VOLUME 42 • ISSUE 3 • 2023

IEP Newsletter

Interagency Ecological Program for the San Francisco Estuary

IN THIS ISSUE

IEP Newsletter

VOLUME 42, ISSUE 3, 2023

J. OCEGUERA ZAVALA / CDFW

About this Newsletter

The IEP Newsletter is a triannual product of the Interagency Ecological Program (IEP) that publishes perspectives on our Program and community, reviews, data reports, research articles, and research notes. The newsletter is a forum for resource managers, scientists, and the public to learn about recent important programmatic and scientific topics from across the San Francisco Estuary. Articles in the newsletter are intended for rapid communication and are not peer reviewed. Primary research results reported in the newsletter should therefore be considered preliminary and interpreted with caution. Any permissions for use of copywritten or otherwise previously published materials, figures, data, etc., is the responsibility of the submitting author and should be obtained prior to submission to the IEP Newsletter editors.

To learn more about the IEP Program, visit our website, https://iep.ca.gov, and subscribe to the IEP Newsletter, https://iep.ca.gov/Subscribe.

Author Guidelines

Authors wishing to submit an article for publication can find guidelines at the following link: iep.ca.gov/Publications/Publication-Guidelines.

Article Submission Deadlines for this Calendar Year

Issue	*Submission Deadline*
1 (Winter)	February 15
2 (Spring)	June 15
3 (Summer/Fall)	October 1

Newsletter Sections

ON THE COVER Tule Perch (*Hysterocarpus traskii*), by Taylor Rohlin / CDFW.

The Interagency Ecological Program (IEP) is a consortium of three State and six federal agencies conducting monitoring and special studies within the Bay-Delta.

https://iep.ca.gov

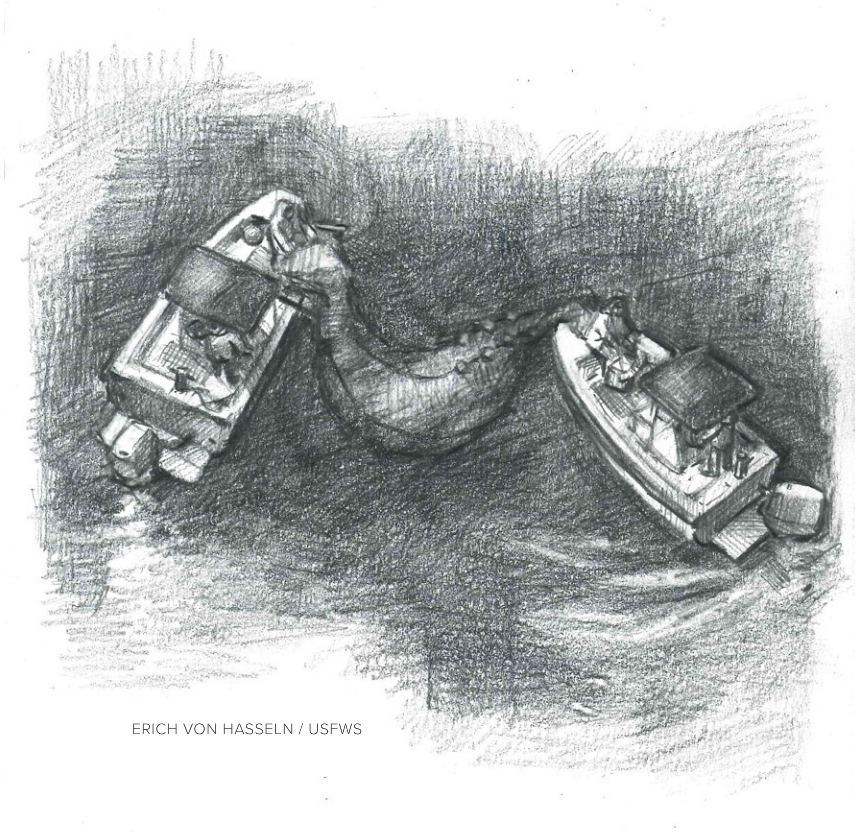
Of Interest to Managers

2022 Status and Trends Report for Pelagic Fishes in the Upper San Francisco Estuary

The authors present the 2022 Status and Trends Report for Pelagic Fishes in the Upper San Francisco Estuary, which provides the annual contractual obligation summarizing indices reported by California Department of Fish and Wildlife studies including the Smelt Larva Survey, the 20-mm Survey, the Summer Townet Survey, the Fall Midwater Trawl Survey, and the San Francisco Bay Study, as well as the US Fish and Wildlife Service Beach Seine Survey. The 2022 indices for American Shad, Threadfin Shad, Delta Smelt, Longfin Smelt, Splittail, and Striped Bass are collated in this report. New to this edition are design-based abundance indices for Delta Smelt and Longfin Smelt, caught by the Smelt Larva Survey, which has not previously been included in the Status and Trends Report. Trends of the included species are largely unchanged, with nearly all species continuing to have low abundances relative to historical values. However, many indices in 2022 did have mild increases relative to the previous year.

2023 Smelt Larva Survey Summary

The 2023 Smelt Larva Survey is summarized by Jennifer Oceguera Zavala, Vanessa Mora, and Jessica Jimenez (California Department of Fish and Wildlife). This survey is conducted annually to monitor the distribution and abundance of larval Longfin Smelt and other larval fishes in the upper San Francisco Estuary, including Delta Smelt. In 2023, Longfin Smelt with yolk-sacs were observed in seven of the eight surveys and present throughout the estuary, but the highest catch occurred in the Suisun and Honker Bay stratum. Despite their presence throughout the estuary, the annual catch remains relatively low. Similarly to 2022, the experimental releases of hatchery-origin Delta Smelt did not result in a high larval Delta Smelt catch for the Smelt Larva Survey. A total of four larval Delta Smelt were caught in late March, likely to have resulted from spawning activity in March.



ERICH VON HASSELN / USFWS

DATA REPORT

2022 Status and Trends Report for Pelagic Fishes in the Upper San Francisco Estuary

Timothy D. Malinich* (California Department of Fish and Wildlife [CDFW]), James R. White (CDFW), Kathy Hieb (CDFW), Adam S. Nanninga (US Fish and Wildlife Service), Steven B. Slater (CDFW), James A. Hobbs (CDFW)

** Corresponding author: Timothy D. Malinich, Timothy.Malinich@wildlife.ca.gov*

Overview

This Status and Trends Report provides the relative annual abundance trends for select pelagic fishes sampled primarily in the upper San Francisco Estuary (estuary). Specifically, this report summarizes indices from seven of the Interagency Ecological Program's (IEP's) long-term fish monitoring surveys: (1) Smelt Larva Survey (SLS), (2) Spring Kodiak Trawl Survey (SKT), (3) 20-mm Survey, (4) Summer Townet Survey (STN), (5) Fall Midwater Trawl Survey (FMWT), (6) San Francisco Bay Study (SFBS), and (7) the US Fish and Wildlife Service (USFWS) Beach Seine Survey. Each year the California Department of Fish and Wildlife (CDFW), along with USFWS, publishes a series of survey memos reporting abundance indices and the distribution of select fishes in the estuary. These include American Shad (*Alosa sapidissima*), Threadfin Shad (*Dorosoma petenense*), Delta Smelt (*Hypomesus transpacificus*), Longfin Smelt (*Spirinchus thaleichthys*), Splittail (*Pogonichthys macrolepidotus*), and Striped Bass (*Morone saxatilis*).

Executive Summary

- American Shad benefited from wet years in 2017 and 2019, retaining higher index values during the most recent drought period (2020–2022). Indices are now near or higher than Pelagic Organism Decline (POD) levels (2002–2012), although they still have not recovered to historical levels.
- Threadfin Shad indices have not rebounded, remaining largely unchanged since dramatic drops in abundance at the start of the POD period.
- The Delta Smelt indices declined to zero for almost all studies. There were minor increases in Delta Smelt catch in the SKT, although this was made up of culture-raised Delta Smelt adults released in 2021 as a part of the Delta Smelt Experimental Release project.
- New design-based abundance indices for Delta Smelt and Longfin Smelt, caught by the SLS, reflect similar trends to other CDFW studies.
- Longfin Smelt (age 0–1) had marginal increases in abundance in 2022. However, indices remained below historical values prior to the POD.
- The 2022 Striped Bass indices were mixed across CDFW studies. The STN age-0 Striped Bass index was not calculable during 2022 due to an absence of Striped Bass at index stations, while FMWT and SFBS showed mild increases. Across all studies, indices have not recovered to pre-POD levels.

Introduction

The estuary is a complex ecosystem that has experienced multiple ecosystem shifts detected through the efforts of one or more long-term monitoring studies over the last 63 years (Tempel et al. 2021). Individually, each study provides a relative abundance index for select fish species of management focus (referred to as *index species*). Collectively, these studies can provide a more holistic picture of the status of the estuary that covers a broader spatial and temporal range than any single survey (Figures 2–4). However, this report does not represent a true "synthesis" of relative abundances (but see Melwani et al. 2022 for future efforts related to this goal). Readers must note that the spatial and temporal scale, study design, and annual index calculation methods vary among all studies. Furthermore, the IEP studies consist of multiple sampling gear types that target different habitats and life stages and retain different size ranges of the many fish species present in the estuary. Annual survey memos are published for each study (except the SFBS) to report the relative abundance and distribution. These memos are linked within the report where appropriate.

This report provides brief summaries of each study and gear type, followed by the 2022 annual indices and long-term trends for the index species, including American Shad, Threadfin Shad, Delta Smelt, Longfin Smelt, Striped Bass, and Splittail. We used data from the CDFW's SLS, SKT, 20-mm Survey, STN, FMWT, and SFBS and the USFWS's Beach Seine Survey. Note that each study samples a different spatial range and period of time and has different retention of life stage and size; these differences have yet to be fully quantified. It is not a priori expected that each study would provide a similar long-term trend. This report aims to provide a greater view of the changing trends for estuary fishes by reporting abundance indices together with associated abundance-outflow relationships.

Reports of previous years may be found in the IEP Publications library. Contrary to previous years, we removed the catch of Wakasagi Smelt (*Hypomesus nipponensis*) to focus on historical index species. In addition, we leave the spatial distributional trends to the relevant reports for each study, all referenced within this document. We have again included Sacramento–San Joaquin Delta (Delta) freshwater outflow and FMWT abundance relationships for Striped Bass, American Shad, and Longfin Smelt to show the impacts of prolonged drought conditions. New to this report is the inclusion of the SLS, which has previously not reported an index. We calculate a novel SLS relative abundance index with confidence intervals for Delta Smelt and Longfin Smelt using a design-based method initially developed by Polansky et al. (2019) for USFWS Delta Smelt life cycle modeling with some modifications (Melwani et al. 2022).

The 2022 water year (October 2021–September 2022) was the third contiguous year of drought in the estuary (see Delta outflow, Figure 4; CDWR 2022a). In 2022, the statewide precipitation was at 76% of the long-term average, and statewide reservoir storage was at 69% of the long-term average (CDWR 2022a). In response to the drought, the State again constructed a temporary emergency salinity control barrier in the West False River (WFR) in the central Delta to preserve reservoir water storage by reducing the need for reservoir releases and preventing further salinity intrusion into the central and south Delta (CDWR 2022b). Barriers alter connectivity within the Delta and impact the catch reported by surveys conducted in the estuary (Kimmerer et al. 2019). A notch was made in the top of the WFR barrier to allow fish movement from January 2022 to April 2022 when the notch was filled, aiding Chinook Salmon migration (DSP 2022). Decreased water flow into the estuary can have complex impacts on fishes. In general, decreased flow can result in poor habitat conditions (i.e., increased temperatures, increase in harmful algal blooms, decreased growth, a more upstream location of the low-salinity zone, lower primary and secondary productivity, etc.), which can negatively impact production and survival of young fish.

The 2022 Water Year and Summary of Sampling Effort

Daily freshwater outflow estimates were obtained from the California Department of Water Resources (CDWR) DAYFLOW data, available on the California Natural Resources Agency website. Data were available through water year 2022 (October 2021–September 2022), and net outflow per day was plotted to present the 2022 water year relative to the highly variable conditions of the last decade (Figure 1). Water year type classifications were provided by CDWR (WSIHIST). Yearly FMWT abundance indices were plotted against mean seasonal freshwater outflow for selected species. The years were classified into different eras as outlined in Tempel et al. 2021, representing regime-shift periods in the estuary. These regimes are also used in the index plots with regression lines for each regime to show the general trends of indices over time.

The results of each study are reported here as relative abundance indices and design-based abundances (SLS only). Relative abundance indices are unique to each study and gear type and are described in detail below and in Table 1. Regional assignment of stations (Figures 2–4) was guided by regions used in the USFWS Delta Smelt Life Cycle Model (DSLCM), which defined regions based on CDFW abundance indices and similar environmental conditions (Polansky et al. 2019). The DSLCM does not include all regions; the Central Bay, the South Bay, the San Joaquin, and the Sacramento regions were added to include regions covered by the USFWS Beach Seine Survey and the SFBS. These regions are coded by shape and each survey by color in Figures 2–4.

The following is a brief description of methods for individual studies. Indices calculated by each study are listed within their respective methods, and index calculations are described in Table 1. More information is available in Honey et al. (2004) and online at CDFW Surveys and USFWS Delta Juvenile Fish Monitoring Program.

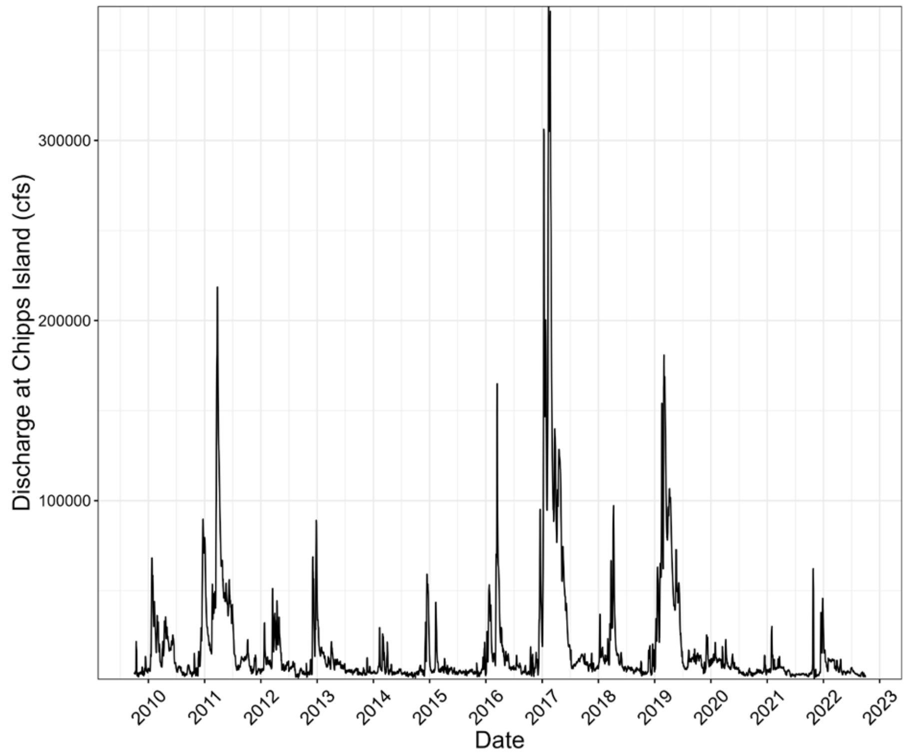
Smelt Larva Survey

Historically, the SLS has been used to track the presence and location of larval Longfin Smelt and Delta Smelt to inform real-time operations of south Delta exports and minimize entrainment into the pumps. This report will be the first use of new design-based abundance indices for the SLS. These new indices are set within 9 or 10 regions (varies among years) located throughout the upper estuary and Delta (see technical report 2; contact author for a copy). Larval fish CPUE (catch per unit of effort; i.e., volume sampled) is expanded by sub-regional volumetric ratios and summed across all sub-regions. Variance of the index is calculated within each region. Additional details on variance calculations can be found in Polansky et al. (2019). The number

Table 1. Detailed descriptions of each index presented in this report and its corresponding study including the years conducted, gear type, index calculation, index species, seasonal sampling period, and targeted life stages. Note that volumetric expansions and weighting factors may differ across studies.

