all available scientific and commercial information, the Service determined that re-classifying the delta smelt from a threatened to an endangered species was warranted but precluded by other higher priority listing actions (Service 2010c). The Service reviews the status and uplisting recommendation for delta smelt during its Candidate Notice of Review (CNOR) process. Each year it has been published, the CNOR has recommended the uplisting from threatened to endangered. Electronic copies of these documents are available at <https://ecos.fws.gov/ecp/species/321>.

The delta smelt is a small fish of the family Osmeridae. In the wild, very few individuals reach lengths over 3.5 inches (90 mm; Damon *et al.* 2016). At the time of its listing, only the basics of the species' life history were known (Moyle *et al.* 1992). In the intervening 26 years, it has become one of the most studied fishes in the United States. Enough has been learned about the delta smelt to support its propagation in captivity over multiple generations (Lindberg *et al.* 2013), to support the development of complex conceptual models of the species life history (Interagency Ecological Program (IEP) 2015), and mathematical simulation models of its life cycle (Rose *et al.* 2013a). Any synthesis of the now extensive literature on the delta smelt requires drawing conclusions across studies that had disparate objectives, but several syntheses have been compiled from existing information (Moyle *et al.* 1992; Bennett 2005; IEP 2015; Moyle *et al.* 2016). In this biological opinion, the Service relied on these previous syntheses where it remains appropriate to do so. We also relied on source study results and analyses of our own to synthesize across a rapidly growing body of scientific information.

The delta smelt has a fairly simple life history because a large majority of individuals live only one year (Bennett 2005; Moyle *et al.* 2016) and because it is an endemic species (Moyle 2002), comprising only one genetic population (Fisch *et al.* 2011), that completes its full life cycle in the northern reaches of the San Francisco Bay-Delta (Merz *et al.* 2011; Figure 6). The schematic of this simple life cycle developed by Moyle *et al.* (2016) and published again by Moyle *et al.* (2018) is shown in Figure 7. Most spawning occurs from February through May in various places from the Napa River and locations to the east including much of the Sacramento-San Joaquin Delta. Larvae hatch and enter the plankton primarily from March through May, and most individuals have metamorphosed into the juvenile life stage by June or early July. Most of the juvenile fish continue to rear in habitats from Suisun Bay and marsh and locations east principally along the Sacramento River-Cache Slough corridor (recently dubbed the 'North Delta Arc'; Moyle *et al.* 2010). The juvenile fish (or 'sub-adults') begin to develop into maturing adults in the late fall. Thereafter, the population spatial distribution expands with the onset of early winter storms and the first individuals begin to reach sexual maturity by January in some

years, but most often in February (Damon *et al.* 2016; Kurobe *et al.* 2016). Delta smelt do not reach sexual maturity until they grow to at least 55 mm in length (~ 2 inches) and 50% of individuals are sexually mature at 60 to 65 mm in length (Rose *et al.* 2013b). In captivity delta smelt can survive to spawn at two years of age (Lindberg *et al.* 2013), but this appears to be rare in the wild (Bennett 2005; Damon *et al.* 2016; Figure 7). The spawning microhabitats of the delta smelt are unknown, but based on adult distribution data (Damon *et al.* 2016; Polansky *et al.* 2018) and the evaluation of otolith microchemistry (Hobbs *et al.* 2007a; Bush 2017), most delta smelt spawn in freshwater to slightly brackish-water habitats under tidal influence. Most individuals die after spawning, but as is typical for annual fishes, when conditions allow, some individuals can spawn more than once during their single spawning season (Damon *et al.* 2016). In a recent study spanning 2 to 3 months, captive males held at a constant water temperature of 12°C (54°F) spawned an average of 2.8 times and females spawned an average of 1.7 times (LaCava *et al.* 2015).



Figure 6. Delta smelt range map. 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.

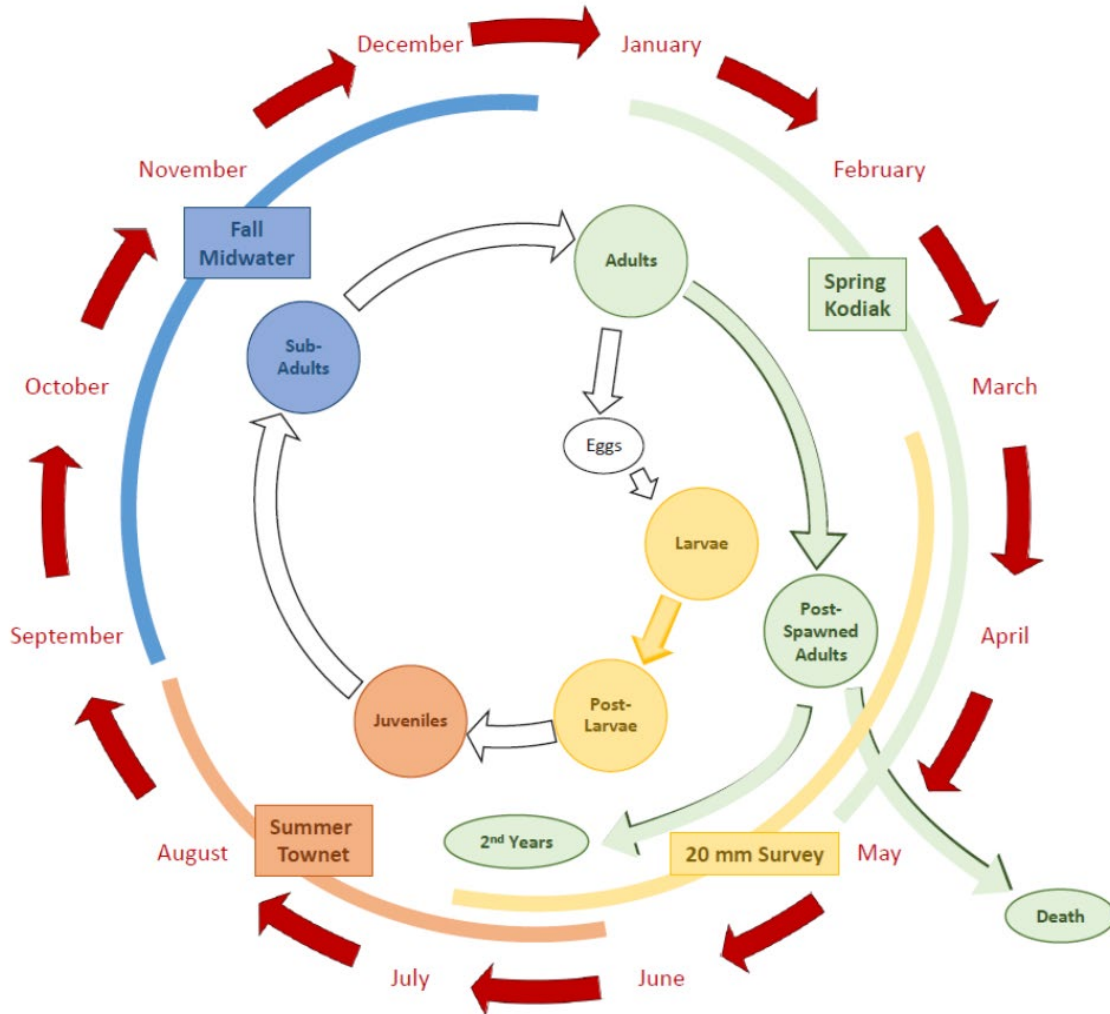


Figure 7. Schematic representation of the delta smelt life cycle. This conceptual model crosswalks delta smelt life stages with calendar months and current monitoring programs (prior to Enhanced Delta Smelt Monitoring) used to evaluate the species’ status. Source: Moyle *et al.* 2016

Detailed Review of the Reproductive Biology of Delta Smelt

Delta smelt spawn in the estuary and have one spawning season for each generation, which makes the timing and duration of the spawning season important every year. Delta smelt are believed to spawn in fresh and low-salinity water (Hobbs *et al.* 2007a; Bush 2017). Therefore, freshwater flow affects how much of the estuary is available for delta smelt to spawn (Hobbs *et al.* 2007a). This is one mechanism in which interannual variation in Delta outflow could play a role in the population dynamics of delta smelt. Given the timing of delta smelt reproduction, Delta outflow during February through May would be most important for this mechanism.

During this time of year, variation in Delta outflow is largely driven by weather variation and regulated by the California State Water Resources Control Board (SWRCB) Decision-1641 (D-1641).

The locations of delta smelt spawning are thought to be influenced by salinity (Hobbs *et al.* 2007a), but the duration of the spawning season is thought to be driven mainly by water temperature (Bennett 2005; Damon *et al.* 2016), which is largely a function of regional air temperature (Wagner *et al.* 2011). Thus, the spawning season duration does not appear to be a freshwater flow mechanism, but rather, a climate-driven mechanism (Brown *et al.* 2016a). Delta smelt can start spawning when water temperatures reach about 10°C (50°F) and can continue until temperatures reach about 20°C (68°F; Bennett 2005; Damon *et al.* 2016). The ideal spawning condition occurs when water temperatures remain between 10°C and 20°C throughout February through May. Few delta smelt ≤ 55 mm in length are sexually mature and 50% of delta smelt reach sexual maturity at 60 to 65 mm in length (Rose *et al.* 2013b). During January and February, many delta smelt are still smaller than these size thresholds (Damon *et al.* 2016). Thus, if water temperatures rise much above 10°C in January, the “spawning season” can start before many individuals are mature enough to actually spawn. If temperatures continue to warm rapidly toward 20°C in early spring, that can end the spawning season with only a small fraction of ‘adult’ fish having had an opportunity to spawn, and perhaps only one opportunity to do so. Delta smelt were initially believed to spawn only once before dying (Moyle *et al.* 1992). It has since been confirmed that delta smelt can spawn more than once if water temperatures remain suitable for a long enough time, and if the adults find enough food to support the production of another batch of eggs (Lindberg *et al.* 2013; Damon *et al.* 2016; Kurobe *et al.* 2016). In a recent study spanning 2 to 3 months, captive males held at a constant water temperature of 12°C (54°F) spawned an average of 2.8 times and females spawned an average of 1.7 times (LaCava *et al.* 2015). As a result, the longer water temperatures remain cool, the more fish have time to mature and the more times individual fish can spawn. Most adults disappear from monitoring programs by May, suggesting they have died (Damon *et al.* 2016; Polansky *et al.* 2018).

The reproductive behavior of delta smelt is only known from captive specimens spawned in artificial environments and most of the information has never been published, but is currently being revisited in new research. Spawning likely occurs mainly at night with several males attending a female that broadcasts her eggs onto bottom substrate (Bennett 2005). Although preferred spawning substrate is unknown, spawning habits of delta smelt’s closest relative, the Surf smelt (*Hypomesus pretiosus*), are sand or small gravel (Hirose and Kawaguchi 1998; Quinn *et al.* 2012).

The duration of the egg stage is temperature-dependent and averages about 10 days before the embryos hatch into larvae (Bennett 2005). It takes the fish about 30-70 days to reach 20-mm in length (Bennett 2005; Hobbs *et al.* 2007b). Similarly, Rose *et al.* (2013b) estimated that it takes delta smelt an average of slightly over 60 days to reach the juvenile life stage. Metamorphosing “post-larvae” appear in monitoring surveys from April into July of most years. By July, most delta smelt have reached the juvenile life stage. Thus, subtracting 60 days from April and July indicates that most spawning occurs from February-May.

Hatching success is highest at temperatures of 15-16°C (59-61°F) and lower at cooler and warmer temperatures and hatching success nears zero percent as water temperatures exceed 20°C (Bennett 2005). Water temperatures suitable for spawning occur most frequently during the months of February-May, but ripe female delta smelt have been observed as early as January and larvae have been collected as late as July, suggesting that spawning itself may extend into June in years with exceptionally cool spring weather.

Detailed Review of the Habitat Use and Distribution of Delta Smelt

Because the delta smelt only lives in one part of one comprehensively monitored estuary, its general distribution and habitat use are well understood (Moyle *et al.* 1992; Bennett 2005; Hobbs *et al.* 2006; 2007b; Feyrer *et al.* 2007; Nobriga *et al.* 2008; Kimmerer *et al.* 2009; Merz *et al.* 2011; Murphy and Hamilton 2013; Sommer and Mejia 2013; Mahardja *et al.* 2017a; Simonis and Merz 2019). The delta smelt has been characterized as a semi-anadromous species (Bennett 2005; Hammock *et al.* 2017) and Sommer *et al.* (2011) characterized the species as a partial diadromous migrant, recognizing individual variation in its life-history. However, both terms emphasize a life cycle in which delta smelt spawn in freshwater and volitionally move ‘downstream’ into brackish water habitat, which is only one endpoint among several individual life cycle strategies that have recently been confirmed through the use of otolith microchemical analyses (Bush 2017). In addition, semi-anadromy and partial diadromy are scale-dependent terms which have caused confusion among researchers and managers alike. For instance, some individual delta smelt clearly migrate between fresh and brackish water during their lives (Bush 2017). Other individuals could appear to have done so based on otolith microchemistry but in reality have moved very little and simply experienced annual salinity variation, which can be very high in much of the range of delta smelt (see Hammock *et al.* 2019). Other individual delta smelt are clearly freshwater and brackish-water resident throughout their lives (Bush 2017). As a result, there are both location-based (*e.g.*, Sacramento River around Decker Island) and conditions-based (low-salinity zone) habitats that delta smelt permanently occupy. There are habitats that some delta smelt occupy seasonally (*e.g.*, for spawning), and there are habitats that a few delta smelt occupy transiently, which we define here as occasional use. Transient habitats include distribution extremes from which delta smelt have occasionally been collected, but were not historically collected every year or even in most years. Thus, the Service suggests the delta smelt may be best characterized as an upper estuary resident species with a population-scale distribution that expands and contracts as freshwater flow seasonally (and interannually) decreases and increases, respectively. This influence of freshwater flow inputs on delta smelt distribution could in turn influence mechanisms that affect the species’ population dynamics when those mechanisms are linked to where the fish reside or how they are distributed in the estuary. We note that water temperature, turbidity, water diversion rates, prey availability, and possibly other factors would also affect these spatial recruitment and survival mechanisms.

Delta smelt have been observed as far west as San Francisco Bay near the City of Berkeley, as far north as Knight’s Landing on the Sacramento River, as far east as Woodbridge on the Mokelumne River and Stockton on the Calaveras River, and as far south as Mossdale on the San Joaquin River (Merz *et al.* 2011; Figure 6). These extremes of the species’ distribution extend beyond the geographic boundaries specified in the critical habitat rule. However, most delta

smelt have been collected from locations within the critical habitat boundaries. In other words, observations of delta smelt outside of the critical habitat boundaries reflect transient habitat use rather than permanent or seasonal habitat use. The Napa River is the only location outside of the critical habitat boundaries that may be used often enough to be considered a seasonal habitat rather than a transient one.

The fixed-location habitats that delta smelt permanently occupy span from the Cache Slough complex down into Suisun Bay and Suisun Marsh (Figure 8). The reasons delta smelt are believed to permanently occupy this part of the estuary are the presence of fresh- to low-salinity water year-round that is comparatively turbid and of a tolerable water temperature. These appropriate water quality conditions overlap an underwater landscape featuring variation in depth, tidal current velocities, edge habitats, and food production (Nobriga *et al.* 2008; Feyrer *et al.* 2011; Murphy and Hamilton 2013; Sommer and Mejia 2013; Hammock *et al.* 2015; 2017; 2019; Bever *et al.* 2016; Mahardja *et al.* 2019; Simonis and Merz 2019). Field observations are increasingly being supported by laboratory research that explains how delta smelt respond physiologically and behaviorally to variation in water quality that can vary with changes in climate, freshwater flow and estuarine bathymetry (e.g., Hasenbein *et al.* 2013; 2016b; Komoroske *et al.* 2014; 2016).

The principal variable-location habitat that delta smelt permanently occupy is the low-salinity zone (LSZ) (Moyle *et al.* 1992; Bennett 2005). The LSZ is a dynamic habitat with size and location that respond to changes in tidal and river flows (Jassby *et al.* 1995; Kimmerer *et al.* 2013; MacWilliams *et al.* 2015; 2016; Bever *et al.* 2016). The LSZ generally expands and moves downstream as river flows into the estuary increase, placing low-salinity water over a larger and more diverse set of nominal habitat types than occurs under lower flow conditions. As river flows decrease, the LSZ contracts and moves upstream. This is perhaps the most frequently assumed freshwater flow mechanism in discussions about X2 (a metric to describe the location of the LSZ described in more detail below) regulations, but as shown by Kimmerer *et al.* (2009; 2013), it does not appear to be a major explanatory mechanism for most fishes including the delta smelt.

The LSZ often encompasses many of the permanently occupied fixed locations discussed above. It is treated separately here because delta smelt distribution tracks the movement of the LSZ somewhat (Moyle *et al.* 1992; Dege and Brown 2004; Feyrer *et al.* 2007; 2011; Nobriga *et al.* 2008; Sommer *et al.* 2011; Bever *et al.* 2016; Manly *et al.* 2015; Polansky *et al.* 2018; Simonis and Merz 2019). Due to its historical importance as a fish nursery habitat, there is a long research history into the physics and biology of the LSZ. The LSZ is frequently defined as waters with a salinity range of about 0.5 to 6 ppt (Kimmerer 2004). This and similar salinity ranges reported by different authors were chosen based on analyses of historical peaks in chlorophyll concentration and zooplankton abundance. Most delta smelt collected in CDFW's 20-mm Survey and Summer Towntown Survey (TNS) have been collected at salinities of near 0 ppt to 2 ppt and most of the (older) delta smelt in the Fall Midwater Trawl (FMWT) have been collected from a salinity range of about 1 to 5 ppt (Kimmerer *et al.* 2013). These fish of different life stages do not tend to be in dramatically different places (Murphy and Hamilton 2013; Figure 8), suggesting that some of the change in occupied salinity with age is due to the seasonal increases in salinity that accompany lower outflow in the summer and fall.

Each year, the distribution of delta smelt seasonally expands when adults disperse in response to winter flow increases that also coincide with seasonal increases in turbidity and decreases in water temperature (Sommer *et al.* 2011; Figure 8). The annual range expansion of adult delta smelt extends up the Sacramento River to about Garcia Bend in the Pocket neighborhood of Sacramento, up the San Joaquin River from Antioch to areas near Stockton, up the lower Mokelumne River system, and west throughout Suisun Bay and the larger sloughs of Suisun Marsh. Some delta smelt seasonally and transiently occupy Old and Middle rivers in the south Delta each year, but face a high risk of entrainment when they do (Kimmerer 2008; Grimaldo *et al.* 2009). The expanded adult distribution initially affects the distribution of the next generation because delta smelt eggs are adhesive and not believed to be highly mobile once they are spawned (Mager *et al.* 2004). Thus, the distribution of larvae reflects a combination of where spawning occurred and freshwater flow when the eggs hatch.

In summary, the delta smelt population spreads out in the winter and then retracts by summer into what is presently a bi-modal spatial distribution with a peak in the LSZ and a separate peak in the Cache Slough complex. Most individuals occur in the LSZ at some point in their life cycle and the use of the Cache Slough complex diminishes in years with warm summers (Bush 2017). *Microhabitat Use:* The delta smelt has been historically characterized as a pelagic fish, meaning one with a spatial distribution that is skewed away from shorelines (Moyle *et al.* 1992; Sommer *et al.* 2007). This has led to some confusion among researchers and managers alike – usually perpetuating a strawman argument that delta smelt either occupy deep-water habitats or shallow-water habitats. Then, catch data from shallow habitats get used to refute the pelagic characterization, but catches in shallow-water say nothing more about a pelagic tendency than catches in deep water would say about a nearshore habitat tendency. The long-term monitoring programs used to characterize delta smelt status and trend are offshore sampling programs – meaning pelagic sampling programs, and surface-trawling appears to be particularly effective at capturing delta smelt away from shorelines (Mitchell *et al.* 2017). However, numerous studies have reported collecting delta smelt from nearshore environments using fishing gear like beach seines and fyke nets from locations that often had a water depth less than or equal to 1 meter (just over three feet) (e.g., Matern *et al.* 2002; Nobriga *et al.* 2005; Gewant and Bollens 2012; Mahardja *et al.* 2017b). Further, it has been established that onshore-offshore movements are one behavior option delta smelt and other fishes can use to maintain position or move upstream in a tidal-flow influenced estuary (Bennett *et al.* 2002; Feyrer *et al.* 2013; Bennett and Burau 2015). Captive delta smelt have been shown to avoid in-water structure like submerged aquatic vegetation (SAV) (Ferrari *et al.* 2014). SAV tends to grow where tidal current velocities are low, which is a habitat attribute that has also been associated with wild delta smelt (Hobbs *et al.* 2006; Bever *et al.* 2016). Thus, the proliferation of SAV in areas that might otherwise be attractive to delta smelt represents a significant habitat degradation, not only because it creates structure in the water column, but also because it is associated with higher water transparency (Hestir *et al.* 2016), and a fish fauna that delta smelt does not seem to be able to coexist with (Nobriga *et al.* 2005; Conrad *et al.* 2016). Based on our review, the Service suggests that the characterization of delta smelt as an open-water fish appears to be accurate and does not imply occupation of a particular water column depth. The species does appear to have some affinity for surface waters (Bennett and Burau 2015; Mitchell *et al.* 2017), but like any microhabitat descriptor, this is not

intended to reflect the location of all individuals because delta smelt are not limited to surface waters (Feyrer *et al.* 2013).

Although the delta smelt is generally an open-water fish, depth variation of open-water habitats is an important habitat attribute (Moyle *et al.* 1992; Hobbs *et al.* 2006; Bever *et al.* 2016). In the wild, delta smelt are most frequently collected in water that is somewhat shallow (4-15 ft deep) where turbidity is often elevated and tidal currents exist, but are not excessive (Moyle *et al.* 1992; Bever *et al.* 2016). For instance, in Suisun Bay, the deep shipping channels are poor quality habitat because tidal velocity is very high (Hobbs *et al.* 2006; Bever *et al.* 2016), but in the Delta where tidal velocity is slower, offshore habitat in Cache Slough and the Sacramento Deepwater Shipping Channel is used to a greater extent (Feyrer *et al.* 2013; CDFW unpublished data).

