Title
Suisun Marsh Fish Study trends in fish and invertebrate populations of Suisun Marsh January 2015 - December 2015.

Authors
O'Rear, Teejay Alexander
Moyle, Peter B

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SUISUN MARSH FISH STUDY

Trends in Fish and Invertebrate Populations of Suisun Marsh

January 2015 - December 2015

Annual Report for the

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Sacramento, California

Teejay A. O'Rear and Peter B. Moyle

Department of Fish, Wildlife, and Conservation Biology

Center for Watershed Sciences

University of California, Davis

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SUMMARY

Suisun Marsh, at the geographic center of the northern San Francisco Estuary, is important habitat for native and non-native fishes. The University of California, Davis, Suisun Marsh Fish Study, in partnership with the California Department of Water Resources (DWR), has systematically monitored the marsh's fish populations since January 1980. The main purpose of the study has been to determine environmental and anthropogenic factors affecting fish distribution and abundance.

The drought beginning in 2012 continued into 2015 and was reflected in Suisun Marsh's environment. The water in Suisun Marsh in 2015 was generally salty, well-oxygenated, warm, and clear. Delta outflows were well below average compared to a typical year, corresponding to the second-highest average annual salinity recorded in Suisun Marsh over the study's 35-year history. Oxygen concentrations were hospitable for most marsh fishes in all months of 2015. Water temperatures were warmer than average through much of the first half of the year and then again in early autumn. Consistent with low Delta outflows, the water in Suisun Marsh was more transparent than usual, particularly during summer and autumn.

Fishes and invertebrates in Suisun Marsh in 2015 mostly reflected the dry, salty year but showed some surprises. Native species more abundant during wetter, cooler years, such as California bay shrimp (*Crangon franciscorum*), longfin smelt (*Spirinchus thaleicthys*), and staghorn sculpin (*Leptocottus armatus*), were few in number during 2015; the non-native yellowfin goby (*Acanthogobius flavimanus*), a species positively associated with higher outflows, also suffered in 2015. Salinity tolerances were likely exceeded for two common euryhaline-freshwater non-native fishes [common carp (*Cyprinus carpio*) and white catfish (*Ameiurus catus*)], resulting in severe declines in their abundances. Salinities sufficient for reproduction throughout 2015 likely facilitated the highest-ever abundance of non-native overbite clam (*Potamocorbula amurensis*) recorded in the study's history. Nevertheless, several fishes and invertebrates appeared to tolerate the drought's fourth year rather well. While numbers in 2015 were down relative to their average in Suisun Marsh, threadfin shad (*Dorosoma petenense*) and striped bass (*Morone saxatilis*) were both comparatively more abundant in the marsh than in the open waters of the estuary's main axis. The non-native Siberian prawn (*Palaemon modestus*), a euryhaline-freshwater species, was also more abundant than expected. Finally, Sacramento splittail (*Pogonichthys macrolepidotus*) in 2015 reached their second-highest abundance since the study's inception in 1980. That these species performed rather well given the conditions suggests food supply (zooplankton, benthic invertebrates) may have been higher in Suisun Marsh than elsewhere in the estuary.

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INTRODUCTION

Suisun Marsh is a brackish-water marsh bordering the northern edges of Suisun, Grizzly, and Honker bays in the San Francisco Estuary (Figure 1); it is the largest estuarine marsh remaining on the western coast of the contiguous United States (Moyle *et al.* 2014, Moyle *et al.* 1986). Much of the marsh area is diked wetlands managed for waterfowl, with the rest of the acreage consisting of tidal sloughs, marsh plain, and grasslands (DWR 2001). The marsh's central location in the northern San Francisco Estuary makes it an important nursery for euryhaline-freshwater, estuarine, and marine fishes; the marsh is also a migratory corridor for anadromous fishes such as Chinook salmon (*Oncorhynchus tshawytscha*; Vincik 2002).

In January 1980, DWR contracted with UC Davis to monitor fish in Suisun Marsh. Since then, monitoring has remained continuous and in compliance with regulatory requirements of (1) the San Francisco Bay Conservation and Development Commission 4-84 (M) Special Condition B, (2) the US Army Corps of Engineers 16223E58B Special Condition 1, and (3) the Revised Suisun Marsh Monitoring Agreement (Agreement Number 4600000634). The study has consistently used two methods for sampling fishes: beach seines and otter trawls. Juveniles and adults of all species have been surveyed systematically since 1980; between 1994 and 1999, larval fishes were also surveyed (Meng and Matern 2001). Other objectives have included (1) evaluating the effects of the Suisun Marsh Salinity Control Gates on fishes (Matern *et al*. 2002), which began operating in 1988 (DWR 2001); (2) examining long-term changes in the Suisun Marsh ecosystem in relation to other changes in the San Francisco Estuary (*e.g.,* Moyle *et al.* 2014, Rosenfield and Baxter 2007); and (3) enhancing understanding of the life history and ecology of key species in the marsh (Brown and Hieb 2014). Secondary objectives have included supporting research by other investigators through special collections (*e.g.,* Liu *et al.* 2012); providing background information for in-depth studies of other aspects of the Suisun Marsh aquatic ecosystem (*e.g.*, studies of jellyfish biology; Meek *et al.* 2012, Wintzer *et al.* 2011*a*, *b*, *c*); serving as a baseline for upcoming restoration and for ancillary studies on off-channel habitats (*e.g.*, Williamson *et al.* 2015); contributing to the general understanding of estuarine systems through publication of peer-reviewed papers (*e.g.,* Schroeter *et al.* 2015, Moyle *et al.* 2013); training undergraduate and graduate students in estuarine studies and fish sampling; and providing a venue for managers, biologists, and others interested in the marsh to experience it firsthand.

Moyle *et al.* (1986) evaluated the first five years of data collected by the study and found three groups of fishes that exhibited seasonal trends in abundance, primarily due to differences in recruitment timing. The structure of the fish assemblage was relatively constant through time; however, total fish abundance declined over the five years. The decline was partly due to strong year classes early in the study period followed by both extremely high river flows and drought that resulted in poor recruitment. The authors also found that native fishes were generally more prevalent in small, shallow sloughs, while non-native species were more prominent in large sloughs. Meng *et al.* (1994) incorporated eight more years into their study, which revealed that the fish assemblage structure was less constant over the longer time period than the earlier study indicated. Additionally, non-native fishes had become more common in small, shallow sloughs. Like Moyle *et al.* (1986), Meng *et al.* (1994) found a general decline in total fish abundance through time, partly because of the drought and high salinity harming native fishes. Matern *et al.*

(2002) found results similar to Meng *et al.* (1994): fish diversity was highest in small sloughs, and native fish abundances continued to fall.

Recent studies have enhanced understanding of Suisun Marsh's aquatic ecosystem. Isotope studies by Schroeter *et al*. (2015) found that many consumers in the marsh are generalists and that submerged aquatic vegetation may be a significant carbon subsidy to upper trophic levels. Surveys in and around a restored tidal marsh (Blacklock Island) and a managed wetland (Luco Pond), utilizing identical gear to the Suisun Marsh Fish Study, found higher fish abundances, higher fish diversity, and a higher proportion of native fishes in the managed wetland relative to the restored marsh, suggesting managed wetlands can provide benefits to desirable fishes while still supporting waterfowl (Williamson *et al.* 2015). Finally, data accumulating from an ongoing companion study, (the "Arc Project") utilizing in part the same sampling methods as the Suisun Marsh Fish Study, are revealing that the marsh still provides vital habitat for at-risk native species, especially Sacramento splittail. Consequently, the Suisun Marsh Fish Study remains instrumental in documenting and understanding changes in the biology of the estuary, especially within the context of climate change and future restoration (Moyle *et al.* 2014).

This report's purpose was to (1) compare water-quality conditions between 2015 and typical conditions in Suisun Marsh; (2) compare abundances of important invertebrates and important fishes in 2015 to study averages, noting abundance changes between 2014 and 2015; (3) describe the pattern in monthly abundance of notable fishes and invertebrates in 2015, pointing out unusual occurrences; and (4) describe the geographic distribution of fishes and invertebrates.

METHODS

Study Area

Suisun Marsh is a mosaic of landscape types totaling about 38,000 hectares, with about 9% of the acreage comprised of tidal sloughs (O'Rear and Moyle 2015, DWR 2001). The marsh is contiguous with the northern boundary of Suisun, Grizzly, and Honker bays and is central to the San Francisco Estuary (Figure 1), with San Pablo Bay to the west and the Sacramento-San Joaquin Delta ("Delta") to the east. The two major subtidal channels (referred to as "large sloughs" in this report) in the marsh are Montezuma and Suisun sloughs (Figure 1). Major tributary sloughs (referred to as "small sloughs" in this report) to Montezuma are Denverton and Nurse; Cutoff Slough and Hunter Cut connect Suisun and Montezuma sloughs (Figure 1). Tributaries to Suisun Slough, from north to south, are Peytonia, Hill, Boynton, Shelldrake, Cutoff, Wells, Cordelia, and Goodyear sloughs (Figure 1). First and Second Mallard sloughs are tributary to Cutoff Slough and are part of Solano Land Trust's Rush Ranch Open Space preserve; Rush Ranch is part of the San Francisco Bay National Estuarine Research Reserve (http://www.sfbaynerr.org).

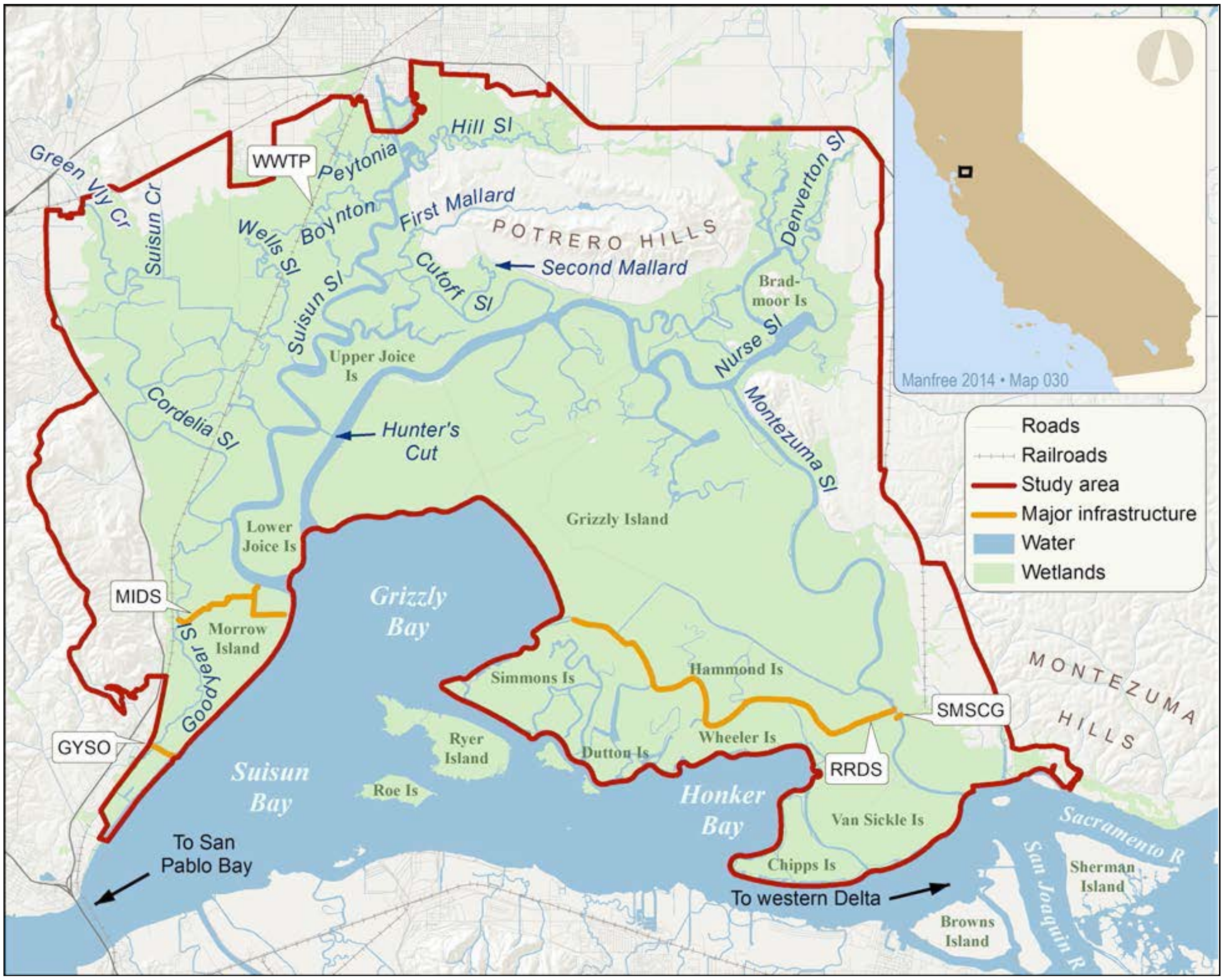

Figure 1. Suisun Marsh study area ("GYSO" = Goodyear Slough Outfall, "MIDS" = Morrow Island Distribution System, "RRDS" = Roaring River Distribution System, "SMSCG" = Suisun Marsh Salinity Control Gates, and "WWTP" = the Fairfield-Suisun Sanitation District's wastewater treatment plant discharge point into Boynton Slough; map by Amber Manfree).