Study	Years Active	Gear Type; Tow Description	Index Description	Index Species	Index Time Period	Sampling Time Period	Targeted Life Stage
Smelt Larva Survey	2009–present	Fixed-mouth, 500 µm mesh net; oblique tow	Design-based abundance indices (Polansky et al 2019, Melwani et al. 2022).	Delta Smelt, Longfin Smelt	All SLS surveys	January–April	Larval
Spring Kodiak Trawl Survey	2004–present	Trawl-net, 7.6 m x 1.8 m mouth size with graduated changes in mesh size beginning at 5 cm stretch-mesh to 0.64 cm stretch mesh at the cod-end; surface tow	To calculate the index, stations are grouped into three spatial regions and a mean catch per 10,000 cubic meters of water (i.e., CPUE) is calculated. The regional means are then summed to create an index for each survey, and survey indices are summed to calculate the SKT index.	Delta Smelt	Four sampling surveys	January–April	Adult
20-mm Survey	1995–present	Fixed-mouth, 1,600 µm mesh net; oblique tow	Catch data averaged by survey (for fish <60 mm fork length) for all stations to determine when mean fork length reaches or surpasses 20 mm. The two surveys before and after when this target is reached are used to calculate the annual abundance index. From this subset of surveys, Delta Smelt CPUE is calculated for each of the 41 index stations. CPUE for each tow is calculated by dividing catch by the volume of water filtered during the sample and multiplied by 10,000 to obtain a whole number. CPUE is then averaged across tows for each index stations. The resulting mean station CPUE values are log ($\log_{10}(x+1)$) transformed. These values are averaged within each survey, and then the mean values are back transformed to return to original scale. One is subtracted from each survey value, and these values are summed across the four surveys to obtain the annual abundance index.	Delta Smelt	Four sampling surveys bracketing when fish reach 20 mm fork length	March–July	Larval–juvenile
Summer Townet Survey	1959–present	Fixed-mouth; 1.27 cm stretched mesh codend; oblique tow	Catch per tow data from the 31 index stations are used for index calculations. For each survey, the total species catch by each station is multiplied by a water volume weighing factor. These products are then summed across all index stations within a survey, then divided by 1,000 to produce the survey abundance index. The annual abundance index for age-0 Striped Bass is interpolated using index values from the two surveys that bound the date when mean fork length reached 38.1 mm. For Delta Smelt, the annual index is the average of the first two survey indices of each year.	Age-0 Striped Bass, Delta Smelt	Two sampling surveys bracketing when age-0 Striped Bass reach 38.1 mm fork length; Delta Smelt index is calculated only for Surveys 1 and 2	June–August	Larval–juvenile
Fall Midwater Trawl Survey	1967–present, except 1974 and 1979	Midwater trawl using 17.7 m long net tapering down to 1.2 cm mesh in codend; oblique tow	100 index stations are grouped into 14 regions. Monthly indices are calculated by averaging catch per tow in each region, multiplying these means by their water volume weighting factors, and summing these products. Annual abundance indices are the sum of the four monthly indices.	Delta Smelt, age-0 Longfin Smelt, age-0 Striped Bass, Threadfin Shad, American Shad	Four monthly surveys	September–December	Juvenile–sub-adult
San Francisco Bay Study	1980–present	Midwater trawl using 17.7 m long net tapering down to 1.2 cm mesh as an oblique tow; otter trawl with a 0.55 cm mesh cod end, demersal tow	Annual abundance indices are calculated as the average of monthly indices over the period for which the age class was most abundant. The 35 index stations are assigned to five regions. The region's water volume weighting factor (for the midwater trawl) or the areal weighting factor (for the otter trawl) is multiplied by the mean regional CPUE, and these products are summed across all five regions for the monthly indices.	Age-0 Longfin Smelt, Delta Smelt, Striped Bass, American Shad, Splittail	Six surveys, May–October (age-0, age-1 and age-2+ Longfin Smelt, Splittail); five surveys, June–October (Delta Smelt, Striped Bass); four surveys, July–October (American Shad)	Monthly year round	Juvenile–sub-adult
USFWS Beach Seine Survey	1994–present	Beach seine; nearshore littoral haul	The catch per cubic meter for seine hauls conducted at each station is averaged by month, CDFW subarea, and year to calculate an annual index per subarea. The annual subarea indices are then averaged by region (Delta, Sacramento River, and San Joaquin River) and across regions to produce the overall annual age-0 Splittail index.	Age-0 Splittail	Eight sampling surveys, May–June	Weekly year round	Larval–juvenile

Figure 1. Net daily Delta outflow (cubic feet per second, cfs) at Chipps Island from October 2009 to September 2022.



of stations sampled by SLS vary in some regions of the Delta but were inconsistently sampled in the West Delta region (including Napa River, Carquinez Strait, and San Pablo Bay), often due to weather conditions and prior changes to the survey design. In years with only one representative station in a region, the region is dropped and not included in the design-based abundance index for that year. The 2022 SLS season included eight surveys sampled bi-weekly; the first survey began on December 13, 2021, and the final survey ended on March 24, 2022. The 2022 season targeted 44 stations per survey, but conditions resulted in reduced effort in the 3rd (n=12 stations) and 5th (n=43 stations) surveys for 319 total samples.

Spring Kodiak Trawl Survey

The SKT has sampled annually since its inception in 2002 and determines the relative abundance and distribution of spawning Delta Smelt (Spring Kodiak Trawl Overview). In 2022, monthly SKT surveys began on January 19 and completed 156 sampling events by April 29. During the 2022 season, only four index stations were not sampled (all in Survey 1; 2022 SKT memo).

20-mm Survey

The 20-mm Survey monitors the distribution and relative abundance of post-yolk sac larval and juvenile Delta Smelt throughout its historical spring range (2022 20-mm memo). The survey name refers to the size of Delta Smelt that the study targets. The 2022 20-mm Survey bi-weekly surveys began on March 21 and completed 1,095 tows by June 30, 2022. The 20-mm Survey occasionally cannot sample all stations in a survey due to barriers such as aquatic vegetation, vessel mechanical challenges, staffing shortages, and weather. Three stations were missed in Surveys 2 and 3, two stations were missed in Survey 6, and one station was missed in Survey 7. Finally, all of Survey 9 could not be sampled (2022 20mm memo).

Summer Townet Survey

The STN began in 1959 to index age-0 Striped Bass abundance and now informs summertime habitat conditions and pelagic fish recruitment in the upper estuary. The 2022 STN season began with Survey 1 on June 7 and ended with Survey 6 on August 19. All index stations were sampled during the 2022 season. Continuing from 2021, station 721, a non-index station, was not sampled due to aquatic vegetation and was replaced by a new station, 722, approximately 2 kilometers downstream of station 721 in Cache Slough (2022 STN Season Report).

Fall Midwater Trawl Survey

The FMWT was established in 1967 to examine the relative abundance and distribution of age-0 Striped Bass but expanded to report on a suite of pelagic fishes. The 2022 FMWT monthly

Figure 2. Station distribution for the winter and spring IEP surveys within this report: 20-mm Survey (41 index stations, 11 non-index stations), Spring Kodiak Trawl Survey (39 index stations, 1 non-index station), and the Smelt Larva Survey (44 index stations).

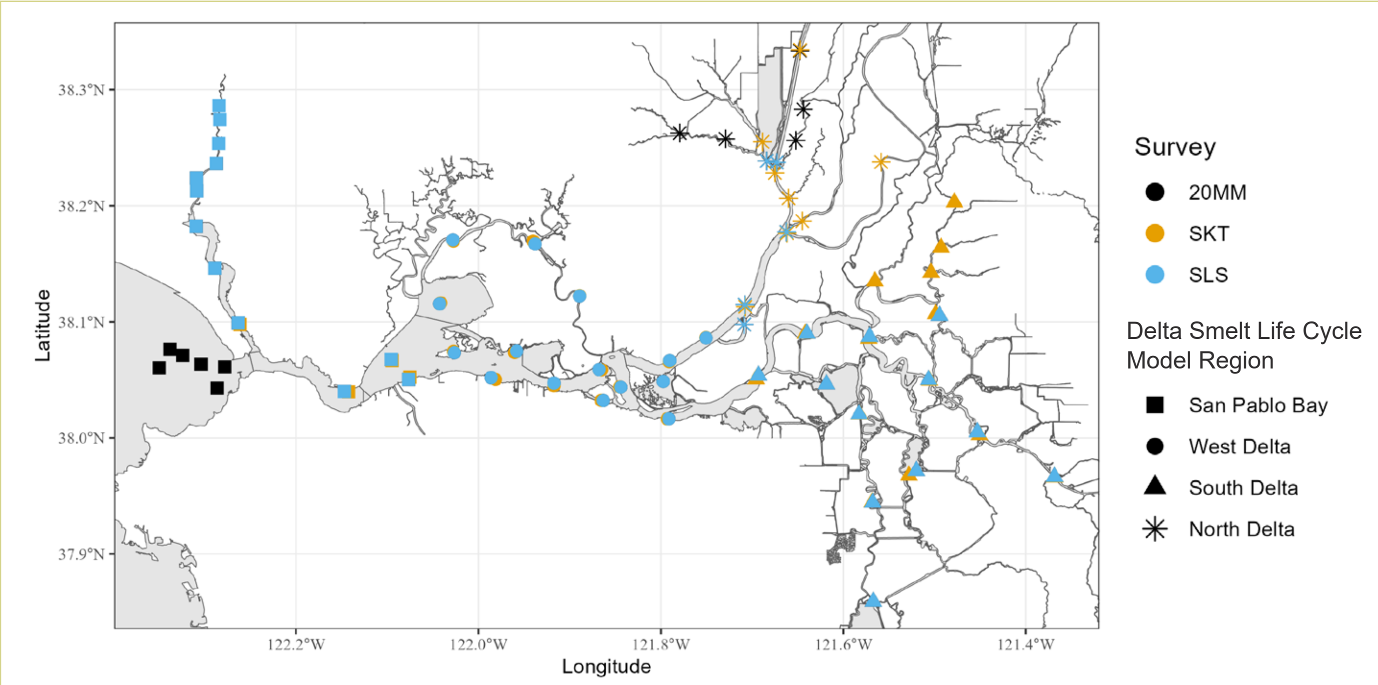


Figure 3. Station distribution for the summer and fall IEP surveys: the Summer Townet Survey (31 index stations, 9 non-index stations) and the Fall Midwater Trawl Survey (100 index stations, 22 non-index stations).

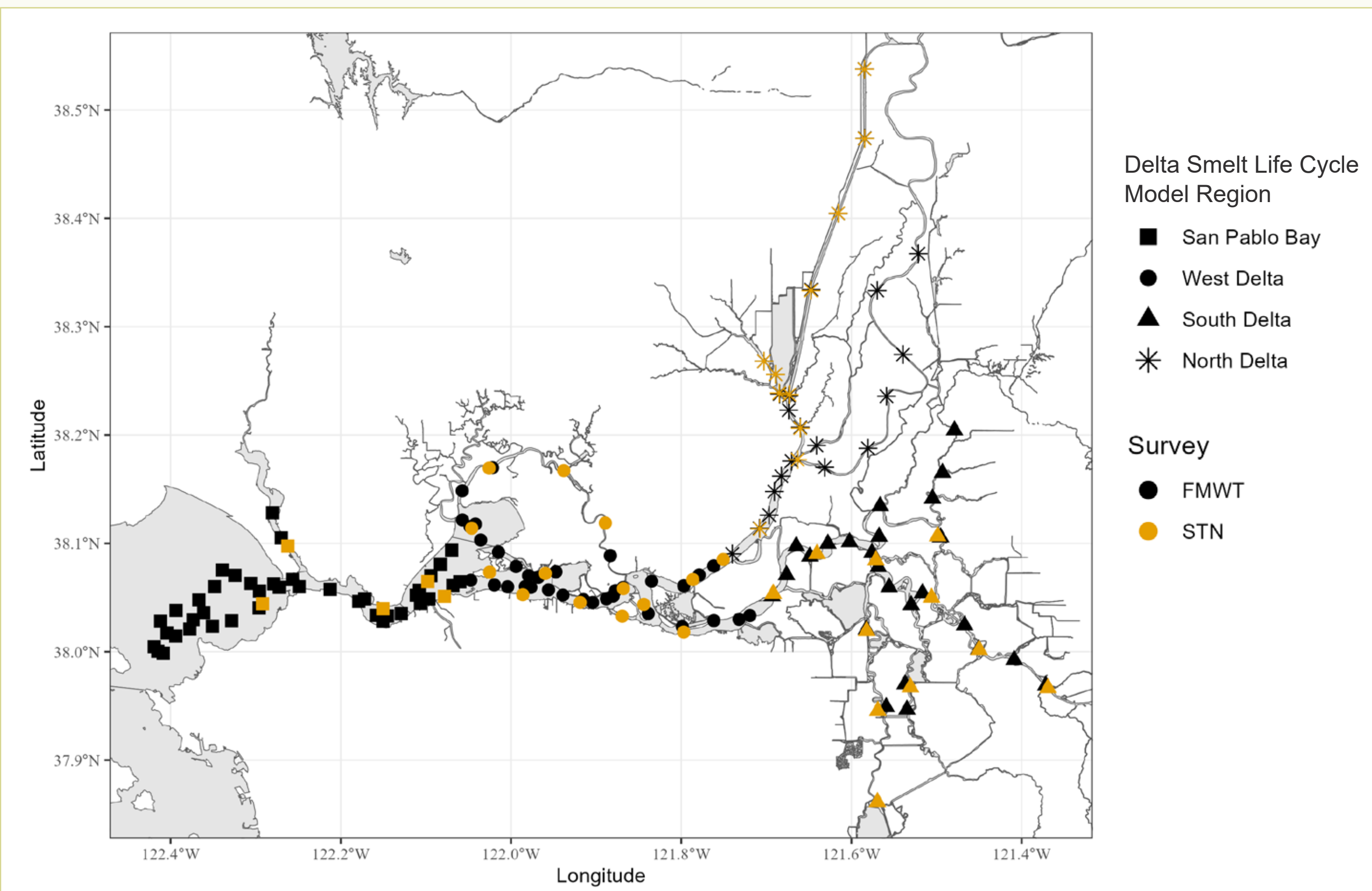
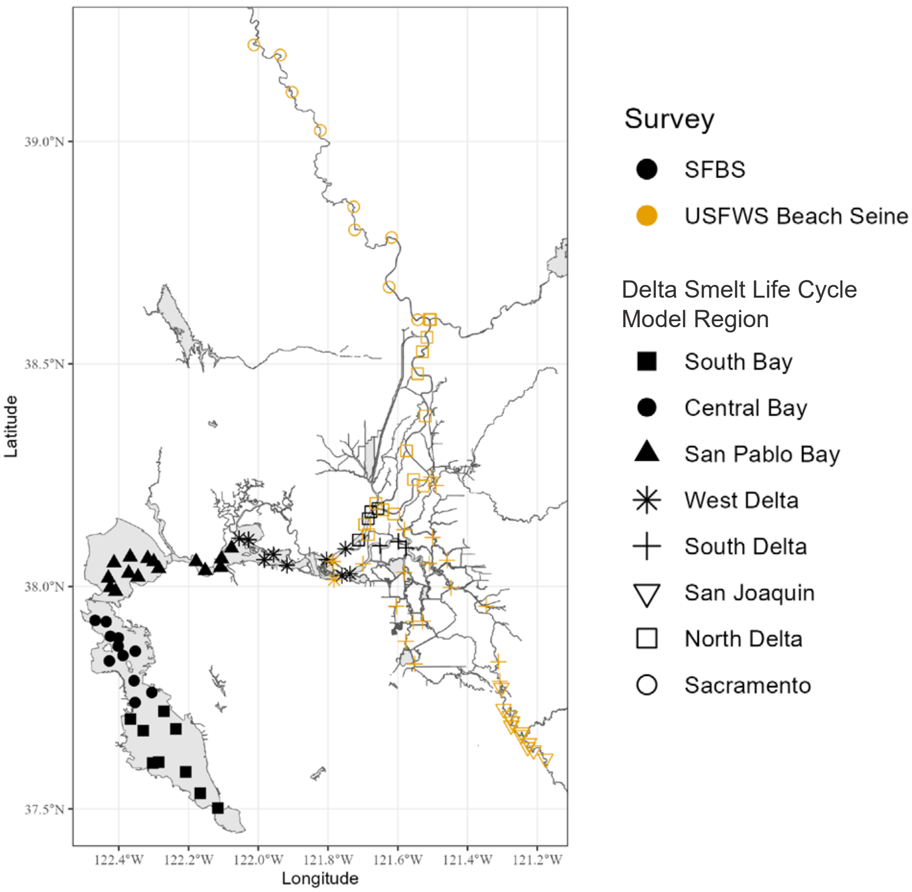


Figure 4. Station distribution for the annual IEP surveys including the San Francisco Bay Study (35 index stations, 17 non-index stations) and USFWS Beach Seine Survey (35 index stations, 5 non-index stations).



survey sampling began on September 1 and was completed on December 16. All stations were sampled for each monthly survey, except for station 721. Continuing from 2021, this station was not sampled due to aquatic vegetation and was replaced by station 722, approximately 2 kilometers downstream of station 721 in Cache Slough (2022 FMWT End of Season Report).