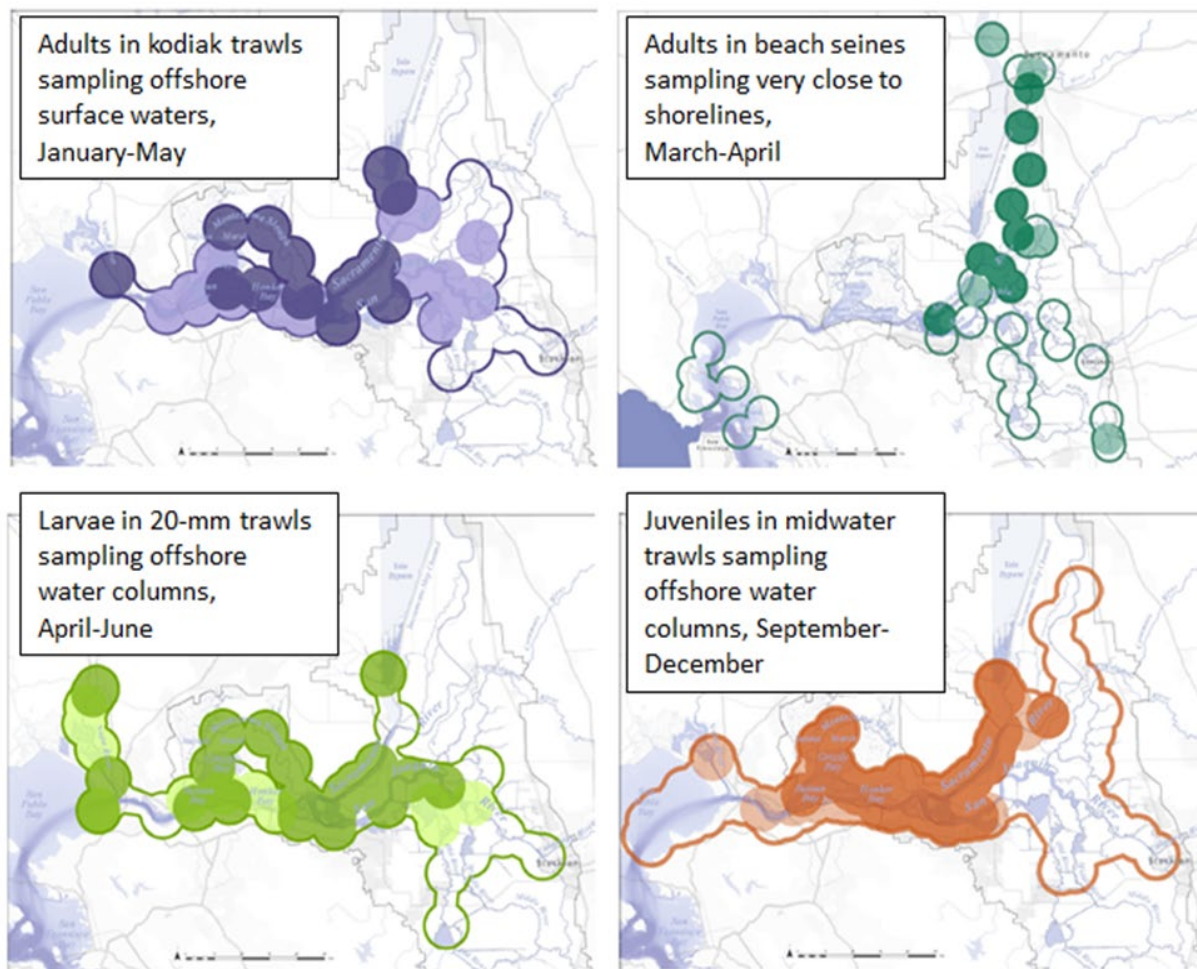


Figure 8. Maps of multi-year average distributions of delta smelt collected in four monitoring programs. The sampling regions covered by each survey are outlined. The areas with dark shading surround sampling stations in which 90 percent of the delta smelt collections occurred, the areas with light shading surround sampling stations in which the next 9 percent of delta smelt collections occurred. Note the lack of sampling sites in Suisun Bay and marsh for the beach seine (upper right panel). Source: Murphy and Hamilton (2013).

Environmental Setting and History of Ecological Change in the Bay-Delta

This section briefly reviews environmental changes that have occurred since 1850; i.e., the California Gold Rush to the present. This section is subdivided into three parts. The first describes the condition that is believed to have existed in 1850. The second covers a period from about 1920 to 1967, which is the year prior to the initiation of State Water Project (SWP) water exports from the Delta. The third sub-section covers 1968, the first year of Central Valley Project (CVP) and SWP dual operations, to the present.

Over the past few years, the scientific information developed to understand pre- and post-water project changes to the estuary's landscape and flow regime has grown substantially. However, as with most scientific endeavors, there are some discrepancies that may affect some conclusions. For instance, Whipple *et al.* (2012) showed the difference between contemporary estimates of unimpaired Delta outflow that were used in the modeling studies reviewed below and measured data from the latter 19th century. These discrepancies can affect the conclusions about the natural hydrograph of the Bay-Delta ecosystem and should be kept in mind when reviewing what follows. The information on ecosystem changes that have accrued through time provides context for the current status of the delta smelt.

The 1850 Bay-Delta estuary: The historical Delta ecosystem was a large tidal marsh at the confluence of two floodplain river systems (Whipple *et al.* 2012; Andrews *et al.* 2017; Gross *et al.* 2018; Figure 9). The Delta itself experienced flooding over spring-neap tidal time scales and seasonal river runoff time scales. This variability in freshwater input to the estuary was likely important to seasonal and interannual variability in the productivity of the ecosystem for the same reasons that smaller-scale tidal marsh plain and floodplain inundation are today. Specifically, these flood cycles deliver organic carbon, but also increase the production of lower trophic levels due to lengthened water residence times and greater shallow, wetted surface areas (Sommer *et al.* 2004; Grosholz and Gallo 2006; Howe and Simenstad 2011; Enright *et al.* 2013). When freshwater flows out of the Delta and into the estuary, it can generate currents that aggregate particulate matter like sediment and phytoplankton (Monismith *et al.* 1996; 2002; MacWilliams *et al.* 2015) – and presumably also did so in the pre-development ecosystem. Prior to the invasion of the overbite clam, these sediment and phytoplankton aggregations, which occurred near the 2 ppt isohaline, demarcated an important fish nursery region (Turner and Chadwick 1972; Jassby *et al.* 1995; Bennett *et al.* 2002).

The estuary's natural hydrograph reached its annual base flows (annual minimum inputs of fresh water) in August or September toward the end of California's dry summers (Figure 10). Freshwater inputs would generally increase during the fall as precipitation in the watershed resumed. Delta outflow reached a broad winter through spring peak fueled first by precipitation followed by additional contributions from melting snow. The annual peak of Delta outflow often spanned January through May before declining back to base flow conditions by the late summer. The year-to-year variation in Delta outflow was considerable, often varying by about an order of magnitude during each month of the year. Water flowing from the Delta mixed into larger open-water habitats in Suisun and San Pablo bays, which themselves were fringed with marshes and tidal creeks. This pre-development ecosystem was shallower than the modern system. As a result, salinity responded more rapidly to changes in freshwater flow than it does now and less

freshwater flow was needed to move salinity isohalines than is presently the case (Andrews *et al.* 2017; Gross *et al.* 2018). Like most native fish, the delta smelt evolved its life history to take advantage of this flow regime (Moyle 2002). In particular, its spawning period and early life stages overlap the months in which historical marsh-floodplain inundation and freshwater inputs to the estuary were highest, and water temperatures were cool, but not as cold as they are in the winter before spawning commences (see above for details of what is known about spawning and early life stages of delta smelt).

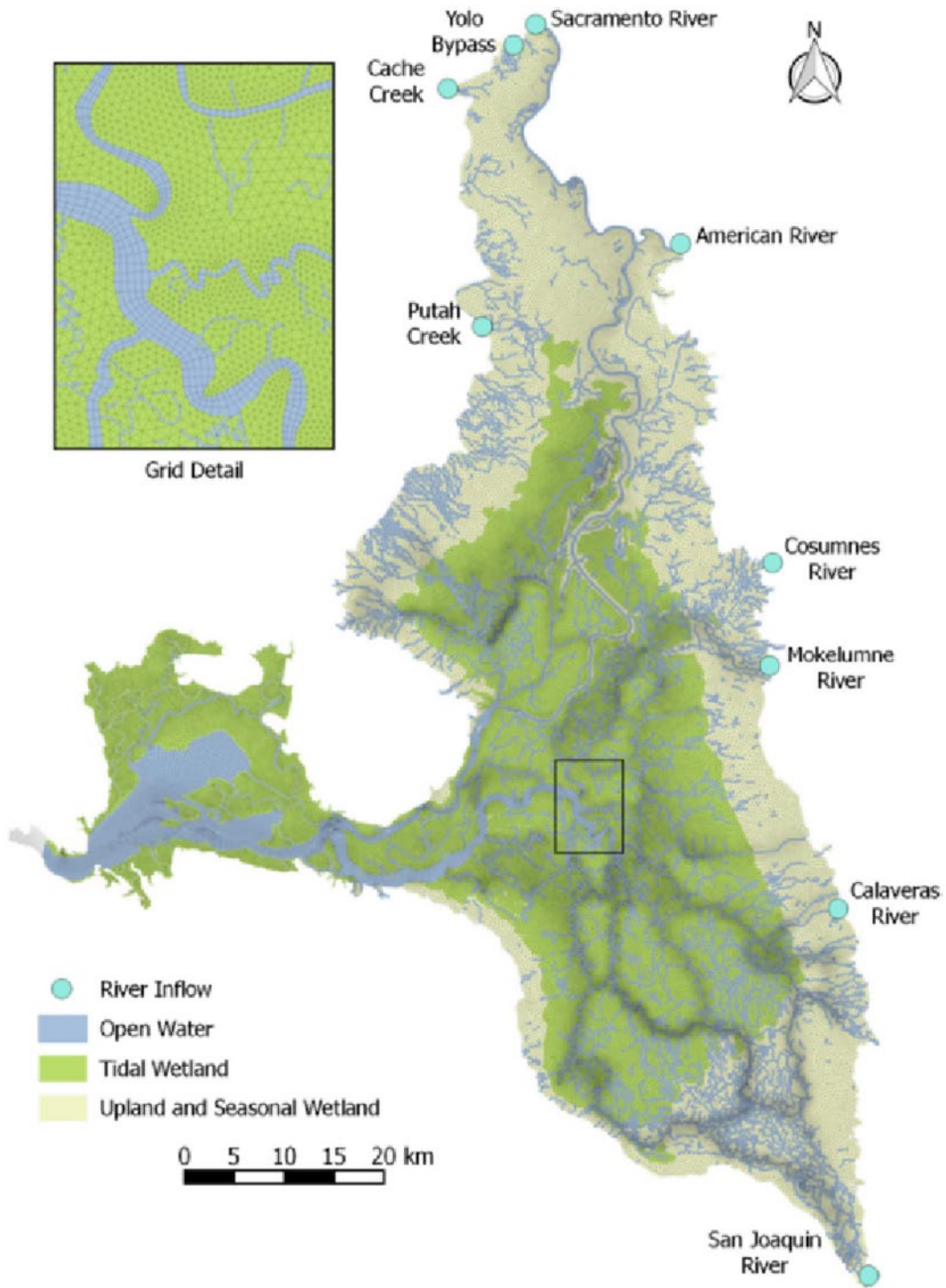


Figure 9. The circa 1850 Delta as depicted in the version of the UnTRIM 3-D hydrodynamic model described by Andrews *et al.* (2017). The model depicts an expansive tidal marsh area of approximately 2,200 square kilometers (km) or 850 square miles. Source: Andrews *et al.* (2017).

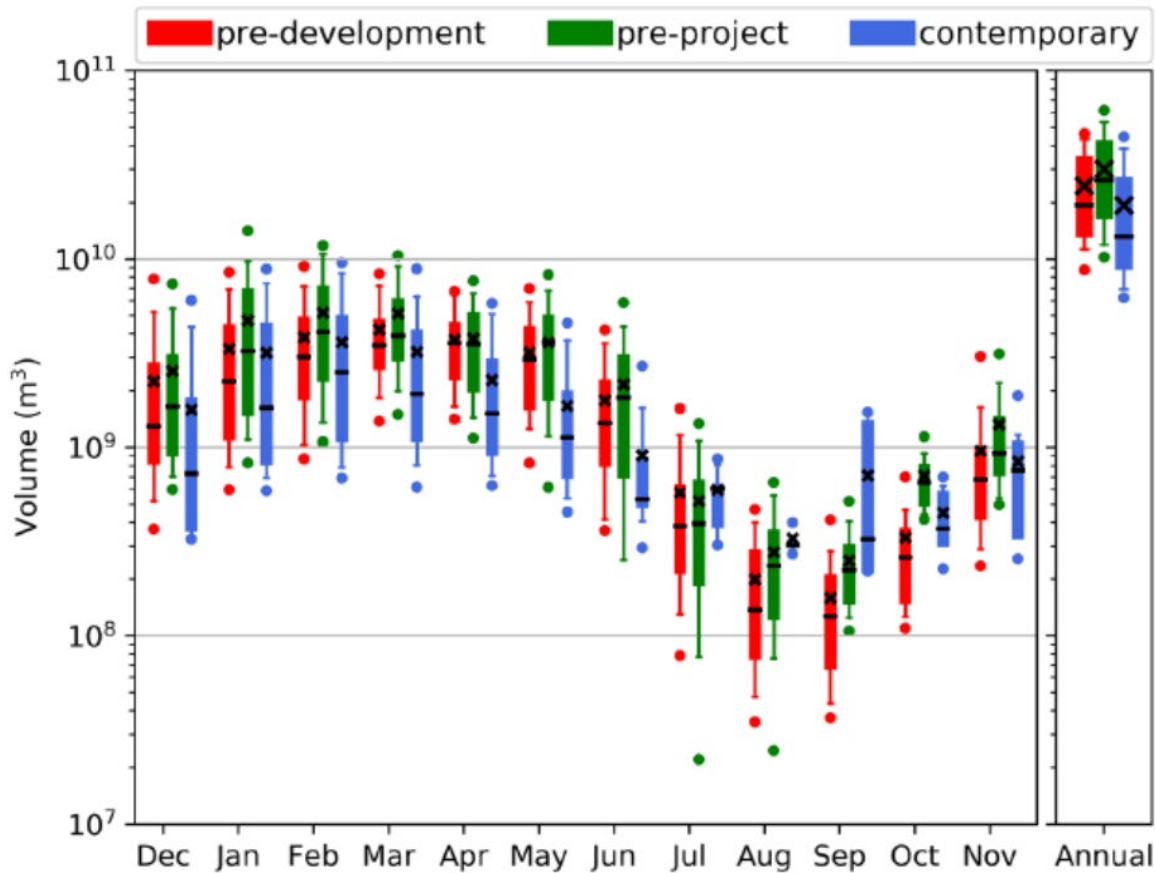


Figure 10. Boxplots of estimated Delta outflow by month for a pre-development Bay-Delta (circa 1850; red boxes), a pre-CVP and SWP Bay-Delta (circa 1920; green boxes), and a contemporary Bay-Delta (blue boxes; precise year not stated by the authors). Source: Gross *et al.* (2018). The inset labeled “Annual” on the x-axis is the boxplot summary of the sum of monthly outflows. Gross *et al.* (2018) attributed the higher outflow in the pre-project era relative to the pre-development era to the levees that had been constructed in the system by 1920.

Many tidal river estuaries form frontal zones where inflowing fresh water begins mixing with seawater (Peterson 2003). In the Bay-Delta, a frontal zone of biological importance is the LSZ (Jassby *et al.* 1995). The LSZ is a mobile and variable habitat region that frequently overlaps the parts of the estuary where many delta smelt reside (as described above). In the Bay-Delta the location and associated function of the LSZ have historically been indexed using a statistic called X2, which is the geographic location of 2 ppt salinity near the bottom of the water column measured as a distance from the Golden Gate Bridge (Jassby *et al.* 1995; MacWilliams *et al.* 2015; Figure 11). When Delta outflow is high, saline water is pushed closer to the Golden Gate, resulting in a smaller distance from the Golden Gate Bridge to X2. Conversely, when Delta outflow is low, salinity intrudes further into the estuary resulting in a larger distance from the Golden Gate Bridge to X2. These changes in how salinity is distributed affect numerous physical and biological processes in the estuary (Jassby *et al.* 1995; Kimmerer 2002a,b; Kimmerer 2004; MacWilliams *et al.* 2015).

X2, rather than another salinity isohaline, was chosen as the low-salinity zone habitat metric because it is a frontal zone or boundary upstream of which, salinity tends to be the same from the surface of the water to the bottom, and downstream of which, salinity varies from top to bottom (Jassby *et al.* 1995). That variability in the vertical distribution of salinity is indicative of currents that help to aggregate sinking particles like sediment and phytoplankton, and as recently modeled, zooplankton (Kimmerer *et al.* 2014a), near X2.

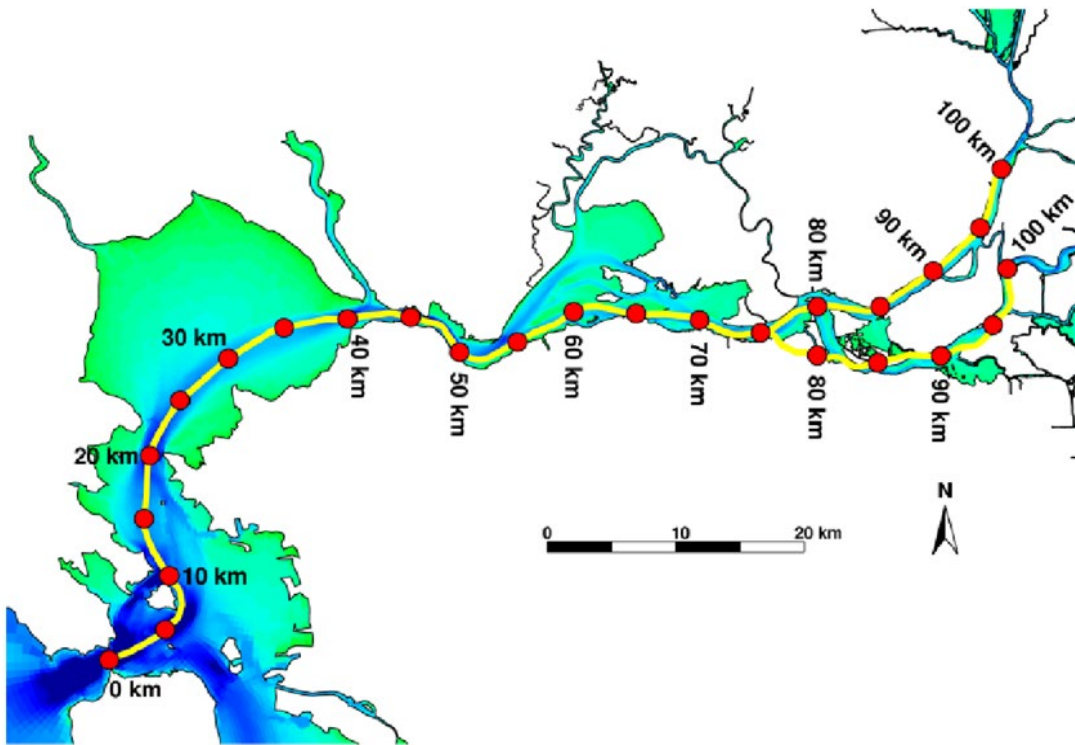


Figure 11. The northern reach of the Bay-Delta as depicted in the UnTRIM 3-D contemporary Bay-Delta model; greener colors represent shallower water and bluer colors represent deeper areas. The yellow lines depict the transect along which the location of X2 is estimated in the model and the associated red circles depict selected km distances from the Golden Gate Bridge along the northern axis of the estuary into the Sacramento and San Joaquin rivers for use in interpreting the variable locations of X2. Source: MacWilliams *et al.* (2015).

Pre-development outflows from the Delta were higher in the winter and spring than they are now while summer and fall outflows may have been lower (Andrews *et al.* 2017; Gross *et al.* 2018; Figure 10). Thus, X2 also varied more within years in the circa 1850 estuary than it now does. In the pre-development estuary, X2 would remain in San Pablo Bay for months at a time in the winter-spring of Above Normal and wetter water year types before retreating landward (upstream) in the summer-fall. In the contemporary estuary, X2 primarily lies in Suisun Bay during the wet season (landward or ‘upstream’ of historical) and between Collinsville and Rio Vista during the dry season (~ 80 to 95 km; Figure 11). These contemporary dry season locations of X2 may be seaward or ‘downstream’ of historical locations (Gross *et al.* 2018).

There are no data on the timing and magnitude of biological productivity in the circa 1850 Bay-Delta, nor are we aware of any information on how delta smelt used the estuary at the time. However, inferences can be made based on general ecosystem function in the northern hemisphere temperate zone and contemporary information. The input of basal food web materials like nutrients and detritus likely co-varied with the timing, duration, and magnitude of freshwater flows (e.g., Delta inflow; Jassby and Cloern 2000), which would likewise have affected the timing, magnitude, and duration of inundation of the system's expansive floodplains (e.g., Whipple *et al.* 2012; Figure 9). The production of planktonic and epibenthic invertebrates from floodplains, tidal wetlands, and open-water habitats that fuel the production of juvenile fishes that feed in open waters may have generally increased during the spring and peaked during the summer in concert with seasonal variation in water temperature (e.g., Heubach 1969; Orsi and Mecum 1986; Merz *et al.* 2016). The summer months are the warmest months in the Bay-Delta region and thus, they support the highest *average* metabolic rates of invertebrates and fish, which rely on water temperature to control their body temperature and metabolic rates. However, there was likely to have been considerable species-specificity to this generalization (e.g., Ambler *et al.* 1985; Gewant and Bollens 2005) because the Bay-Delta's native biotic community includes numerous cold-water adapted species.

The seasonal timing of delta smelt reproduction (February-May; detailed below) would have more broadly coincided with the general timing of peak freshwater flow into the Bay-Delta (Figure 10). The higher outflow and shallower average depth of the system resulted in frequent occurrence of the LSZ in San Pablo Bay during the wet season. Thus, it is likely that delta smelt reared in San Pablo Bay, taking advantage of its greatly expanded low-salinity habitat area (see MacWilliams *et al.* 2015), to much greater extent prior to development of the system than they are able to now. Lower flows in the summer-fall likely caused delta smelt distribution to seasonally retract back into Suisun Bay/marsh and the Delta; ecosystems which were likely much more productive at the time due to the expansive tidal marshes and greater connection between land and water (Whipple *et al.* 2012). Delta smelt's population-level demand for prey annually peaks at some combination of water temperature and growth of the population's biomass. This timing could be estimated from the model developed by Rose *et al.* (2013a), but we are not aware that such a calculation exists.