Suisun and Montezuma sloughs are generally 100-150 meters (m) wide and 3-7 m deep, with banks consisting of a mix of riprap and fringing marsh (Meng *et al.* 1994). Tributary sloughs are usually 10-20 m wide, 2-4 m deep, and fringed with common reed (*Phragmites australis*) and tules (*Schoenoplectus* spp.). Most sloughs in the marsh are diked to some extent, although some small sloughs (*e.g.,* First Mallard) within the Rush Ranch preserve are undiked and thus have marsh plains regularly inundated by high tides. Substrates in all sloughs are generally fine organics, although a few sloughs also have bottoms partially comprised of coarser materials (*e.g.*, Denverton Slough; Matern *et al.* 2002), and the larger, deeper sloughs (*e.g.*, Montezuma Slough) can have sandy channel beds.

The amount of fresh water flowing into Suisun Marsh is the major determinant of its salinity. Fresh water enters the marsh primarily from the western Delta through Montezuma Slough, although small creeks, particularly on the northwest and west edges of the marsh, also contribute fresh water. As a result, salinities are generally lower in the eastern and northwestern portions of the marsh and higher in the southwestern section by Grizzly Bay. Freshwater inflows are highest in winter and spring due to rainfall and snowmelt runoff; consequently, marsh salinities are lowest in these seasons. Salt water enters the marsh mainly through lower Suisun and lower Montezuma sloughs from Grizzly Bay via tides, although the effect of the tides is more pronounced on water-surface elevation than on salinity throughout much of the year (Matern *et al.* 2002). During extreme tides, water depths can change as much as 2 m over a tidal cycle, often dewatering much of the smaller sloughs at low tide and overtopping dikes at high tide.

Several water management facilities alter the hydrology and water quality of the marsh. State Water Project and Central Valley Project water-pumping facilities in the southern Delta affect the timing and magnitude of freshwater flow into Suisun Marsh (DWR 1984). The Suisun Marsh Salinity Control Gates, located in Montezuma Slough just downstream of the confluence of the Sacramento and San Joaquin rivers, inhibit saltwater intrusion into the marsh during flood tides, providing fresher water for diked wetlands (DWR 2001; Figure 1). Numerous water control structures, most of which are unscreened for fish, are located throughout the marsh; they are opened in early autumn for flooding wetlands to attract wintering waterfowl, with water diverted from adjacent subtidal sloughs. Most water control structures remain open to some extent (or are reopened) during winter and spring, mainly to maintain water elevations in the wetlands, to leach salts from wetland soils, and to promote growth of desired waterfowl plants (DWR 1984). Diversions are restricted in some sloughs of the marsh during winter and spring to reduce entrainment of endangered fishes. Most wetlands are drained in late spring, with drainage water being discharged directly into sloughs within the marsh, and remain dry throughout summer. Several canal systems - the Roaring River Distribution System, the Morrow Island Distribution System, and the Goodyear Slough Outfall - redirect water in the marsh, with the goal of providing lower-salinity water for managed wetlands (Figure 1; DWR 2001). The Fairfield-Suisun Sewer District discharges tertiary-treated wastewater into Boynton Slough; the wastewater's salinity and dissolved-oxygen (DO) concentration are often low and high, respectively (Figure 1; Siegel *et al.* 2011).

Sampling

Since 1980, juvenile and adult fish have been sampled monthly at standard sites within subtidal sloughs of Suisun Marsh. Originally, 47 sites in 13 sloughs were sampled; several of these sites were sampled only in 1980 and 1981, with 17 sites in seven sloughs being sampled consistently until 1994 (see O'Rear and Moyle 2008). From 1994 to the present, 21 sites in nine sloughs have been regularly sampled by otter trawl (Figure 2). We continued sampling two additional sites in Denverton and Nurse sloughs (DV1 and NS1, respectively; Figure 2) in 2015 that were sampled as part of the Arc Project (O'Rear and Moyle 2016); their data were included in monthly and slough-to-slough comparisons in this report. Several historic sites were sampled in 2015 for other projects [GR3 and GR4 in Second Mallard Slough; and MZ6 ("Montezuma new"; Appendix C); Figure 2], but their data were not included in monthly or slough-to-slough comparisons due to inconsistent sampling.

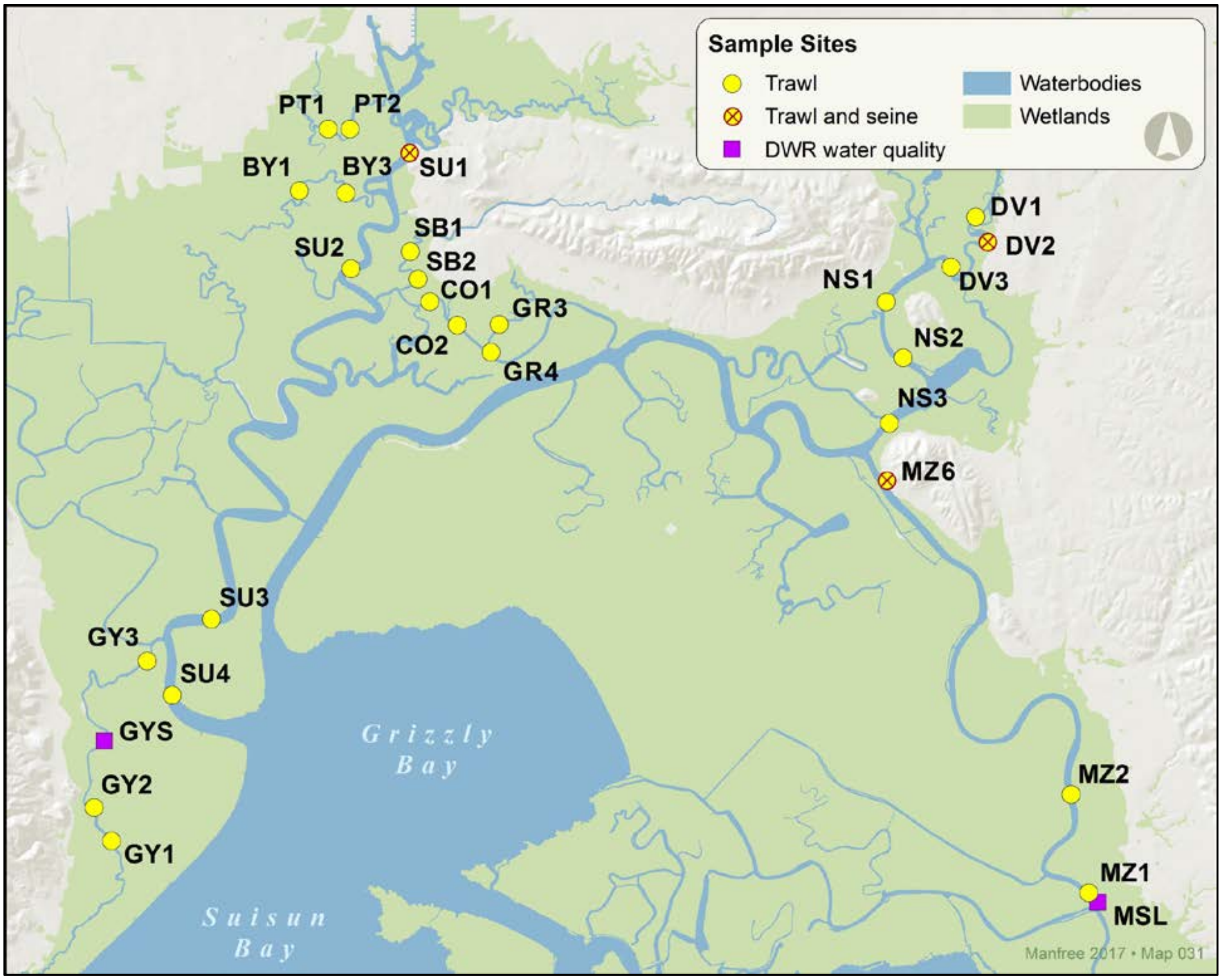

Figure 2. Current Suisun Marsh Fish Study sampling sites and DWR water-quality monitoring stations used in this report (map by Amber Manfree).

Trawling was conducted using a four-seam otter trawl with a 1.5-m X 4.3-m opening, a length of 5.3 m, and mesh sizes of 35-millimeter (mm) stretch in the body and 6-mm stretch in the cod end. The otter trawl was towed at 4 km/hr for 5 minutes in small sloughs and at the same speed for 10 minutes in large sloughs. In Denverton, upper Suisun, and eastern Montezuma sloughs, inshore fishes were sampled with a 10-m beach seine having a stretched mesh size of 6 mm. For each site, temperature (degrees Celsius, °C), salinity (parts per thousand, ppt), and specific conductance (microSiemens, μS) were recorded with a Yellow Springs Instruments PRO2030 meter. Dissolved oxygen parameters (milligrams per liter, mg/l, and % saturation), first sampled in 2000, were also measured with the PRO2030. Water transparency (Secchi depth, cm), tidal stage (ebb, flood, high, low), and water depths (m) were also recorded.

Contents of each trawl or seine were placed into large containers of water. Fishes were identified, measured to the nearest mm standard length (mm SL), and returned to the water. Sensitive native species were processed first and immediately released. Numbers of Black Sea jellyfish (*Maeotias marginata*), Siberian prawn, oriental shrimp (*Palaemon macrodactylus*), California bay shrimp, Harris mud crab (*Rhithropanopeus harrisii*), overbite clam, Asian clam (*Corbicula fluminea*), and other macroinvertebrate species were also recorded. Siberian prawn were first positively identified in February 2002, although they likely comprised a large percentage of the 2001 and early 2002 shrimp catch that was recorded as oriental shrimp. Abundances of Siberian prawn for this report are only considered from 2002 onward. Crustaceans from the order Mysida were pooled into one category, “mysids," and given an abundance ranking: 1 = 1-3 mysids, 2 = 4-50 mysids, 3 = 51-100 mysids, 4 = 101-500 mysids, and 5 = >500 mysids.