San Francisco Bay Study

The SFBS began in 1980 to determine the effects of freshwater outflow on the abundance and distribution of fishes and mobile crustaceans throughout the estuary (Figure 4). The SFBS samples 52 stations monthly with a midwater trawl (MWT) and an otter trawl (OT). All the SFBS surveys and stations were completed in 2022.

Additional information about study methods, including index calculation, can be found in IEP Technical Report 63 (Baxter et al. 1999). See Hieb et al. (2019) for fish abundance and distribution trend information for other species through 2016.

USFWS Beach Seine Survey

The USFWS has conducted the Beach Seine Survey since 1976 to sample outmigrant salmon and has held its current design since 1994. In May and June of 2022, the USFWS Beach Seine Survey was minimally impacted by COVID-19 mitigation measures, with only four of the seine sites canceled on one occasion due to COVID-19 mitigation measures. Scheduled sampling was not able to occur for other reasons, including vegetation growing in the site or an excess of mud that made sampling impossible. In total, 147 out of 277 scheduled beach seine hauls were completed (about 53%), and a total of 339 age-0 Splittail were captured.

Index Species Trends

American Shad

American Shad is native to the Atlantic Coast of North America and was introduced to the estuary in the 1800s. It once supported a commercial fishery in California but gradually declined in popularity until it was banned as a commercial fish in 1957 in favor of sport fishing (Dill and Cardone 1997, Moyle 2002). Juveniles are common prey species for larger fish, such as Striped Bass, and prior to their decline, they may have served as an important staple of Striped Bass diets. American Shad is anadromous, and adults return from the ocean to freshwater, passing through the upper estuary in the spring to spawn. Juveniles are usually detected by surveys as early as late spring through summer and into fall as they rear in the estuary and migrate to the ocean.

In 2022 the American Shad FMWT (index=698) and SFBS MWT (index=4,849) slightly increased from 2021 (Figure 5). Note that, due to differences in regional weightings for FMWT and SFBS index calculations, the scale of the index values is different. In general, both studies had similar trends in American Shad indices. Indices remained low during the POD years, but FMWT indices improved following a large increase in abundance in 2017. The SFBS MWT also reported a large increase in 2017 and 2019, followed by lower values since 2020. American Shad indices have been closely related to freshwater outflow for both studies with peaks corresponding to wet years followed by lower and often declining abundances during prolonged drought periods.

Threadfin Shad

Threadfin Shad is native to the Gulf Coast of North America and was introduced to California in the 1950s as a prey species for other pelagic species (Dill and Cordone 1997) such as Striped Bass. It spawns in freshwater (Delta regions) during late spring and summer and often has large boom and bust cycles (Moyle 2002). Threadfin Shad is one of the most numerous pelagic prey species in the upper estuary and could act as a competitor with native species.

Threadfin Shad has a mix of trends among indices recorded by the FMWT (Figure 6). However, the index mildly increased in 2022 (index=257). The low, largely unchanged trend in indices during the current Climate-Shift regime could be attributed to the drastic decline in Threadfin Shad abundances at the start of the POD around 2000. This was observed by FMWT following a strong 1999 index. Trends suggest that Threadfin Shad did not recover from this decline and instead continued to decline throughout the POD until 2009.

Delta Smelt

Delta Smelt is an environmentally sensitive species due to an annual life cycle, dependence on a spatially-limited oligohaline to freshwater habitat, and low fecundity (1,200–2,600 eggs per female on average; Moyle et al. 1991). Low freshwater outflow and high water temperatures (>22°C; Swanson et al. 2000) can be stressful conditions for the Delta Smelt population. Accordingly, Delta Smelt is a good indicator for low-salinity habitat. Many species, native and non-native, are also dependent on this

Figure 5. American Shad annual abundance indices from (top): Fall Midwater Trawl Survey (all sizes, 1967–2022) and San Francisco Bay Study Midwater Trawl (age-0, 1980–2022). Trend lines are included to visually aid in long-term trend changes across four identified regime shifts (Tempel et al. 2021), including the pre-clam years (cyan, <1986), pre-POD years (green, 1987–2001), POD years (yellow, 2002–2012), and the Climate-Shift years (red, 2013–present).

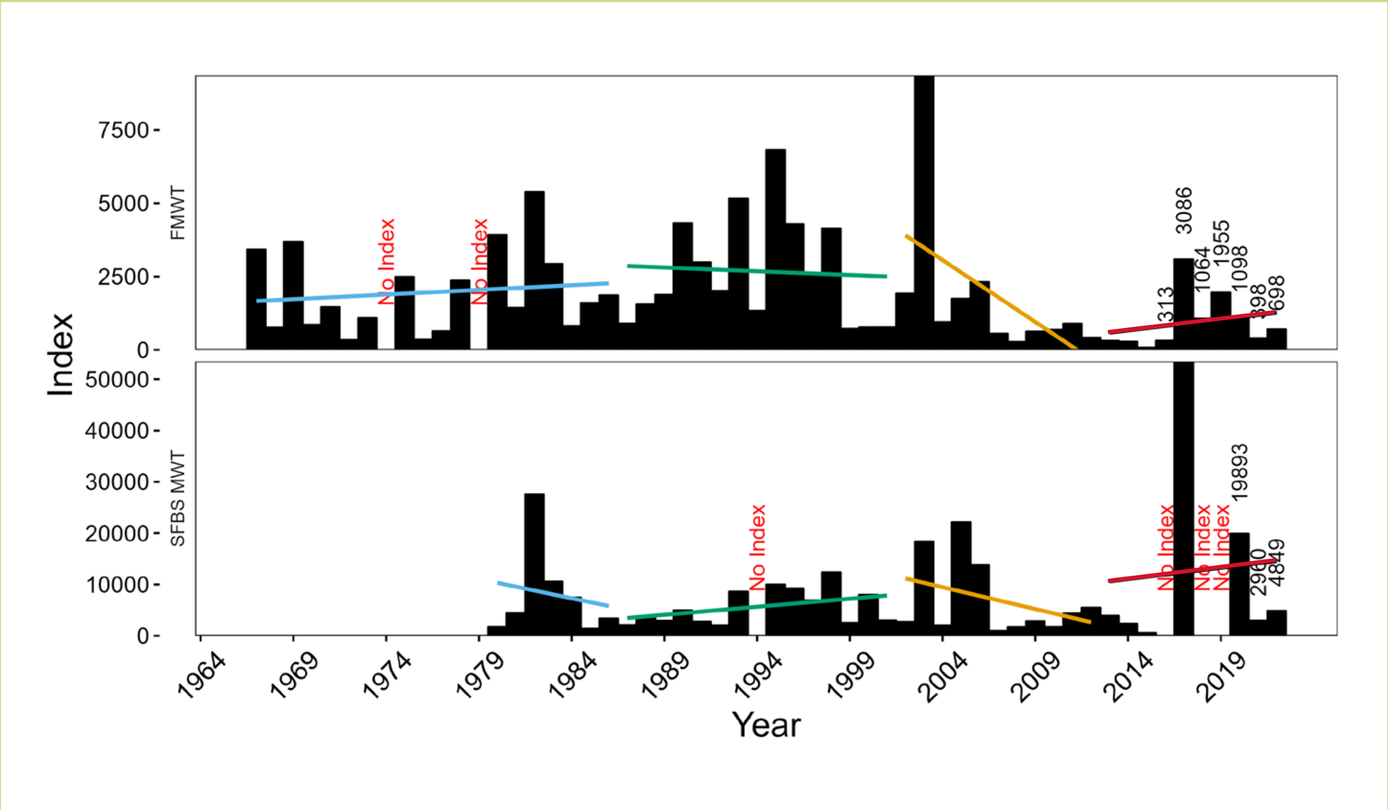
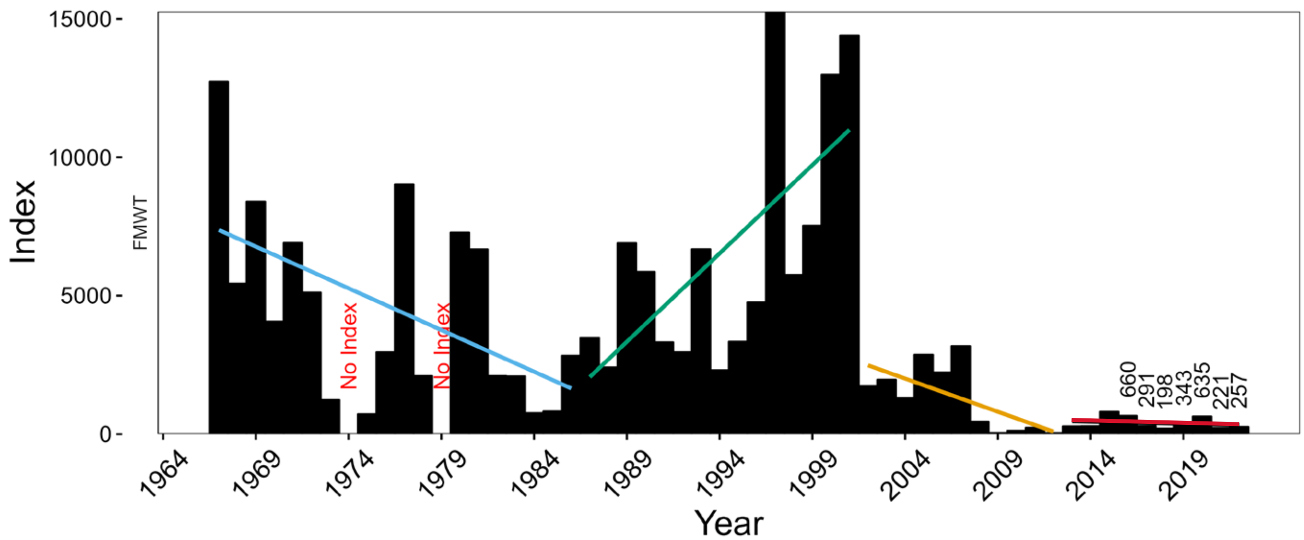


Figure 6. Threadfin Shad annual abundance indices from Fall Midwater Trawl Survey (all sizes, 1967–2022). Trend lines are included to visually aid in long-term trend changes across four identified regime shifts (Tempel et al. 2021), including the pre-Clam years (cyan, <1986), pre-POD years (green, 1987–2001), POD years (yellow, 2002–2012), and the Climate-Shift years (red, 2013–present).



low-salinity zone as valuable nursery habitat. This zone can be impacted by water project exports, particularly during periods of low freshwater input into the Delta.

Delta Smelt was collected by the SLS, 20-mm Survey, and the SKT in 2022. The long-term trend of a severe population decline (Figure 7), which has been observed among several monitoring programs within the last 40 years, continued in 2022. The SKT collected a total of 18 fish in 2022, resulting in an index of 1.7, all of which were recently released cultured fish identified by a clipped adipose fin. These fish were part of the 55,733 cultured Delta Smelt released between December 2021 and February 2022 (USFWS 2022). Unfortunately, we could not determine the release event or location due to the lack of unique fish markings in the release events. Increased Delta Smelt catch by SKT may be a positive indicator for the survivorship of cultured Delta Smelt in the upper estuary.

Interestingly, the SLS caught a single Delta Smelt at station 815 in March (Jimenez 2022). While the SLS was implemented to sample larval Longfin Smelt, the survey occasionally captures early-hatching Delta Smelt. The SLS has not developed an annual index of relative abundance; accordingly, here we employed a new design-based approach to abundance estimation for Delta Smelt caught in the SLS (Figure 8). Abundance was highest in 2012, following the last year of high recruitment of Delta Smelt (Figure 8), with increases in abundance in 2018 and 2020, following wet years. The 20-mm Survey caught a total of nine Delta Smelt but could not calculate an index in 2022 (Jimenez 2022). Unfortunately, no Delta Smelt were collected by the STN, FMWT, or SFBS in 2022.

Longfin Smelt

Longfin Smelt in the estuary represent the southernmost distribution of the species, which is found in multiple bays and estuaries along the Pacific coastline (Garwood 2017). It is an anadromous species and, while considered euryhaline, juveniles and adults are more often observed in higher salinities, including the ocean, than in freshwater. However, Longfin Smelt abundance indices have been strongly correlated with freshwater outflow (Figure 16). Spawning occurs within freshwater habitats, typically from January to April, although it may occur earlier and last later into the year (Moyle 2002). Because of their high numbers, reliable catch, sensitivity to temperature, and freshwater outflow, Longfin Smelt make an ideal index species for tracking environmental changes throughout the estuary.

Age-0 Longfin Smelt abundance indices were calculated from the FMWT (age-0 index=371) and the SFBS (MWT and OT) for age-0 (MWT index=9,027; OT=9,449), and age-1 fish (MWT index=2,664; OT index=10,549). Note: standard reporting of FMWT Longfin Smelt relative abundance indices is all ages (FMWT Indices) but was limited to catch of age-0 size fish for this report. In both midwater trawls, the age-0 Longfin Smelt indices slightly increased since 2015 which was a 0 index for FMWT. Year 2015 was the third lowest recorded index in the SFBS MWT at 231, and the second lowest index in the SFBS OT

Figure 7. Delta Smelt annual abundance indices from (top to bottom): 20-mm Survey (larvae and juveniles, 1995–2022), Spring Kodiak Trawl Survey (adults, 2002–2022), Summer Townet Survey (all sizes, 1959–2022), Fall Midwater Trawl Survey (age-0, 1967–2022), and the San Francisco Bay Study midwater trawl (age-0, 1980–2022). Trend lines are included to visually aid in long-term trend changes across four identified regime shifts (Tempel et al. 2021), including the pre-clam years (cyan, <1986), pre-POD years (green, 1987–2001), POD years (yellow, 2002–2012), and the climate-shift years (red, 2013–present).