1920-1967: By 1920, most of the Delta's tidal wetlands had been reclaimed (Whipple *et al.* 2012; Figure 12). The data provided by Gross *et al.* (2018; Figure 9) suggest that Delta outflow may have been a little higher circa 1920 than it had been circa 1850 due to levee construction. However, this may (Hutton and Roy 2019) or may not be consistent with historical observations (Whipple *et al.* 2012). Regardless, Delta outflow and several other net flow metrics from within the Delta did begin to decline between the early 1920s and 1967 (Hutton *et al.* 2017a; 2019). These changes occurred because of four factors: (1) water storage in the Bay-Delta watershed increased from about 4 million acre feet (MAF) to about 40 MAF because of the construction of dams upstream of the Delta, (2) the CVP began exporting water from the Delta in 1951, (3) non-project water diversions within and upstream of the Delta increased, and (4) shipping channels were dredged through the estuary and into the Sacramento and San Joaquin rivers. These changes facilitated a general water management strategy in California to store water during the wet season and re-distribute it during the dry season to provide a more reliable supply than was available naturally. In addition, the CVP and SWP have had to offset a considerable summertime

water deficit to protect the quality of their exported water and to protect water quality for senior water rights holders in the Delta. These uses would be highly impaired without water released from CVP and SWP reservoirs during the summer and fall (Hutton *et al.* 2017b).

During the 1930s to 1960s, the navigation channels were dredged deeper (~12 meters) to accommodate shipping traffic from the Pacific Ocean and San Francisco Bay to ports in Sacramento and Stockton and to increase the capacity of the Delta to convey floodwaters. Channel deepening interacted with the simultaneously increasing water storage to change the Bay-Delta ecosystem into one in which Suisun Bay and the Sacramento-San Joaquin River confluence region became the largest and most depth-varying places in the typical range of the LSZ. Even with these changes, the LSZ remained a highly productive fish nursery habitat for many decades (Stevens and Miller 1983; Moyle *et al.* 1992; Jassby *et al.* 1995).

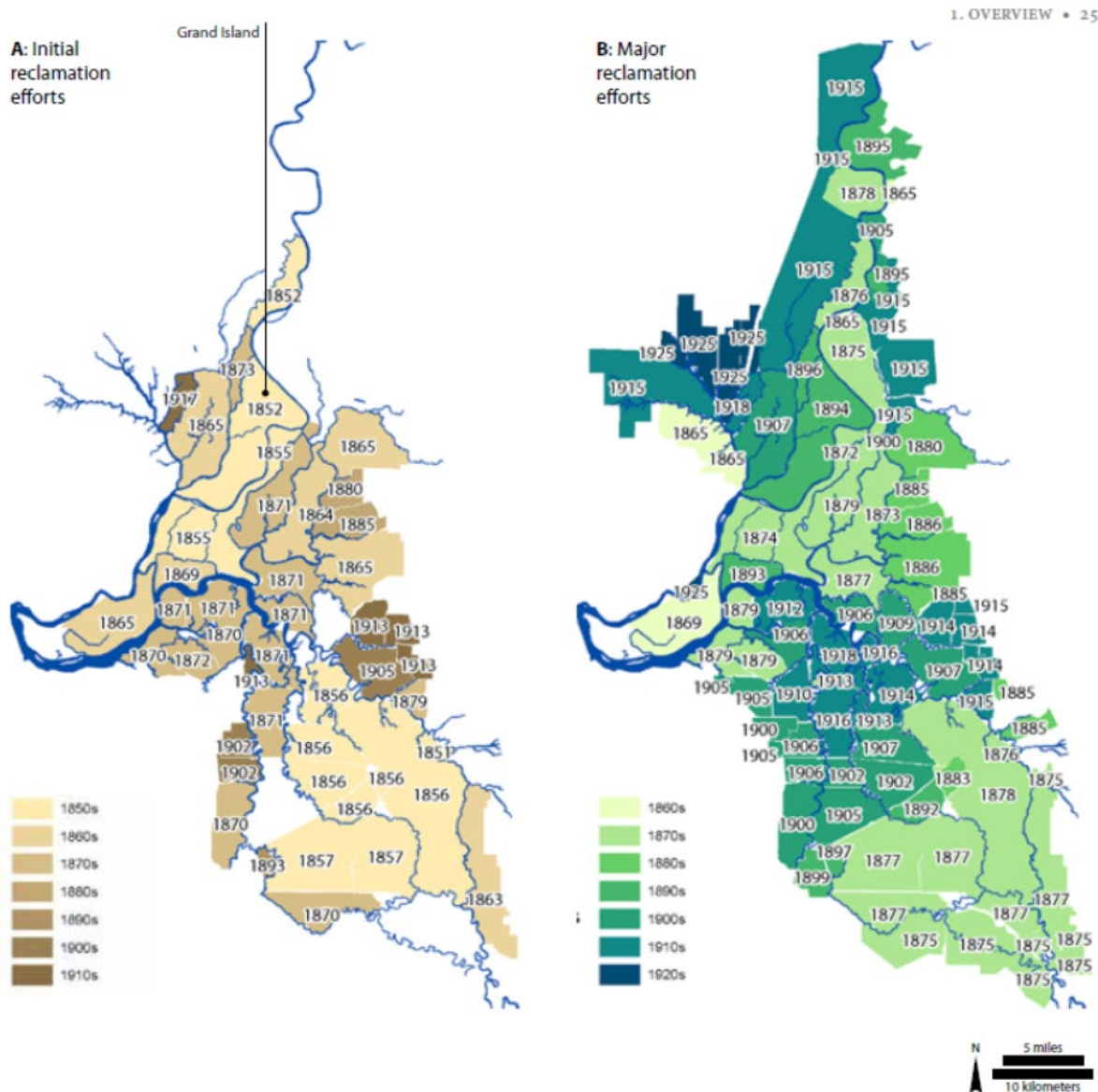


Figure 12. Maps of the Delta showing years of initial land reclamation attempts on the left and major land reclamation efforts on the right. Note that a large majority of the major reclamation efforts were underway by 1915 and the last efforts in the vicinity of Liberty Island began in 1925. Source: Whipple *et al.* (2012).

1968-present: The SWP began exporting water from the Delta in 1968 and its exports generally increased until about 1989 (Figure 13). CVP exports reached present-day levels by the end of the 1970s. During the 1980s water storage capacity in the Bay-Delta watershed reached its present-day level of a little over 50 MAF (Cloern and Jassby 2012; Hutton *et al.* 2017a). Thereafter, combined CVP-SWP exports began to increase in year-to-year variability, which increased the uncertainty about how much water would be supplied south of the Delta annually. This has combined with the increasing human demand for fresh water to result in a conflict between human water demand and environmental water uses, including the maintenance of the hydraulic salinity barrier needed to protect exported water and other in-Delta water users from salinity intrusion (Hutton *et al.* 2017b; Reis *et al.* 2019).

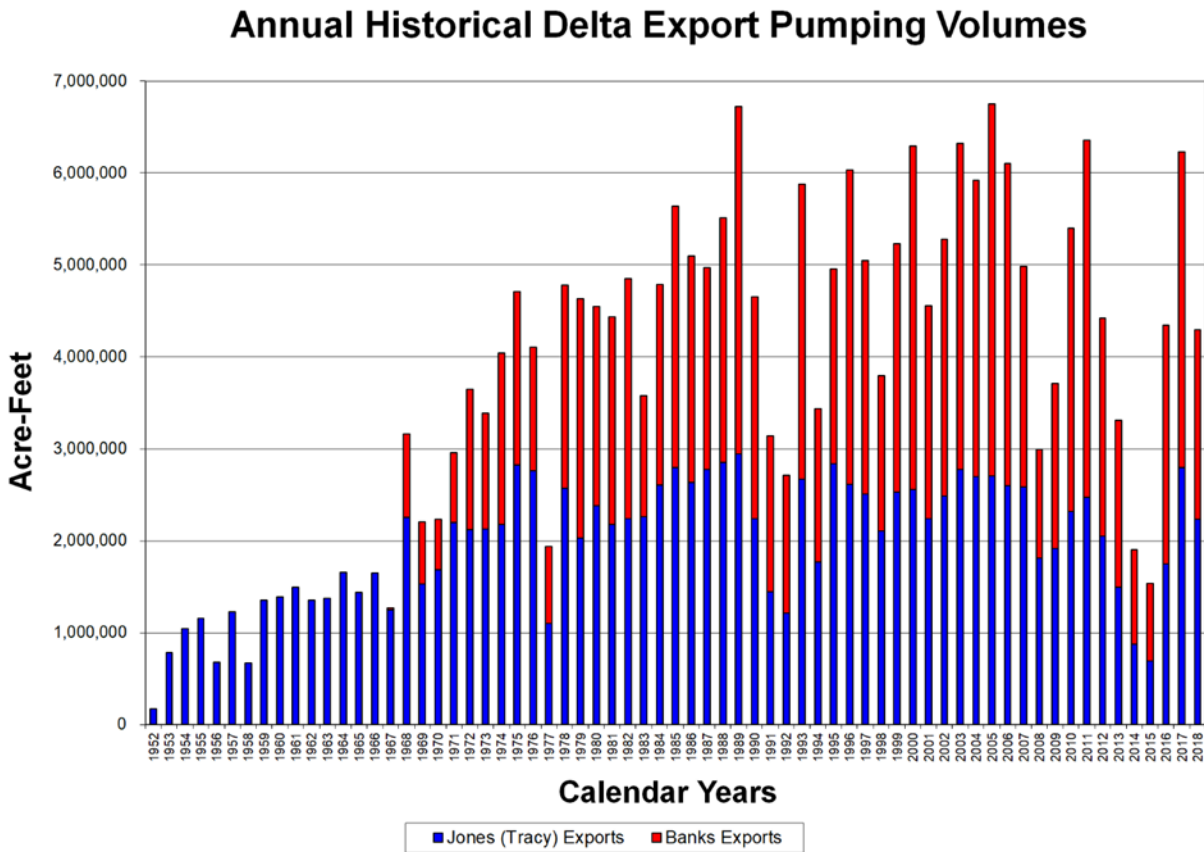


Figure 13. Time series of Central Valley Project and State Water Project exports from the Delta for 1952 through 2018. State Water Project exports began in water year 1968. Source: DAYFLOW data base.

The changes discussed above have continued to lower Delta outflow (Hutton *et al.* 2017a,b; Reis *et al.* 2019; Figures 14 and 15), though D-1641 appears to have halted the trend for years in which the eight river index is lower than 20 MAF (middle panel of Figure 14). In Figure 14, exports were modeled as depletions of water from the system, so the more negative the number on the y-axis of the middle panel, the higher the exports. Thus, the graphic shows that in years

when the eight river index is more than 20 MAF, exports continue to increase, but in years when the eight river index is lower than 20 MAF, exports have been trending lower. Both of these trends cause the higher year-to-year variability in water exports shown in Figure 13.

In general, major changes to the flow regime of an aquatic ecosystem are expected to be accompanied by ecological change (Benson 1981; Bunn and Arthington 2002; Poff and Zimmerman 2010; Gillson 2011), and that is what has been observed over time in the Bay and Delta (e.g., Matern *et al.* 2002; Moyle and Bennett 2008; Winder *et al.* 2011; Feyrer *et al.* 2015; Conrad *et al.* 2016). Delta outflow is a driver of many ecological mechanisms in the Bay-Delta and an indicator of several others (Kimmerer 2002a). Thus, the changes to the estuary's freshwater flow regime have likely interacted with the changes to the estuary's landscape, specifically its deeper channels and greatly reduced land-water connections (Andrews *et al.* 2017), to lower the total biological productivity of the estuary. In addition, changes to the freshwater flow regime detailed above appear to have affected the reproductive success of fishes that use the Delta and Suisun Bay as rearing habitats. The evidence for this is that the native fish assemblage had reproductive seasons timed to winter-spring peak flows, whereas currently dominant non-native species generally spawn later in the spring and into the summer when inflows to the Delta are generally high to support human water use, but outflow from the Delta is generally low (Moyle 2002; Moyle and Bennett 2008). Reis *et al.* (2019) recently described super-critical water years with respect to Delta outflow. Several studies have indicated that low flow years and droughts in particular result in low native fish production in the Bay-Delta (Meng *et al.* 1994; Jassby *et al.* 1995; Kimmerer 2002b; Feyrer *et al.* 2015). Droughts recur and may contribute to cumulative impacts to native fishes like delta smelt. For instance, recent droughts have been particularly problematic for delta smelt (Moyle *et al.* 2018). Thus, the frequency of these super-critical water years, which has been much higher since 1968 than it was from 1920-1967 (Figure 15), is a conservation challenge that the Service and its partners have to contend with.

There are several fish species in the Bay-Delta that have historically been shown to have demonstrable positive population responses to freshwater flows into or out of the Delta. These include the well-described relationships for the survival of emigrating Sacramento basin Chinook salmon (*Oncorhynchus tshawytscha*) smolts with Sacramento River inflows (Kjelson and Brandes 1989; Perry *et al.* 2010), the relationship of Sacramento splittail (*Pogonichthys macrolepidotus*) production to Yolo Bypass flow (Moyle *et al.* 2004; Feyrer *et al.* 2006), and the 'fish-X2' relationships for striped bass (*Morone saxatilis*), longfin smelt (*Spirinchus thaleichthys*), and starry flounder (*Platichthys stellatus*) (Turner and Chadwick 1972; Jassby *et al.* 1995; Kimmerer 2002b). The life-history of delta smelt with its affinity for fresh and low-salinity waters seems consistent with that of a fish one could expect to respond similarly to variation in Delta outflow or X2. Researchers searched for some form of analogous relationship for the delta smelt for several decades, but no persistent relationship was found (Stevens and Miller 1983; Moyle *et al.* 1992; Jassby *et al.* 1995; Kimmerer 2002b; Bennett 2005; Mac Nally *et al.* 2010; Thomson *et al.* 2010; Miller *et al.* 2012). Further, Rose *et al.* (2013a,b) did not find salinity variation *per se* to have much impact on predictions of delta smelt population growth rate. The larger predicted impact in their individual-based model related to flow was due to simulated entrainment in exported water (Rose *et al.* 2013b; Kimmerer and Rose 2018). Although entrainment was predicted to lower the population growth rate, in and of itself, it could

not convert a strongly positive growing population into a declining one without at least one additional factor impacting survival at the same time.

The IEP (2015) reported a correlation between February-May X2 and ratios of the 20-mm Survey index for delta smelt and either the Spring Kodiak Trawl (SKT) or FMWT indices of the parental stock that produced the 20-mm fish. This relationship emerged in data beginning at the time of the pelagic organism decline (POD) in 2002. This relationship is stronger when considered in terms of salinity at Chipps Island (He and Nobriga 2018), possibly because salinity can be measured more accurately than Delta outflow when net freshwater flow is very low (Monismith 2016). Castillo *et al.* (2018) used a simulation based on SKT data to suggest a link between Delta outflow and adult delta smelt abundance. In addition, several teams have reported statistical associations of delta smelt spatial distribution and salinity that imply the population spatial distribution co-varies with Delta outflow, X2, or similar indices of freshwater input to the estuary (Feyrer *et al.* 2007; 2011; Nobriga *et al.* 2008; Kimmerer *et al.* 2009; 2013; Bever *et al.* 2016; Polanksy *et al.* 2018; Simonis and Merz 2019). The strength of this covariation and its management utility have been contested (e.g., Murphy and Hamilton 2013; Manly *et al.* 2015; Latour 2016; Polanksy *et al.* 2018) and supported (Sommer *et al.* 2011; Bever *et al.* 2016; Feyrer *et al.* 2016; Mahardja *et al.* 2017a) in several recently published papers.

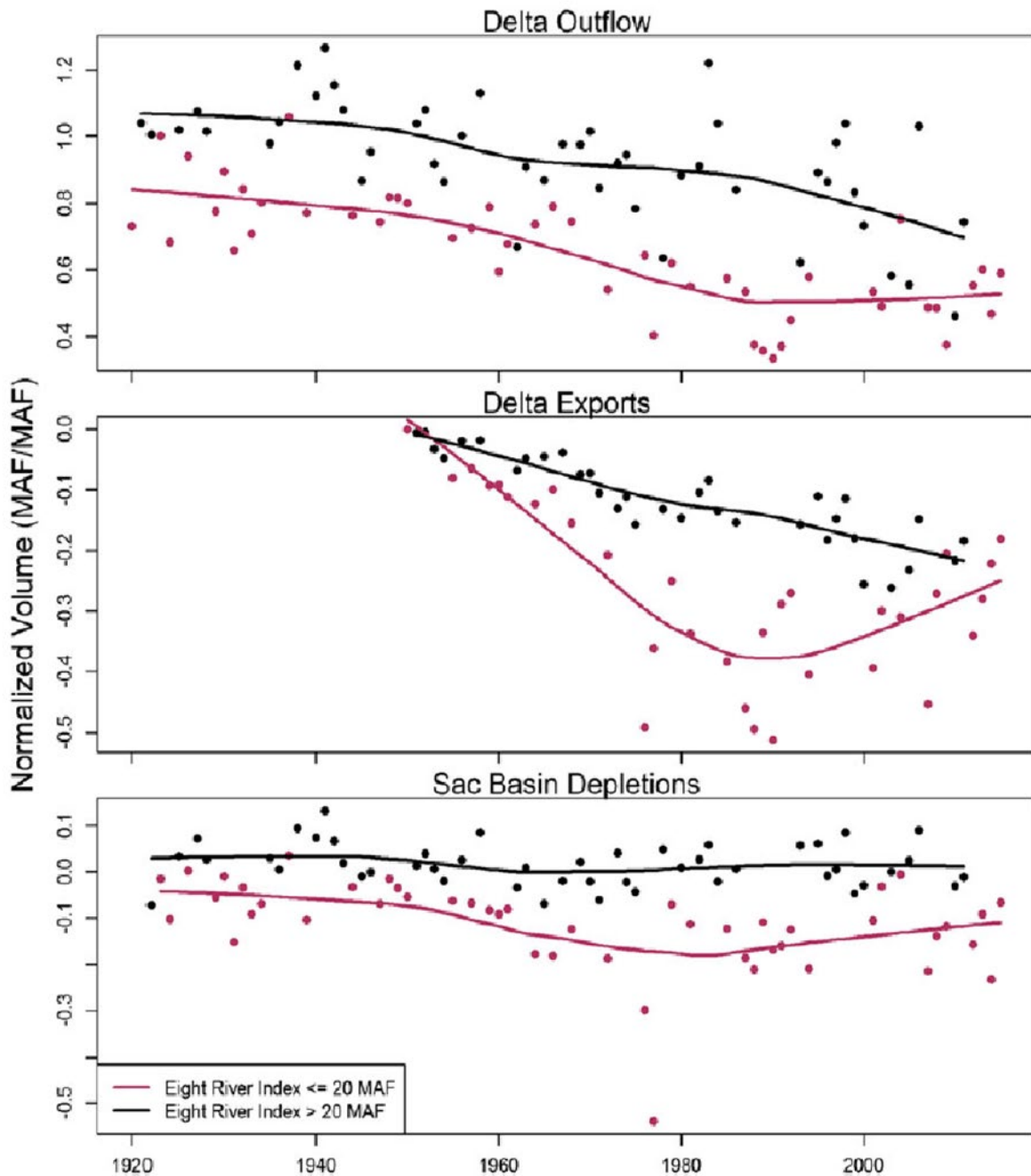


Figure 14. Time series (1922-2015) of statistical trend outputs of annual Delta outflow (top panel), Delta exports treated as depletions so increasing exports are represented by more negative values (middle panel), and water diversions from the Sacramento River basin upstream of the Delta (bottom panel). Black symbols and lines are for years in which the eight river index, a measure of water availability in the Bay-Delta watershed, was greater than 20 MAF. Red symbols and lines are for years in which the eight river index was less than or equal to 20 MAF. Source: Hutton *et al.* (2017b).

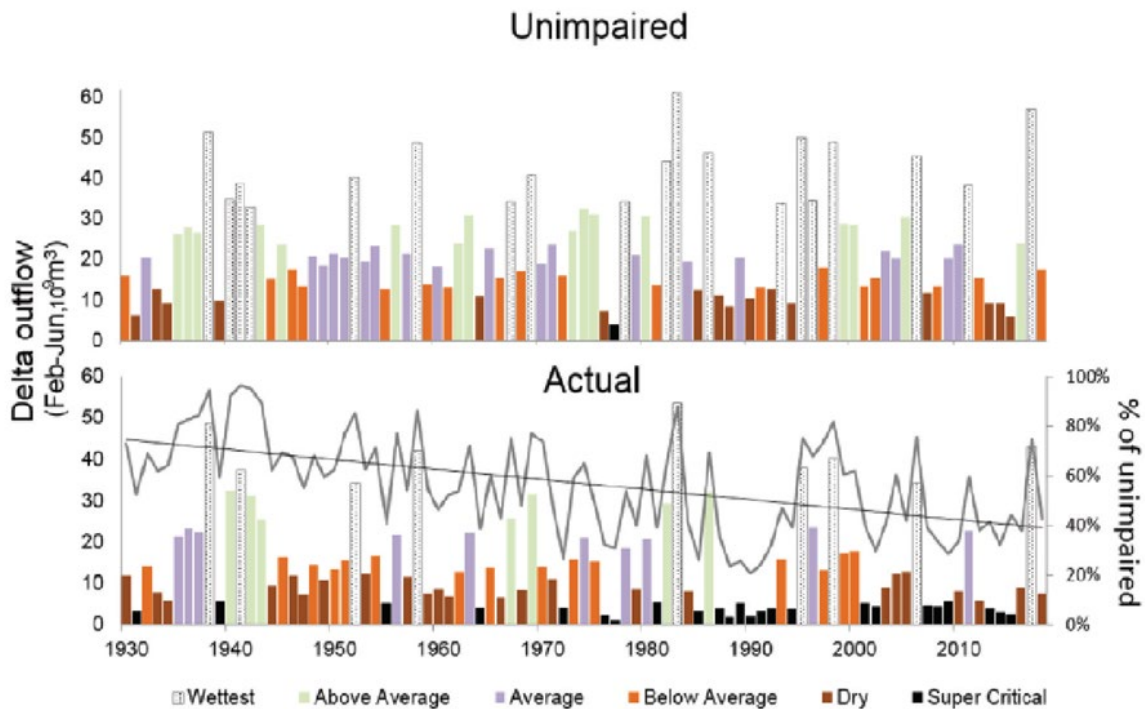


Figure 15. Time series of estimates of unimpaired (upper panel) and actual (lower panel) Delta outflow (February-June) color-coded according to six water year types, 1930-2018. The water year types based on basin precipitation are shown in the upper panel. In the lower panel, the water year types were re-assessed based on their fraction of the estimated unimpaired outflow. The long-term trend in this fraction as “% of unimpaired” is shown on the second y-axis of the bottom panel. Source: Reis *et al.* (2019).