Data analysis

For this report, catch-per-unit-effort (CPUE) values were calculated differently depending on the type of comparison. For comparisons made among calendar years, CPUE for beach seines and otter trawls was calculated as

$$CPUE = \frac{annual\ number\ of\ fish\ caught\ in\ trawls/seines}{annual\ number\ of\ trawls/seines}$$

to remain consistent with previous reports (*e.g.*, Schroeter *et al.* 2006); CPUE values for invertebrates were also calculated likewise, with the annual number of individuals for the invertebrate of interest substituting for "annual number of fish." Slough-to-slough CPUE values for select species were calculated similarly except that, to account for unequal effort, minutes rather than number of trawls were used in the denominator. For monthly comparisons, to account for unequal effort among sloughs, CPUE values for otter trawls were calculated as

$$CPUE_i = \frac{\sum_{i=1}^{n} \frac{number\ of\ fish_{ij}}{number\ of\ trawls_{ij}}}{n}$$

where i = slough, j =month, and n is the number of sloughs; once again, CPUE values for beach seines and for invertebrates were calculated likewise. Age classes of fishes except Sacramento splittail and striped bass were determined from peaks and valleys in length-frequency graphs. Sacramento splittail age classes were determined following Matern and Sommer (unpublished data). Age-0 striped bass were classified as those fish belonging to the length-frequency-graph peak corresponding to the smallest size classes after April, adults were considered fish larger than 423 mm SL, and all others were classified as "juveniles." To describe geographic distribution, proportion of the 2015 otter trawl catch from the sampled sloughs was computed for dominant species, and annual CPUE with minutes as the denominator was calculated for each slough for age classes of striped bass and Sacramento splittail. Monthly water-quality averages for 2015 were calculated as for CPUE values, with the sum of the measurements of the water-quality parameter of interest (*e.g.*, Secchi depth, water temperature) substituting for "number of fish." The Net Delta Outflow Index ("Delta outflow"), a proxy for water leaving the Delta, was calculated by summing river flows entering the Delta, channel depletions, in-Delta diversions, and State Water Project, Central Valley Project, and Contra Costa Water District exports. Delta outflow was obtained from the California Department of Water Resource's Dayflow website (DWR 2016*b*).

Annual CPUE values for otter trawls and beach seines were graphed, as were monthly CPUE values for dominant invertebrate and fish species. Monthly water-quality results of 2015 were graphed and compared to averages for all years of the study. Fifteen-minute salinity and water temperature data from DWR fixed stations - GYS and MSL (Figure 2) - were graphed with the water-quality data collected during fish sampling to provide additional context. These two stations were chosen because (1) they were the DWR stations closest to our fish-sampling sites and (2) they were in sloughs that exhibited opposing extremes of habitat conditions (*e.g.*, slough cross section, geographical position) and so serve as useful bookends.

Catch of all fishes and by each method from 1979 to 2015 are found in Appendix A; annual catch of each slough and number of trawls/seines in each slough in 2015 are found in Appendix B and C.

RESULTS AND DISCUSSION

Abiotic Conditions

Delta Outflow

Delta outflow in 2015 was considerably below the average for all years of the study (Figure 3), representing the fourth consecutive year of lower-than-normal outflows and continuing the multi-year drought. With the exception of a few autumn days, outflow in 2015 did not equal or exceed average outflow at any time. During the typical winter-spring wet season, outflow rose notably only once, which occurred during February and lasted about two weeks. Thereafter, Delta outflow basically flat-lined, hovering around 5,400 cubic feet per second (cfs), for the remainder of winter, through spring and summer, and into early autumn before increasing again in late October.

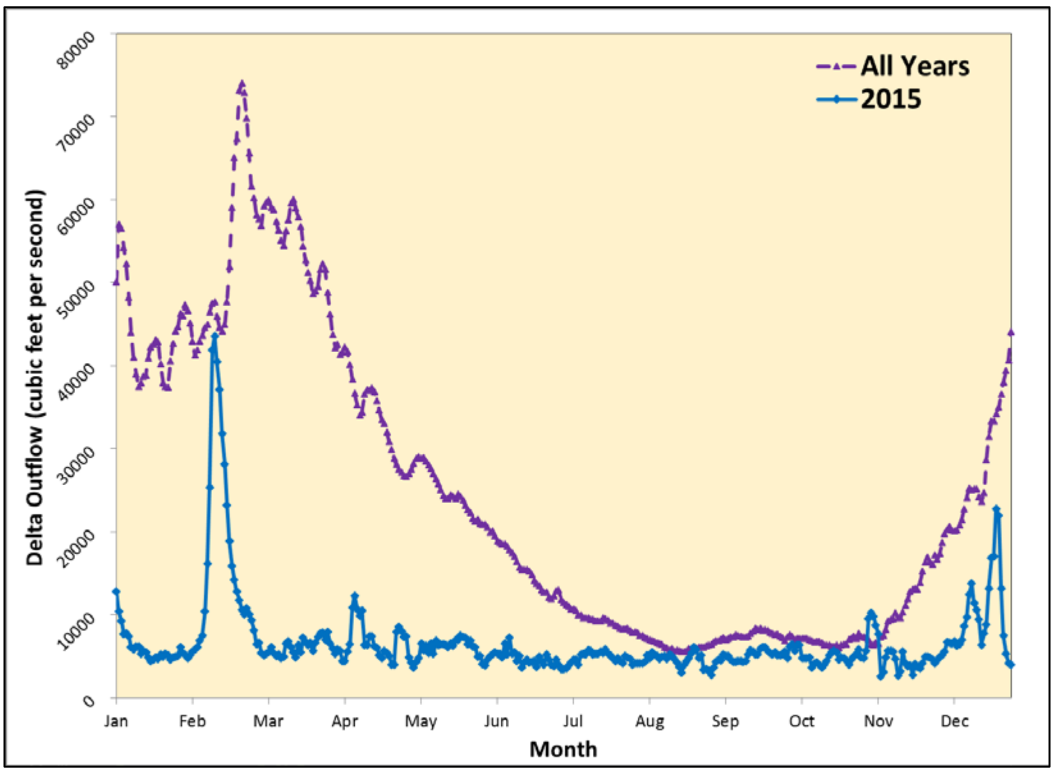

Figure 3. Daily Delta outflow in 2015 and the average for all years of the study (1980 – 2015; DWR 2016*b*).

Salinity

Of the years of the fish study (1980-2015), only 1991 charted a higher annual average salinity than 2015. Monthly average salinities in 2015 were well above average except in January and February (Figure 4). Salinities recorded by the fish study tended to be closer to the MSL gauge's values rather than the GYS gauge's values for the first half of the year (Figure 5), mostly because of low values recorded by the fish study at stations near freshwater sources: the BY1 station near the wastewater treatment plant's discharge point; the Peytonia Slough stations, which receive flow from Ledgewood Creek; and the eastern Montezuma Slough stations, which are the closest of the fish study's stations to the Sacramento River (Figure 2). For the latter half of the year, average fish-study salinities were well within the bounds of the two continuous monitoring gauges. Average salinities in 2015 increased more rapidly than average from February to August, after which operation of the salinity control gates and autumn storms freshened the marsh somewhat (Figure 4). The fish study recorded a large range of salinity in the marsh throughout 2015 because of persistently high salinities in upper Goodyear Slough, a slough that also exhibits highly variable salinity over a tidal cycle.

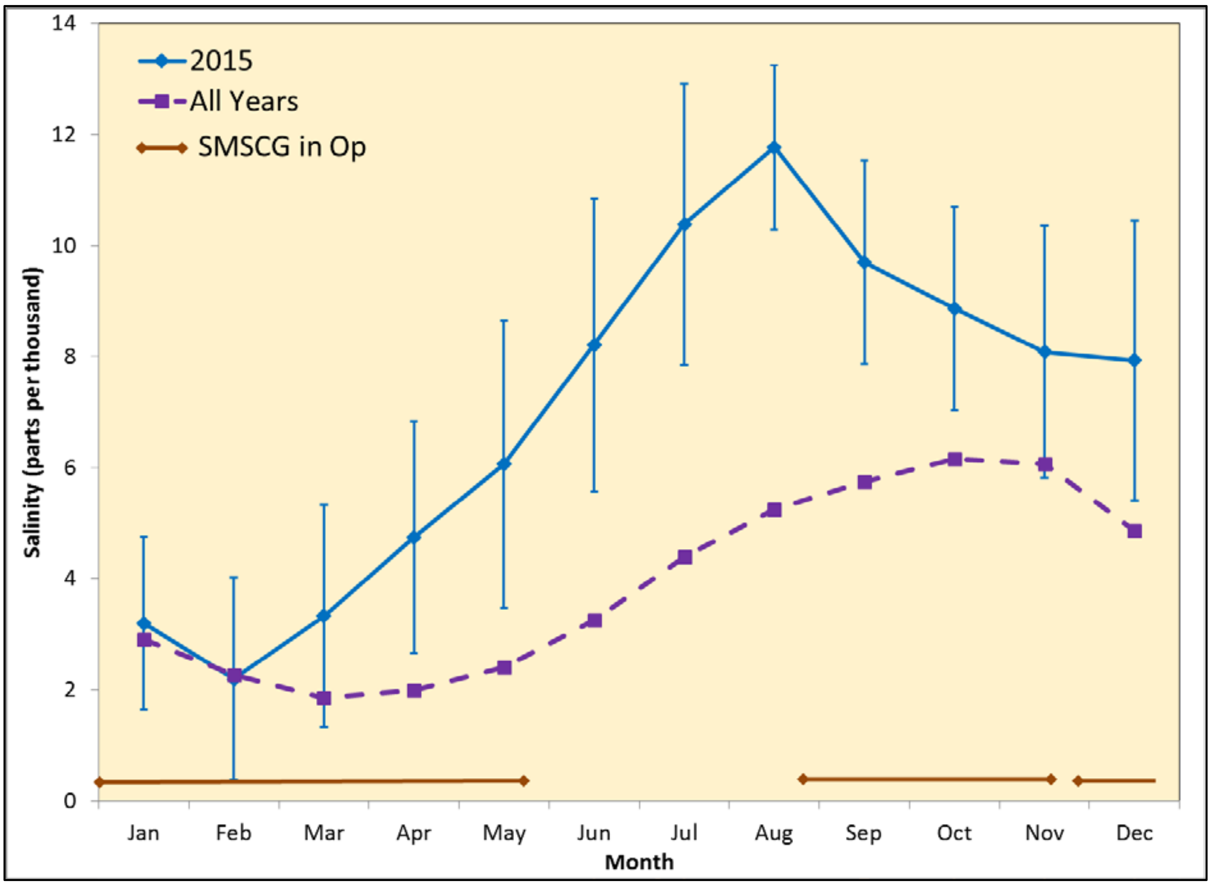

Figure 4. Monthly average salinity in 2015 and for all years of the study (1980 - 2015); error bars are standard deviations in 2015. Brown bars show when the SMSCG were operating in 2015.