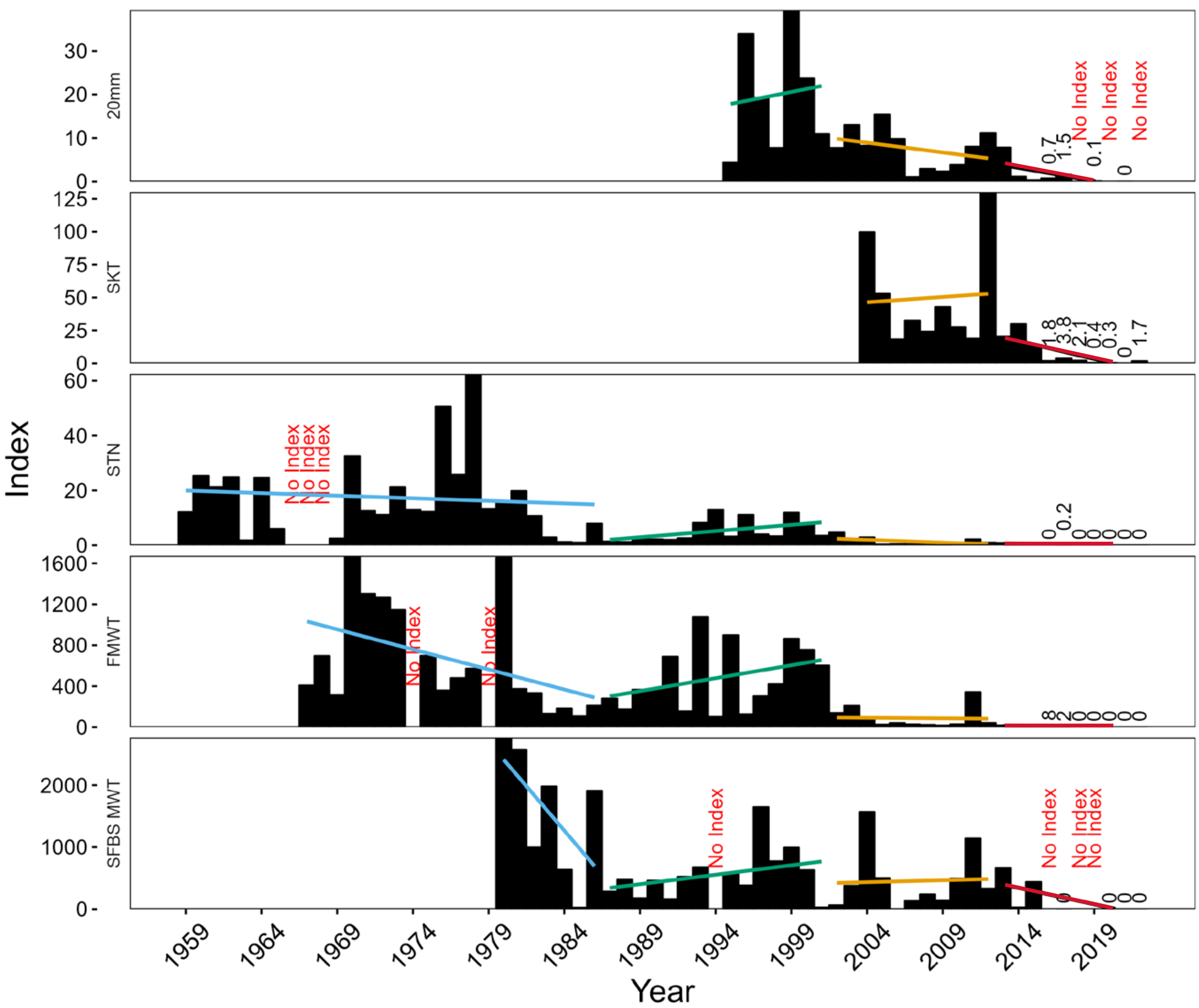
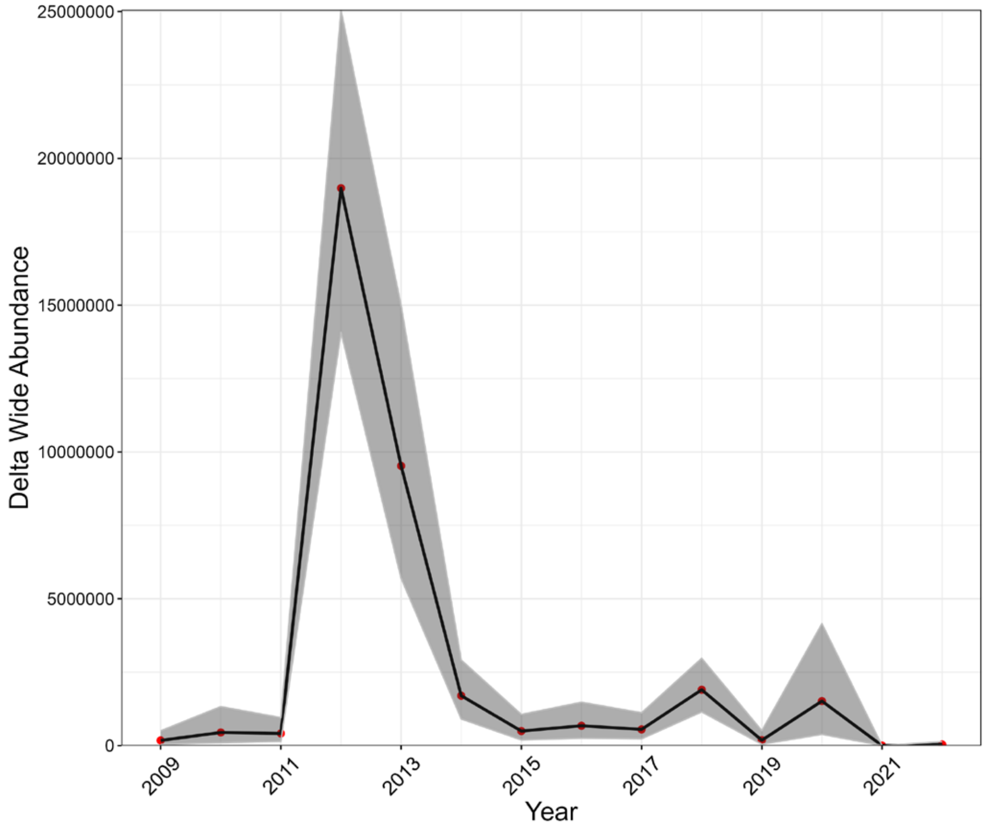


Figure 8. The Delta Smelt annual design-based abundance indices (points connected by black line +/- standard deviation in gray) for the Smelt Larva Survey (2009–2022) in the upper San Francisco Estuary.



at 536 (Figure 9). Meanwhile, the SFBS age-0 OT indices showed a downturn in 2021 and 2022. It is likely the differences in midwater and demersal (OT) trends in recent years are a symptom of sampling noise. However, neither study has observed indices comparable to the historic, pre-POD index.

The SFBS adult (age-1) Longfin Smelt indices increased in 2021 and 2022 (Figure 10). Missing index data due to vessel issues complicate our ability to determine changes in Longfin Smelt trends for this age class.

Using a new design-based approach to abundance estimation, we calculated an annual abundance for larval Longfin Smelt caught in the SLS (Figure 11). Like the trend in the FMWT, the abundance of larval Longfin Smelt increased since 2015 but remains a small fraction of the abundance found in 2013. With such a short time series, it is difficult to speculate what historical larval abundances may have been.

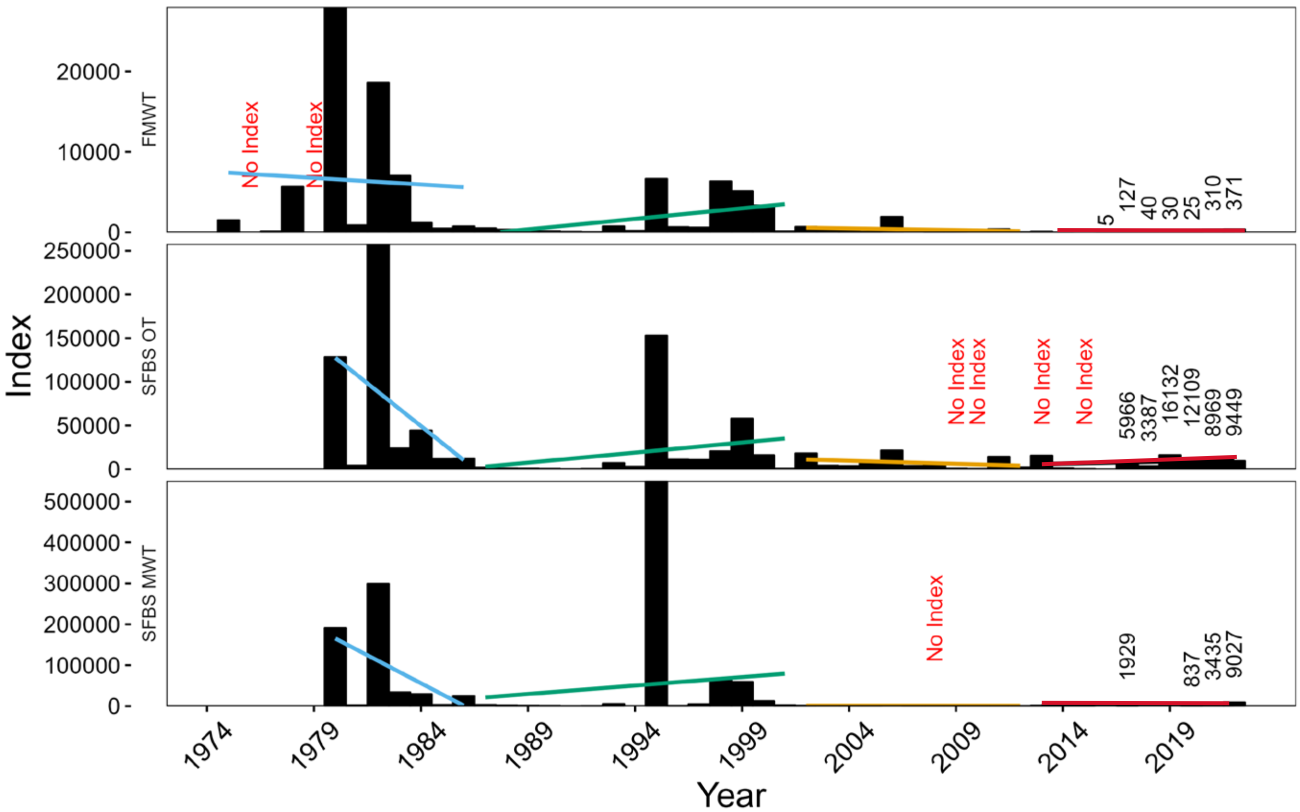
Longfin Smelt typically rear in habitats with higher salinity such as Central and San Pablo Bays (see Lewis et al. 2019 for residence in San Francisco South Bay tidal wetlands). Continued low freshwater flow into the estuary due to drought conditions from 2020 to 2022 may have encouraged Longfin Smelt residence farther upstream in the estuary, increasing catchability (and thus increased Longfin Smelt indices) at some CDFW sampling stations.

Splittail

Splittail is a large cyprinid endemic to central California that forages in shallow habitats of the estuary, such as inundated floodplains and river margins (Sommer et al. 1997; Moyle et al. 2004). As such, Splittail is commonly collected by the USFWS Beach Seine Survey. It is also caught by pelagic and demersal surveys (FMWT and SFBS) when the Splittail population is particularly high.

Splittail spawns in the Sacramento, San Joaquin, Cosumnes, Napa, and Petaluma Rivers' floodplains, as well as in Butte Creek and other small tributaries (Moyle et al. 2004; Feyrer et al. 2015) from March through May. The resulting larvae and small juveniles disperse downstream in late spring and summer. The outmigration of Splittail coincides with reduced river flows that decrease available backwater and edge-water habitats. The FMWT and SFBS surveys generally detect strong Splittail year classes, such as in 1998, 2011, and 2017 (Figure 12), related to high outflow and long periods of floodplain inundation (Moyle et al. 2004).

Figure 9. Age-0 Longfin Smelt annual abundance indices from (top to bottom) Fall Midwater Trawl Survey (age-0, 1975–2022), San Francisco Bay Study (SFBS) otter trawl (age-0, 1980–2022), and the SFBS midwater trawl (age-0, 1980–2022). Note differences in the y-axis scales for each graph. Trend lines are included to visually aid in long-term trend changes across four identified regime shifts (Tempel et al. 2021), including the pre-clam years (cyan, <1986), pre-POD years (green, 1987–2001), POD years (yellow, 2002–2012), and the climate-shift years (red, 2013–present).



The 2022 age-0 Splittail abundance index was 0 for FMWT and both SFBS trawls (Figure 12). This value is typical of Splittail trends for MWT and OT surveys, which generally do not sample littoral areas where Splittail are present. The low to zero catch across most years makes it difficult to follow Splittail abundance trends. However, the presence of 0 indices has increased with increasing drought frequency in recent years.

The 2022 USFWS Beach Seine Survey index for age-0 Splittail was 0.04 fish per m^3, which was lower than the running survey average from 1994 to 2021 (0.60 fish per m^3) and is the lowest value on record (Figure 12). Regional abundance was highest in the Delta region (0.08 fish per m^3), followed by the Sacramento River region (0.04 fish per m^3), and lowest in the San Joaquin River (0 fish per m^3).

Age-0 Striped Bass

The Striped Bass is a long-lived anadromous fish first introduced to the estuary in 1897 (Dill and Cordone 1997), becoming a successful fishery within 10 years. Mature fish forage in near-shore marine habitats, including coastal bays and estuaries. Many adults migrate to the Delta in fall and early winter, where they remain until swimming upstream to spawn in the spring. Spawning takes place in the water column, and both eggs and larvae rely on river and tidal currents to keep them suspended during early development. Larvae are then transported to rearing areas in fresh and brackish waters (Chadwick 1964; Dill and Cordone 1997). Striped Bass provides a consistent index for upper trophic level influences in the estuary. It is a top predator in many areas of the estuary and feeds on a variety of prey items,

Figure 10. Age-1 Longfin Smelt annual abundance indices from (top to bottom) San Francisco Bay Study (SFBS) otter trawl (age-1, 1980–2022) and the SFBS midwater trawl (age-1, 1980–2022). Note differences in the y-axis scales for each graph. Trend lines are included to visually aid in long-term trend changes across four identified regime shifts (Tempel et al. 2021), including the pre-clam years (cyan, <1986), pre-POD years (green, 1987–2001), POD years (yellow, 2002–2012), and the climate-shift years (red, 2013–present).

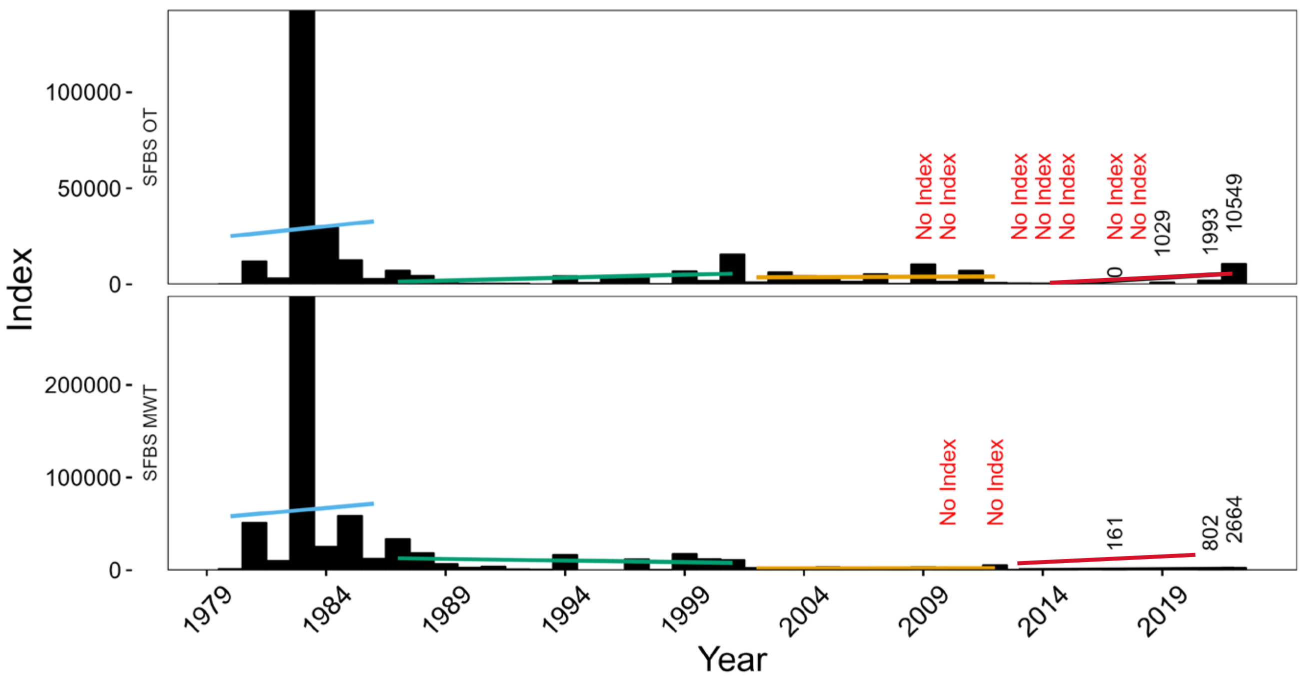


Figure 11. The age-0 Longfin Smelt annual design-based abundance indices (points connected by black line +/- standard deviation in gray) for the Smelt Larva Survey (2009–2022) in the upper San Francisco Estuary.