Delta Smelt Population Trend

The CDFW’s TNS (<http://www.dfg.ca.gov/delta/data/townet/indices.asp?species=3>) and FMWT Survey (<http://www.dfg.ca.gov/delta/data/fmwt/indices.asp>) are the two longest running indicators of the delta smelt’s abundance trend. Indices of delta smelt relative abundance from these surveys date to 1959 and 1967, respectively (Figures 16 and 17). The FMWT index has traditionally been the primary indicator of delta smelt trend because it samples later in the life cycle, providing a better indicator of annual recruitment than the TNS (Service 1996). It has also sampled more consistently and more intensively than the TNS. The FMWT deploys more than 400 net tows per year over its four-month sampling season (September through December). The highest FMWT index for delta smelt (1,673) was recorded in 1970 and a comparably high index (1,654) was reported in 1980 (Figure 17). The last FMWT index exceeding 1,000 was reported in 1993. The last FMWT indices exceeding 100 were reported in 2003 and 2011. In 2018, the FMWT index was zero for the first time. The TNS index for delta smelt has been zero four times since 2015. Thus, the TNS and FMWT have recorded a 40-50 year decline in which delta smelt went from a minor (but common) species to essentially undetectable by these long-term surveys (Figures 16 and 17).

Following the listing of the delta smelt, the CDFW launched a 20-mm Survey (1995) and a SKT Survey (SKT; 2002) to monitor the distribution and relative abundance of late larval stage and

adult delta smelt, respectively. These newer indices have generally corroborated the trends implied by the TNS and the FMWT (Figures 16 and 17). The CDFW methods generate abundance indices from each survey but each index is on a different numeric scale. This means the index number generated by a given survey only has quantitative meaning relative to other indices generated by the same survey. Further, the CDFW indices lack estimates of uncertainty (variability) which limits interpretation of abundance changes from year to year even within each sampling program. The Service recently completed a new delta smelt abundance indexing procedure using data from all four of these surveys (Polansky *et al.* 2019). The Service method improves upon the CDFW method because it generates abundance indices in units of numbers of fish, including attempts to correct for different sampling efficiencies among surveys, and the method includes measures of uncertainty. Service indices of spawner abundance based on combined January and February SKT sampling are listed with their confidence intervals in Table 2. The estimates show the most recent 20 years of the delta smelt's longer-term decline in numbers of fish as best as they can be approximated with currently available information. The Service's Enhanced Delta Smelt Monitoring (EDSM) is designed to complete Delta wide surveys at a weekly time scale while SKT does this at a monthly scale, so the Service calculated EDSM abundance estimates using all weekly survey data within the January-February time interval (Table 3). For both surveys, data collected from January and February of each year were combined to derive a single abundance estimate. Beginning in 2022, estimates include cultured delta smelt released in the Delta between December 2021 and February 2022 described below and in Table 4. The effects of survey specific sampling times and locations in relation to release times and locations have not been fully evaluated.

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 5 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 releases occurred in various locations including Rio Vista, the Sacramento Deep Water Ship Channel, and Suisun Marsh. A subsample of those marked fish were recaptured in the Deep Water Ship Channel, central Delta, south Delta, and Suisun March by EDSM, Chipps Island Trawl, SKT, Bay Study, and in the CVP salvage facility.

Experimental release of captively produced, marked delta smelt continued for a second year in November 2022 through January 2023. These releases occurred at both Rio Vista and the Sacramento Deep Water Ship Channel. A total of 43,705 delta smelt were released (Table 5). A small subsample of those marked fish have also been recaptured.

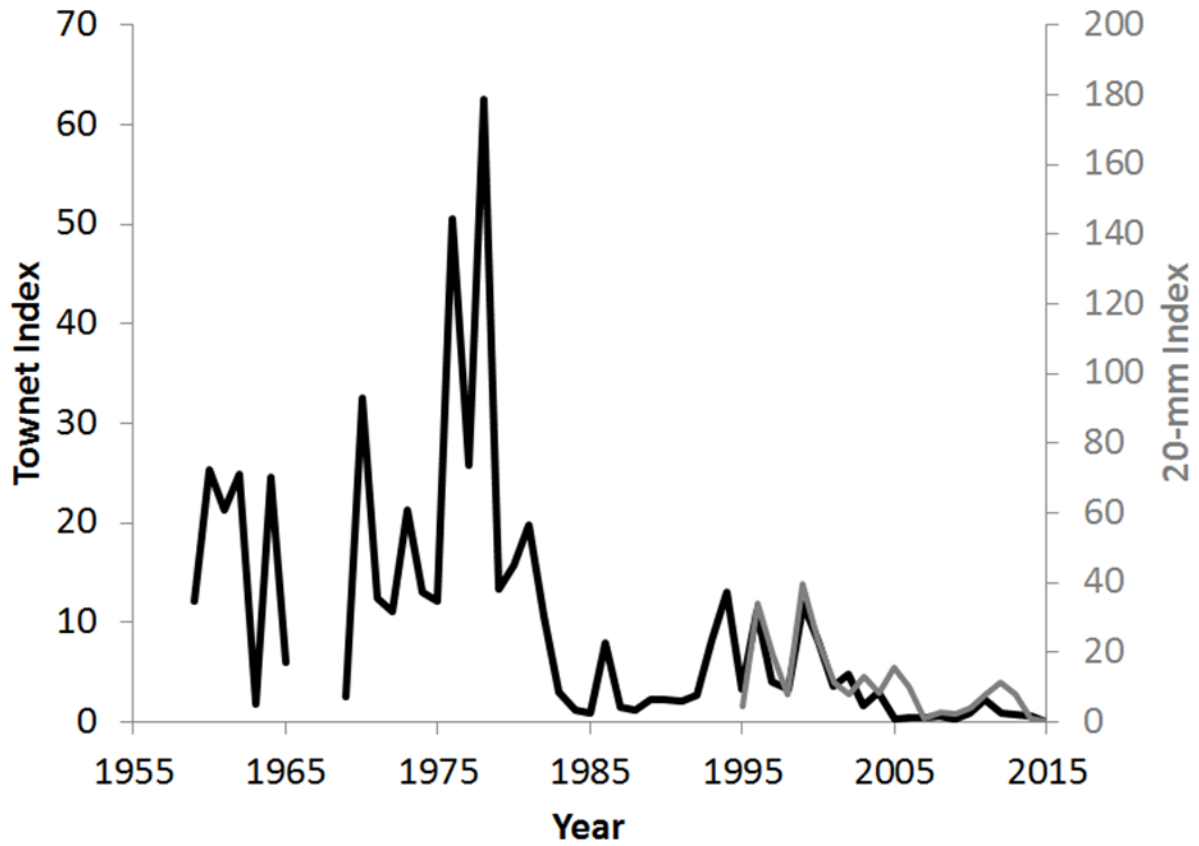


Figure 16. Time series of juvenile and larval delta smelt relative abundance as depicted by the California Department of Fish and Wildlife’s TNS and 20-mm Survey, respectively. The TNS began in 1959 and the 20-mm Survey began in 1995. The second y-axis was scaled to better align the indices which are calculated on different numeric scales.

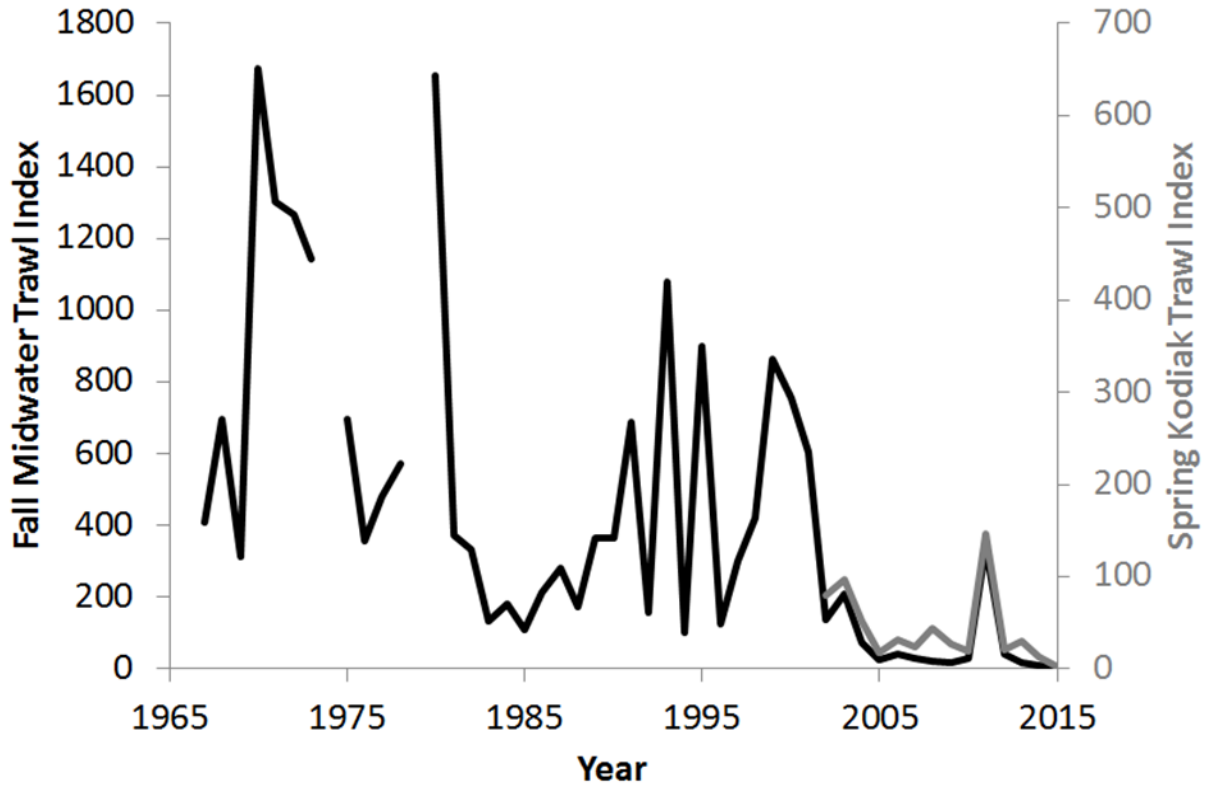


Figure 17. Time series of juvenile and larval delta smelt relative abundance as depicted by the California Department of Fish and Wildlife’s FMWT and SKT Survey, respectively. The FMWT survey began in 1967 and the SKT trawl survey began in 2002. The second y-axis was scaled to better align the indices which are calculated on different numeric scales.

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.

Year	Abundance Estimate	Standard Error	95% Confidence Interval		Total delta smelt caught (total tows) by the SKT survey		Year-to-Year Ratio
			Lower Bound	Upper Bound	January	February	
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	Not Defined	Not Defined	0 (39)	0 (36)	0
2022	12,679	9,033	2,942	36,250	0 (36)	5 (40)	NA

Table 3. Enhanced Delta Smelt Monitoring (EDSM) Survey abundance estimates with columns as in Table 2.

Year	Abundance Estimate	Standard Error	95% Confidence Interval		Total delta smelt caught (total tows) by the EDSM survey		Year-to-Year Ratio
			Lower Bound	Upper Bound	January	February	
2017	85,162	21,362	50,902	134,047	54 (401)	33 (684)	NA
2018	6,821	2,778	2,931	13,614	10 (727)	3 (610)	0.08
2019	4,500	1,075	2,758	6,947	17 (724)	7 (518)	0.66
2020	1,079	544	379	2,448	3 (625)	2 (606)	0.23
2021	267	189	63	760	2 (327)	0 (466)	0.26
2022	4,909	2,232	1,911	10,450	6 (468)	12 (484)	18.39

Table 4: Summary of delta smelt releases for December 2021 through February 2022.

Release	Site	Date(s)	Total Released
1	Rio Vista	Dec 14-15, 2021	12,800
2	Rio Vista	Jan 11-12, 2022	12,800
3	Sacramento Deep Water Ship Channel	Feb 3, 2022	6,400
4	Suisun Marsh	Feb 9-10, 2022	12,800
5	Sacramento Deep Water Ship Channel	Feb 16-17, 2022	10,933

Table 5: Summary of delta smelt releases for November 2022 through January 2023.

Release Event	Release Date	Release Site	Release method	VIE (Side/color/Location)	Ad-clip	Total released	Release status
1a	11/29/2022	Rio Vista	soft	Right/ blue/ PD	None	6,584	Complete
1b	11/30/2022	Rio Vista	hard	Left/ red/ AD	None	6,556	Complete
2a	01/18/2023 01/19/2023	Rio Vista	hard	Right/ orange/ PD	None	14,524	Complete
2b	01/18/2023	Rio Vista	Trailer release	None	Yes	3,046	Complete
3a	01/25/2023	SDWSC	hard	Left/ orange/ AD	None	6,775	Complete
3b	01/26/2023	SDWSC	soft	Right/ green/ PD	None	6,240	Complete
Total						43,705	

Climate Change

Climate projections for the San Francisco Bay-Delta and its watershed indicate that changes will be substantial by mid-century and considerable by the year 2100. Climate models broadly agree that average annual air temperatures will rise by about 2°C at mid-century and about 4°C by 2100 if current atmospheric carbon emissions accelerate as currently forecasted (Dettinger *et al.* 2016). It remains highly uncertain whether annual precipitation in the Bay-Delta watershed will trend wetter or drier (Dettinger 2005; Dettinger *et al.* 2016). The warmer air temperature projections suggest more precipitation will fall as rain rather than snow and that storms may increase in intensity, but will have more dry weather in between them (Knowles and Cayan 2002; Dettinger 2005; Dettinger *et al.* 2016). The expected consequences are less water stored in spring snowpacks, increased flooding and an associated decrease in runoff for the remainder of the year (Hayhoe *et al.* 2004). Changes in storm tracks may lead to increased frequency of flood and drought cycles during the 21st century (Dettinger *et al.* 2015).

As of 2009, sea level rise had not had much effect on X2 (Hutton *et al.* 2017b). However, additional sea level rise is another anticipated consequence of a warming global climate and if it is not mitigated, sea level rise will likely increase saltwater intrusion into the Bay-Delta (Rath *et al.* 2017). During the summer of 2015, variation in sea level interacted with very low Delta inflows to cause frequent recurrence of net negative Delta outflow (Monismith 2016).

Since the early 1980s, climate change is thought to have increased wind speed along the central California coast, resulting in a more frequent and longer lasting upwelling season (Garcia-Reyes and Largier 2010). Coastal upwelling causes colder deep water to rise to the ocean surface, bringing with it nutrients that stimulate the coastal food web. One effect of wind blowing over the estuary is that it resuspends sediment deposited in shallow areas like San Pablo Bay, Grizzly

Bay, and Honker Bay (Ruhl *et al.* 2001). Thus, higher wind speeds blowing onto the coast might be expected to result in higher turbidity of the water in parts of the estuary. In contrast to this expectation, Bever *et al.* (2018) reported a recent reduction in wind speed over the Bay-Delta during 1995-2015, which these authors associated with lower turbidity in Suisun Bay. The Service notes these contrasting results for completeness but we cannot reconcile these opposing trends in wind speed at this time. We show below that Secchi disk depths (an indicator of water turbidity) have not increased since the mid-1980s near the (mobile) location of X2 even though suspended sediment concentrations in Suisun Bay have decreased since about 2000 (Schoellhamer 2011; Bever *et al.* 2018).

Central California's warm summers are already a source of energetic stress for delta smelt and warm springs can already severely compress the duration of their spawning season (Rose *et al.* 2013a,b). We expect warmer estuary temperatures to present a significant conservation challenge for delta smelt in the coming decades (Brown *et al.* 2013; 2016a; Figure 18). Feyrer *et al.* (2011) and Brown *et al.* (2013; 2016a) have evaluated the anticipated effects of projected climate change on several delta smelt habitat metrics. Collectively, these studies indicate the future will bring chronically compressed fall habitat, fewer 'good' turbidity days (defined by the authors as a mean turbidity greater than or equal to 18 Nephelometric Turbidity Units (NTU)), a spawning window of similar duration but that is shifted 2 to 3 weeks earlier in the year, and a substantial increase in the number of days delta smelt will need to endure lethal or near lethal summer water temperatures.

The delta smelt lives at the southern limit of the inland distribution of the family Osmeridae along the Pacific coast of North America. The anticipated effects of a warming climate are expected to create increasing temperature related challenges for delta smelt at some future point. The amount of anticipated change to the regional climate expected in the near term is lower than it is for the latter half of the century (Figure 18). Therefore, it is less certain that any measurable change from current conditions will occur in the next approximately 10 years than by 2050 or 2100. For the time being, water temperatures are stressful to delta smelt, but not of themselves lethal in most of the upper estuary (Komoroske *et al.* 2015).

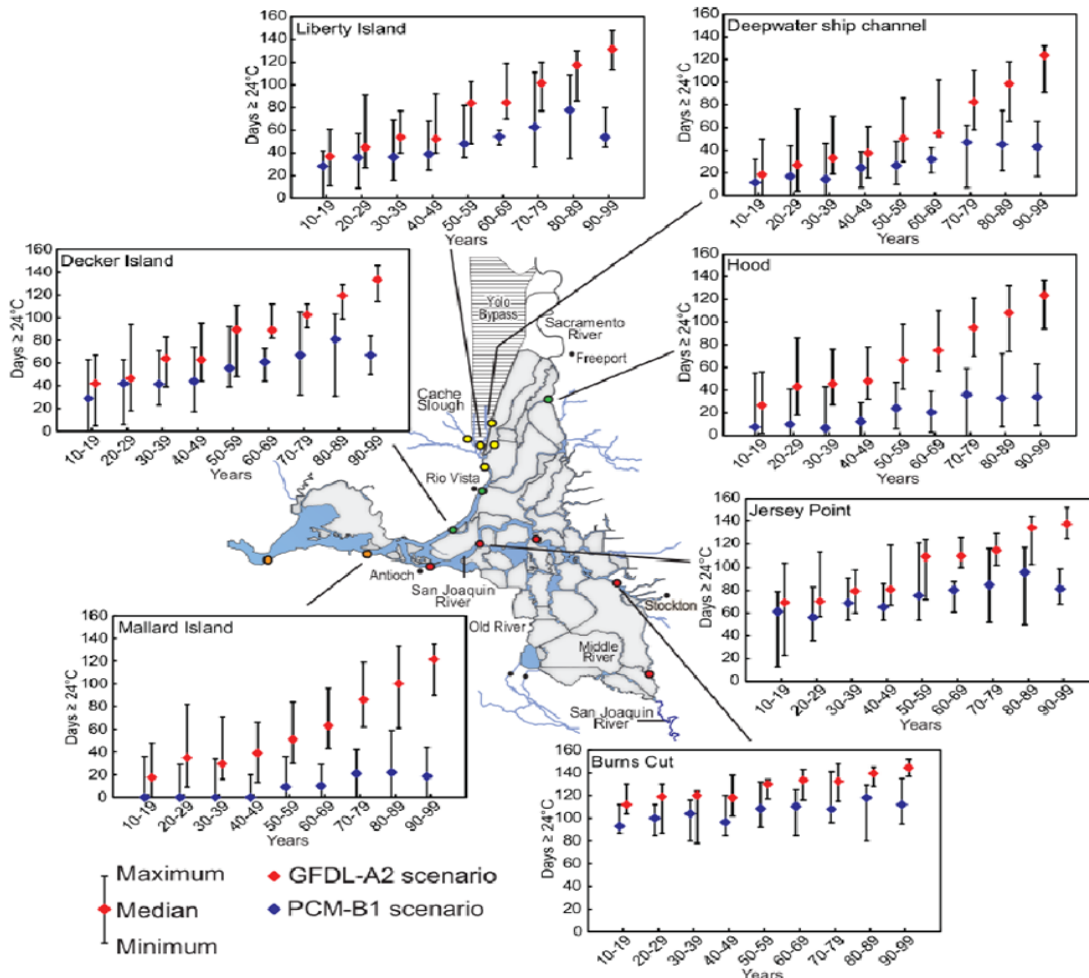


Figure 18. Plots of median, maximum, and minimum number of days each year with an estimated average daily water temperature greater than or equal to 24°C (75°F) at selected sites in the Delta by decade for the 21st century. The water temperature threshold reflects one chosen by the authors to represent near lethal conditions for delta smelt. Source: Brown *et al.* (2016a).

Recovery and Management

Following Moyle *et al.* (1992), the Service (1993) indicated that SWP and CVP exports were the primary factors contributing to the decline of delta smelt due to entrainment of larvae and juveniles and the effects of low flow on the location and function of the estuary mixing zone (now called the low-salinity zone). In addition, prolonged drought during 1987-1992, in-Delta water diversions, reduction in food supplies by nonindigenous aquatic species (specifically overbite clam and nonnative copepods), and toxicity due to agricultural and industrial chemicals were also factors considered to be threatening the delta smelt. In the Service's December 15, 2008 *Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP)* (2008 BO), the Reasonable and Prudent Alternative (RPA) required protection of all life stages from entrainment and augmentation of Delta outflow during the fall of Wet and Above-Normal years as classified by the State of California (Service 2008). The expansion of entrainment protection for delta smelt in the 2008 BO was in response to large increases in juvenile and adult salvage in the early 2000s

(Kimmerer 2008; Brown *et al.* 2009). The fall X2 requirement in the 2008 RPA was in response to increased fall exports that had reduced variability in Delta outflow and lowered habitat suitability during the fall months and the 2008 proposed action was anticipated to reduce it further (Feyrer *et al.* 2011).