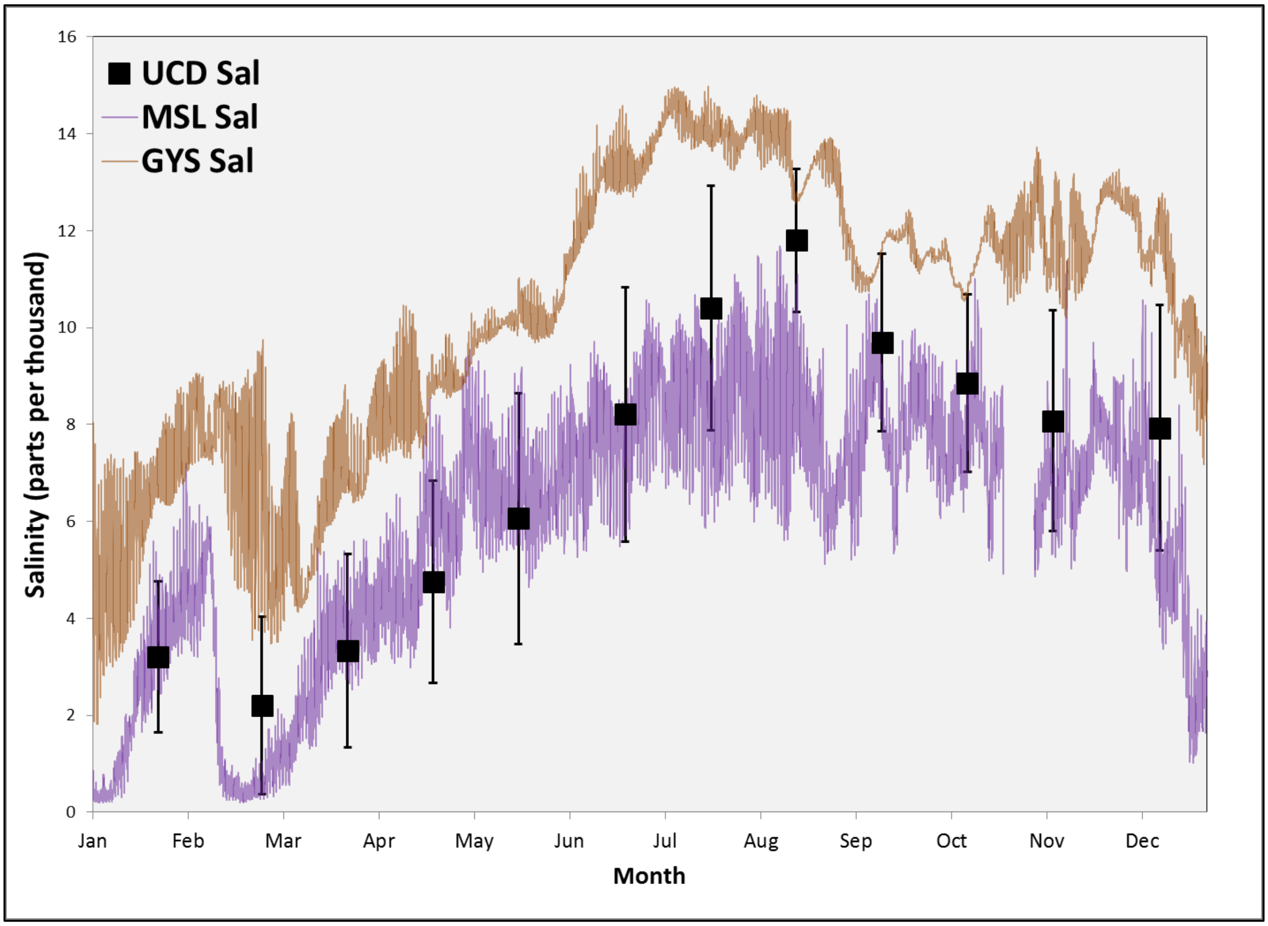

Figure 5. Fifteen-minute salinity from fixed stations in Goodyear Slough (GYS) and Montezuma Slough (MSL), with average monthly salinities and standard deviations from the Suisun Marsh Fish Study ("UCD Sal").

Dissolved Oxygen (DO)

Dissolved oxygen (DO) concentrations in the marsh are affected by decomposition of organic material, temperature, salinity, wind, and diverting and draining of managed wetlands. High wind speeds and the resultant greater turbulence can increase DO, as has been commonly observed in the marsh during summertime concurrent with afternoon westerly coastal winds, likely due to enhanced mixing of surface and subsurface water layers. Because oxygen solubility decreases with higher salinities and temperatures, DO concentrations are frequently lower in summer and autumn than in winter. Water discharged into sloughs from managed wetlands during autumn has been occasionally observed to contain low DO concentrations and may compound regional low DO concentrations in some areas of the marsh (Siegel *et al*. 2011). Likewise, draining wetlands in spring by discharging to the sloughs can also depress marsh DO levels (Siegel *et al*. 2011), though not nearly to the extent of that which occurs in autumn. Consequently, marsh DO is usually high in winter, lower in spring and summer, and lowest in autumn.

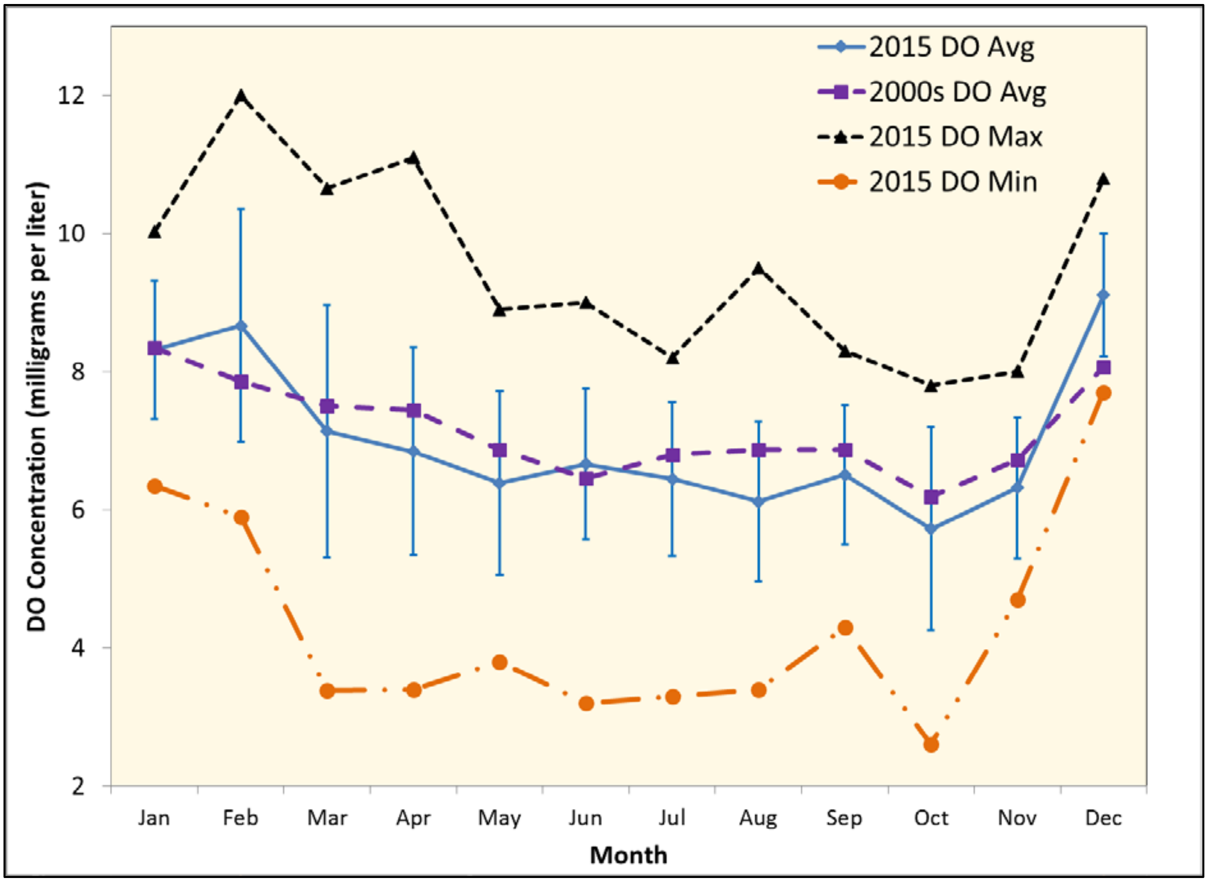

Figure 6. Monthly average DO concentration in 2015 and for the 2000s (2000 - 2015), maximum DO concentration in 2015, and minimum DO concentration in 2015. Error bars are standard deviations in 2015.

Average DO concentrations in 2015 were fairly consistent and followed the average for all years that DO has been measured (2000 – 2015; Figure 6). DO values were highest in the coldest months (January, February, and December) and lowest in October (Figure 6). Minimum and maximum trends in DO in 2015 generally mirrored the trend in average DO concentration (Figure 6). Except in December, the lowest monthly DO concentrations were at small-slough stations well into the marsh's interior (*i.e.*, BY1, GY1, GY2, PT1, and PT2; Figure 2), with the year's lowest value recorded (2.6 mg/L) at the PT1 site on October 15 during late ebb tide. The same station – PT1 – had the highest DO value in 2015 (11.5 mg/L), which occurred on February 25 during, again, late ebb tide. Generally, however, sloughs of the eastern marsh – Denverton, Nurse, and Montezuma (Figure 1) – had the highest monthly DO concentrations.

Water Temperature

Calendar year 2015 was generally warm, particularly from January to April and then again from August to October (DWR 2016*a*). Average water temperatures in 2015 were especially elevated relative to the all-years average during winter and early spring (Figure 7); October was also notably warmer than usual. Average water temperatures from the fish study in 2015 were within the ranges of the two fixed monitoring stations (Figure 8). The highest and lowest annual temperatures recorded by the fish study were found at small-slough stations, consistent with the GYS station showing greater temperature fluctuations than the MSL station (Figure 8).

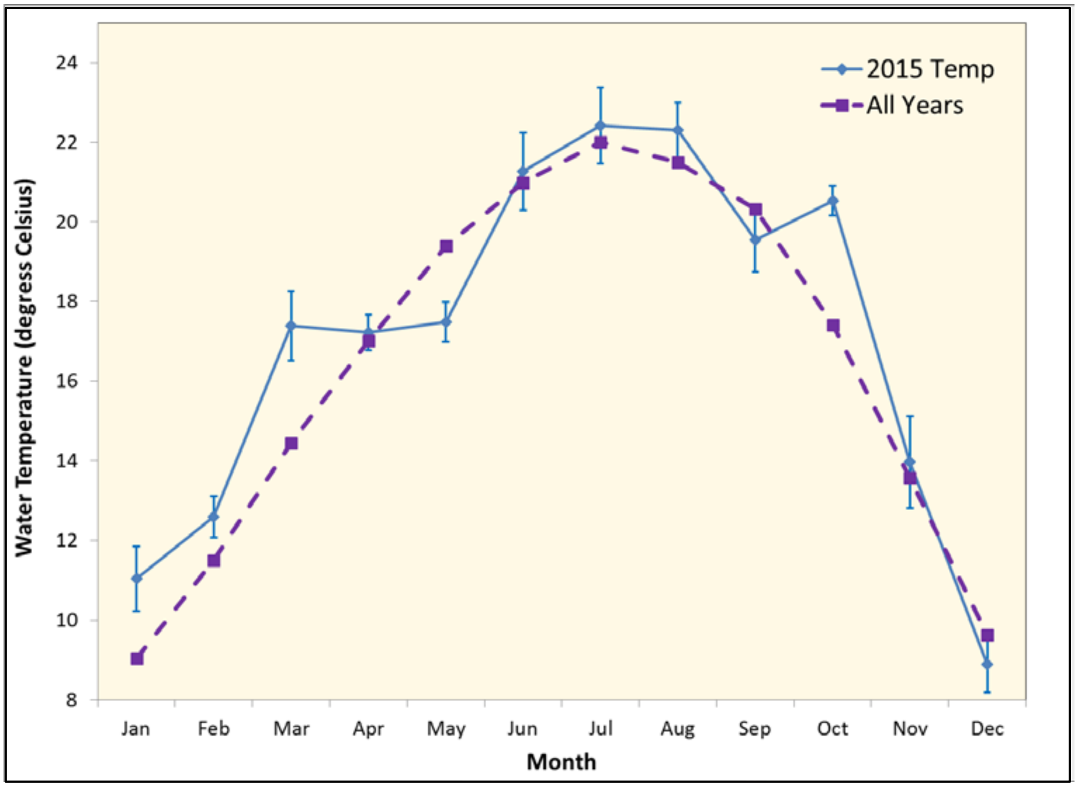

Figure 7. Monthly average water temperature in 2015 and for all years of the study (1980 - 2015); error bars are standard deviations in 2015.