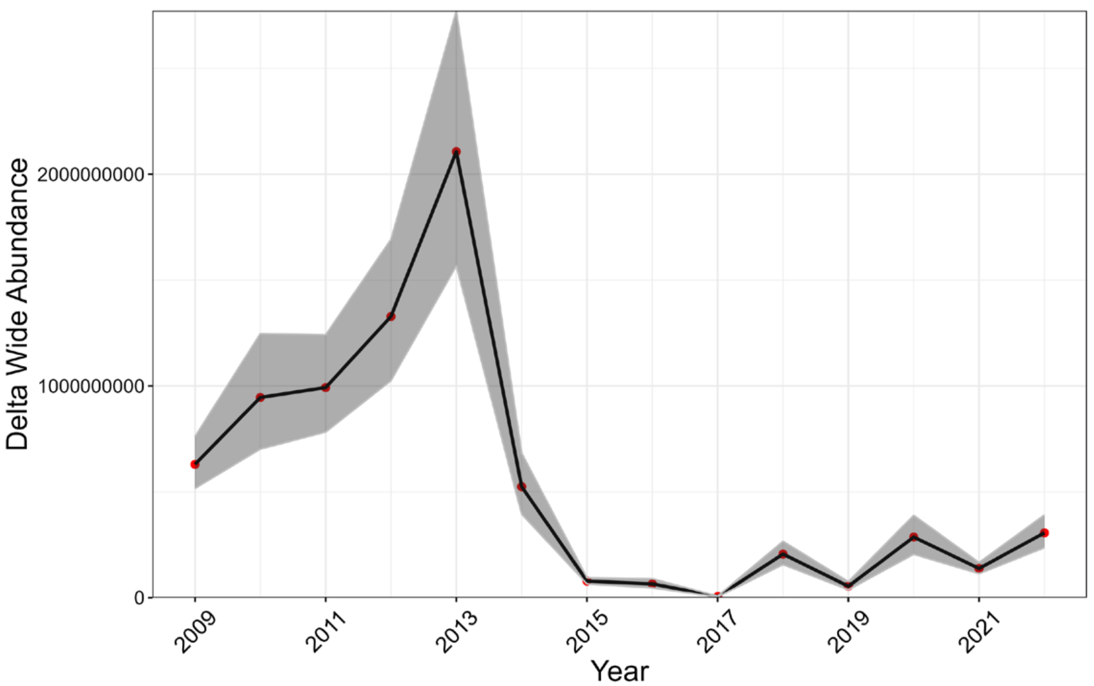
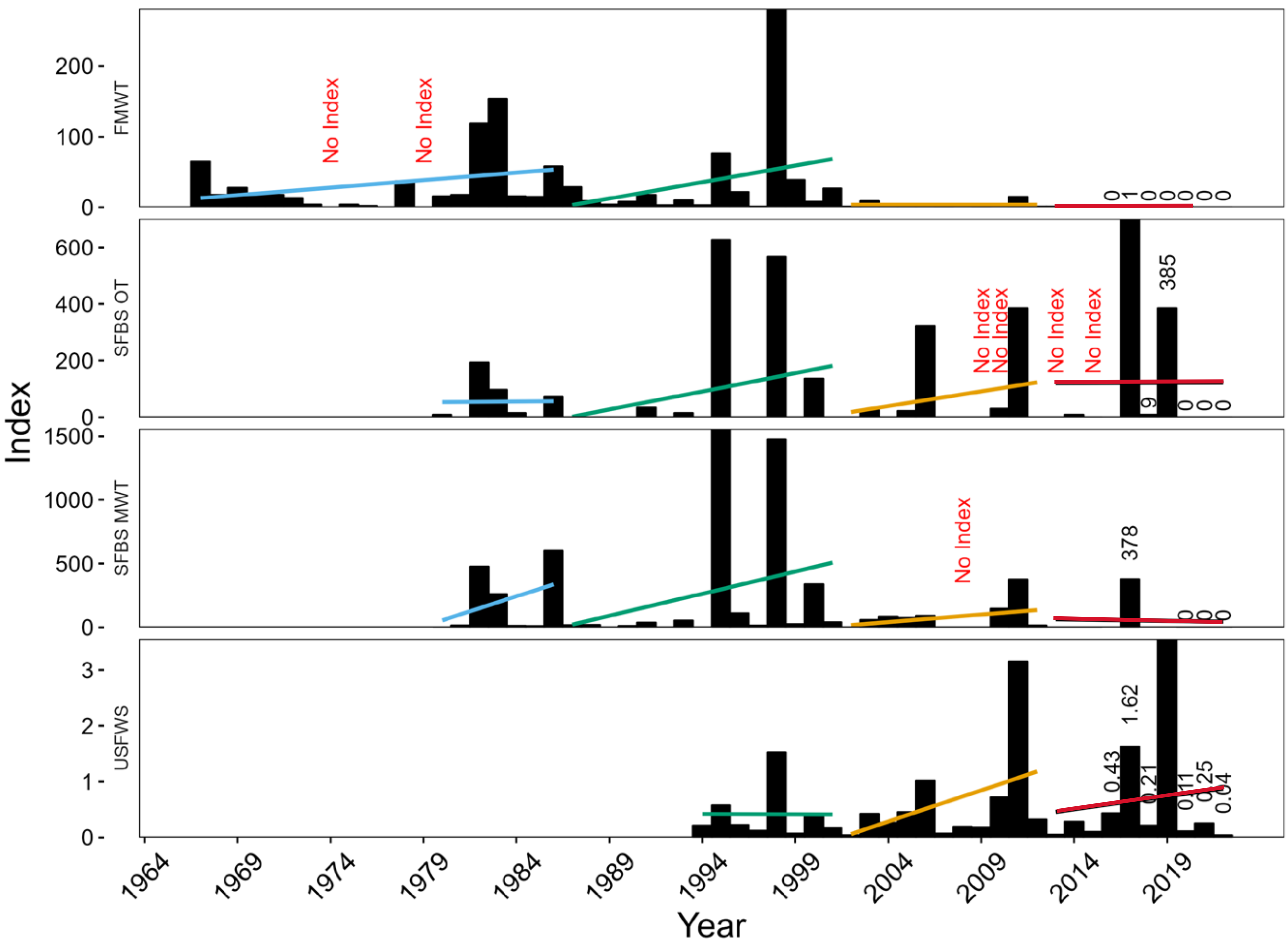


Figure 12. Splittail annual abundance indices from (top to bottom) Fall Midwater Trawl Survey (all sizes; 1967–2022), San Francisco Bay Study (SFBS) otter trawl (age-0, 1980–2022), SFBS midwater trawl (age-0, 1980–2022), and the USFWS Beach Seine Survey (juveniles ≥ 25 mm; 1994–2022). Note differences in the y-axis scales for each graph. Trend lines are included to visually aid in long-term trend changes across four identified regime shifts (Tempel et al. 2021), including the pre-clam years (cyan, <1986), pre-POD years (green, 1987–2001), POD years (yellow, 2002–2012), and the climate-shift years (red, 2013–present).

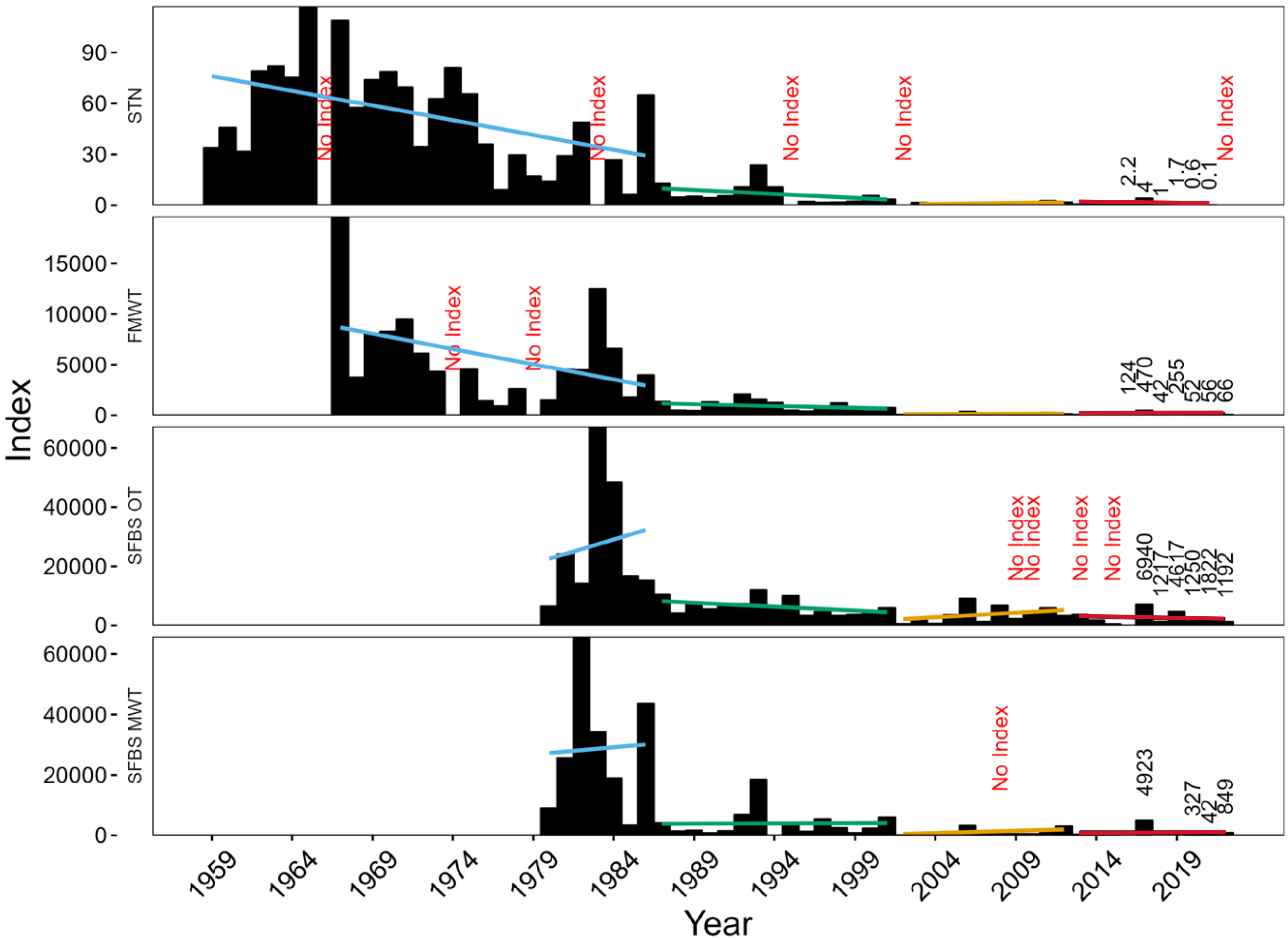


including bay shrimp, smelt, and juvenile salmonids (Moyle 2002; Nobriga and Smith 2020). In addition to their wide spatial coverage, many of the CDFW long-term monitoring surveys began with the intention of monitoring impacts to the Striped Bass fishery (Chadwick 1964). Striped Bass catch has reflected many of the noted regime changes in the estuary and, until recently, has consistently been collected in many regions of the upper estuary across multiple studies.

The CDFW long-term monitoring surveys had mixed patterns for age-0 Striped Bass in 2022 (Figure 13). The STN index could not be calculated in 2022, when no Striped Bass were caught at index stations during the third survey. This observation follows 2021 when STN recorded its lowest age-0 Striped Bass index at 0.1. Contrary to the low presence of Striped Bass in STN, the FMWT indices continued a slow increase to 66 in 2022. The SFBS MWT has also slightly increased in 2022 to 849. However, the SFBS OT index decreased to 1,192 in 2022, continuing a general decline in Striped Bass abundance.

The most recent trends in the MWTs (SFBS and FMWT) appear to be stagnant, changing little over the past 10 years. The last "peak" of age-0 Striped Bass was in 2017, and abundance indices have yet to approach levels equivalent to that wet year (Figure 13).

Figure 13. Age-0 Striped Bass annual abundance indices from (top to bottom) Summer Townet Survey (all sizes; 1959–2022), Fall Midwater Trawl Survey (all sizes; 1967–2022), San Francisco Bay Study (SFBS) otter trawl (age-0, 1980–2022), and the SFBS midwater trawl (age-0, 1980–2022). Note differences in the y-axis scales for each graph. Trend lines are included to visually aid in long-term trend changes across four identified regime shifts (Tempel et al. 2021), including the pre-clam years (cyan, <1986), pre-POD years (green, 1987–2001), POD years (yellow, 2002–2012), and the climate-shift years (red, 2013–present).



Flow and FMWT Catch Relationships

The long-term trends of several upper estuary pelagic species are strongly related to the magnitude of freshwater Delta outflow. Despite major regime changes (Tempel et al. 2021), the relationships between indices and Delta outflow have generally remained unchanged. We highlight this point below, showcasing the relationships between the FMWT indices of American Shad, age-0 Striped Bass, and age-0 Longfin Smelt.

The American Shad and Striped Bass abundance maintained a positive relationship to freshwater outflow (Figures 14 and 15, respectively) with the addition of the 2022 indices. Pre-clam years and climate-shift years both had a positive and significant relationship between American Shad indices and outflow (Table 2). Between these two regimes (the clam and POD years), American Shad did not have a strong relationship with outflow. Striped Bass had a positive and significant relationship in all regime periods, except during the POD years (Table 2).

Similar to 2021, age-0 Longfin Smelt had a higher-than-expected abundance index relative to Delta outflow in 2022 (Figure 16). This observation continues a recent trend that breaks away from the historical positive and linear relationship observed between Longfin Smelt indices and outflow.

Table 2. Regression results for Fall Midwater Trawl Survey fish indices vs. Delta outflow (Figures 14–16). Regime periods are based upon Tempel et al. 2021.

Fish	Regime	R^2adj	F	*p*
American Shad	Pre-Clam	0.71	43.45	0.000
	Clam	0.12	2.83	0.116
	POD	0.14	2.64	0.139
	Climate	0.54	11.49	0.010
Striped Bass	Pre-Clam	0.33	9.38	0.007
	Clam	0.03	1.49	0.243
	POD	0.29	5.18	0.049
	Climate	0.67	19.93	0.002
Longfin Smelt	Pre-Clam	0.59	13.73	0.006
	Clam	0.62	23.94	0.000
	POD	0.46	9.47	0.013
	Climate	-0.12	0.05	0.829

Figure 14. Relationships between the Fall Midwater Trawl American Shad indices (log scale, all ages, 1967–2022) and log April to June outflow at Chipps Island (cfs). Temporal ranges are from Tempel et al. 2021 and correspond to era (regime) shift periods in the San Francisco Estuary. The point indicating year 2022 has been enlarged and labeled.

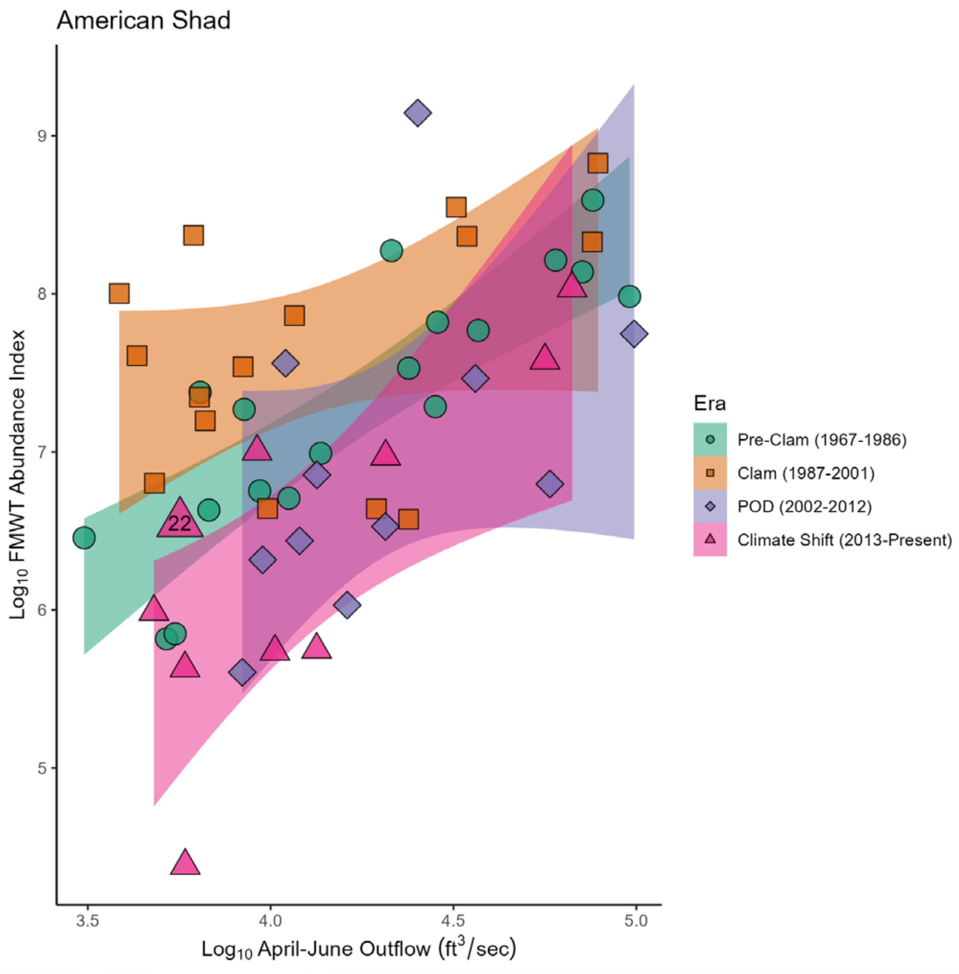
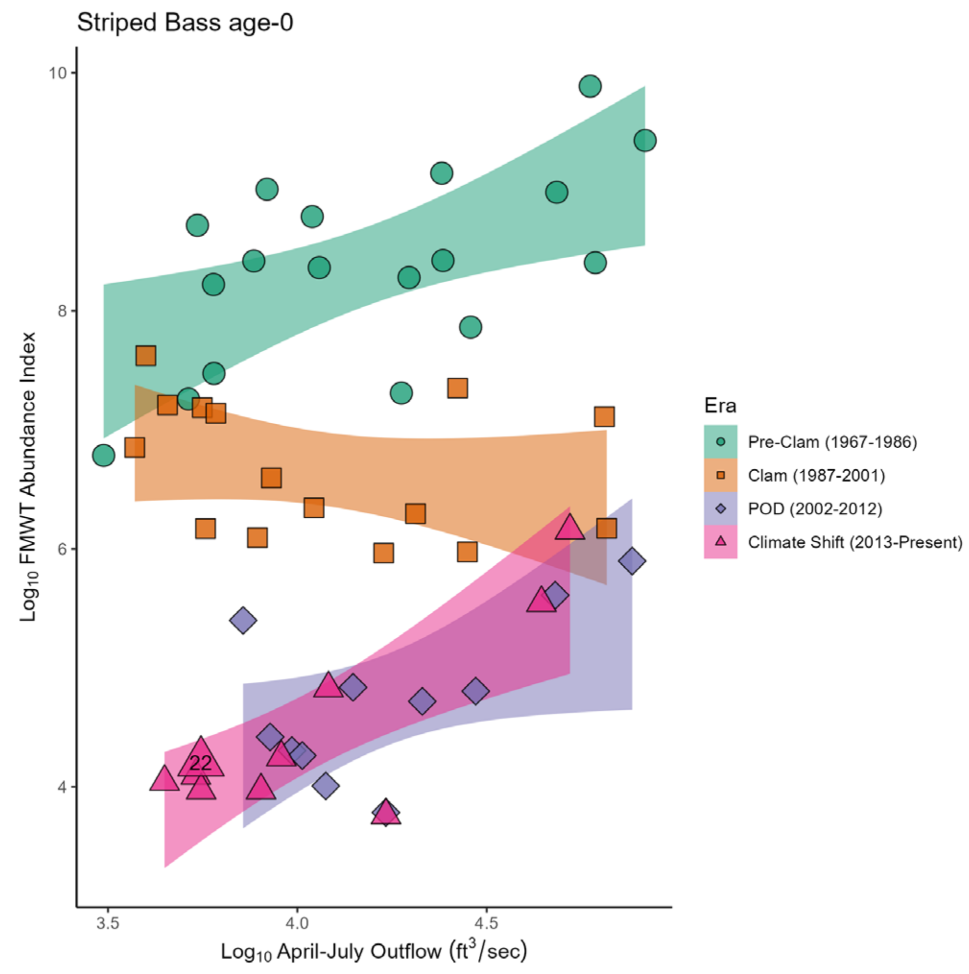