The Service's (2010c) recommendation to uplist delta smelt from threatened to endangered included a discussion of threats related to reservoir operations and water diversions upstream of the estuary as additional water operations mechanisms interacting with exports from the Delta to restrict the LSZ and concentrate delta smelt with competing and predatory fish species. In addition, Brazilian waterweed (*Egeria densa*) and increasing water transparency were considered new detrimental habitat changes. Predation was considered a low-level threat linked to increasing waterweed abundance and increasing water transparency. Additional threats considered potentially significant by the Service in 2010 were entrainment into power plant diversions, contaminants, and reproductive problems that can stem from small population sizes. Conservation recommendations included: establish Delta outflows proportionate to unimpaired flows to set outflow targets as fractions of runoff in the Central Valley watersheds; minimize reverse flows in Old and Middle rivers; and, establish a genetic management plan for captive-reared delta smelt with the goals of minimizing the loss of genetic diversity and limiting risk of extinction caused by unpredictable catastrophic events. The Service (2012) recently added climate change to the list of threats to the delta smelt.

Maintaining protection of the delta smelt from excessive entrainment, improving the estuary's flow regime, suppression of nonnative species, increasing zooplankton abundance, and improving water quality are among the actions the Service has previously indicated are needed to recover the delta smelt.

There have been several recent papers suggesting it is time to consider supplementation of the wild delta smelt population with captive-bred fish as part of a broad-based conservation strategy to avoid extinction in the wild, also known as extirpation (Moyle *et al.* 2016; 2018; Hobbs *et al.* 2017; Lessard *et al.* 2018). In 2019, pilot research conducted by the DWR has demonstrated that captive-bred delta smelt held within steel enclosures can survive in the Delta for at least 30 days. This is long enough to show that the fish can feed themselves and did not die from acute water toxicity in either of two locations tested thus far. These results were promising, and the first experimental releases of cultured delta smelt into the Delta occurred between December 2021 and February 2022.

The status of the delta smelt is poor. The current estimated delta smelt population sizes are so low that it seems unlikely the species can be habitat- or food-limited even though both physical and food web-related habitat attributes have degraded over time. It is more likely that delta smelt have been marginalized by non-native fishes and invertebrates that compete with and prey on them. When fish populations reach very low levels, they can fall victim to demographic problems (often termed Allee effects in the scientific literature). These include problems concentrating enough individuals in particular locations for successful spawning, successful feeding, or maintaining large enough egg supplies, or shoals and schools of juvenile and adult fish to provide effective protection from predators (Liermann and Hilborn 2001; Keith and Hutchings 2012).

Summary of the Status of Delta Smelt

The relative abundance of delta smelt has reached very low numbers for a small forage fish in an ecosystem the size of the Bay-Delta and the species is approaching extinction in the wild (Moyle *et al.* 2016; 2018; Hobbs *et al.* 2017). The extremely low 2018-2020 abundance indices reflect decades of habitat change and marginalization by non-native species that prey on and out-compete delta smelt. The anticipated effects of climate change on the Bay-Delta and its watershed such as warmer water temperatures, greater salinity intrusion, lower snowpack contribution to spring outflow, and the potential for frequent extreme drought, indicate challenges to delta smelt survival will increase.

Delta Smelt Critical Habitat

Legal Status

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

Conservation Role of Delta Smelt Critical Habitat

The Service's primary objective in designating critical habitat was to identify the key components of delta smelt habitat that support successful completion of the life cycle, including spawning, larval and juvenile transport, rearing, and adult migration back to spawning sites. Delta smelt are endemic to the Bay-Delta and the vast majority only live one year. Thus, regardless of annual hydrology, the Bay-Delta estuary must provide suitable habitat all year, every year. The primary constituent elements considered essential to the conservation of the delta smelt as they were characterized in 1994 are physical habitat, water, river flow, and salinity concentrations required to maintain delta smelt habitat for spawning, larval and juvenile transport, rearing, and adult migration (Service 1994). The Service recommended in its designation of critical habitat for the delta smelt that salinity in Suisun Bay should vary according to water year type, which it does. For the months of February through June, this element was codified by the SWRCB "X2 standard" described in D-1641 and the SWRCB's current Water Quality Control Plan.

See the *Detailed Review of the Habitat Use and Distribution of Delta Smelt* above in the *Status of the Species* section.

Description of the Primary Constituent Elements

PCE #1: “Physical habitat” is defined as the structural components of habitat (Service 1994). As reviewed above, physical habitat in the Bay-Delta has been substantially changed with many of the changes having occurred many decades ago (Andrews *et al.* 2017; Gross *et al.* 2018). Physical habitat attributes are important in terms of spawning substrate, rearing habitat in terms of how geographic location and bathymetry affect tidal current velocities (Bever *et al.* 2016), and possibly, foraging opportunities near the edges of emergent marshes (Whitley and Bollens 2014; Hammock *et al.* 2019). Information on spawning habitat is incomplete and it is difficult to protect spawning habitat without knowing what it is.

PCE #2: “Water” is defined as water of suitable quality to support various delta smelt life stages that allow for survival and reproduction (Service 1994). Certain conditions of turbidity, water temperature, and food availability characterize suitable habitat for delta smelt and are discussed in detail below. Contaminant exposure can degrade this primary constituent element even when the basic habitat components of water quality are otherwise suitable (Hammock *et al.* 2015).

Turbidity: Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is a measurement of the amount of light scattered by material in the water when a light is shined through the water sample. The higher the intensity of scattered light, the higher the turbidity. Material that causes water to be turbid can include clay, silt, particulate organic matter, algae, dissolved colored organic compounds, and other microscopic organisms. In the Bay-Delta, turbidity results mainly from sediment suspended in the water column and to a lesser degree phytoplankton (Cloern and Jassby 2012). Turbidity can play an important role in structuring fish communities; one mechanism by which this can occur is the scale dependence in how fish of different sizes can have their prey detection enhanced or impaired (Utne-Palm 2002). Turbidity typically lowers the reactive distance of fishes feeding on zooplankton or each other. However, if the turbidity increases prey contrast (which it often does for fish larvae and planktivorous species), then it can enhance the feeding of these small fishes while still impairing the ability of their predators to see them.

The delivery of suspended sediment to the estuary increased substantially following the era of hydraulic gold mining in the watershed (Schoellhamer 2011). It increased again during rapid regional population growth and development after World War II. Since then, the delivery of new sediment to the estuary has declined (Wright and Schoellhamer 2004; Schoellhamer 2011). In addition, summertime phytoplankton production has been greatly diminished (Cloern and Jassby 2012). These changes have resulted in a general clearing of the estuary’s waters (Figure 19); however, the clearing trend has been strongest in the Delta where expansive beds of SAV further filter fine sediment from the water (Kimmerer 2004; Feyrer *et al.* 2007; Nobriga *et al.* 2008; Hestir *et al.* 2016). Water exports from the south Delta may also have contributed to the trend toward clearer estuary water by removing suspended sediment in exported water (Arthur *et al.* 1996); however, the contribution of exports to the total suspended sediment budget in the estuary is small (Schoellhamer 2012).

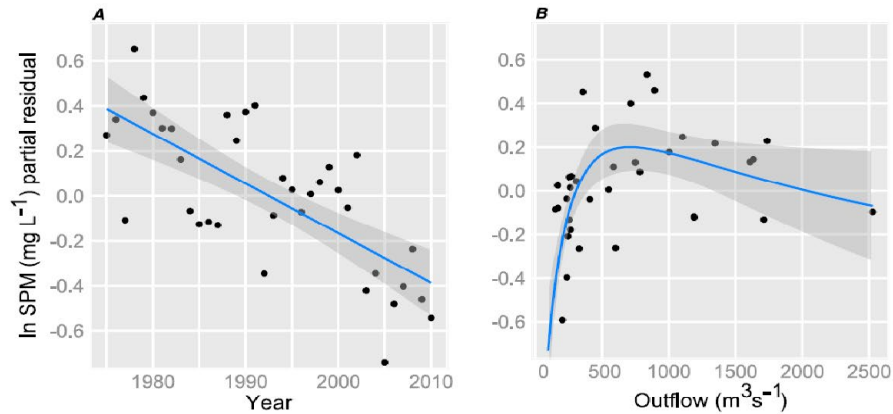


Figure 19. Partial residual plots for a regression model that accounts for variability in annual average concentration of suspended particulate matter at IEP station D8 in Suisun Bay as a result of its long-term trend (left panel) and its relationship to annual average Delta outflow (right panel). The blue lines are loess smoothers and the gray shading is the 95% confidence interval around the line. Source: Cloern and Jassby (2012).

The available catch data for delta smelt imply the species has an affinity for turbid water throughout most, if not all, of its free-swimming life (e.g., Nobriga *et al.* 2005; 2008; Feyrer *et al.* 2007; 2011; Grimaldo *et al.* 2009; Kimmerer *et al.* 2009; Mahardja *et al.* 2017a; Polansky *et al.* 2018; Simonis and Merz 2019), but there have been some recent suggestions that turbidity in the water affects the ability of fishing gears to catch delta smelt perhaps more than it is an actual habitat attribute (Latour 2016). The aquaculture techniques developed for delta smelt include rearing in black tanks under low light conditions because the fish are sensitive to highly lit circumstances (Lindberg *et al.* 2013; Hasenbein *et al.* 2016a). In addition, the tanks are circular and kept free of in-water structures. These captive rearing techniques are consistent with inhabitation of low visibility environments in the wild such as maintaining a spatial association with turbid water.

Below, we review process-based laboratory research that supports the ‘turbidity as habitat’ hypothesis. Then, we summarize long-term data on Secchi disk depths to demonstrate how water has remained relatively turbid where estuarine physics (Monismith *et al.* 1996; 2002) interacting with shallow water wind wave mixing (Ruhl *et al.* 2001; Bever *et al.* 2016) may contribute to an important refuge for delta smelt even though the biological productivity of this region has been substantially diminished (i.e., that phytoplankton currently contributes less to the turbidity than it once did). This turbid-water refuge occurs in the LSZ and is one of only two remaining in the range of the delta smelt. Turbid water may be a needed present-day habitat attribute because it provides cover for foraging delta smelt (Ferrari *et al.* 2014). By extension, it may be a factor modulating feeding success; one recent study found histopathologic evidence of elevated delta smelt feeding success in the turbid Cache Slough Complex and Suisun Marsh (Hammock *et al.* 2015); a follow-up study found elevated stomach fullness of delta smelt inhabiting the LSZ even though they were spatially disconnected from where zooplankton density was highest (Hammock *et al.* 2017). These findings are also qualitatively consistent with a more macroscopic study of the Delta’s fish assemblages that found most native fishes, including delta smelt, to be more common in lower productivity turbid habitats than higher productivity SAV habitats (Nobriga *et al.* 2005). For these reasons, the Service believes delta smelt’s association with turbid water,

which in the present state of the Bay-Delta system is mainly caused by sediment suspended in the water, is a true habitat association.

It has been shown experimentally that delta smelt larvae require particles in the water to see their transparent prey (Baskerville-Bridges *et al.* 2004). Thus, without some kind of turbidity in the water, delta smelt larvae will starve to death. Another recent laboratory study using late larval stage delta smelt found that feeding success and survival varied across a gradient of turbidity (Hasenbein *et al.* 2016a). The results implied bell-shaped response curves in which both survival and feeding success were highest at intermediate values, though the results among treatment levels were only significantly different in a few cases. A similar experiment using 120-day-old juvenile delta smelt produced different results (Hasenbein *et al.* 2013). In this experiment, the authors reported that feeding success decreased as turbidity was increased; however, their results indicate that statistically speaking, turbidity had no effect except at the highest treatment level. The highest treatment level was 250 NTU which is exceptionally turbid water. It is worth noting two things about these studies. First, the turbidity in the tanks was created using algae, which is not the dominant source of water turbidity in the estuary. Second, in the studies described by Hasenbein *et al.* (2013; 2016b), the experiments were conducted under low light conditions even when turbidity was low (~ 1 lux). In the wild, a surface-oriented fish might have the benefit of both turbidity and high light conditions similar to those that experimentally optimized successful first feeding (Baskerville-Bridges *et al.* 2004).

In another laboratory experiment, the vulnerability of delta smelt to predation by largemouth bass was lower in a circa 3 NTU treatment (again, using algae) than a clear-water treatment (Ferrari *et al.* 2014). In a DNA-based diet study of field-caught predators, the predation of delta smelt larvae was strongly affected by water turbidity (Schreier *et al.* 2016). Thus, the available evidence suggests that delta smelt require turbid water to succeed in the contemporary Bay-Delta food web.

In fish survey data, the longest-term indicator of water turbidity is Secchi disk depth measurements that for several decades have accompanied most individual net tows. Secchi disk depths are basically inverses of turbidity because the less turbid the water is, the deeper into the water column a Secchi disk remains visible. The FMWT Secchi disk depth data set summarized below dates to 1967 (Figure 20).

The Secchi disk depth information suggests the increasing water clarity trends discussed above are not uniform across the upper estuary (Figure 20). From a regional perspective, they have been most pronounced in the San Joaquin River half of the Delta where SAV proliferation has been most expansive (Feyrer *et al.* 2007; Nobriga *et al.* 2008; Hestir *et al.* 2016). Consistent with this, boxplots depicting the time series of Secchi disk depth measurements from the FMWT show the previously reported increasing trend is most pronounced when and where the Secchi disk depths were taken in fresh water (upper left panel of Figure 20). In this upper left panel for which the Secchi disk depth data were summarized only when and where salinity was lower than 1.25 ppt, the previously reported trend of increasing water transparency is apparent; median Secchi disk depths have increased from about 0.5 meters with extreme values seldom exceeding 1 meter early in the time series to medians typically exceeding 1 meter and extreme values near 4 meters in recent years. When data summaries include these freshwater samples along with

samples from the LSZ, the trend and extreme data points remain (upper right panel of Figure 20). This could lead to the erroneous conclusion that Secchi disk depths have been similarly increasing in the LSZ.

However, it is also important to consider the hydrodynamic aspect of water turbidity in the estuary. As mentioned above, X2 is a boundary upstream of which salinity tends to be the same from the surface of the water to the bottom, and downstream of which salinity varies from top to bottom (Jassby *et al.* 1995). That variability in salinity from surface to bottom waters is indicative of a front that helps to aggregate turbidity near X2. This does not mean it all aggregates precisely at X2; tidal dispersion results in a spatially complex distribution of sinking particles widely distributed in the LSZ (Kimmerer *et al.* 2014a). Thus, when the FMWT Secchi disk depth data set are constrained to brackish water samples, the long-term trend looks very different (lower panels of Figure 20). There is still an increasing trend over time, but it is much more modest. In particular, at a salinity near 2 to 5 ppt, Secchi disk depths have not consistently increased since the mid-1980s and observations exceeding 1 meter are still rare. Thus, there is a turbid water refuge for delta smelt that persists in the LSZ similar to the one that persists in the Cache Slough Complex.

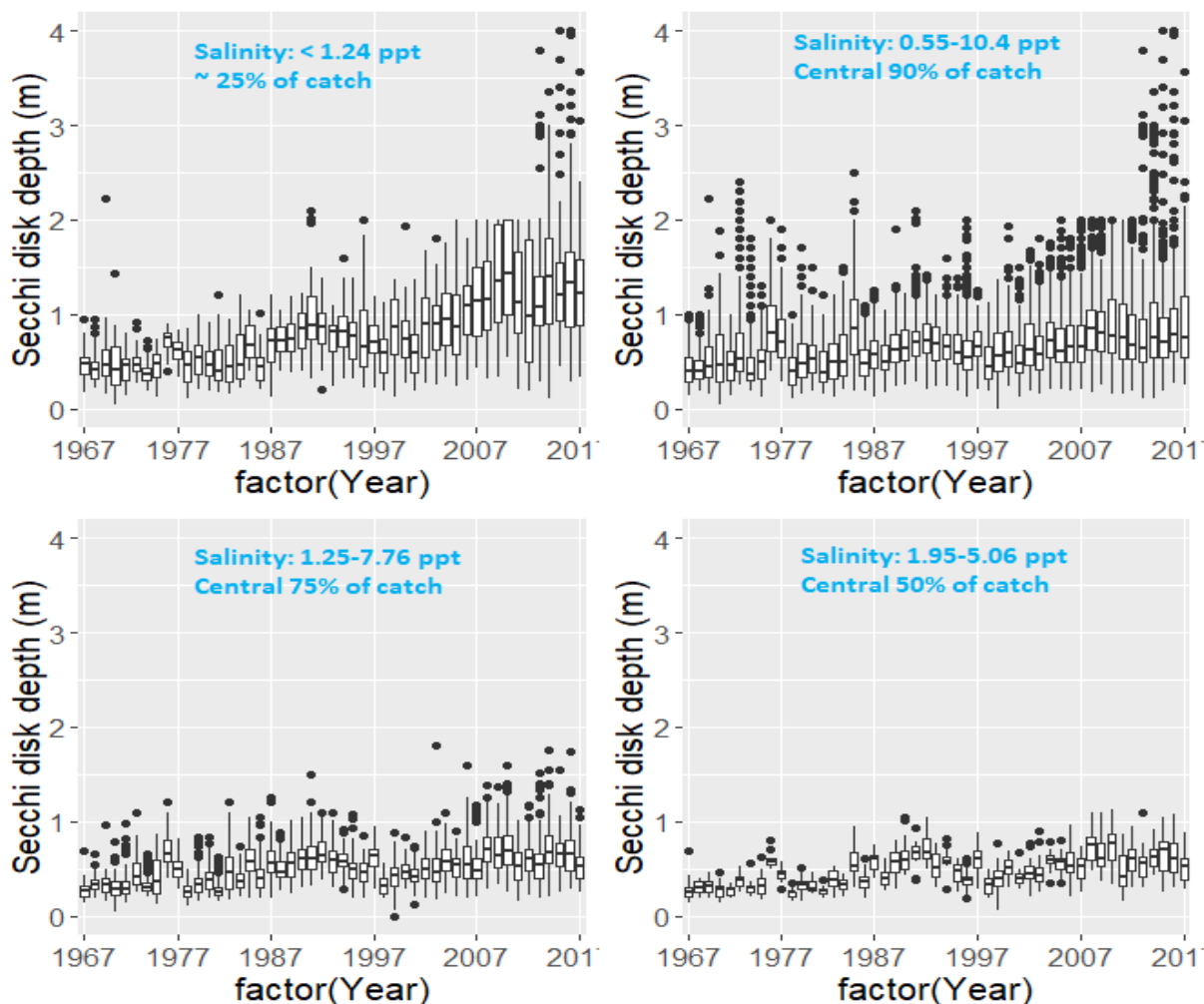


Figure 20. Boxplot time series of Secchi disk depth measurements taken during the California Department of Fish and Wildlife Fall Midwater Trawl Survey, 1967-2017. The boxes depict the central 50% of observations; the line through each box is the median. The black circles are observations outside the central 95% of observations. The data have been grouped into four salinity bins based on statistical summaries of delta smelt data (Kimmerer *et al.* 2013). The salinity range graphed is reported on each panel as is the predicted fraction of FMWT delta smelt catch. Source: Service unpublished data analysis using a specific conductance to salinity conversion described by Schemel (2001) and generalized additive model results provided by W. Kimmerer.

Water temperature: Water temperature is the primary driver of the timing and duration of the delta smelt spawning season (Bennett 2005). Water temperature also affects delta smelt's metabolic and growth rates which in turn can affect their susceptibility to contaminants (Fong *et al.* 2016), food limitation (Rose *et al.* 2013a), and readiness to spawn (Hobbs *et al.* 2007b). Water temperature is not strongly affected by variation in Delta inflows or outflows except at the margins of the Delta where these inflows enter (Kimmerer 2004). The primary driver of water temperature variation in the delta smelt critical habitat is air temperature (Wagner *et al.* 2011). Very high flows can transiently cool the upper estuary (*e.g.*, flows in the upper 10th percentile, Kimmerer 2004), but the system rapidly re-equilibrates once air temperatures begin to warm. Thus, like duration of the spawning season, other water temperature-driven mechanisms affecting recruitment and survival are not freshwater flow mechanisms.

Research initially suggested an upper water temperature limit for delta smelt of about 25°C, or 77°F (Swanson *et al.* 2000). Newer research suggests delta smelt temperature tolerance decreases as the fish get older, but is a little higher than previously reported, ranging from nearly 30°C or 86°F in the larval life stage down to about 25°C in post-spawn adults (Komoroske *et al.* 2014). These are upper *acute* water temperature limits meaning these temperatures will kill, on average, one of every two fish. Subsequent research into delta smelt's thermal tolerances indicated that molecular stress response begins to occur at temperatures at least 4°C cooler than the acute thermal maxima (Komoroske *et al.* 2015).

In the laboratory and the wild, delta smelt appear to have a physiological optimum at temperatures of about 16-20°C or 61-68°F (Nobriga *et al.* 2008; Rose *et al.* 2013a; Eder *et al.* 2014; Jeffries *et al.* 2016). Most of the upper estuary exceeds this water temperature from May or June through September (Komoroske *et al.* 2015). Thus, during summer, many parts of the estuary are energetically costly and physiologically stressful to delta smelt (Komoroske *et al.* 2014). Generally speaking, spring and summer water temperatures are cooler to the west and warmer to the east due to the differences in overlying air temperatures between the Bay Area and the warmer Central Valley (Kimmerer 2004). In addition, there is a strong water temperature gradient across the Delta with cooler water in the north and warmer water in the south. The much higher summer inflows from the Sacramento River probably explain this north-south gradient. Note that water temperatures in the north Delta near Liberty Island and the lower Yolo Bypass where summer inflows are low to non-existent, are also typically warmer than they are along the Sacramento River. This may have consequences for the survival of freshwater-resident delta smelt during comparatively warm summers (Bush 2017).

Food: Food and water temperature are strongly interacting components of the “Water” element of delta smelt critical habitat because the warmer the water, the more food delta smelt require

(Rose *et al.* 2013a). If the water gets too warm, then no amount of food is sufficient. The more food delta smelt eat (or must try to eat) the more they will be exposed to predators and contaminants.