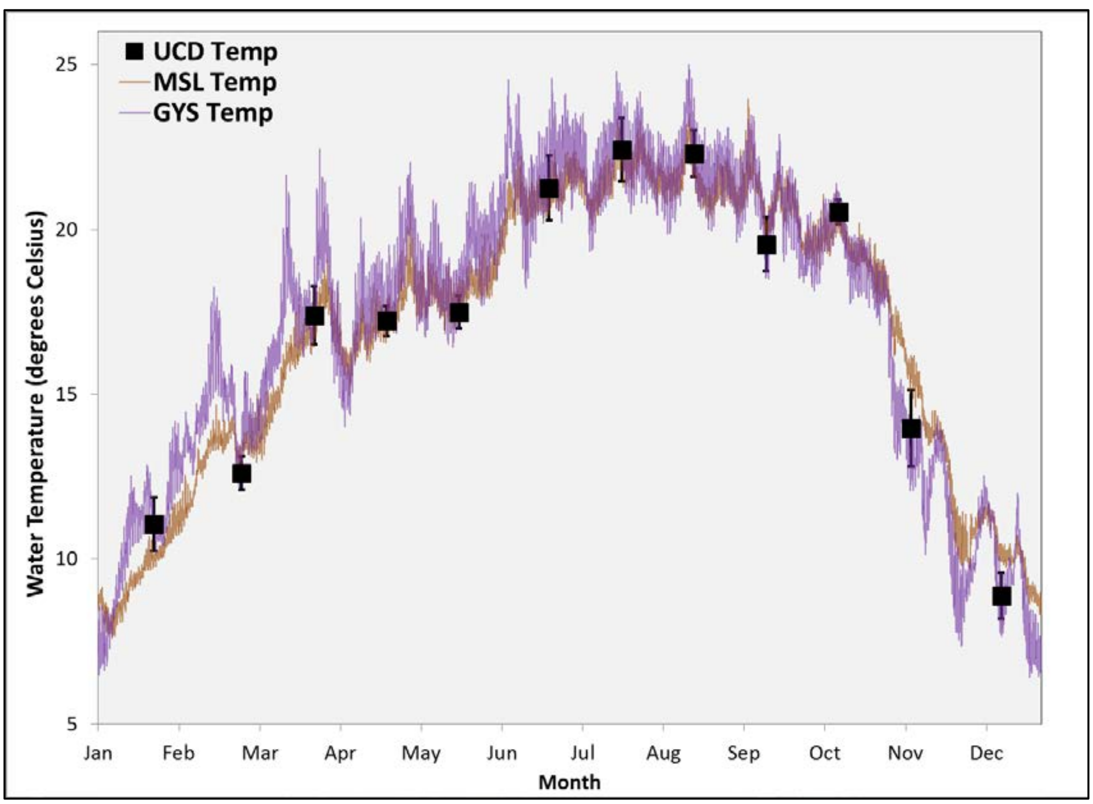

Figure 8. Fifteen-minute water temperatures from fixed stations in Goodyear Slough (GYS) and Montezuma Slough (MSL), with monthly average temperatures and standard deviations from the Suisun Marsh Fish Study ("UCD Temp").

Water Transparency

Water transparency is partially a function of Delta outflow, with lower outflows corresponding to higher transparencies in the marsh (O'Rear and Moyle 2014*a*, 2008, Moyle *et al.* 1986). The dry year of 2015 followed this trend, with all months in 2015 exhibiting higher-than-average transparencies (Figure 9). Lowest average transparency in 2015 occurred in February coincident with the spike in Delta outflow; thereafter, average transparencies roughly increased until peaking in October and then remaining fairly stable to the year's end. Except in August, highest transparencies were recorded in either eastern Montezuma (nine months) or lower Nurse [the NS3 station (Figure 2); two months, July and December] sloughs. Lowest transparencies occurred in either small sloughs or Suisun Slough. Considerable monthly variability in transparencies was present in all months of 2015, especially in June, October, and November (Figure 9).

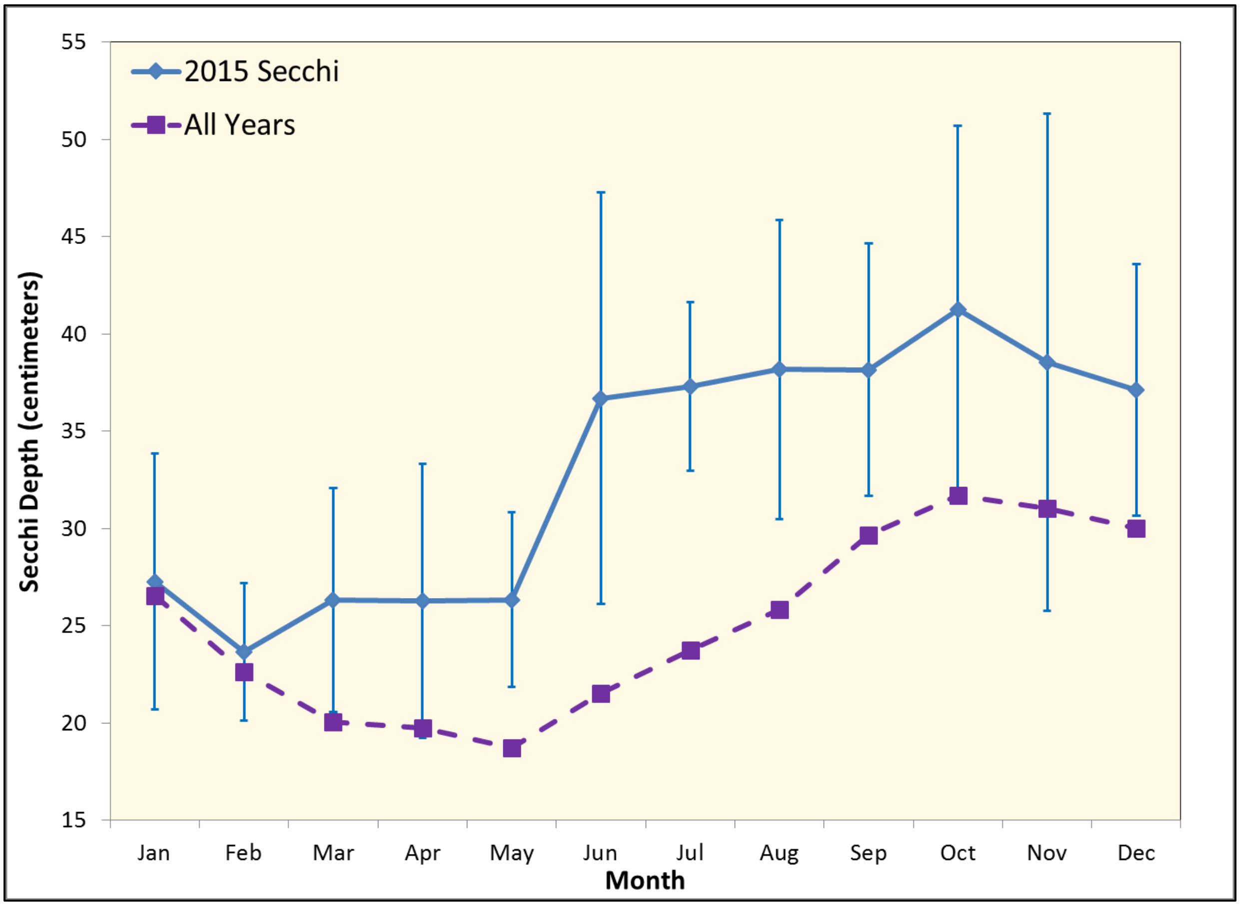

Figure 9. Monthly average water transparency in 2015 and for all years of the study (1980 - 2015); error bars are standard deviations in 2015.

Trends in Invertebrate Distribution and Abundance

Four plankton-feeding macroinvertebrates are commonly captured in high abundance in Suisun Marsh: California bay shrimp, Siberian prawn, Black Sea jellyfish, and overbite clam, of which only the bay shrimp is native. These invertebrates are important food-web components, either as competitors [*e.g.*, Black Sea jellyfish (Wintzer *et al.* 2011), overbite clam (Feyrer *et al.*

2003)] or as fish food [*e.g.*, California bay shrimp and Siberian prawn (Nobriga and Feyrer 2008)].

Black Sea Jellyfish

Black Sea jellyfish annual CPUE rose mildly from 2014 to 2015 (19 to 20 medusae per trawl; Figure 10), with the 2015 CPUE nearly triple the average for the entire study period (20 and 8 medusae per trawl, respectively). Monthly CPUE was typical, with large catches first occurring in July, high numbers continuing through September, and then steeply declining numbers through the remainder of the year (Figure 11). About one-quarter of 2015's medusa catch came from eastern Montezuma Slough, negligible numbers were captured in three small dead-end sloughs (Goodyear, First Mallard, and Denverton), and medusae were fairly abundant in the remainder of the study sloughs.

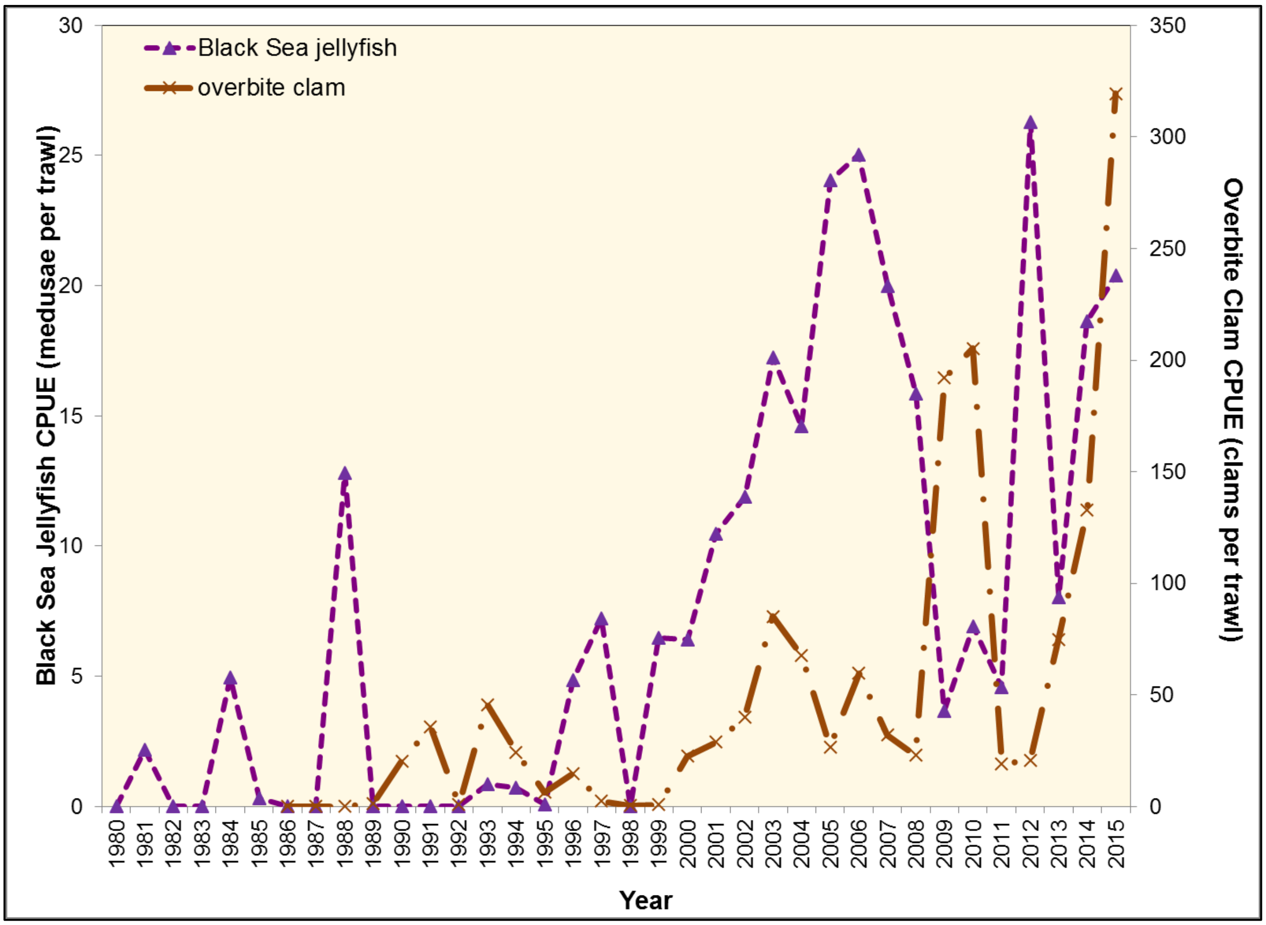

Figure 10. Annual otter trawl CPUE of Black Sea jellyfish and overbite clam.