Figure 15. Relationships between the Fall Midwater Trawl age-0 Striped Bass indices (log scale, 1967–2022) and log April to June outflow at Chipps Island (cfs). Temporal ranges are from Tempel et al. 2021 and correspond to era (regime) shift periods in the San Francisco Estuary. The point indicating year 2022 has been enlarged and labeled.



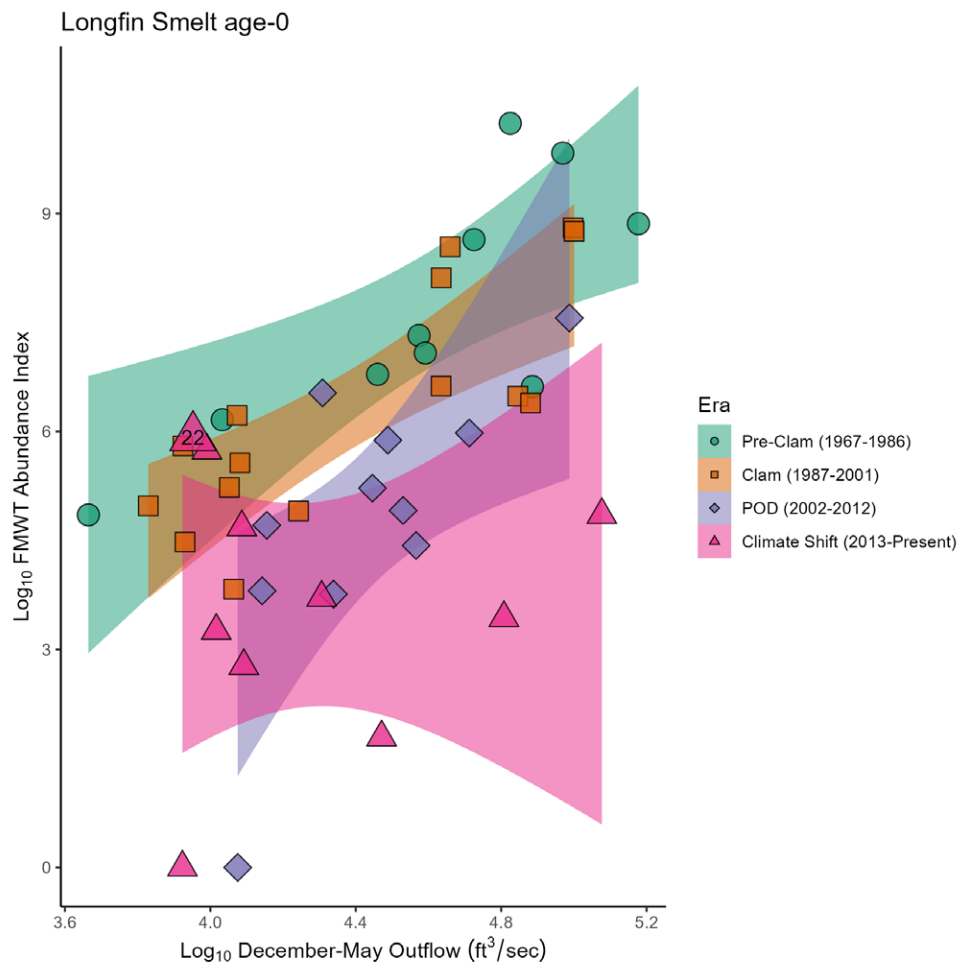
Conclusions

This report included new Delta Smelt and Longfin Smelt indices for the SLS. The annual indices from the SLS follow the general patterns of historical indices from other CDFW long-term monitoring surveys. These indices are design-based abundance indices reliant on regional CPUE and volumetric expansions. A strength of this new approach is the ability to calculate variance within and among years sampled. This new index calculation will provide a valuable tool for monitoring the future population trends of index species.

Year 2022 was the third year of drought to impact the upper estuary. Despite the challenging drought conditions, modest increases in fish abundance indices were observed in 2022. Longfin Smelt (age 0–1) increased slightly in all studies that report an index. MWTs (FMWT and SFBS) also observed small increases for American Shad, Threadfin Shad (SFBS not used to report on Threadfin Shad), and Striped Bass. No major changes in Splittail indices were observed by CDFW surveys, but the USFWS Beach Seine Survey observed a decrease in Splittail in 2022.

Despite increases in the 2022 indices, long periods of drought, interspersed with occasional wet years, continued to have dramatic, stochastic impacts on fish population responses and recoveries. The abundance trends since 2013 for the species included in this report agree across almost all studies on a decreasing or stagnant index trend. The exceptions to these patterns, for the moment, appear to be American Shad in midwater trawls and an increased abundance of Longfin Smelt in OT samples. The latter may not represent an increase in abundance but a shift in Longfin

Figure 16. Relationships between the Fall Midwater Trawl age-0 Longfin Smelt indices (log scale, 1975–2022) and log December to May outflow at Chipps Island (cfs). Temporal ranges are from Tempel et al. 2021 and correspond to era (regime) shift periods in the San Francisco Estuary.



Smelt preference from pelagic habitats, where water clarity has increased greatly, to demersal or near-bottom habitats.

For more information on CDFW surveys, annual indices, catch values, length frequency data, and access to the various datasets discussed visit CDFW Bay-Delta Surveys. In addition, you may contact Timothy.Malinich@wildlife.ca.gov for more information. For more information on the USFWS Beach Seine Survey, visit the Delta Juvenile Fish Monitoring Program.

Appendix A: Survey Background

Smelt Larva Survey

The SLS was implemented in 2009 to monitor the distribution and abundance of larval Longfin Smelt in near real-time to assess the vulnerability of Longfin Smelt to entrainment into the water export facilities. The SLS currently samples 44 stations (Figure 1) and runs every other week from December to March for a total of eight surveys. At each station, a 10-minute oblique tow is conducted using an egg and larva net with 500 µm mesh. All larval fish are preserved in 10% formalin and brought back to the laboratory for identification and enumeration.

SLS Design-Based Abundance Index Calculation

This report will be the first use of new design-based abundance indices for the SLS. Historically, this study has been used to track the presence and location of larval smelts. These new indices are set within 9 or 10 regions estuary and Delta (contact author for a copy). Larval fish catch per unit effort (CPUE) is expanded by sub-regional volumetric expansions and summed across all sub-regions. Variance of the index is calculated within each of the regions. Additional information on variance calculations can be found in Polansky et al. (2019). The number of stations sampled by the SLS vary in some regions of the Delta but were inconsistently sampled in the West Delta region (including Napa River, Carquinez Strait, and San Pablo Bay), often due to weather conditions and prior changes to the survey design. In years with only one representative station in a region, the region is dropped and not included in the design-based abundance index for that year.

Spring Kodiak Trawl Survey

The SKT has sampled annually since its inception in 2002 and determines the relative abundance and distribution of spawning Delta Smelt (SKT web page). The SKT samples 40 stations (Figure 1) monthly from January to May. All fish, shrimp, and jellyfish collected in the tow are identified and enumerated. Striped Bass are not separated by age class and were not included in this report.

20-mm Survey

The 20-mm Survey monitors the distribution and relative abundance of post-yolk sac larval and juvenile Delta Smelt throughout its historical spring range (20-mm Survey web page). The survey name refers to the size of Delta Smelt that the study targets, which corresponds to the size at which Delta Smelt are readily identifiable and counted at the State Water Project and Central Valley Project fish salvage facilities. Although designed for Delta Smelt, the 20-mm Survey is effective at sampling the pelagic larval fish community present in the spring and early summer. Since 1995, CDFW has conducted the 20-mm Survey on alternate weeks from mid-March through early July, completing nine surveys per year. Three tows are conducted at each of the 47 stations (Figure 1) using a fixed-mouth, 1,600 µm mesh net (Dege and Brown 2004).

Summer Townet Survey

The STN began in 1959 to index age-0 Striped Bass abundance, which it has done for all years except 1966, 1983, 1995, and 2002. Delta Smelt indices were also calculated for the period of record, except for 1966 through 1968. Historically, the STN conducted two to five surveys annually, but in 2003 CDFW standardized sampling to six surveys per year, beginning in early June and continuing every other week into August (Hieb et al. 2005). The STN samples 40 stations, 9 of which are considered non-index stations. Non-index stations are not used in index calculations (Figure 2 and Table 1), but they are included in CPUE reports. More detailed descriptions of field procedures can be found at the CDFW STN web page.

Fall Midwater Trawl Survey

The FMWT was established in 1967 to examine the relative abundance and distribution of age-0 Striped Bass. It has been conducted in all years except 1974 and 1979 (for additional information, see the CDFW FMWT web page). Over time, the FMWT Survey has also been used to track other common pelagic fish species in the upper estuary (Stevens 1977), including American Shad, Threadfin Shad, Delta Smelt, Longfin Smelt, and Splittail. The FMWT Survey currently conducts a single tow at 122 stations monthly from September through December (Figure 2). The annual abundance index calculation uses catch per tow data from 100 index stations (Stevens 1977). The remaining 22 stations were added in 1990, 1991, 2009, and 2010 to improve understanding of Delta Smelt distribution and habitat use. The 100 index stations were grouped into 14 regions to calculate monthly and annual abundance indices (see Table 1). The catch from the 22 non-index stations can be substantial, as areas like the Sacramento Deep Water Ship Channel and Cache Slough appear to be refuge habitats for many pelagic species as conditions deteriorate in other areas of the estuary.

San Francisco Bay Study

The SFBS began in 1980 to determine the effects of freshwater outflow on the abundance and distribution of fishes and mobile crustaceans throughout the estuary (Figure 3). Each month the SFBS samples 52 stations; 35 stations are core stations (i.e., original stations), which have been consistently sampled since 1980 and used to calculate the annual abundance indices (see Table 1, Baxter et al. 1999). Every station is sampled with an otter trawl to sample the demersal fishes, shrimp, and crabs plus a midwater trawl to sample pelagic fishes and gelatinous zooplankton (see the CDFW SFBS web page for additional information).

USFWS Beach Seine Survey

The USFWS has conducted the Beach Seine Survey since 1976 to sample out-migrating salmon and has held its current design since 1994. The USFWS conducts weekly beach seine sampling year-round at approximately 40 stations in the Delta and in the lower Sacramento and San Joaquin Rivers (Figure 3; Brandes and McLain 2001). Data collected from 35 stations in May and June are used to calculate the annual age-0 Splittail abundance index (see Table 1). These stations range from Sherman Lake to Ord Bend on the Sacramento River and to just downstream of the Tuolumne River confluence with the San Joaquin River. To limit the analysis to age-0 Splittail, all Splittail (measured individuals and proportions resulting from plus counts) <25 mm FL and ≥85 mm in May and <25 mm FL and ≥105 mm in June (cutoffs for age-1) are removed prior to calculations. To calculate the annual abundance index, the catch per cubic meter for seine hauls conducted at each station is averaged by month, CDFW subarea, and year to calculate an annual index per subarea. The annual subarea indices are then averaged by region (Delta, Sacramento River, and San Joaquin River) and finally across regions to produce the overall annual age-0 Splittail index.

References

Baxter R, Breuer R, Brown L, Chotkowski M, Feyrer F, Gingras M, Herbold B, Mueller-Solger A, Nobriga M, Sommer T, Souza K. 2008. Pelagic organism decline 2007 synthesis of results. Interagency Ecological Program for the San Francisco Estuary.

Baxter R, Hieb K, DeLeon S, Fleming K, Orsi J. 1999. Report on the 1980–1995 fish, shrimp and crab sampling in the San Francisco Estuary, California. Technical Report 63, The Interagency Ecological Program for the Sacramento–San Joaquin Estuary. 503 pp.

Benjamin A, Sağlam İK, Mahardja B, Hobbs J, Hung TC, Finger AJ. 2018. Use of single nucleotide polymorphisms identifies backcrossing and species misidentifications among three San Francisco estuary osmerids. Conserv Genet. 19(3):701–712. http://doi.org/10.1007/s10592-018-1048-9

Brandes PL, McLain JS. 2001. Juvenile Chinook Salmon abundance, distribution, and survival in the Sacramento–San Joaquin Estuary. In: Contributions to the biology of Central Valley salmonids.

[CDWR] California Department of Water Resources. 2020. Dayflow. [accessed 2021 Apr 21]. Available from: https://data.ca.gov/dataset/dayflow

[CDWR] California Department of Water Resources. 2022a. New water year begins amid preparations for continued drought. [accessed 2023 Feb 15]. Available from: https://water.ca.gov/News/News-Releases/2022/Oct-22/New-Water-Year-Begins-Amid-Preparations-for-Continued-Drought. Department of Water Resources

[CDWR] California Department of Water Resources. 2022b. Saltwater intrusion and drought salinity barriers. [accessed 2022] Available from: https://water.ca.gov/Water-Basics/Drought/Saltwater-Intrusion-and-Drought-Salinity-Barriers

Chadwick HK. 1964. Annual abundance of young striped bass, *Roccus saxatilis*, in the Sacramento–San Joaquin Delta, California. Calif Fish Game. 50(2)(September):69–99.

Damon L, Mora V. 2022. 2022 20-mm Survey Delta Smelt index. CA Department of Fish and Wildlife Memorandum. Available from: https://wildlife.ca.gov/Conservation/Delta/20mm-Survey/Bibliography

Dege M, Brown LR. 2004. Effect of outflow on spring and summertime distribution and abundance of larval and juvenile fishes in the upper San Francisco Estuary. Am Fish Soc Symp. 2004(39):49–65.

[DSP] Delta Science Program. 2022. Emergency drought barriers information sheet. Delta Science Program. Delta Stewardship Council. Sacramento, California. Available from: https://deltacouncil.ca.gov/pdf/science-program/information-sheets/2022-04-26-27-salinity-management-workshop-drought-barrier-information-sheet.pdf

Dill WA, Cordone AJ. 1997. History and status of introduced fishes in California, 1871–1996: Conclusions. Fisheries. 22(10):15–18.

Feyrer F, Hobbs J, Acuna S, Mahardja B, Grimaldo L, Baerwald M, Johnson RC, Teh S. 2015. Metapopulation structure of a semi-anadromous fish in a dynamic environment. Can J Fish Aquat Sci. 72(5):709–721. http://doi.org/10.1139/cjfas-2014-0433

Garwood RS. 2017. Historic and contemporary distribution of longfin smelt (*Spirinchus thaleichthys*) along the California coast. California Fish and Game. 103(3):96–117.