The open-water habitat use of delta smelt is reflected in their diet composition, which is largely made up of planktonic and epibenthic crustaceans (Moyle *et al.* 1992; Nobriga 2002; Hobbs *et al.* 2006; Slater and Baxter 2014). Some of the epibenthic crustaceans discussed below (e.g., amphipods and mysids) ascend into the water column at times (Kimmerer *et al.* 2002) and are therefore available to predators foraging in the open water. A large majority of the identifiable prey of delta smelt larvae is copepods, particularly the early life stages of copepods (Nobriga 2002; Hobbs *et al.* 2006; Slater and Baxter 2014). Juvenile delta smelt feeding in the summer months also have copepod-dominated diets, but these larger individuals tend to eat adult copepods and also begin to include prey taxa in their diets that grow larger than copepods (Slater and Baxter 2014; Figure 21). The older juveniles and adults continue to prey on copepods, but have less reliance on them and greater diet diversity (Moyle *et al.* 1992; Slater and Baxter 2014; Whitley and Bollens 2014; Figures 22 and 23). All of the delta smelt's major prey taxa (e.g., copepods, amphipods) are ubiquitously distributed, but which prey species are present at particular times and locations changes from early morning to mid-day, season to season, and has changed dramatically over time (Kimmerer *et al.* 2002; Winder and Jassby 2011; Kratina *et al.* 2014). The latter two have likely affected delta smelt feeding success (Kimmerer and Rose 2018).

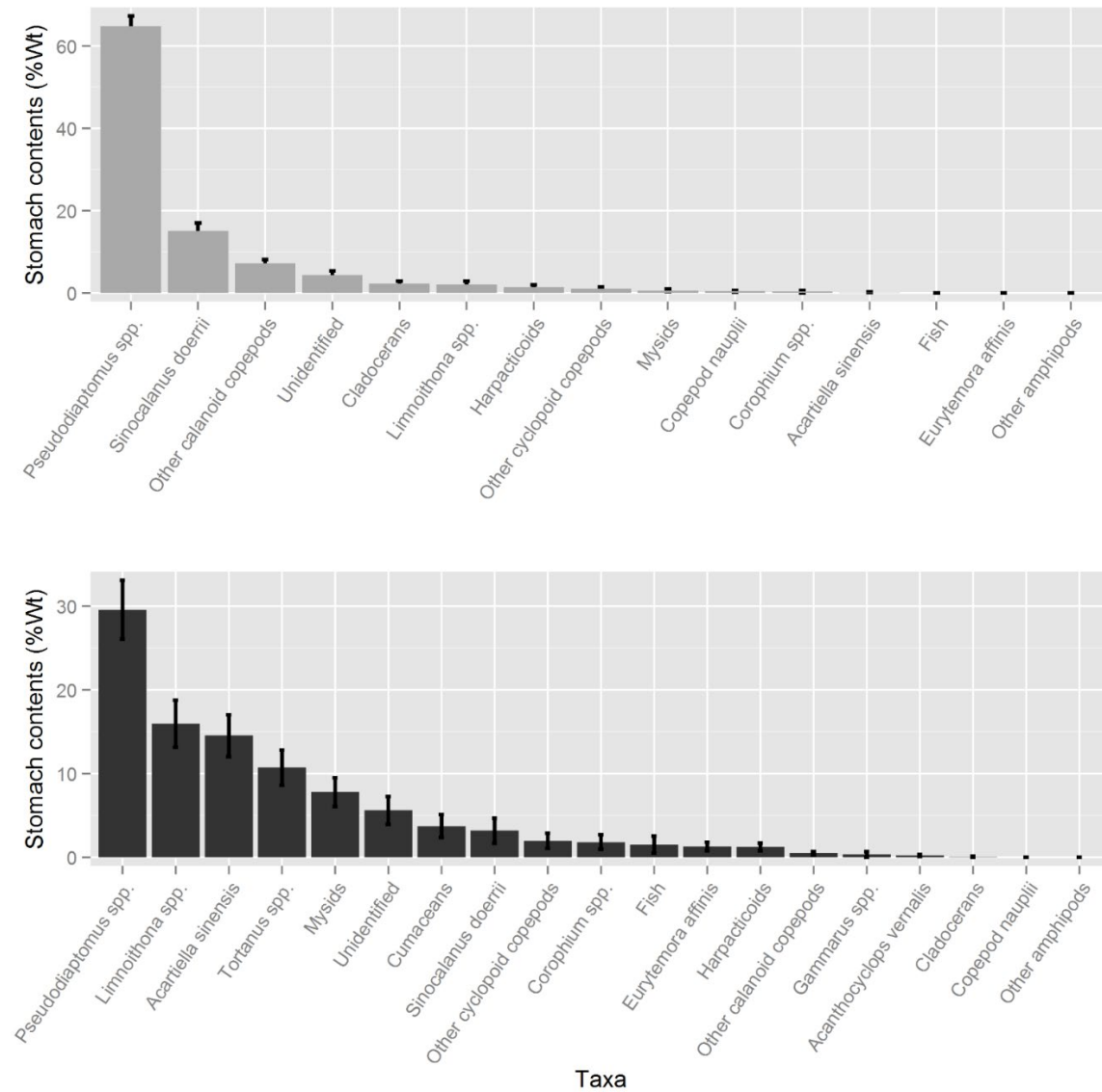


Figure 21. Diet compositions of delta smelt collected by the TNS upper panel for stations with a salinity lower than 0.55 ppt and lower panel for stations with a salinity greater than or equal to 0.55 ppt. Of the prey taxa listed on the x-axis, the ones that are *not* copepods are Cladocerans, Mysids, Corophium spp., Fish, Other Amphipods, Cumaceans, and Gammarus spp. Source: supplemental material for Hammock *et al.* (2017).

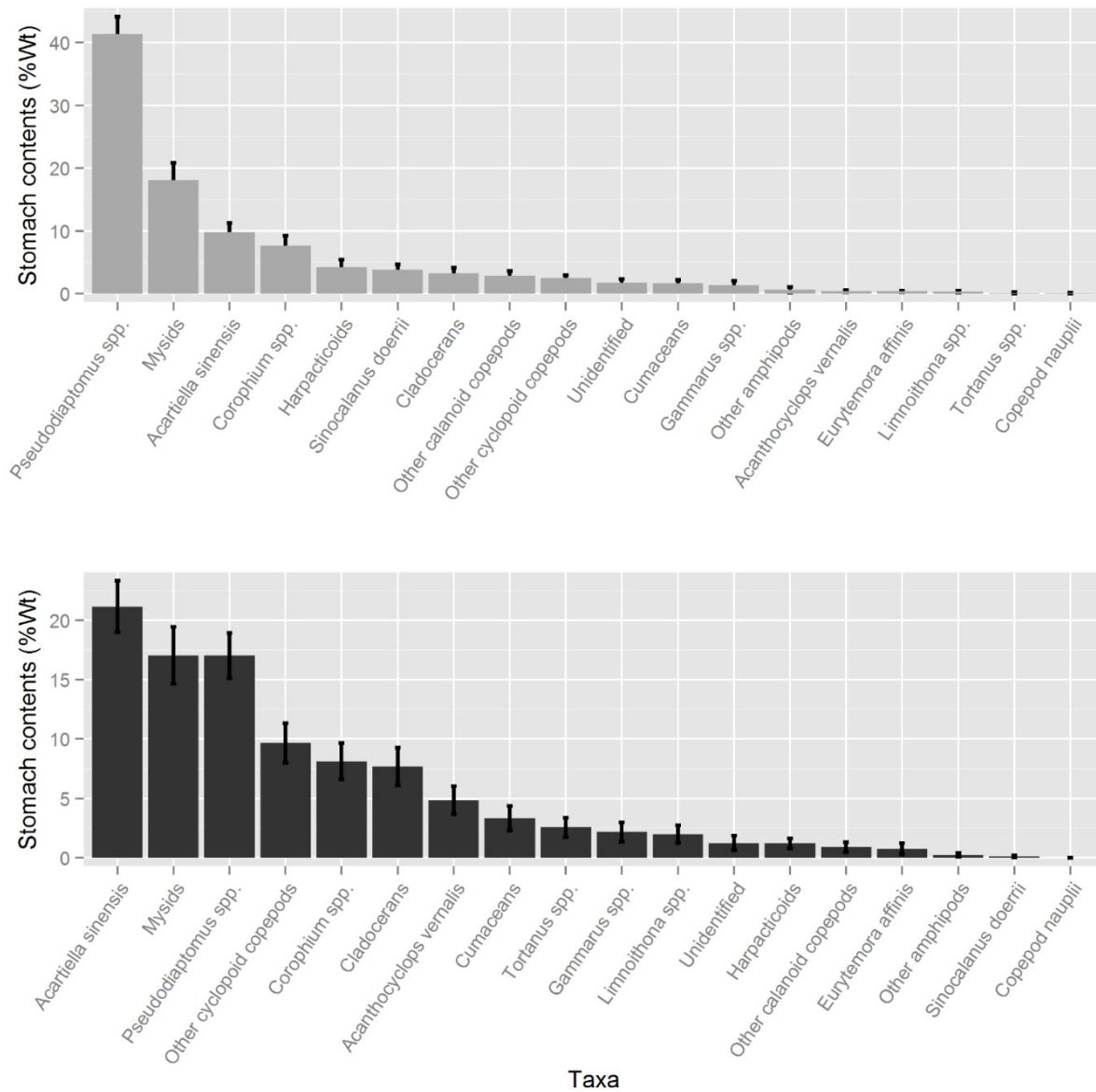


Figure 22. Diet compositions of delta smelt collected by the FMWT upper panel for stations with a salinity lower than 0.55 ppt and lower panel for stations with a salinity greater than or equal to 0.55 ppt. Of the prey taxa listed on the x-axis, the ones that are *not* copepods are Cladocerans, Mysis, *Corophium* spp., Other Amphipods, Cumaceans, and *Gammarus* spp. Source: supplemental material for Hammock *et al.* (2017).

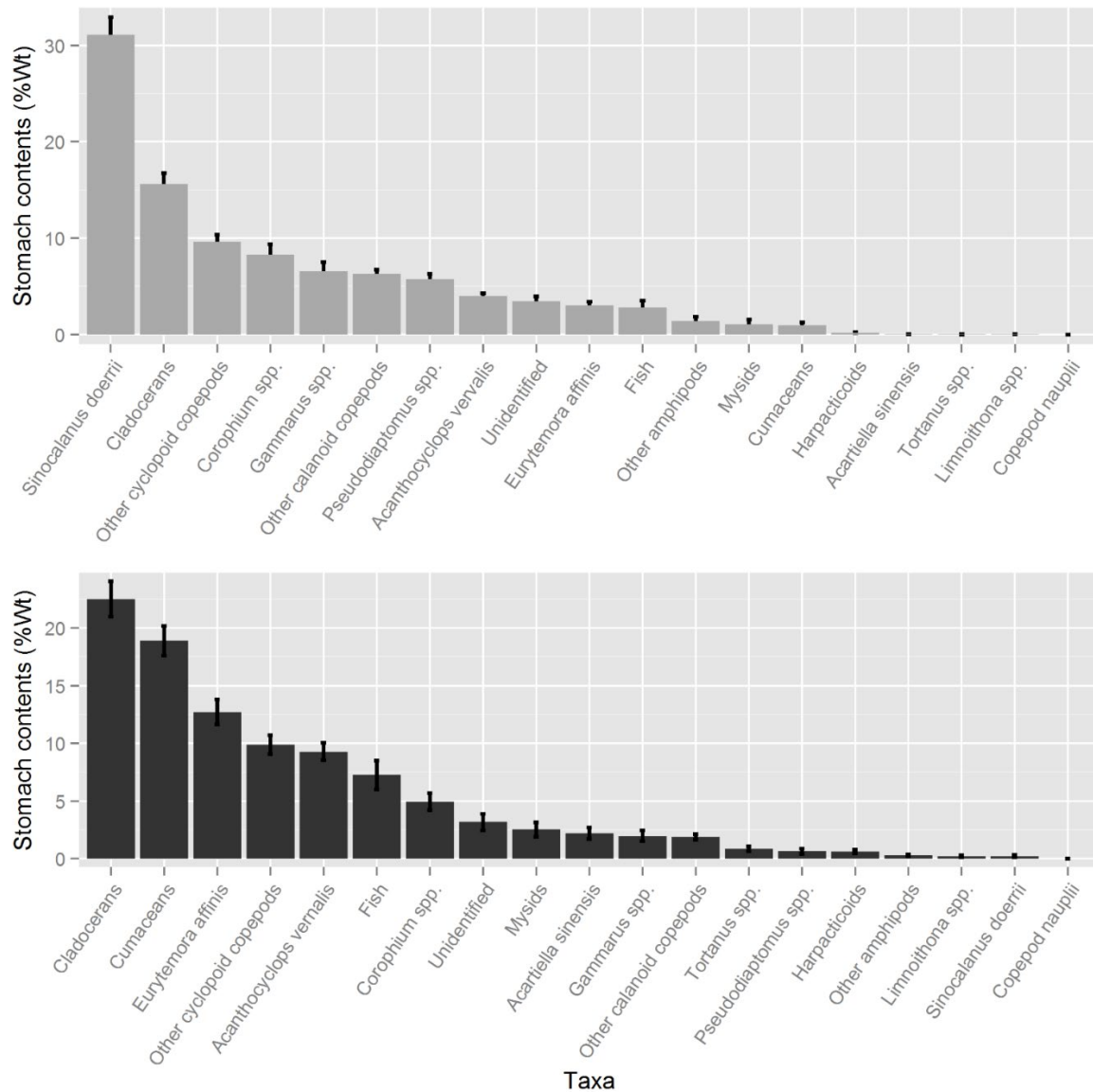


Figure 23. Diet compositions of delta smelt collected by the SKT upper panel for stations with a salinity lower than 0.55 ppt and lower panel for stations with a salinity greater than or equal to 0.55 ppt. Of the prey taxa listed on the x-axis, the ones that are *not* copepods are Cladocerans, Mysids, Corophium spp., Fish, Other Amphipods, Cumaceans, and Gammarus spp. Source: supplemental material for Hammock *et al.* (2017).

An influence of copepod production on the production of delta smelt has been a common finding in quantitative modeling research on delta smelt’s population dynamics (Mac Nally *et al.* 2010; Maunder and Deriso 2011; Miller *et al.* 2012; Rose *et al.* 2013a; Hamilton and Murphy 2018; Kimmerer and Rose 2018).

The earliest published paper on a freshwater flow influence on fish production in the Bay-Delta posited that the mechanisms producing striped bass worked primarily through the LSZ food web (Turner and Chadwick 1972). Specifically, these authors suggested that higher Delta inflow stimulated the food web that supported striped bass and increased turbidity which hid them from

their predators. Because IEP monitoring was originally set up to better understand striped bass recruitment, the IEP has monitored the pelagic food web extensively since the 1970s (Brown *et al.* 2016b).

The varied sources of primary productivity that fuel estuarine fish production are an area of active research in the Bay-Delta (Sobczak *et al.* 2002; 2005; Grimaldo *et al.* 2009; Howe and Simenstad 2011; Schroeter *et al.* 2015). As is the general case in open-water food webs of estuaries and coastal marine systems, diatoms are the dominant source of primary productivity supporting open-water fish production (Sobczak *et al.* 2002; 2005; Grimaldo *et al.* 2009). Phytoplankton-based and submerged aquatic vegetation-based food webs can be separated on the basis of stable isotopes of carbon and nitrogen, but phytoplankton-based food web paths cannot be clearly separated from pathways based on terrestrial vegetation using these isotopes (Grimaldo *et al.* 2009; Schroeter *et al.* 2015). Sulfur isotopes may provide greater ability to discern among sources within and near tidal marsh environments, but to date, have not been extensively evaluated in the Bay-Delta (Howe and Simenstad 2011). The production of littoral and bottom-feeding fishes is supported by a greater fraction of non-planktonic primary producer sources (Grimaldo *et al.* 2009; Schroeter *et al.* 2015). These non-planktonic food web pathways likely have some importance to delta smelt (Whitley and Bollens 2014; Hammock *et al.* 2019).

There may be tremendous potential for benthic and epiphytic processes to periodically subsidize delta smelt's food supply, and these subsidies may occur at critical times of need, yet such pathways remain underemphasized and understudied. It is common for estuarine amphipods to rise into the water column to relocate to newly formed depositional areas, where they feed on deposited detritus and other organic materials; their successive landward movements via repeated use of selective tidal stream transport (STST, or "tidal surfing") diminish in terms of distance of upstream travel, but ultimately place them within depositional habitats (Hough and Naylor 1992; Forward and Tankersley 2001; Naylor 2006). This behavior results in the amphipods spending a great deal of time in the water column, especially when the water is dimly lit. Being in the water column may make the amphipods more available as prey for delta smelt, but the amphipods are nevertheless energetically tied to benthic basal resources, despite their spending a great deal of time in the water column (i.e., they are still energetically tied to primary production that is bottom-associated: vascular plant detritus, phytodetritus, or benthic microalgae, as opposed to phytoplankton). Mysids, on the other hand, are harder to generalize, as some species are herbivorous, some are predatory, and some are omnivorous. They also use STST, which likely increases their availability to (adult) delta smelt (Wooldridge and Erasmus 1980; Orsi 1986). Thus, depending on mysid species, they may or may not link delta smelt to benthically driven energy pathways.

Jassby *et al.* (1993) estimated benthic microalgae to be responsible for nearly 30% of the primary production in upper San Francisco Bay, inclusive of delta smelt habitat. Light penetration has since improved as turbidity has decreased (Parker *et al.* 2012a), and so this ~30% contribution may have increased dramatically. Jassby *et al.* (1993) provided no estimate for epiphytic microalgae associated with SAV and the zones of emergent grass stems (in marshes) that are near the surface and within the photic zone. Even if the photic zone is just a few centimeters deep, these substrates, when added together, can provide very large surface areas for epiphytic production.

There are two clam species that affect phyto- and zooplankton biomass within the distribution of the delta smelt population. The freshwater *Corbicula fluminea*, which has been in the Delta and its tributary rivers since the 1940s, and the estuarine overbite clam *Potamocorbula amurensis*, which started invading the estuary in 1986 and was well-established within a year (Alpine and Cloern 1992). The freshwater clam can suppress diatom production in shallow freshwater habitats (Lucas *et al.* 2002; Lopez *et al.* 2006). However, the overbite clam appears to have a larger impact on the food web than the freshwater clam (Alpine and Cloern 1992; Jassby *et al.* 2002; Kimmerer and Thompson 2014), so the focus of this review will be on the overbite clam.

In the 1970s and early 1980s, scientists had learned that year-to-year variation in Delta inflow (or salinity at Chipps Island) - especially during the spring and summer - drove the year-to-year variation in the productivity of the low-salinity zone food web (Cloern *et al.* 1983; Knutson and Orsi 1983). In wet years, the flow brought a lot of nutrients and organic carbon into the low-salinity zone (Jassby and Cloern 2000) where it fueled food web production as Delta outflow seasonally decreased into an optimal range estimated by Cloern *et al.* (1983) to be about 100 to 350 cubic meters per second (about 3,500 to 12,400 cubic feet per second (cfs)). In dry years, elevated salinity allowed a marine clam (*Mya arenaria*) to colonize Suisun Bay and graze the diatoms down to low levels. This in turn lowered the production of the mysid shrimp (*Neomysis mercedis*), which was a key food source for several fish species, particularly striped bass (Knutson and Orsi 1983; Orsi and Mecum 1996; Feyrer *et al.* 2003). This stimulation of mysid shrimp production was one of the food web mechanisms that Turner and Chadwick (1972) had hypothesized led to higher striped bass production in higher flow years. Similar 'fish-flow' relationships were later established for longfin smelt (*Spirinchus thaleichthys*) and starry flounder (*Platyichthys stellatus*); both of these fish are also mysid shrimp predators and were shown to have step-declines in their abundance indices associated with the overbite clam invasion (Kimmerer 2002b).

The overbite clam, once established (~ 1987), resulted in a permanent source of loss to diatoms and copepods in the LSZ that resulted in rapid step-declines in the abundance of the most important historical food web components: diatoms, mysid shrimp, and *Eurytemora affinis*; the latter is a copepod that was a major prey for both the opossum shrimp (Knutson and Orsi 1983) and delta smelt (Moyle *et al.* 1992). Unlike striped bass, longfin smelt, and starry flounder, no change in delta smelt abundance occurred coincident with the establishment of the overbite clam (Stevens and Miller 1983; Jassby *et al.* 1995; Kimmerer 2002b; Mac Nally *et al.* 2010; Thomson *et al.* 2010). However, the average size of delta smelt declined somewhat (Sweetnam 1999; Bennett 2005).

Some scientists have hypothesized that the diatom decline was caused by wastewater treatment plant inputs of ammonium or changes in the ratios of dissolved forms of nitrogen that support aquatic plant growth more than by overbite clams (Glibert *et al.* 2011; Dugdale *et al.* 2012; Parker *et al.* 2012b; Wilkerson *et al.* 2015). One piece of evidence used to support this hypothesis is an observation that ammonium was frequently crossing a critical 4 micro-molar threshold concentration for diatom growth at about the same time the overbite clam became established. These researchers have established that uptake of dissolved ammonium inhibits the growth rate of diatoms in the Bay-Delta. However, diatoms can still grow on ammonium, and

actually take it into their cells preferentially over nitrate; they just grow more slowly using ammonium as their cellular nitrogen source (Glibert *et al.* 2015). This means that ‘but for’ the overbite clam, the diatom population in the LSZ would eventually build up enough biomass each year to metabolize ambient ammonium concentrations to levels below the 4 micro-molar threshold and then increase their growth rate using the nitrate that is also in the water. Thus, although nitrogen chemistry could be a problem, a more fundamental one is that as Delta outflow declines during the spring into early summer to levels that could enable diatom blooms, the water temperature is rising and that supports reproduction of the overbite clam. With help from a few other abundant grazers (Kimmerer and Thompson 2014), the growing overbite clam population depletes diatoms faster than they can metabolize the ammonium in the water. Thus, clam grazing is the fundamental reason that summer-fall diatom blooms no longer occur (Cloern and Jassby 2012; Kimmerer and Thompson 2014; Cloern 2019). During spring when Delta outflow is higher, outflow can interact with other factors to limit diatom accumulation as well (Dugdale *et al.* 2012; 2016). Note that Dugdale *et al.* (2016) suggested that available estimates of the overbite clam grazing rate were over-estimates, but this assertion has been contested (Kimmerer and Thompson 2014; Cloern 2019).

The largest source of dissolved ammonium is the Sacramento Regional Wastewater Treatment Plant. Upgrades to the facility are expected to occur in 2021-2023, which will result in reductions in dissolved ammonium concentrations in the Delta. It is scheduled to significantly reduce its nitrogen effluent concentrations beginning in 2023. Once that happens, it should become apparent within a few years how important ammonium ratios are in limiting diatom production in the Bay-Delta.