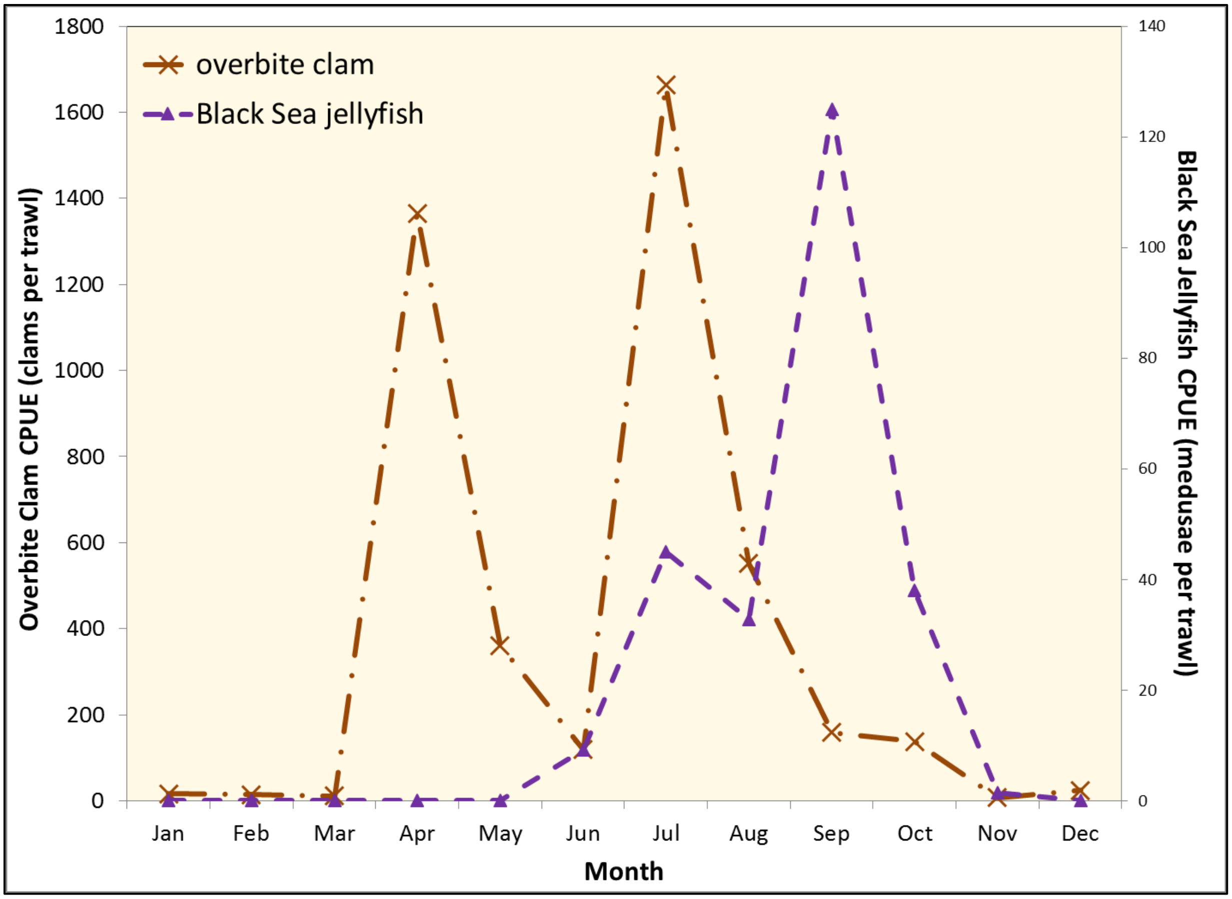

Figure 11. Monthly average CPUE of Black Sea jellyfish and overbite clam in Suisun Marsh in 2015.

Overbite Clam

Annual overbite clam CPUE in 2015 reached its highest point (319 clams per trawl) since the clam's introduction and was well above the average (50 clams per trawl) since 1986, the first year overbite clams were captured in the estuary (Figure 10). While monthly overbite clam CPUE was highly variable in 2015, large numbers were commonly observed in all seasons except winter, likely due to favorable salinities being present somewhere in the marsh for the entire year (Baumsteiger *et al.* 2017, Miller and Stillman 2013, Nicolini and Penry 2000). As in most previous years, nearly all overbite clams in 2015 - 97% - were captured in Suisun Slough, with the catch in Suisun Slough split roughly evenly between the upper (*i.e.*, SU1 and SU2; Figure 2) and lower reaches (*i.e.*, SU3 and SU4). This is the sixth year in a row in which a substantial proportion of the overbite clam catch came from upper Suisun Slough. Of the 89,393 overbite clams captured in 2015, only 50 came from the combined catch of Boynton, Cutoff, Denverton, Nurse, Peytonia, and First Mallard sloughs, further supporting previous patterns that smaller sloughs in the marsh are inhospitable to the clam (Baumsteiger *et al.* 2017, O'Rear and Moyle 2014*a*).

California Bay Shrimp

California bay shrimp annual CPUE dropped to its second-lowest study-history value in 2015 (4 shrimp per trawl) and was well below the average for the entire study period (29 shrimp per trawl; Figure 12), likely in part due to unfavorable climatic conditions (*e.g.*, warm sea surface temperatures; Cloern *et al.* 2010). Monthly CPUE steadily rose from February to May, after which numbers crashed and remained at low levels for the year's remainder (Figure 13). Both the monthly CPUE peak in May and the low maximum monthly CPUE were consistent with effects of the dry, salty year: earlier recruitment and lower abundances in years of low Delta outflows have been observed throughout the estuary (O'Rear and Moyle 2014*b*, *c*, Hatfield 1985, Siegfried 1980). Most of the bay shrimp in 2015 were caught in the large sloughs, with Suisun and Montezuma sloughs comprising 64% and 20% of the annual catch, respectively, while the six fresher, smaller sloughs - Boynton, Cutoff, Denverton, Nurse, Peytonia, and First Mallard - together only comprised 9% of the catch. These patterns were consistent with both the bay shrimp's requirement for higher salinities (Krygier and Horton 1975) and the preference for deeper water as they grow (Israel 1936).

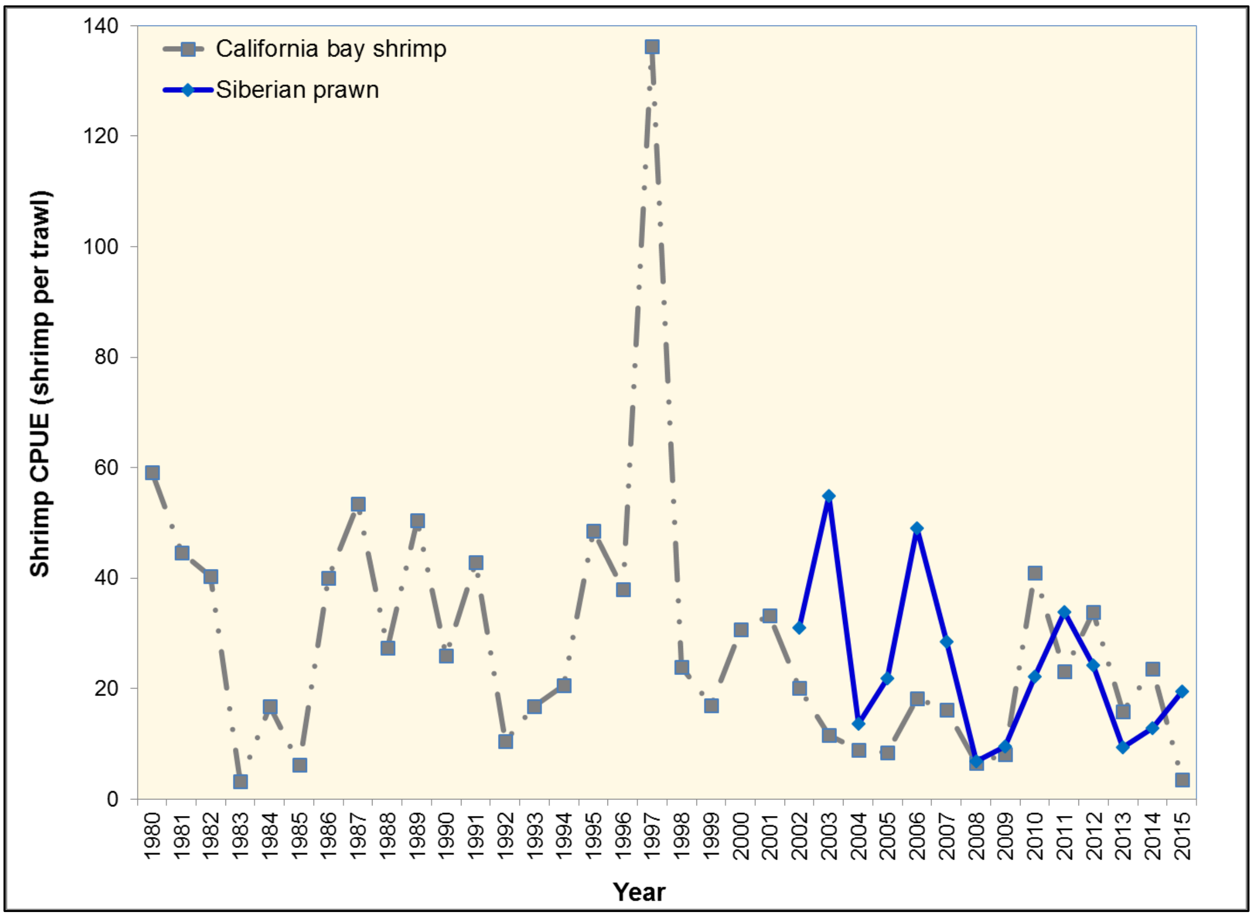

Figure 12. Annual otter trawl CPUE of California bay shrimp and Siberian prawn.

Siberian Prawn

Annual CPUE of Siberian prawn increased mildly from 2014 to 2015 (13 and 19 shrimp per trawl, respectively), although 2015's annual CPUE was below the average annual value (24 shrimp per trawl) since the prawn's introduction in 2002 (Figure 12). Monthly CPUE was variable in the first half of 2015, reaching a minimum in June (Figure 13); thereafter, CPUE rose mildly until November. Siberian prawn were relatively ubiquitous in the marsh, being most abundant in, but not overwhelmingly so, in Denverton, Boynton, and upper Suisun sloughs (20%, 16%, and 18% of 2015's catch, respectively). The relative abundance of Siberian prawn in 2015, given the salty year, was rather surprising given the prawn's higher abundances in wetter years (Brown and Hieb 2014) and ability to complete its life cycle in fresh water (*e.g.*¸ Tiffan and Hurst 2016), possibly due to high food density mitigating increased metabolic demands for maintaining osmotic balance.