Gibson-Reinemer DK., Ickes BS, Chick JH. 2017. Development and assessment of a new method for combining catch per unit effort data from different fish sampling gears: Multigear mean standardization (MGMS). Can J Fish Aquat Sci. 74(1):8–14. https://doi.org/10.1139/cjfas-2016-0003

Hieb K, Bautista J, Giannetta J. 2019. Bay Study fishes status and trends report for the San Francisco Estuary. IEP Newsletter. 31(2):3–29.

Hieb K, Bryant ME, Dege M, Greiner T, Souza K, Slater SB. 2005. Fishes in the San Francisco Estuary, 2004 status and trends. IEP Newsletter. 18(2):19–36.

Honey K, Baxter R, Hymanson Z, Sommer T, Gingras M, Cadrett P. 2004. IEP Long-term Fish Monitoring Program Element Review.

[IEP] Interagency Ecological Program, Damon L, Chorazyczewski A. 2021a. Interagency Ecological Program San Francisco Estuary Spring Kodiak Trawl Survey 2002– 2021 ver 4. Environmental Data Initiative. [accessed 2023 Oct 17]. https://doi.org/10.6073/pasta/f0e2916f4a026f3f812a0855cee74a8d

[IEP] Interagency Ecological Program, Damon L, Chorazyczewski A. 2021b. Interagency Ecological Program San Francisco Estuary 20mm Survey 1995–2021 ver 3. Environmental Data Initiative. [accessed 2023 Oct 17]. https://doi.org/10.6073/pasta/292cd283cb636b8adae9bb97761ba5d3

[IEP] Interagency Ecological Program, Mora VG, Oceguera Zavala J, Jimenez JA. 2023. Interagency Ecological Program San Francisco Estuary Smelt Larva Survey 2009–2023 ver 8. Environmental Data Initiative. [accessed 2023 Oct 17]. https://doi.org/10.6073/pasta/276607dd985336d9796f0625b323b79c

Jimenez JA. 2022. 2022 Smelt Larva Survey Summary. IEP Newsletter. 41(3): 37–44.

Kimmerer W, Wilkerson F, Downing B, Dugdale R, Gross ES, Kayfetz K, Khanna S, Parker AE, Thompson J. 2019. Effects of drought and the emergency drought barrier on the ecosystem of the California Delta. San Francisco Estuary Watershed Science. 17(3). Article 2.

Kimmerer WJ, Gross ES, MacWilliams ML. 2009. Is the response of estuarine nekton to freshwater flow in the San Francisco Estuary explained by variation in habitat volume? Estuaries and Coasts. 32(2). http://doi.org/10.1007/s12237-008-9124-x

Lewis, LS, Willmes, M, Barros A, Crain PK, Hobbs JA. 2020. Newly discovered spawning and recruitment of threatened Longfin Smelt in restored and underexplored tidal wetlands. Ecology. https://doi.org/10.1002/ecy.2868

Malinich TD. 2023. Report: 2022 Summer Townet Survey seasonal summary. CA Department of Fish and Wildlife Technical Report. Available from: https://wildlife.ca.gov/Conservation/Delta/Townet-Survey/Bibliography

Melwani A, Tillotson M, Hobbs J, Slater S, Hennessy A, Schreier B, Arend K, McLain J. 2022. Evaluation and analysis of five long-term biological monitoring studies in the upper San Francisco Estuary. 2021 Final Report for 6 Agency Steering Committee. Available from: https://essexpartnership.app.box.com/s/apkt8f34texh6qie2lblm2g48yzsapud/file/940890323476

Mora V. 2022. 2022 Spring Kodiak Trawl Delta Smelt index. CA Department of Fish and Wildlife Memorandum. Available from: https://wildlife.ca.gov/Conservation/Delta/Spring-Kodiak-Trawl/Bibliography

Moyle PB. 2002. Inland fishes of California. Revised and Expanded Edition. University of California Press, Berkeley, CA, 502 pp.

Moyle PB, Baxter R, Sommer T, Foin T, Matern S. 2004. Biology and population dynamics of Sacramento Splittail (*Pogonichthys macrolepidotus*) in the San Francisco Estuary: a review. San Francisco Estuary Watershed Science. 2(2).

Moyle PB, Herbold B, Stevens DE, Miller LW. 1991. Life history and status of Delta Smelt in the Sacramento–San Joaquin Estuary, California. Trans Am Fish Soc. 121(1):67–77.

Nobriga ML, Smith WE. 2020. Did a shifting ecological baseline mask the predatory effect of Striped Bass on Delta Smelt? San Francisco Estuary and Watershed Science. 18(1):0–26.

Polansky L, Mitchell L, Newman, KB. 2019. Using multistage design-based methods to construct abundance indices and uncertainty measures for Delta Smelt. Trans Am Fish Soc. 148(4):710–724. https://doi.org/10.1002/tafs.10166

Sommer T, Baxter R, Herbold B. 1997. Resilience of Splittail in the Sacramento–San Joaquin Estuary. Trans Am Fish Soc. 126(6):961–976. http://doi.org/10.1577/1548-8659(1997)126<0961:rosits>2.3.co;2

Sommer T, Mejia F, Hieb K, Baxter R, Loboschefsky E, Loge F. 2011. Long-term shifts in the lateral distribution of age-0 striped bass in the San Francisco Estuary. Trans Am Fish Soc. 140(6):1451–1459. http://doi.org/10.1080/00028487.2011.630280

Stevens D. 1966. Distribution and food habits of the American shad (*Alosa sapidissima*) in the Sacramento–San Joaquin Delta. Ecological Studies of the Sacramento–San Joaquin Delta. Part II Calif Fish Game Fish Bulletin 136.

Stevens DE. 1977. Striped bass (*Morone saxatilis*) year class strength San Joaquin Estuary, California. Trans Am Fish Soc. 106:34–42.

Swanson C, Reid T, Young PS, Cech JJ. 2000. Comparative environmental tolerances of threatened Delta Smelt (*Hypomesus transpacificus*) and introduced wakasagi (*H. nipponensis*) in an altered California estuary. Oecologia. 123:384–390.

Tempel T, Malinich TD, Burns J, Barros A, Burdi CE, Hobbs JA. 2021. The value of long-term monitoring of the San Francisco Estuary for Delta Smelt and Longfin Smelt. Calif Fish Game. 107:148–171.

Turner JL, Chadwick HK. 1972. Distribution and abundance of young-of-the-year Striped Bass, *Morone saxatilis*, in relation to river flow in the Sacramento–San Joaquin Estuary. Trans Am Fish Soc. 3:442–452.

[USFWS] US Fish and Wildlife Service. 1993. Determination of threatened status for the Delta Smelt. Endangered and Threatened Wildlife and Plants. Federal Register. Vol 58. No. 42.

[USFWS] US Fish and Wildlife Service. 2022. Brood Year 2021 Experimental Release Technical Team (ERTT) summary of activities. Report prepared by US Fish and Wildlife Service. Sacramento, California. 55 pp.

Wang JCS. 1986. Fishes of the Sacramento–San Joaquin Estuary and adjacent waters, California: A guide to the early life histories.

White JR. 2023. FMWT 2022 Survey summary. CA Department of Fish and Wildlife Technical Report. Available from: https://wildlife.ca.gov/Conservation/Delta/Fall-Midwater-Trawl/Bibliography

DATA ARTICLE

2023 Smelt Larva Survey Summary

Jennifer C. Oceguera Zavala* (California Department of Fish and Wildlife [CDFW]), Vanessa Mora (CDFW), Jessica A. Jimenez (CDFW)

* Corresponding author: Jennifer.OceugueraZavala.@wildlife.ca.gov

The California Department of Fish and Wildlife (CDFW) annually conducts the Smelt Larva Survey (SLS) to monitor the distribution and abundance of larval Longfin Smelt (*Spirinchus thaleichthys*) in the upper San Francisco Estuary (estuary). Near real-time catch data are provided to resource managers to assess the risk of entrainment of Longfin Smelt at water export facilities. The survey also collects data on other larval fishes in the upper estuary, including Delta Smelt (*Hypomesus transpacificus*).

The SLS began in 2009, and a total of 35 stations were sampled until 2013. In compliance with requirements of Incidental Take Permits (ITPs) for long-term operations of the State Water Project (SWP), nine additional stations in the Napa River were sampled from 2014 to 2018 and again from 2022 to the present. In December 2022, 15 additional stations in the San Pablo Bay region were added in response to the 2020 ITP, totaling 59 stations (Figure 1, Melwani et al. 2022). From 2009 to 2020, a total of six surveys were conducted in a single season. Beginning in December 2021, two additional surveys were added (Surveys 12 and 13), bringing the total to eight surveys every season. Surveys are currently conducted every other week in 10 different strata (Figure 1), from early December through mid-March, when larval Longfin Smelt are most likely to be present in the survey area.

Environmental Scientist Vanessa Mora and Boat Operator Spencer Lewis are captured trying to retrieve an SLS net clogged with mud.

At each station, one oblique tow is conducted using a 500-µm Nitex mesh plankton on a solid frame with a net mouth area of 0.37 m². The conical net tapers back from the frame 3.35 m to a 1-liter cod-end jar, which collects the sample. Immediately after each tow, the contents of the cod-end jar are preserved in 10% formalin for later identification at the CDFW Lab in Stockton. The presence or absence of a yolk-sac or oil globule is noted for larval smelts.

The 2023 SLS season was conducted from December 5, 2022, to March 17, 2023. All stations were sampled during Surveys 12, 13, 2, 3, 4, and 6. In Survey 1, a bomb cyclone storm event prevented sampling at 10 stations in the Napa and South Delta regions. Station 329, located in San Pablo Bay, was dropped in Survey 5 (Table 1). A total of 200,902 fishes, comprising 37 taxa, were observed in 461 samples collected during the 2023 season (Table 2). In 2023, six times more fish were collected compared to 32,423 fishes collected in 2022 despite only about 33% more samples collected this year. Five new fish species were recorded for the first time in the history of the SLS: Bluefin Killifish (*Lucania goodei*), Warmouth (*Lepomis gulosus*), Starry Flounder (*Platichthys stellatus*), California Halibut (*Paralichthys californicus*), and rockfish (*Sebastes* spp.). Bluefin Killifish were recently introduced to the estuary (Mahardja et al. 2020). A total of 11 individuals were collected in Surveys 1 and Survey 2. A single Warmouth was collected at station 704 (Figure 1). Starry Flounder, California Halibut, and rockfish were observed as a result of the expansion efforts into San Pablo Bay. Four species made up 99% of the total SLS catch for the 2023 sampling season: Pacific Herring (*Clupea pallasi*), Yellowfin Goby (*Acanthogobius flavimanus*), Prickly Sculpin (*Cottus asper*), and Longfin Smelt (Figure 2).

Longfin Smelt were observed in all eight of the SLS surveys, with the first individual being detected in Survey 12 on December 6, 2022. The highest catch densities (n=1,153) in 2023 occurred during Survey 5 (February 27 to March 1). Yolk-sac larvae were observed in seven of the eight surveys (Figure 3). The highest numbers of Longfin Smelt with a yolk-sac were collected in March when they were between 6 and 9 mm in length (Figure 3D). The highest numbers of yolk-sac larvae were observed in the Suisun & Honker Bay stratum and followed closely by San Pablo Bay & Carquinez Strait stratum (Figure 4).

In 2023, the SLS implemented design-based abundance calculations to standardize catch abundance estimates. Consistent with previous analyses, the regional abundance estimates

J. CHAGOYA / CDFW

This fish is a California Halibut caught on March 16, 2023, in Survey 6 at station 323. This particular specimen was 10 mm in length and represents the first California Halibut ever caught by the SLS survey.

revealed a declining pattern for the Longfin Smelt population that began after 2013 but has shown a gradual increase in recent years from 2021 to 2023 (Figure 5).

Year 2023 represented the second year of a planned multi-year Delta Smelt Experimental Release effort. A total of 42,550 hatchery-raised Delta Smelt were released into the lower Sacramento River near Rio Vista and the Sacramento Deep Water Ship Channel between November 2022 and January 2023 (USFWS 2023). Four larval Delta Smelt were collected in the SLS Survey 6 (March 13–16, 2023) in three strata: Suisun & Honker Bay, Suisun Marsh, and Confluence. Similarly sized Delta Smelt larvae were observed by CDFW's 20-mm Survey during the same week in the San Pablo Bay & Carquinez Strait and Suisun & Honker Bay strata (CDFW 2023). This suggests that spawning likely occurred in March 2023, similar to previous years (Jimenez 2022).

For additional information on SLS methods, sampling design, and prior year summary reports, see our online bibliography. For catch per unit of effort values and data visualizations, see the SLS web page; for Survey data see the FTP site.

References

[CDFW] California Department of Fish and Wildlife. 2023. Fish distribution map. Available from: https://wildlife.ca.gov/Conservation/Delta/20mm-Survey/Map

[IEP MAST] Interagency Ecological Program Management, Analysis, and Synthesis Team. 2015. An updated conceptual model of Delta Smelt biology: our evolving understanding of an estuarine fish. Interagency Ecological Program for the San Francisco Estuary, Technical Report 90. Available from: https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/petitioners_exhibit/dwr/part2/DWR-1089%20IEP_MAST_Team_2015_Delta_Smelt_MAST_Synthesis_Report_January%202015.pdf

Jimenez JA, Mora V. 2022. 2022 Smelt Larva Survey summary. IEP Newsletter Summer/Fall. 41(3):37–44.

Mahardja B, Goodman A, Goodbla A, Schreier AD, Johnston C, Fuller RC, Contreras D, McMartin L. 2020. Introduction of Bluefin Killifish *Lucania goodei* into the Sacramento–San Joaquin Delta. San Francisco Estuary & Watershed Science. 18(2):Article 3.

Melwani A, Tillotson M, Hobbs J, Slater S, Hennessy A, Schreier B, Arend K, and McLain J. 2022. CDFW/USBR/DWR/USFWS monitoring survey design team evaluation and analysis of five long-term biological monitoring studies in the upper San Francisco Estuary. 2021 Final Report. Available from: https://csamp.baydeltalive.com/docs/25928.

[USFWS] US Fish and Wildlife Service. 2023. Brood year 2022 experimental release technical team summary of activities. Report prepared by US Fish and Wildlife Service. Sacramento, California. 55 pp. plus appendices.

Table 1. Sampling effort for the California Department of Fish and Wildlife's 2023 Smelt Larva Survey.

Survey	Stations Sampled	Comments
12	59	All stations sampled
13	59	All stations sampled
1	49	10 stations dropped due to hazardous weather
2	59	All stations sampled
3	59	All stations sampled
4	59	All stations sampled
5	58	Station 329 dropped
6	59	All stations sampled

Table 2. Total number and percent of species caught in the 2023 California Department of Fish and Wildlife's Smelt Larva Survey. Data include the December surveys from the 2023 sampling season.

Common Name	Total Catch (Number of Individuals)	Percent of catch
Pacific Herring	152,750	76%
Yellowfin Goby	28,036	14%
Prickly Sculpin	14,502	7%
Longfin Smelt	4,620	2%
Arrow Goby	498	0.25%
Pacific Staghorn Sculpin	87	0.04%
Longjaw Mudsucker	73	0.04%
Bay Goby	54	0.03%
Northern Anchovy	47	0.02%
Rainwater Killifish	44	0.02%
White Croaker	41	0.02%
Rockfish (unid)	24	0.01%
Starry Flounder	22	0.01%
Cheekspot Goby	20	0.01%
Shokihaze Goby	17	0.01%
Bluefin Killifish	11	0.01%
Wakasagi	7	<0.01%
River Lamprey	5	<0.01%
Sacramento Sucker	5	<0.01%
Threespine Stickleback	5	<0.01%
Delta Smelt	4	<0.01%
Striped Bass	4	<0.01%
Chinook Salmon	3	<0.01%
Shimofuri Goby	3	<0.01%
Tridentiger spp.	3	<0.01%
White Catfish	3	<0.01%
Bay Pipefish	2	<0.01%
Bigscale Logperch	2	<0.01%
Cyprinids (Unid)	2	<0.01%
Bluegill Sunfish	1	<0.01%
California Halibut	1	<0.01%
Inland Silverside	1	<0.01%
Pacific Lamprey	1	<0.01%
Sculpins (Unid)	1	<0.01%
Threadfin Shad	1	<0.01%
Topsmelt	1	<0.01%
Warmouth	1	<0.01%

Figure 1. Map of the Smelt Larva Survey station locations sampled by the California Department of Fish and Wildlife. Station locations are grouped into 10 strata.