Because the overbite clam repressed the production of historically dominant diatoms and zooplankton, there were numerous successful invertebrate species invasions and changes in plant communities that followed for a decade or so thereafter (Kimmerer and Orsi 1996; Bouley and Kimmerer 2006; Winder and Jassby 2011). Changing nutrient ratios (including the forms of nitrogen and the ratios of nitrogen and phosphorus) necessary for plant growth may also have contributed to changing phytoplankton and plant communities (Glibert *et al.* 2015; Dahm *et al.* 2016). In addition, extreme drought and propagule pressure are also thought to have directly contributed to the zooplankton species changes (Winder *et al.* 2011). The most important changes for delta smelt have been changes to the copepod community. The copepod invasions of the late 1980s and early 1990s actually helped stem (but not recover the system from) what had been a major decline in copepod abundance (Winder and Jassby 2011). Prior to the overbite clam, delta smelt had diets dominated by *E. affinis* from the time the larvae started feeding in the spring until at least the following fall (Moyle *et al.* 1992). The overbite clam suppressed the production of *E. affinis* (Kimmerer *et al.* 1994; Kimmerer and Orsi 1996) and that seems to have opened the door for several non-native copepods including *Pseudodiaptomus forbesi*, which became the new main prey of delta smelt from late spring into the fall (Moyle *et al.* 1992; Nobriga 2002; Hobbs *et al.* 2006; Slater and Baxter 2014; Hammock *et al.* 2017; Figures 21 and 22).

There is general agreement among quantitative delta smelt models that the production of copepods including *P. forbesi* are important to recruitment and survival (Kimmerer 2008; Maunder and Deriso 2011; Miller *et al.* 2012; Hamilton and Murphy 2018; Kimmerer and Rose

2018; Simonis and Merz 2019). Recognition of *P. forbesi*'s importance to delta smelt led to substantial research into this non-native copepod's population dynamics (Kimmerer and Gould 2010; Sullivan *et al.* 2013; Kimmerer *et al.* 2014b; Kayfetz and Kimmerer 2017; Kimmerer *et al.* 2018a,b). The delta smelt's primary historical prey (*E. affinis*) bloomed from within the LSZ and had peak abundance near X2 (Orsi and Mecum 1986). This copepod still blooms each spring, but disappears by summer due to overbite clam grazing (Kimmerer *et al.* 1994). The same thing happens to *P. forbesi* in the LSZ (Kayfetz and Kimmerer 2017). However, the *P. forbesi* population survives the summer because its center of reproduction is in freshwater habitats landward of the LSZ. It would disappear from the LSZ altogether were it not for a constant replenishment (or subsidy) from upstream where the overbite clam and a predatory non-native copepod are less abundant. It is the combination of tidal mixing and Delta outflow that seems to provide this subsidy (Kimmerer *et al.* 2018a,b). Thus, this subsidy of *P. forbesi* to delta smelt inhabiting the turbid water refuge of the LSZ appears to be of substantial importance – particularly during the summer and fall.

The most obvious test of whether the overbite clam affected delta smelt is a before-after comparison. As mentioned above, this has been tested several times and no obvious effect like the ones reported for striped bass, longfin smelt, and starry flounder has been established. Rather, the first big decline in delta smelt abundance occurred prior to the overbite clam invasion and the second one about 15 years afterward. Thus, if copepod production limits delta smelt production, it is either a part-time limit (e.g., Hamilton and Murphy 2018), or (a) it was a limiting factor prior to the overbite clam, and (b) it did not become a further limit until sometime thereafter. These are not mutually exclusive hypotheses.

Contaminants: Research conducted over the past 10 years suggests that delta smelt are fairly susceptible to contaminants (e.g., Connon *et al.* 2009; 2011a,b; Hasenbein *et al.* 2014; Jeffries *et al.* 2015; Jin *et al.* 2018). The effects of ambient Sacramento River water, pyrethroid pesticides, several herbicides, copper, and ammonium have all been examined and all of these compounds have shown at least sub-lethal effects represented by changes in gene expression. In some cases, delta smelt were exposed to higher than observed concentrations of some compounds in order to estimate their LC₅₀, the estimated concentration that kills half of the test fish over the study duration. Exposure durations have varied widely among studies (4 hour to 1 week), which limits the ability to quantitatively compare toxicity among studies. The loading of some contaminants into the habitats occupied by delta smelt can be functions of freshwater flow inputs (e.g., Kuivila and Moon 2004; Weston *et al.* 2014; 2015) so in some instances, the impacts of contaminants can be freshwater flow mechanisms. However, the impacts of others may be related to where individuals are located (Hammock *et al.* 2015), what delta smelt eat, or water temperature-based demand for prey, all of which could affect the quantities of biomagnifying substances that get ingested over the life span of the fish.

PCE #3: “River flow” was originally believed to be critical as transport flow to facilitate an extended spawning migration by adult fish and the transport of offspring to LSZ rearing habitats (Service 1994). However, it has since been shown that although some individual fish may embark on what could be considered a short spawning migration, there is no population-scale spawning migration *per se*, and that most transport and retention mechanisms for delta smelt (and their prey) involve the selective use of tidal currents rather than net flows (Kimmerer *et al.*

1998; 2002; Bennett *et al.* 2002; Kimmerer *et al.* 2014a; Bennett and Burau 2015). River flow includes both inflow to and outflow from the Delta, both of which influence the net movements of water through the Delta and further into the estuary (Kimmerer and Nobriga 2008). As mentioned above, these variations in freshwater flow affect the spatial distribution of salinity including X2, which in turn exert some influence on the distribution of delta smelt (Sweetnam 1999; Dege and Brown 2004; Feyrer *et al.* 2007; Nobriga *et al.* 2008; Sommer *et al.* 2011; Manly *et al.* 2015; Polansky *et al.* 2018; Simonis and Merz 2019).

Net water movements in the Delta have recently been reconstructed and analyzed for long-term trend attribution (Hutton *et al.* 2019; Figure 24). This analysis demonstrated several net flow variables have experienced strong time trends since water exports from the Delta began. In particular, cross-Delta flows have increased during the summer and fall, Rio Vista flows have decreased in the winter and spring and increased in the summer, Jersey Point flow and Old and Middle river flow (OMR) have decreased year-around. The change attribution indicated that CVP and SWP operations were predominantly the source of these net flow changes except for Jersey Point flow in the spring, which is also strongly influenced by in-Delta irrigation demand. The net flow changes ultimately influence Delta outflow, which as discussed above, has been trending downward for more than 100 years.

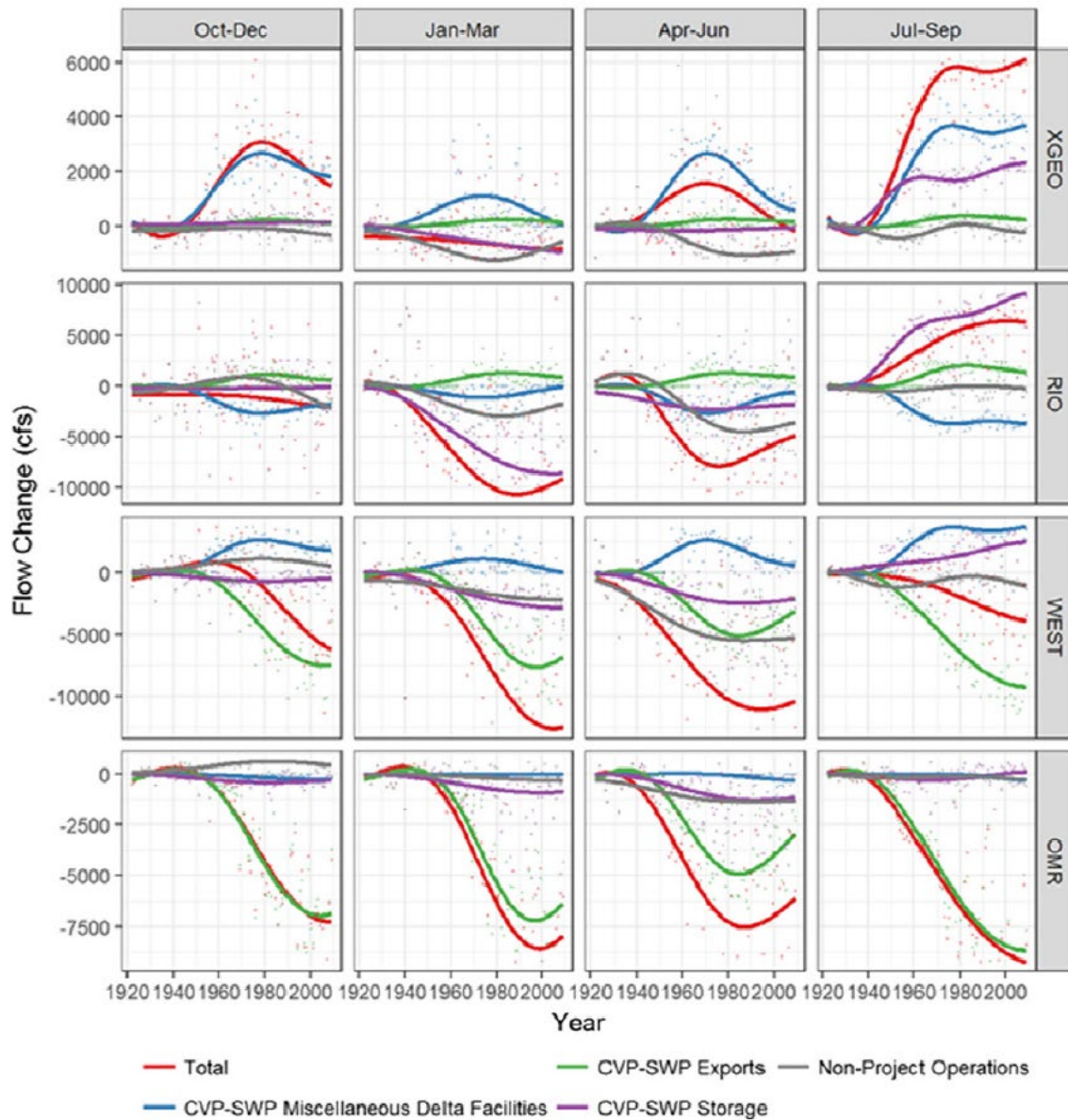


Figure 24. Time series (1922-2009) of statistical trend outputs of annual cross Delta flows (XGEO), net flow at Rio Vista (RIO), net flow at Jersey Point on the San Joaquin River (WEST), and net flow in Old and Middle rivers (OMR). For XGEO net north to south flows have positive values. For RIO and WEST, net seaward (downstream) flows have positive values. For OMR, which seldom has positive values, net north to south flows are depicted as negative values. The colored lines reflect the statistical trend in the time series with the different colors reflecting the relative contributions of the sources listed in the legend. Source Hutton *et al.* (2019).

A concise summary of the contemporary Delta outflow hydrograph is shown in Figure 25. A value on the y-axis of 0.5 suggests that an outflow on a given day has had an equal chance of being at least as high as one or in some cases all three of the chosen thresholds. Delta outflow at least as high as the Roe Island standard freshens the estuary enough for delta smelt to spawn in typically brackish regions like the Napa River and western Suisun Marsh, and tends to reduce the likelihood of entrainment. Delta outflows at least as high as the Chipps Island standard tend to

generate LSZ coverage throughout much or all of Suisun Bay. Outflows near the Collinsville standard are associated with a typical X2 slightly upstream of the confluence of the Sacramento and San Joaquin rivers with low-salinity conditions extending into, but not throughout Suisun Bay and marsh. The water management response to D-1641 has been to increase the intra-annual variability in outflows. The greater intra-annual variability is related to the more frequent meeting of these flow thresholds in the winter and spring as required by D-1641, with lower frequency in the fall. This pattern is especially pronounced for outflows greater than or equal to 7,100 cfs (“Collinsville”) and 11,400 cfs (Chippis Island; Figure 25). The same pattern is visible for 27,200 cfs (“Roe Island”; Figure 25), but with less change (mainly days 100-150 and 325-350, which correspond to April and the November-December transition). This does more closely mimic the timing and duration of the natural Delta outflow hydrograph than occurred during the 1968-1994 period, though the magnitude is considerably lower as discussed above (Figures 10, 14, and 15). Note that the DAYFLOW calculations used to make Figure 25 can be highly uncertain at values lower than about 10,000 cfs (Monismith 2016).

The tidal and net flow of water toward the south Delta pumping plants is frequently indexed using OMR (Grimaldo *et al.* 2009; Andrews *et al.* 2017; Figure 24). The tidal and net flows in Old and Middle rivers influence the vulnerability of delta smelt larvae, juveniles, and adults to entrainment at the Banks and Jones facilities (Kimmerer 2008; 2011; Grimaldo *et al.* 2009). Currently available information indicates that OMR is a very good indicator of larval delta smelt entrainment risk (Kimmerer 2008; 2011). When the fish reach the juvenile stage, they can leave the south Delta to avoid adverse water temperatures (Kimmerer 2008). When maturing adults disperse the following winter, their advection into the south Delta can be affected by OMR flow, but turbidity is also an important mediator of their entrainment risk (Grimaldo *et al.* 2009). The Service’s experience, particularly since 2008, is that the risk of seeing entrained fish in CVP or SWP fish salvage is low if south Delta turbidity remains less than 12 NTU.

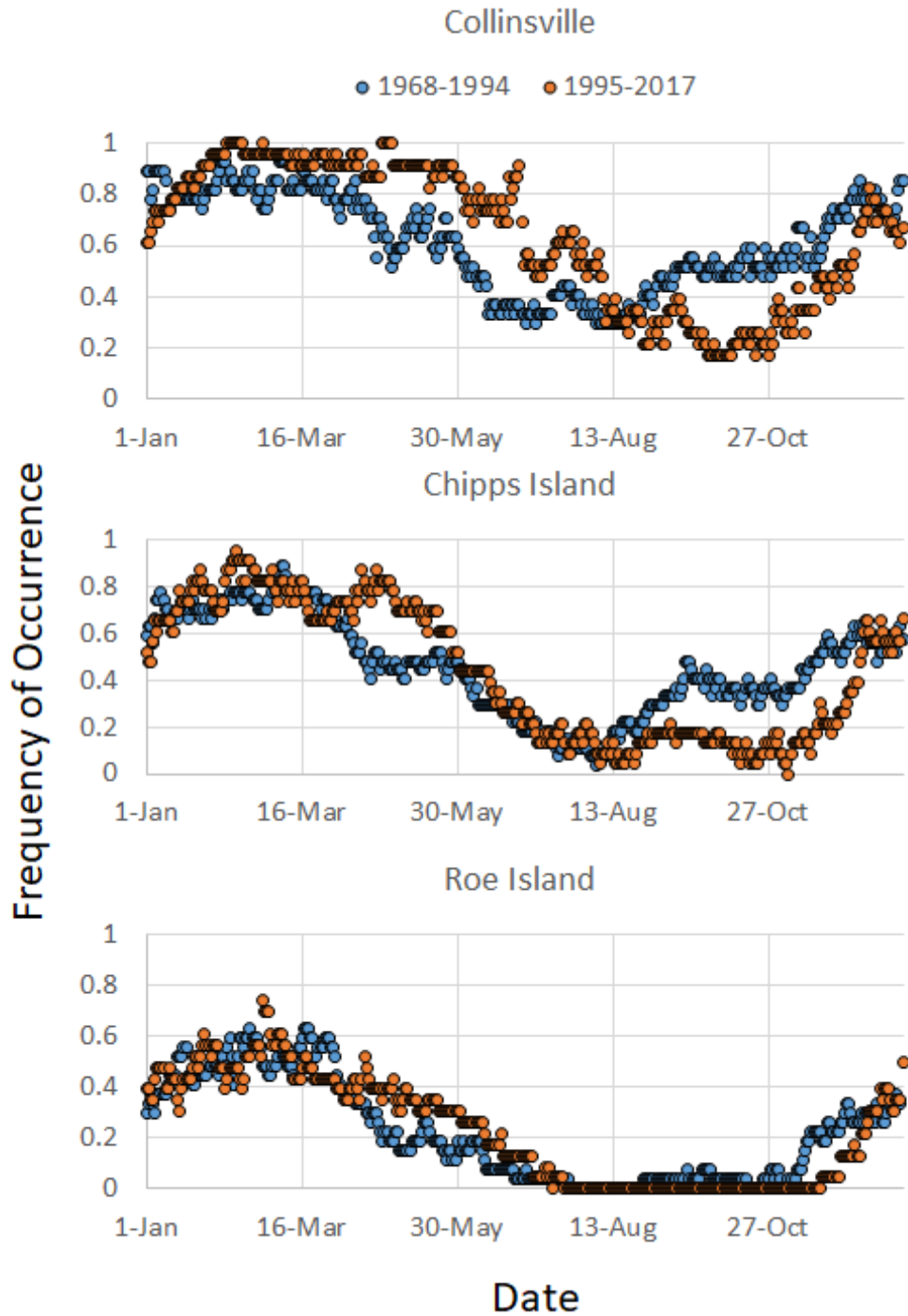


Figure 25. Daily frequency that the Net Delta Outflow Index (NDOI) was at least as high as the steady-state thresholds for the D-1641 ‘X2 standard’ for January 1 to December 31, 1968-1994 (pre-Bay Delta Accord; blue symbols) and 1995-2017 (post Bay Delta Accord; orange symbols). The X2 standards outlined in the Bay Delta Accord were adopted into D-1641. The steady-state NDOI thresholds used to calculate the frequencies were Roe Island $\geq 27,200$ cfs, Chipps Island $\geq 11,400$ cfs, and Collinsville $\geq 7,100$ cfs. For reference, a frequency of 0.5 means an NDOI at least as high as the threshold occurred half of the time on a given day. Note that this plot is intended to provide a concise view of the seasonality of Delta outflow. It is not intended

to reflect anything about compliance or non-compliance with D-1641, which can be based on Delta outflow, salinity, or X2. Source: Service unpublished analysis of the DAYFLOW database.

PCE #4: “Salinity”. Fish assemblages are able to lessen competition among species and life stages by partitioning habitats. For instance, some fish species and life stages are more shoreline oriented whereas others are more offshore oriented. Some species are better adapted to midwater or surface waters, while others are more adapted to stay close to the substrate. Some fish are tolerant of turbidity, while others are not. In estuaries, salinity is often a dominant factor separating different groups of fishes (e.g., Bulger *et al.* 1993; Edgar *et al.* 1999). Similarly, in the Bay-Delta, dominant fishes replace one another at several places along the salinity gradient (Feyrer *et al.* 2015).

Delta smelt is part of the fish assemblage that uses the low-salinity waters of the estuary (Kimmerer *et al.* 2009; 2013). Thus, the Primary Constituent Element “Salinity” helps define its nursery habitat (Service 1994). Freshwater flow into the estuary, and Delta outflow in particular, is the most significant mechanism affecting the salinity distribution of the estuary (Jassby *et al.* 1995; MacWilliams *et al.* 2015). Thus any recruitment or survival mechanisms that change in intensity as functions of salinity, or where particular ranges of salinity are distributed, are ultimately freshwater flow mechanisms (see Kimmerer 2002a). As discussed above, these may include the spatial extent of spawning habitat (Hobbs *et al.* 2007a), the availability of low velocity water refuges that remain turbid (Bever *et al.* 2016), and population-scale entrainment in water diversions (Kimmerer and Nobriga 2008; Kimmerer 2008). Some contaminant exposure and dilution mechanisms are also related to changes in freshwater flow inputs. For instance, the toxicity of water in creeks flowing into Suisun Marsh and the Delta can increase when storms increase flows that mobilize contaminated sediment (Weston *et al.* 2014; 2015). At a larger spatial-temporal scale, water toxicity varies regionally and seasonally, and may on average, be higher in years with low winter-spring inflows (Werner *et al.* 2010).

Initial research indicated that delta smelt have an upper acute salinity tolerance of about 20 ppt (Swanson *et al.* 2000) which is about 60% of seawater’s salt concentration of 32-34 ppt. Newer research suggests that some individual delta smelt can acclimate to seawater, but that about one in three juveniles and one in four adults die within a few days if they are rapidly transitioned from low-salinity water to marine salinity water (Komoroske *et al.* 2014). The survivors can live for at least several weeks in seawater, but lose weight (Komoroske *et al.* 2014; 2016). This clear evidence of physiological stress for delta smelt exposed to seawater has not been observed at lower salinity challenges – including salinities as high as 18-19 ppt. Different molecular responses have been observed, particularly at salinities higher than 6 ppt (Komoroske *et al.* 2016). These different molecular responses may reflect physiological stress, but this is not certain. There are currently several published studies that have examined aspects of delta smelt physiology at salinities in the 12-19 ppt range; none have found obvious evidence of an inability of the delta smelt to adjust its physiology to handle salinity in this range (Komoroske *et al.* 2014; 2016; Kammerer *et al.* 2016; Davis *et al.* 2019).

These findings are interesting because peak catches of early life stage wild delta smelt have occurred in fresh- or very low-salinity water and peak catches of juvenile and sub-adult fish have

occurred at salinities that typify the LSZ. This contrast between where most wild delta smelt have been collected and what laboratory research indicates they can tolerate suggests one of three things. One possibility is there is a persistent laboratory artifact, though we are not aware of what such an artifact would be. A second possibility is that the analyses that have been done to date may not have accounted for change through time that has covaried with declining catches. For instance, in a recent analysis of the SKT Survey, Castillo *et al.* (2018) found that when salinity was higher during sampling (i.e., during periods of low outflow) delta smelt and other fishes were collected from a higher mean salinity. The third possibility is that a discrepancy between field salinity distribution and laboratory results may be evidence that delta smelt's distribution along the estuary salinity gradient is due to a factor or factors other than salinity *per se*. Historically, delta smelt's prey were most abundant in the LSZ, but that has not been the case for more than 30 years. One explanation that may better align with recent laboratory research is that turbidity is the more important physical habitat attribute. Relatively turbid waters occur as a mobile front within the LSZ (Figure 20), occur regularly in Grizzly and Honker bays (Bever *et al.* 2016), and the Cache Slough complex (Sommer and Mejia 2013), all of which are places delta smelt have frequently been collected. This could mean that hiding from predators or minimizing competition are the more relevant drivers of delta smelt distribution. The Service has permitted the use of cultured fish enclosures placed along the estuary salinity gradient to explore this possibility.