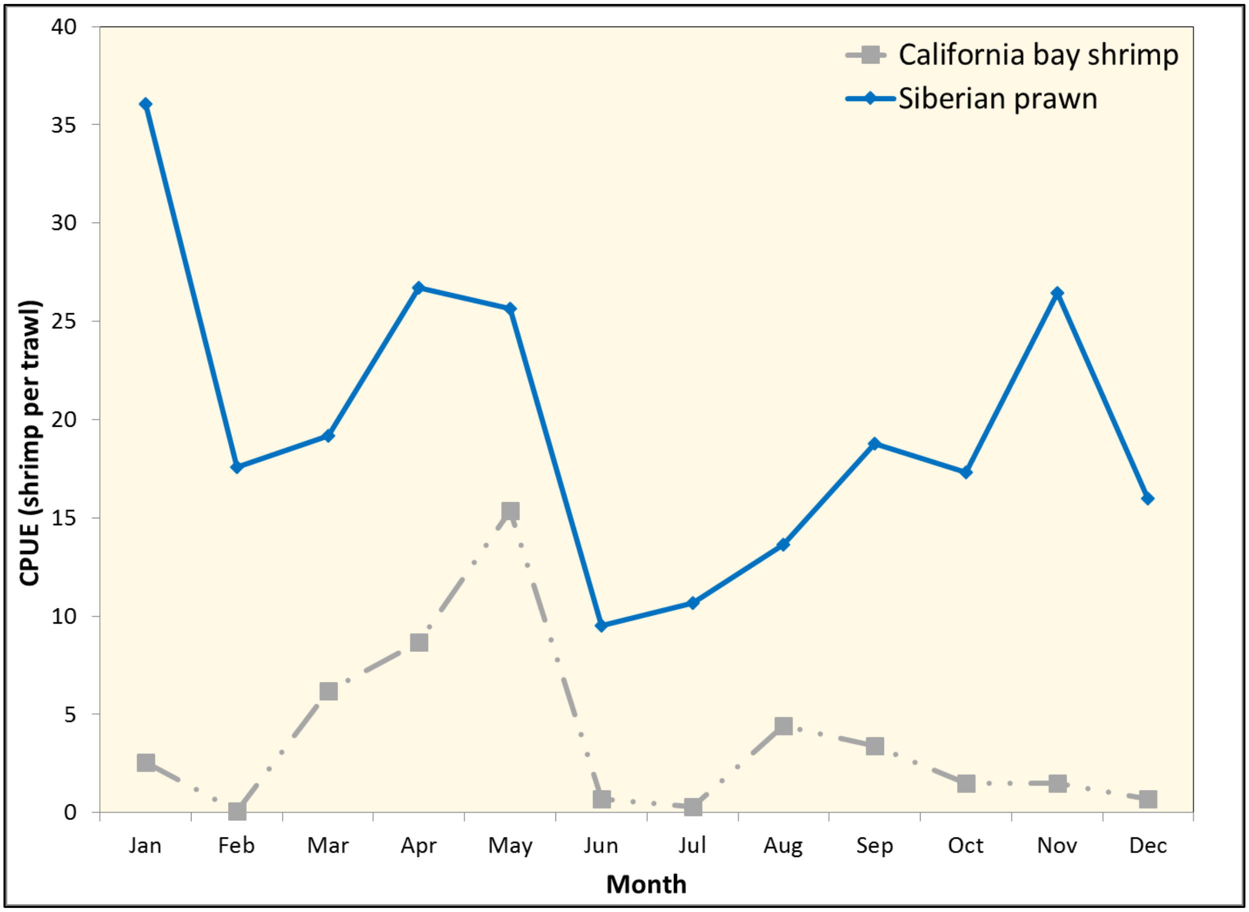

Figure 13. Monthly average CPUE of California bay shrimp and Siberian prawn in Suisun Marsh in 2015.

Trends in Fish Distribution and Abundance

Otter Trawls

Annual otter trawl CPUE in 2015 was well below the average for the whole study period (25 fish per trawl), dropping slightly from 19 fish per trawl in 2014 to 17 fish per trawl in 2015 (Figure 14). The below-average CPUE in 2015 was due to lower non-native fish numbers, the CPUE of which was less than half that of the all-years average (7 and 15 fish per trawl, respectively). In contrast, the native fish CPUE in 2015 was actually about the average for the whole study (11 and 10 fish per trawl, respectively). Non-native fishes declined by about one fish per trawl from 2014 to 2015, while native fishes increased by about one fish between the two years (Figure 14). Euyhaline-freshwater fishes (common carp and white catfish) and the partially catadromous yellowfin goby were the fishes most responsible for the decline in non-native CPUE from 2014 to 2015 (Table 1). Native fishes that contributed most to 2015's value were Sacramento splittail and northern anchovy (*Engraulis mordax*), which offset declines in staghorn sculpin, prickly sculpin (*Cottus asper*), and longfin smelt CPUE from 2014 to 2015 (Table 1). In addition to anchovies, several marine fishes were captured in 2016 for which there are few records in Suisun Marsh: plainfin midshipman (*Porichthys notatus*), white croaker (*Genyonemus lineatus*), and California halibut (*Paralichthys californicus*; Appendix B).

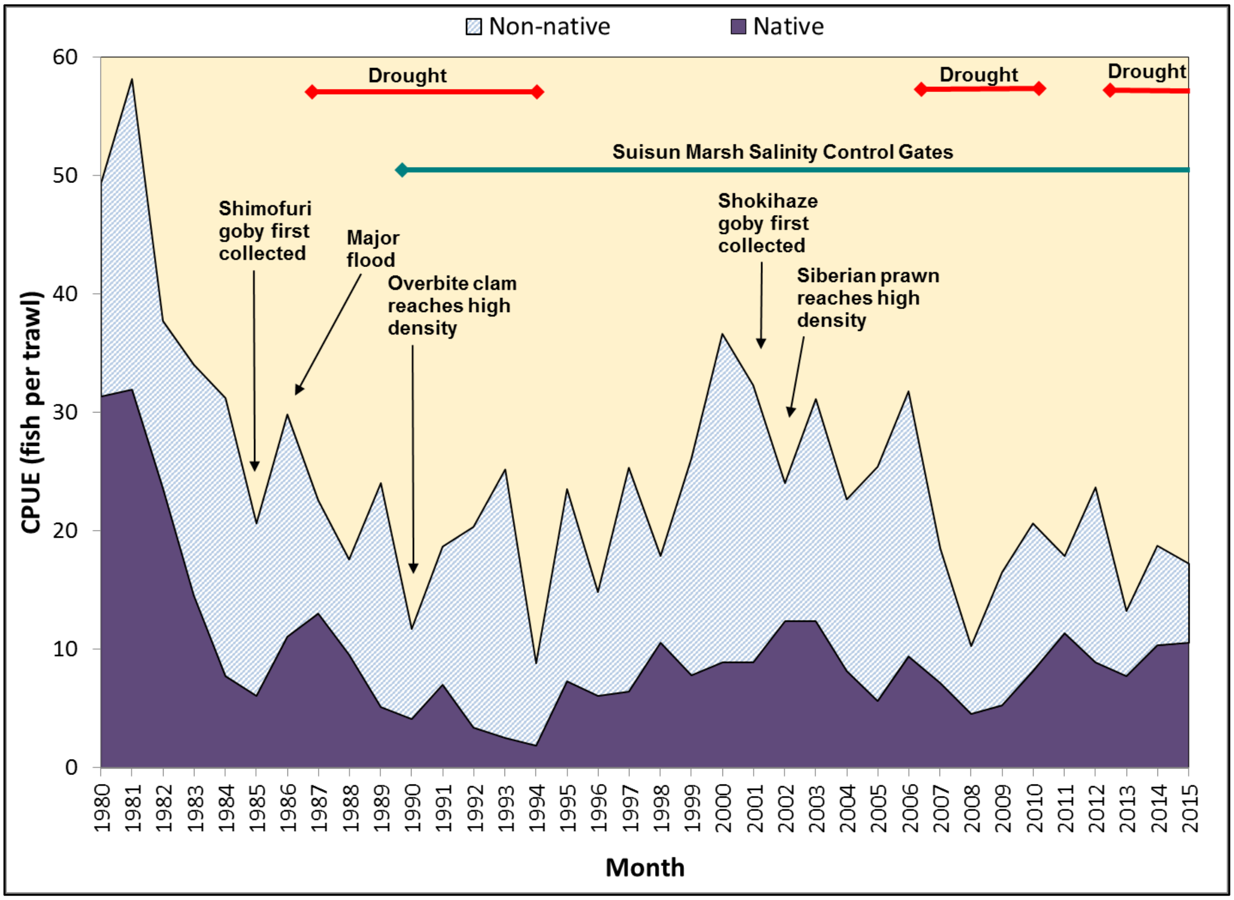

Figure 14. Annual otter trawl CPUE of native and non-native fishes, with important events highlighted.

Table 1. Percent change in annual otter trawl CPUE of eight common marsh fishes (% increases are equivalent to percentage points, such that a 100% increase indicates that the value has doubled; species in bold are native; "all years" is the average for 1980 - 2015).

Species	All Years CPUE	2014 CPUE	2015 CPUE	2015/2014 % Change
northern anchovy	**0.03**	**0.01**	**0.20**	**+1900%**
Sacramento splittail	**2.84**	**5.15**	**6.90**	**+34%**
longfin smelt	**1.16**	**0.23**	**0.03**	**-87%**
staghorn sculpin	**0.26**	**0.16**	**0.00**	**-98%**
prickly sculpin	**1.09**	**0.55**	**0.20**	**-64%**
common carp	0.52	0.49	0.19	-61%
white catfish	0.63	0.94	0.43	-54%
yellowfin goby	2.31	0.47	0.26	-45%

Beach Seines

Annual beach seine CPUE in 2015 was similar to the average from 1980 to 2015 (57 fish per seine; Figure 15), declining mildly from 2014 to 2015 (62 and 52 per seine, respectively). CPUE declined slightly for both non-native and native fishes from 2014 to 2015 (Figure 15); as usual, non-native fish, dominated by Mississippi silversides (*Menidia audens*), were far more abundant in seine hauls than native fish (Table 2). The drop in native fish CPUE was mainly due to lower numbers of Sacramento splittail, staghorn sculpin, and threespine stickleback (Table 2). For non-native fishes, striped bass but especially yellowfin goby CPUE values declined (Table 2).

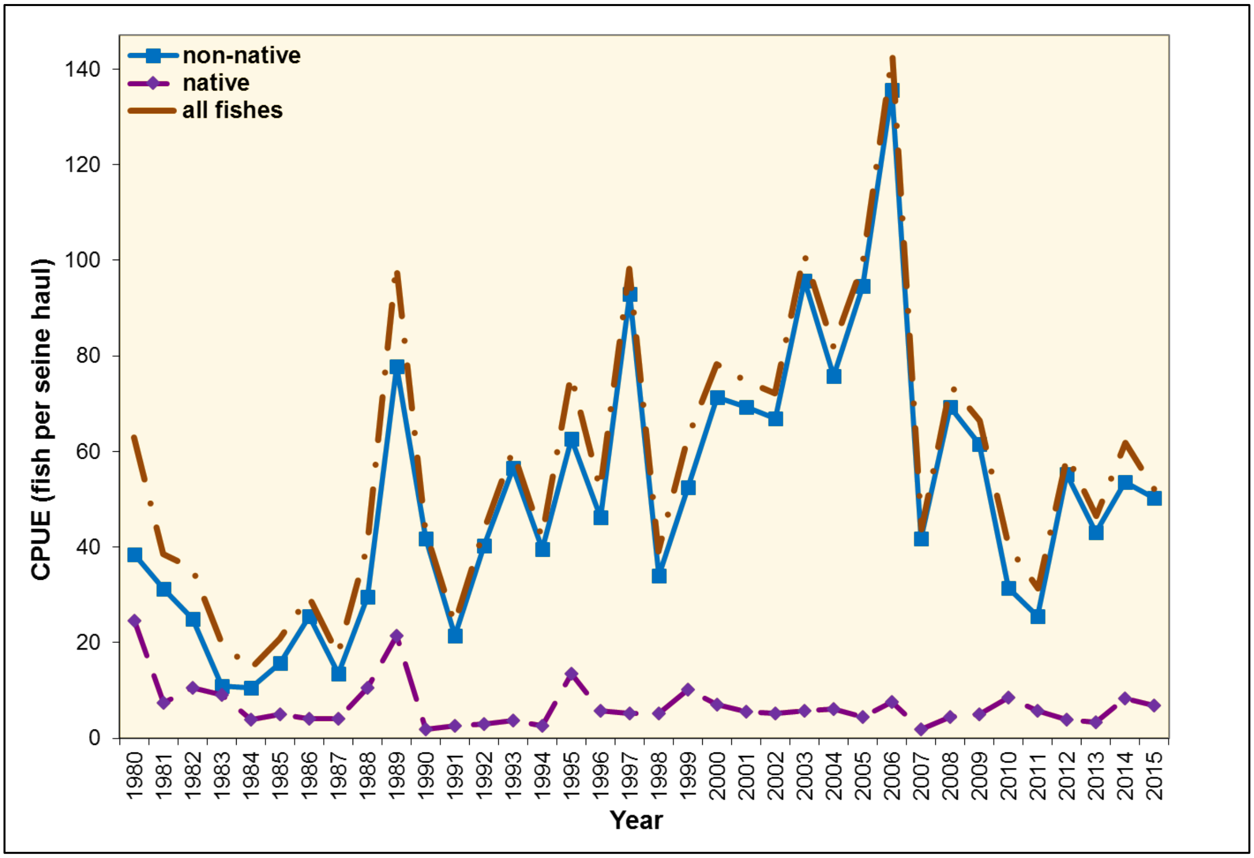

Figure 15. Annual beach seine CPUE of non-native, native, and both categories of fishes combined ("All Fishes").