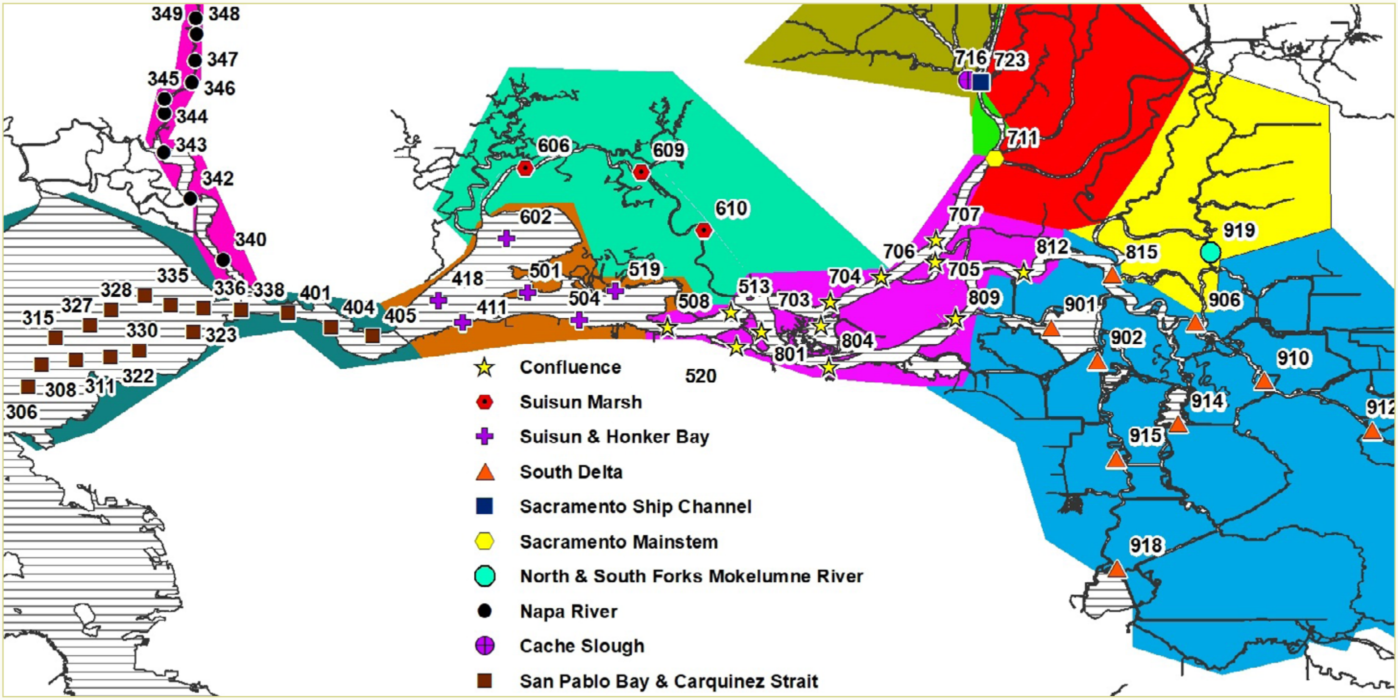


Figure 2. Annual percent species composition from the California Department of Fish and Wildlife's Smelt Larva Survey. Data include the December surveys from 2021 to 2023.

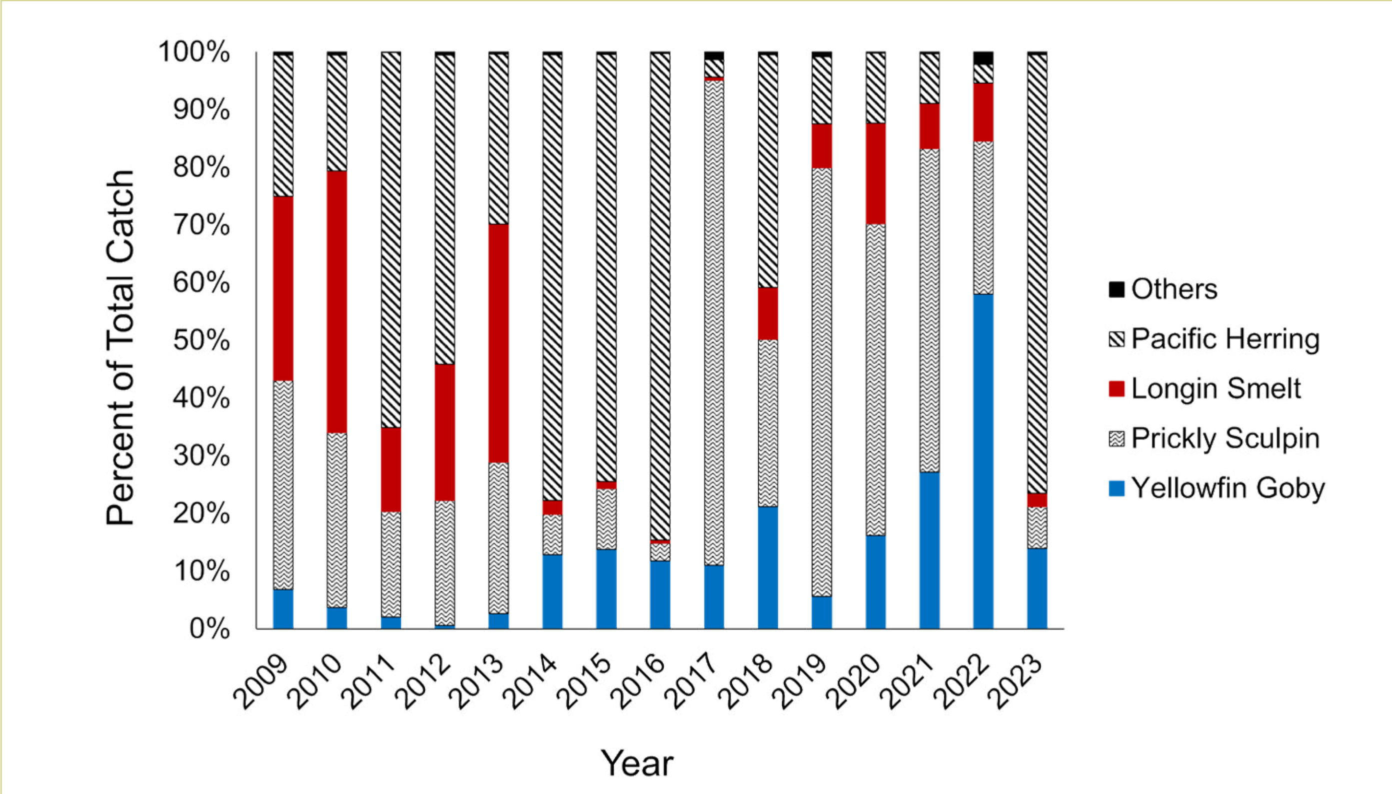


Figure 3. Length frequency with proportion of yolk-sac presence and absence of larval Longfin Smelt caught during each month of the 2023 California Department of Fish and Wildlife's Smelt Larva Survey. (A) December 2022 (B) January 2023 (C) February 2023 (D) March 2023.

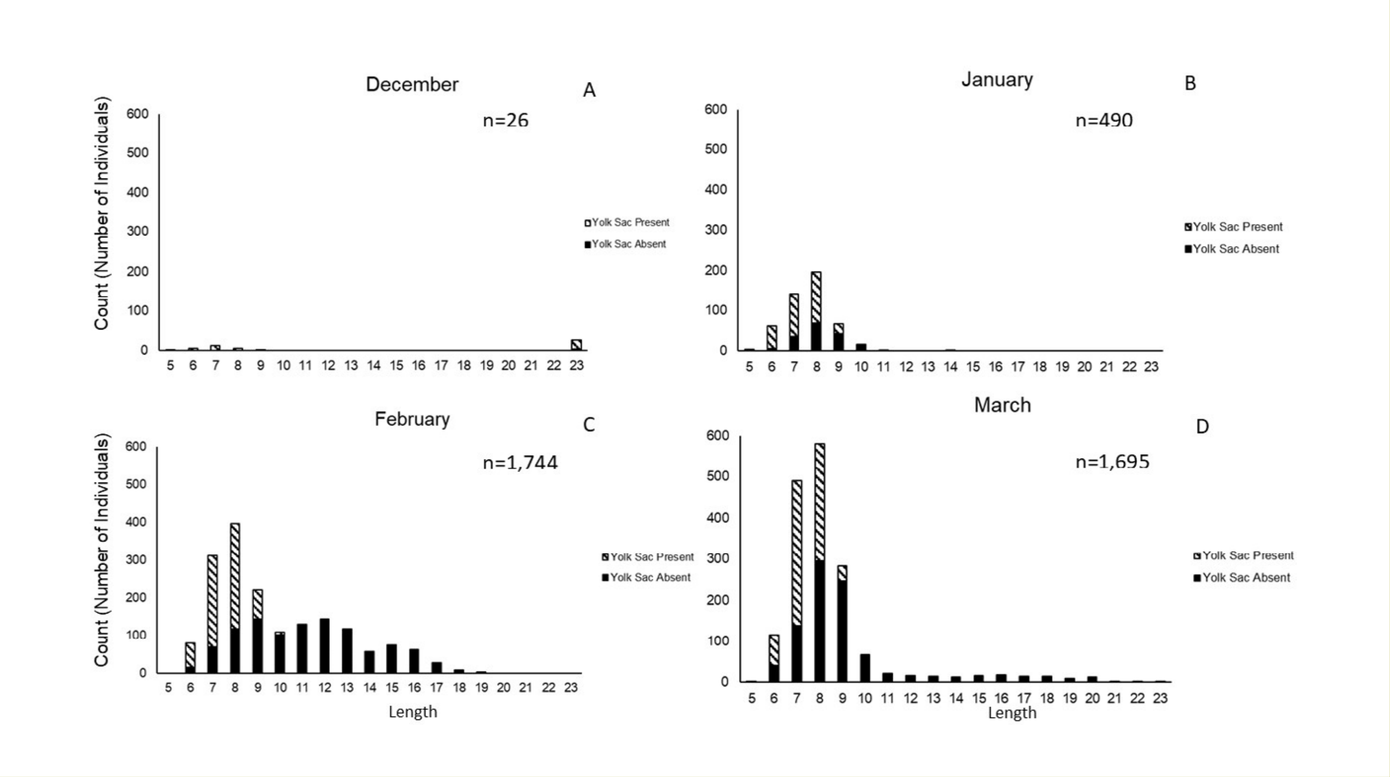


Figure 4. Number of larval Longfin Smelt and proportion of yolk-sac presence and absence caught in each strata of the 2023 California Department of Fish and Wildlife's Smelt Larva Survey. Data include the December surveys from 2021 to 2023.

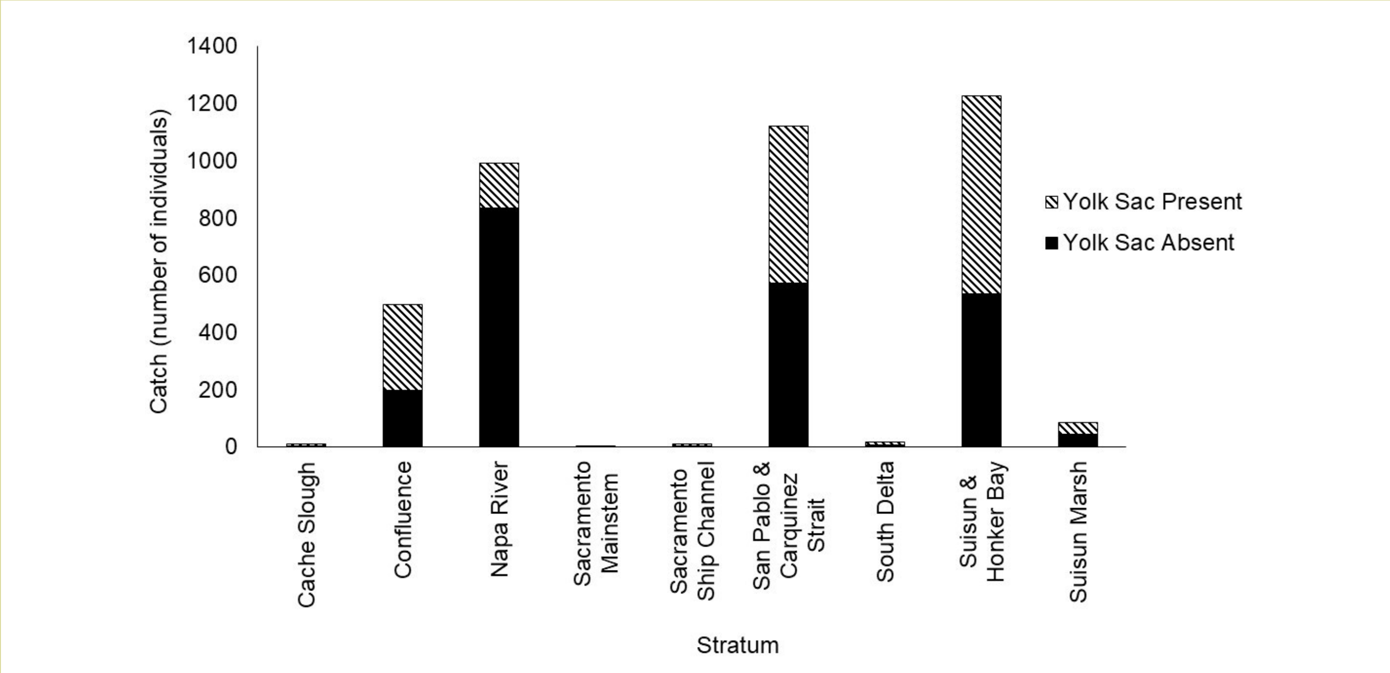
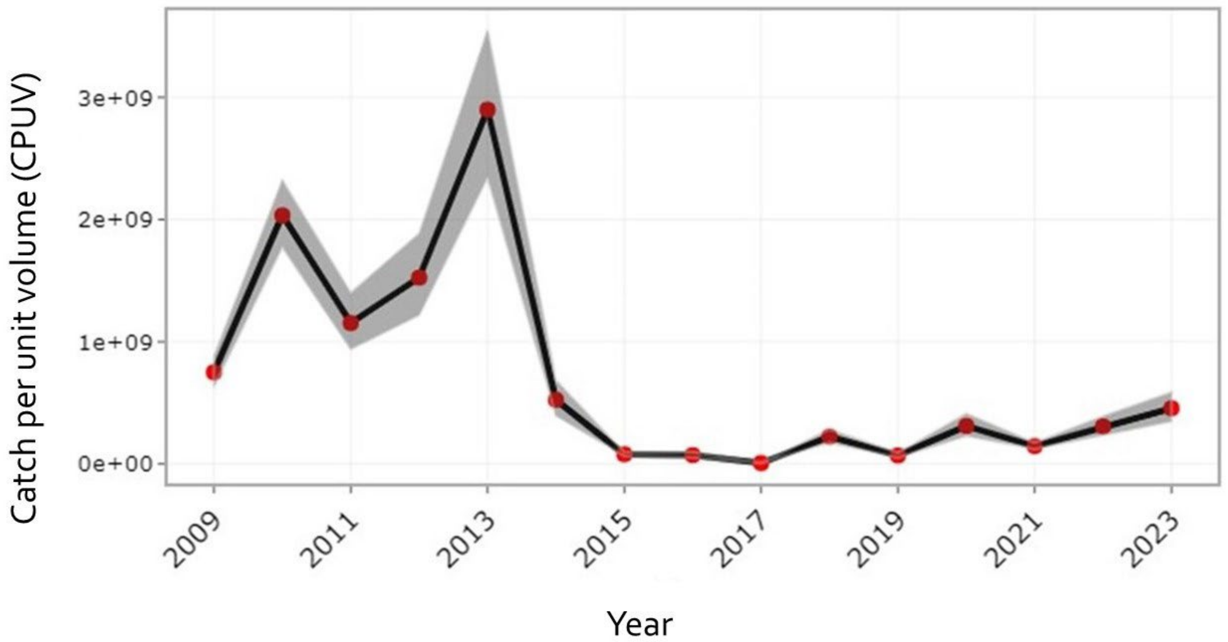


Figure 5. Annual Longfin Smelt design-based abundance estimates from 2009 to 2023 sampled by the California Department of Fish and Wildlife's Smelt Larva Survey. Data include the December surveys from 2021 to 2023 (points connected by black line +/- standard deviation in gray).



IEP

Interagency Ecological Program for the San Francisco Estuary

The Interagency Ecological Program for the San Francisco Estuary
is a cooperative effort of the following agencies:

California Department of Fish and Wildlife
California Department of Water Resources
State Water Resources Control Board
National Marine Fisheries Service
US Army Corps of Engineers
US Bureau of Reclamation
US Environmental Protection Agency
US Fish and Wildlife Service
US Geological Survey