The Service used the FMWT data to re-evaluate delta smelt salinity distribution and included equivalent data for five other open-water species to provide context. We analyzed the data separately for pre- and post-overbite clam eras given the large changes in food web function and fish distribution that occurred following its invasion (e.g., Kimmerer 2002b; Kimmerer 2006). To generate Figure 26, we converted the specific conductance data recorded during FMWT sampling to salinity using the equation provided by Schemel (2001) and created salinity bins spanning 1 ppt. We normalized the catch of each species each year relative to salinity so that years of high abundance would not contribute to the results more than years of low abundance. We did this by setting each year's maximum catch of each species to one, and converting smaller catches to fractions of these annual maxima. We then summarized the results with boxplots that show the interannual variability in normalized catch relative to the salinity gradient. Note that catch data were converted to biomass estimates before normalizing.

Of the species summarized in Figure 26, the delta smelt showed the smallest change in distribution relative to salinity after the overbite clam invasion. This is partly because delta smelt is the only one that has never been recorded at a salinity higher than about 20 ppt, which is consistent with previous field data summaries and the laboratory results reviewed above. There are small modes in delta smelt biomass in the LSZ and a general tapering off (with occasional exceptions in particular 1 ppt bins) out to 20 ppt. The northern anchovy data show the skew toward more marine waters that was described by Kimmerer (2006). Longfin smelt and age-0 striped bass had a more even distribution relative to salinity after the overbite clam than they did before. In contrast, American shad had a relatively even distribution across the salinity gradient before the overbite clam, but its distribution has been skewed into somewhat fresher water since. Threadfin shad appear to have greater relative use of the LSZ since the overbite clam, and perhaps higher salinity water more generally. Collectively, these data suggest some re-distribution of the upper estuary fish assemblage has occurred since the 1980s. We note that

because mean salinity of the FMWT sampling grid has increased as well (Feyrer *et al.* 2007; 2011) some of these changes may also reflect that trend (e.g., northern anchovy, longfin smelt, striped bass, and threadfin shad). In contrast, the shift toward fresher water by American shad and the lack of major change by delta smelt suggest these species' spatial distribution has changed – if it had not, they would be distributed in more saline water like the other four species. For delta smelt, this distribution shift to the east is consistent with what has been reported previously (Feyrer *et al.* 2007; 2011; Sommer *et al.* 2011; Sommer and Mejia 2013).

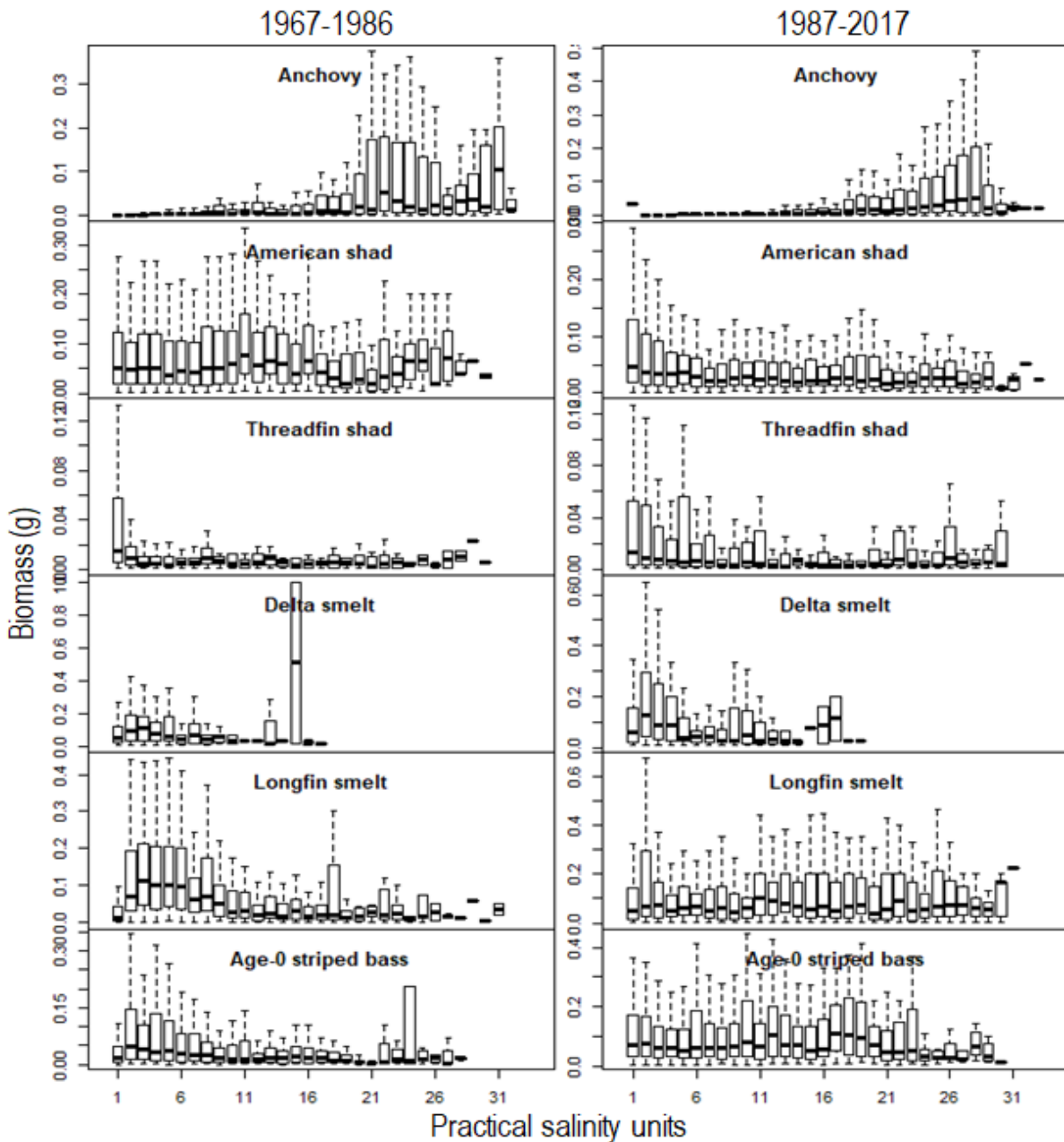


Figure 26. Salinity distributions of Fall Midwater Trawl catch for six pelagic San Francisco Estuary fishes, summarized by pre-overbite clam invasion years (1967-1986) and post-invasion years (1987-2017). Each Fall Midwater Trawl sample was associated with a specific conductance measurement, which was converted to

practical salinity units. Annual frequencies of positive catches for each species, binned into one salinity unit increments, were divided by the total positive catch for each year-species combination, to yield proportional positive catch by salinity. Proportions represented annual distributions along the salinity gradient. Within each salinity bin and across years, the distributions of proportional catches were summarized with boxplots.

Summary of Status of Delta Smelt Critical Habitat

The Service's primary objective in designating critical habitat was to identify the key components of delta smelt habitat that support successful completion of the life cycle. The delta smelt's critical habitat is currently not adequately serving its intended conservation role and function because there are very few locations that consistently provide all the needed habitat attributes for larval and juvenile rearing at the same times and in the same places (Table 6). The Service's review indicates it is rearing habitat that remains most impacted by ecological changes in the estuary, both before and since the delta smelt's listing under the Act. As described above, those changes have stemmed from chronic low outflow, changes in the seasonal timing of Delta inflow, and lower flow variability, species invasions and associated changes in how the upper estuary food web functions, declining prey availability, high water temperatures, declining water turbidity, and localized contaminant exposure and accumulation by delta smelt.

Table 6. Summary of habitat attribute conditions for delta smelt in six regions of the estuary that are permanently or seasonally occupied in most years.

	Landscape	Turbidity	Salinity	Temperature	Food
Montezuma Slough	Appropriate	Appropriate	Appropriate <i>when outflow is sufficient, or when the Suisun Marsh Salinity Control Gates are operated to lower salinity</i>	Usually appropriate	Appropriate
Suisun Bay (including Honker and Grizzly bays)	Appropriate except in shipping channel	Usually appropriate	Appropriate <i>when outflow is sufficient</i>	Usually appropriate	Depleted
West Delta	Limited area 4 to 15 feet deep	Marginal, declining	Appropriate	Can be too high during summer	Depleted
North Delta (Cache Slough region)	Appropriate	Appropriate	Appropriate	Can be too high during summer	Appropriate, but associated with elevated contaminant impacts
Sacramento River above Cache Slough confluence	Limited area 4 to 15 feet deep; swift currents	Marginal except during high flows, declining	Appropriate, but possibly lower than optimal	Usually appropriate	Likely low due to swift currents and wastewater inputs

South Delta	Appropriate except too much coverage by submerged plants	Too low	Appropriate	Too high in the summer	Appropriate
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Environmental Baseline

Environmental baseline refers to the condition of the listed species or its designated critical habitat in the Action Area, without the consequences to the listed species or designated critical habitat caused by the proposed action. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the Action Area, the anticipated impacts of all proposed Federal projects in the Action Area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process. The consequences to listed species or designated critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the *Environmental Baseline*.

Delta Smelt

The proposed project has been implemented yearly since 1991 and occurs within the south Delta and San Joaquin River within the range of delta smelt and in designated critical habitat. As detailed in the Status of the Species section of this biological opinion, the delta smelt abundance is at its historical low. Delta smelt have been collected as far up the San Joaquin River as Mossdale and the Service’s Delta Juvenile Fish Monitoring Program beach seine has occasionally collected delta smelt in the vicinity of the head of Old River. The Service considers delta smelt that ascend this far up the San Joaquin River system to be entrained and as such, not functionally contributing to the next generation of fish. Not all entrained delta smelt die in water diversions because many are eaten by predators or otherwise perish in the poor quality habitat of the southern Delta’s flooded islands (Franks Tract, Mildred Island) and canals with net reverse flows (Old and Middle river) before they reach the fish facilities. Some of these ‘entrained’ fish may even have the opportunity to spawn, but Particle Tracking Modeling shows their larvae would seldom have a hydrodynamic opportunity to escape the south Delta (Kimmerer and Nobriga 2008). In addition, most delta smelt that reach the CVP and SWP intakes are eaten by predators before they can be salvaged (Castillo *et al.* 2012). Delta smelt are seldom collected anywhere in the southern Delta beyond June due to entrainment, increasing water temperature (Kimmerer 2008; Service 2008), and increasing sensitivity to high transparency water as they metamorphose into juveniles (Nobriga *et al.* 2008).

Although the barrier locations are in areas with relatively poor habitat conditions for delta smelt, migrating and spawning adult delta smelt may be present in the Action Area during the construction of the rock barriers as construction activities in May occur immediately after the peak of delta smelt spawning. Juvenile and larval delta smelt could also be affected by the

construction activities associated with the TBP, but as described above these fish are in the entrainment zone for the CVP and SWP and likely lost to the population. Delta smelt (all life stages) are not expected to be present in the Action Area at the time of barrier removal.

As discussed in the *Status of the Species* section, delta smelt abundance is historically low and continues to trend downward with the exception of the 2021-2022 and 2022-2023 brood stock experimentally released fish.

California is currently in a multi-year drought. Over several months in 2021, Reclamation and DWR operated the CVP and SWP under a Temporary Urgency Change Petition (TUCP) to allow relaxation of D-1641 water quality standards. A rock barrier was installed at West False River in June 2021 and was in place until November 2022. In April 2022, Reclamation and DWR began operating under a TUCP for spring 2022 CVP and SWP operations. Construction of barriers and reduced water quality as a result of drought likely contribute to the decline of the wild population and may negatively affect the experimentally released fish and their progeny. The January 2023 storms resulted in high turbid outflow and increased water supply, but most of the state remains in drought status. A separate TUCP approved February 21, 2023, resulted in reduced Delta outflows for a brief period in late February and early March. This TUCP was modified due to improved hydrologic conditions on March 9th, 2023.

Delta Smelt Critical Habitat

The proposed project is within the delta smelt's designated critical habitat and contains some of the Primary Constituent Elements described in the critical habitat designation, but quality and amount vary depending on conditions as discussed in the *Status of the Critical Habitat* section.

Effects of the Proposed Action

Effects of the action are all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action. A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. *Effects of the action* may occur later in time and may include consequences occurring outside the immediate area involved in the action.

Delta Smelt

Construction

The construction of the barriers may result in annual adverse effects from increased turbidity, increased underwater noise, physical habitat modification, and creation of temporary predator habitat; however, these effects are expected to be minor. Few delta smelt are expected to be in this area during construction. Sound data taken during installation of the rock barriers showed that noise levels at 100 meters from construction were generally below the NMFS criteria for adverse behavioral effects as noted in Table 15 in the biological assessment. The effects of noise on fish would likely be limited to avoidance behavior in response to movements, noises, and shadows caused by construction personnel and equipment operating in or adjacent to the water

body and most fish are expected to move away from the area of disturbance. The effects would be temporary (from 5 to 34 days for barrier installation and a similar duration for barrier removal, depending on the barrier and whether or not culverts are installed; sediment removal would add no more than 14 additional days, if necessary). Culvert replacement is only needed once every 10–15 years. Only delta smelt that may be present in a very small channel area would be disturbed or affected by construction and implementation of the measures described in the *Conservation Measures* would avoid or minimize adverse effects.

Habitat

The installation of the agricultural barriers directly impacts approximately 58,500 square feet of channel bottom (1.34 acres). The ORT barrier has a footprint of approximately 250 feet by 60 feet (15,000 square feet; 0.34 acre), and the GLC barrier has a footprint of 300 feet by 100 feet (30,000 square feet; 0.69 acre). The MR barrier has the smallest footprint of the agricultural barriers, measuring 270 feet by 50 feet (13,500 square feet; 0.31 acre). The channel bottom is occupied by the three agricultural barriers for approximately 7 months (May through November). The barrier footprints are the historical site of the TBP and have been repeatedly disturbed for several years. Sediment removal at the barrier sites, if necessary, would temporarily disturb (up to 14 days) a maximum substrate area at each barrier site up to 2.73 acres (GLC barrier) but result in a semi-permanent impact for a total of 4.07 acres of habitat disturbance.

Delta Smelt Critical Habitat

The overall effects of construction, operation, and removal on critical habitat would be minimal. Approximately 1.34 acres of potential spawning substrate (PCE #1) would be lost for up to 7 months per year but during a time when most spawning has already occurred and in an area where smelt are unlikely to spawn to due conditions mentioned in the *Status of the Species and Critical Habitat* sections. An additional 2.73 acres of substrate could be modified if sediment removal is required. Disturbance of the substrate during construction, sediment removal, and removal would potentially increase turbidity and contaminant concentration in the water column and to water (PCE #2) but would be temporary and localized. Localized river flow (PCE #3) in the Action Area would be altered from installation and depends on CVP and SWP operations (not discussed in this biological opinion). The Service does not anticipate effects to salinity (PCE #4).

Cumulative Effects

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

Adverse effects to delta smelt and delta smelt critical habitat may result from point and non-point source chemical contaminant discharges within the Action Area. These contaminants include but are not limited to ammonia and free ammonium ion, numerous pesticides and herbicides from agricultural activities, and oil and gasoline product discharges. Oil and gasoline product

discharges may be introduced into Delta waterways from shipping and boating activities and from urban activities and runoff. Implicated as potential stressors, these contaminants may adversely affect fish reproductive success and survival rates.

Conclusion

After reviewing the current *Status of the Species* status for the delta smelt and its critical habitat, the *Environmental Baseline* for the Action Area, the *Effects of the Proposed Action*, and the *Cumulative Effects*, it is the Service's biological opinion that the South Delta Temporary Barriers Project, as proposed, is not likely to jeopardize the continued existence of the delta smelt and is not likely to destroy or adversely modify delta smelt critical habitat. The Service reached this conclusion because the project-related effects to the species, when added to the *Environmental Baseline* and analyzed in consideration of all potential *Cumulative Effects*, will not rise to the level of reducing the likelihood of survival or recovery of these species and will not rise to the level of precluding the function of the delta smelt's critical habitat to serve its intended conservation role for the species based on the following: (1) low likelihood of delta smelt occupying the Action Area during construction and removal; (2) poor baseline habitat conditions; and (3) implementation of the proposed *Conservation Measures* intended to reduce and minimize project effects to delta smelt and its critical habitat.

INCIDENTAL TAKE STATEMENT

Section 9 of the Act and Federal regulation pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm in the definition of "take" in the Act means an act which actually kills or injures wildlife. Such [an] act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering (50 CFR 17.3) Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not the purpose of the agency action is not considered to be prohibited taking under the Act provided that such taking is in compliance with the proposed protective measures and the terms and conditions of an incidental take statement and occurs as a result of the action as proposed.

The measures described below are nondiscretionary and must be implemented by the Corps so that they become binding conditions of this action, in order for the exemption in section 7(o)(2) to apply. The Corps has a continuing duty to regulate the activity covered by this incidental take statement. If the Corps (1) fails to require the applicant to adhere to the terms and conditions of the incidental take statement and/or (2) fails to retain oversight to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, the Corps must report the progress of the action and its impact on the species to the Service as specified in the incidental take statement [50 CFR § 402.14 (i)(3)].

Amount or Extent of Take

The Service anticipates incidental take of delta smelt will be difficult to detect and quantify because of the species' small size and cryptic nature and, therefore, it is not possible to provide precise numbers of delta smelt that could be harmed, injured, or killed from the proposed project. There are numerical limitations with respect to detecting individual delta smelt in the wild, and for that reason, it is not practical to express the amount or extent of anticipated take of this species or monitor take-related impacts in terms of individual delta smelt. Due to the difficulty in quantifying the number of delta smelt that will be taken as a result of the proposed project, the Service is using habitat as a surrogate to quantify incidental take of the species. Therefore, to quantify the level of incidental take associated with the proposed project, the Service anticipates that all delta smelt the 1.43-acre barriers footprint and 2.73-acre sediment removal footprint will be subject to incidental take in the form of injury, harm or kill. However, low fish mortality is anticipated because of the location and timing of the proposed project activities, habitat quality, and extremely low population size. Upon implementation of the *Reasonable and Prudent Measures*, incidental take associated with the project will become exempt from the prohibitions described under section 9 of the Act.

Effect of the Take

In the accompanying biological opinion, the Service determined that this level of anticipated take is not likely to result in jeopardy to the delta smelt.

Reasonable and Prudent Measure

The following reasonable and prudent measure is necessary and appropriate to minimize the effects of the proposed project to the delta smelt:

1. The Corps shall minimize the potential for take of the delta smelt.

Term and Condition

In order to be exempt from the prohibitions of section 9 of the Act, the Corps shall ensure compliance with the following term and condition, which implement the reasonable and prudent measure described above. This term and condition is nondiscretionary.

1. The following Terms and Conditions implement Reasonable and Prudent Measure Number One (1):
 - a. The Corps shall minimize the potential for incidental take of delta smelt resulting from proposed project related activities by implementation of the *Conservation Measures* as described in the *Description of the Proposed Action* in this biological opinion.
 - b. The Corps shall educate and inform staff and contractors involved in the project as to the *Conservation Measures* and *Term and Condition* in this biological opinion.

Reporting Requirements

In order to monitor whether the amount or extent of incidental take anticipated from implementation of the project is approached or exceeded, the Corps shall adhere to the following reporting requirements. Should this anticipated amount or extent of incidental take be exceeded, the Corps must reinitiate formal consultation as per 50 CFR 402.16.

1. The Service must be notified within 24 hours of the finding of any injured or dead listed species or any unanticipated damage to its habitat associated with the proposed project. Injured listed species shall be cared for by a licensed veterinarian or other qualified person. Notification will be made to the contact below in *Reporting Requirements*, and must include the date, time, and precise location of the individual/incident clearly indicated on a USGS 7.5 minute quadrangle or other maps at a finer scale, as requested by the Service, and any other pertinent information. When an injured or dead individual of the listed species is found, the Corps shall follow the steps outlined in the *Disposition of Individuals Taken* section below.
2. Sightings of any listed or sensitive animal species shall be reported to the Service and California Natural Diversity Database (<https://www.wildlife.ca.gov/Data/CNDDDB/Submitting-Data>).

Disposition of Individuals Taken

Injured listed species must be cared for by a licensed veterinarian or other qualified person(s), such as the Service-approved biologist. Dead individuals must be sealed in a resealable plastic bag containing a paper with the date and time when the animal was found, the location where it was found, the name of the person who found it, and the bag containing the specimen frozen in a freezer located in a secure site, until instructions are received from the Service regarding the disposition of the dead specimen. The Service contact person is Jana Affonso, Assistant Field Supervisor of the Endangered Species Division at (916) 930-2664.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information. The Service recommends the following actions:

1. The Service recommends the Corps maintain current knowledge of Delta species biology, ecology, and status to inform project design and species-specific *Conservation Measures*.

2. Assist the Service with implementing other recovery actions identified within the most current recovery plans for these species.

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

REINITIATION - CLOSING STATEMENT

This concludes the consultation for the South Delta Temporary Barriers Project. As provided in 50 CFR §402.16,

(a) Reinitiation of consultation is required and shall be requested by the Federal agency or by the Service, where discretionary Federal involvement or control over the action has been retained or is authorized by law and:

(1) If the amount or extent of taking specified in the incidental take statement is exceeded;

(2) If new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered;

(3) If the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the biological opinion or written concurrence; or

(4) If a new species is listed or critical habitat designated that may be affected by the identified action.

(b) An agency shall not be required to reinitiate consultation after the approval of a land management plan prepared pursuant to 43 U.S.C. 1712 or 16 U.S.C. 1604 upon listing of a new species or designation of new critical habitat if the land management plan has been adopted by the agency as of the date of listing or designation, provided that any authorized actions that may affect the newly listed species or designated critical habitat will be addressed through a separate action-specific consultation. This exception to reinitiation of consultation shall not apply to those land management plans prepared pursuant to 16 U.S.C. 1604 if:

(1) Fifteen years have passed since the date the agency adopted the land management plan prepared pursuant to 16 U.S.C. 1604; and

(2) Five years have passed since the enactment of Public Law 115-141 [March 23, 2018] or the date of the listing of a species or the designation of critical habitat, whichever is later.

Please address any questions or concerns regarding this response to Kim Squires, Section 7 Division Manager, at Kim_Squires@fws.gov. Please refer to Service file numbers 2023-0004507-S7-001, in any future correspondence.

Sincerely,

Donald Ratcliff
Field Supervisor

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