Table 2. Percent change in annual beach seine CPUE of six common marsh fishes (% increases are equivalent to percentage points, such that a 100% increase indicates that the value has doubled; native species in bold).

Species	All Years CPUE	2014 CPUE	2015 CPUE	2015/2014 %Change
Sacramento splittail	**1.43**	**4.03**	**2.30**	**-43%**
staghorn sculpin	**1.86**	**0.91**	**0.09**	**-90%**
threespine stickleback	**1.82**	**2.06**	**1.25**	**-39%**
Mississippi silverside	34.4	41.3	39.4	-5%
striped bass	5.72	4.45	3.24	-27%
yellowfin goby	6.48	5.61	1.42	-75%

Fish Species of Interest

Fishes of the Pelagic Organism Decline

LONGFIN SMELT

Otter trawl CPUE in 2015 was the fifth lowest value in the study's history and the lowest since 1997, declining from 0.23 to 0.03 fish per trawl from 2014 to 2015, respectively (Figure 16). The poor catch of longfin smelt in Suisun Marsh in 2015 reflected low abundances estuary-wide: the California Department of Fish and Wildlife's (CDFW) larval and Fall Midwater Trawl surveys, which span the main axis of the estuary, also posted very low longfin smelt numbers for the year (CDFW 2017, Morris and Damon 2016). Of the 8 longfin smelt captured by otter trawl, all but one individual were age-0 fish. Consistent with trends in previous years, all age-0 fish were caught during spring, with the one adult-sized fish (94 mm SL) captured in September in lower Suisun Slough (O'Rear and Moyle 2014*c*,*d*, Rosenfield and Baxter 2007). Age-0 fish were widely distributed, being captured in Denverton, eastern Montezuma, lower Suisun, Nurse, and Peytonia sloughs.

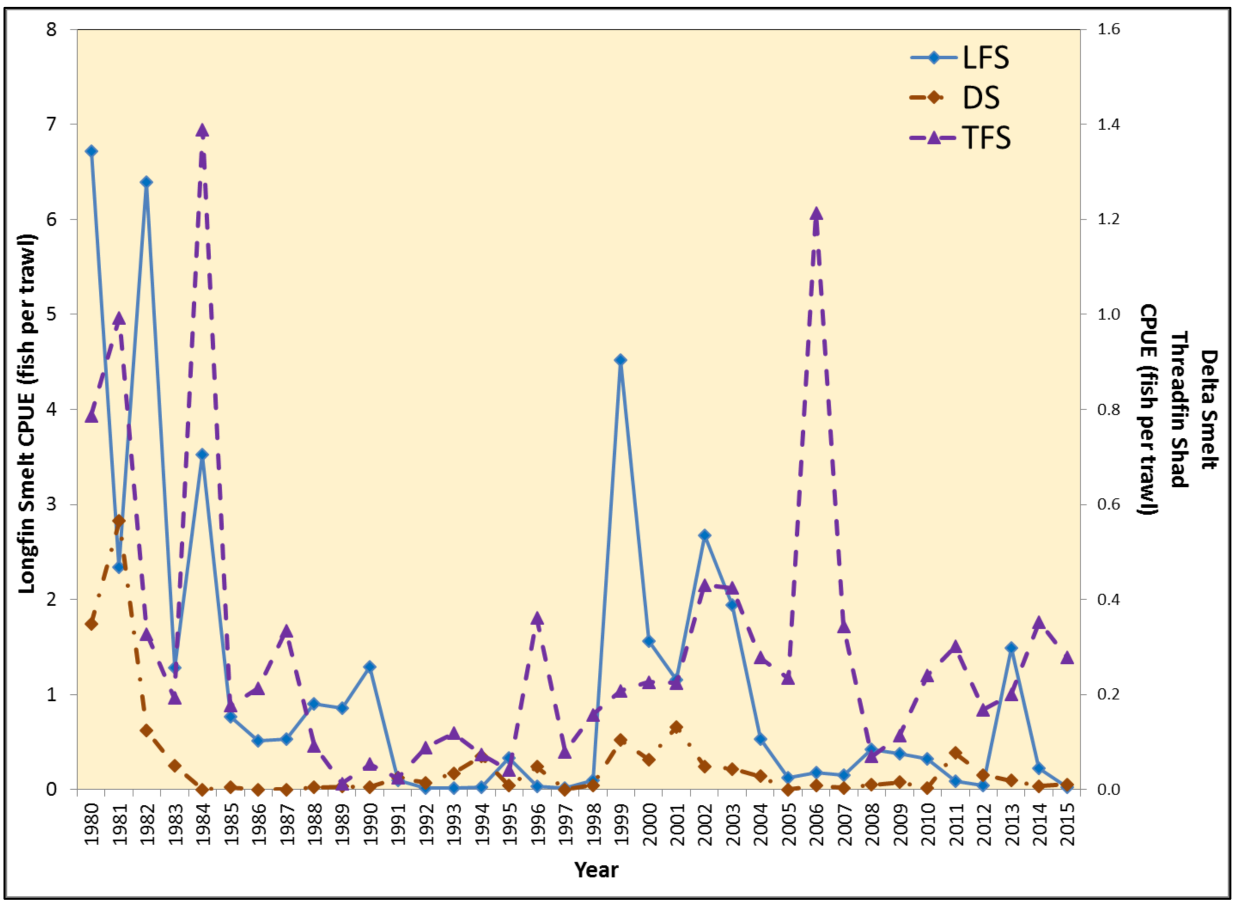

Figure 16. Annual otter trawl CPUE of three fishes of the Pelagic Organism Decline ("DS" = delta smelt, "TFS" = threadfin shad, and "LFS" = longfin smelt).

DELTA SMELT

Delta smelt otter trawl CPUE in 2015 was very low, similar to most years of the 2000s after 2001 (Figure 16) and well below the average for all study years (0.01 and 0.05 fish per trawl for 2015 and all years, respectively). Similar low numbers of delta smelt were seen throughout the estuary in 2015 (Damon 2016, Morris 2016). Only one otter trawl in 2015 caught delta smelt, which occurred in lower Suisun Slough in December and contained three individuals. The three fish measured about 70 mm SL and were in water with a salinity of 11.4 ppt.

THREADFIN SHAD

Threadfin shad CPUE in otter trawls declined slightly from 2014 to 2015 (0.4 to 0.3 fish per trawl, respectively; Figure 16) but remained the same in beach seines (0.7 fish per seine); the 2015 CPUEs were about the same as the all-years average for otter trawls but lower than the all-years average for beach seines. Threadfin shad were captured by otter trawl in all sampled sloughs, with about one-third of 2015's catch coming from just three stations: NS1, SB1, and MZ2 (Figure 2). Threadfin shad were fairly equally distributed among the three seining beaches (0.9, 0.7, and 0.5 fish per seine in Denverton, Montezuma, and upper Suisun sloughs, respectively). The comparatively average CPUEs in 2015 in such a dry, salty year was unusual given the association of threadfin shad with fresher water (O'Rear and Moyle 2014*b*, Feyrer *et al*. 2009, Feyrer *et al.*2007, Meng and Matern 2001) and very low abundances of threadfin shad elsewhere in the estuary (CDFW 2017).

STRIPED BASS

Striped bass abundance in Suisun Marsh in 2015 was quite low, although abundance in Suisun Marsh was not nearly as low relative to average values as in the main axis of the estuary (CDFW 2017). Otter trawl CPUE in 2015 was about the same as in 2014 (5 and 4 fish per trawl, respectively) and considerably below the all-year average (9 fish per trawl), while beach seine CPUE declined from 2014 to 2015 and was also below the all-years average (4, 3, and 6 fish per seine, respectively; Figure 17). Age-0 monthly beach seine CPUE was very high in June, declined to a lower level in July, and thereafter dropped rapidly to negligible numbers by the year's end (Figure 18). The pattern was different for age-0 monthly otter trawl CPUE: fair numbers of fish were first observed in May, CPUE then increased and reached its peak in July, remained relatively high in August, and finally declined through the remainder of the year but not as severely as for beach seine CPUE. Trends in neither beach seine nor otter trawl monthly CPUEs appeared to correspond to changes in abundance of mysids, a major prey of young striped bass (Bryant and Arnold 2007, Feyrer *et al.* 2003), which was different than previous years (O'Rear and Moyle 2014*a*, *b*). Conversely, juvenile otter trawl CPUE roughly paralleled mysid abundance, both of which increased in early winter, with mysid CPUE peaking before juvenile striped bass CPUE, and then declined to lower levels in summer and autumn (Figure 18). Geographic distribution of age-0 striped bass among sampled sloughs was disparate: CPUE in eastern Montezuma Slough was especially high while being quite low in Cutoff and upper Suisun sloughs (Figure 19). Unlike in 2014, distribution of juvenile striped bass in 2015 was quite similar to age-0 fish, although juvenile striped bass were also notably abundant in Denverton and Peytonia sloughs and much less so in lower Suisun Slough.

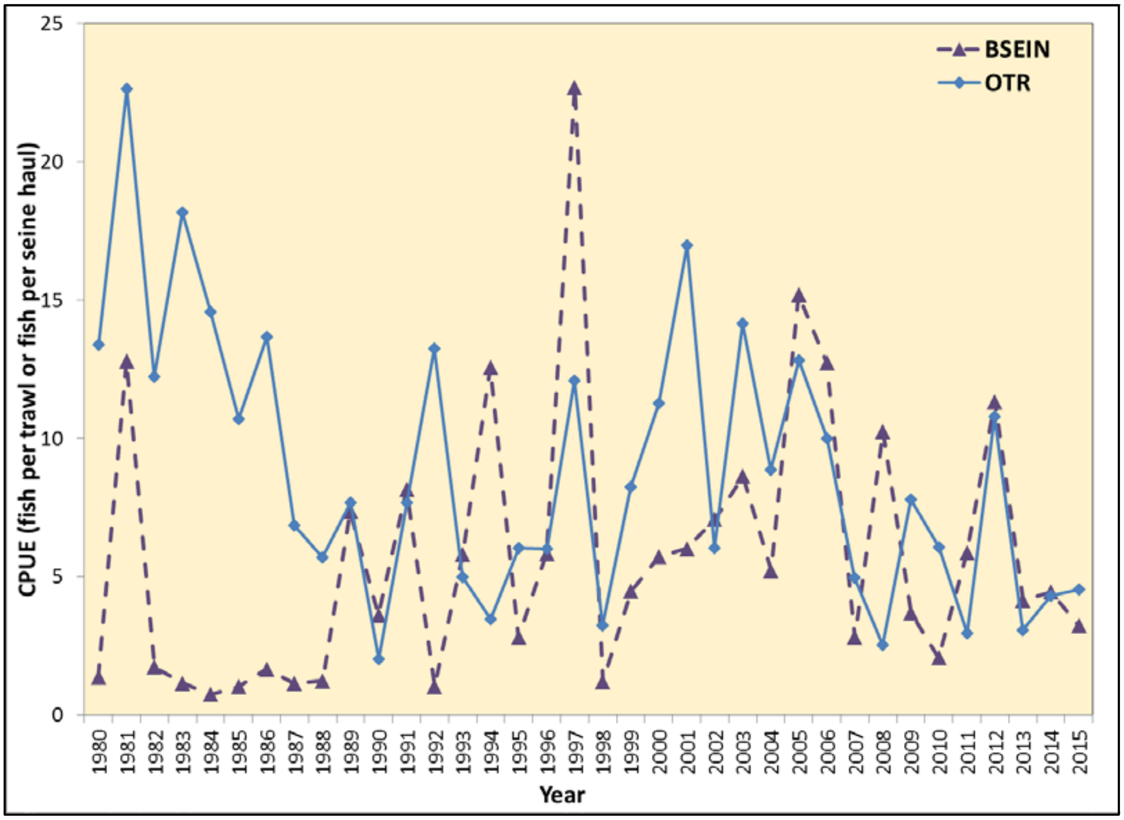

Figure 17. Annual otter trawl and beach seine CPUE of striped bass ("OTR" = otter trawl, "BSEIN" = beach seine).

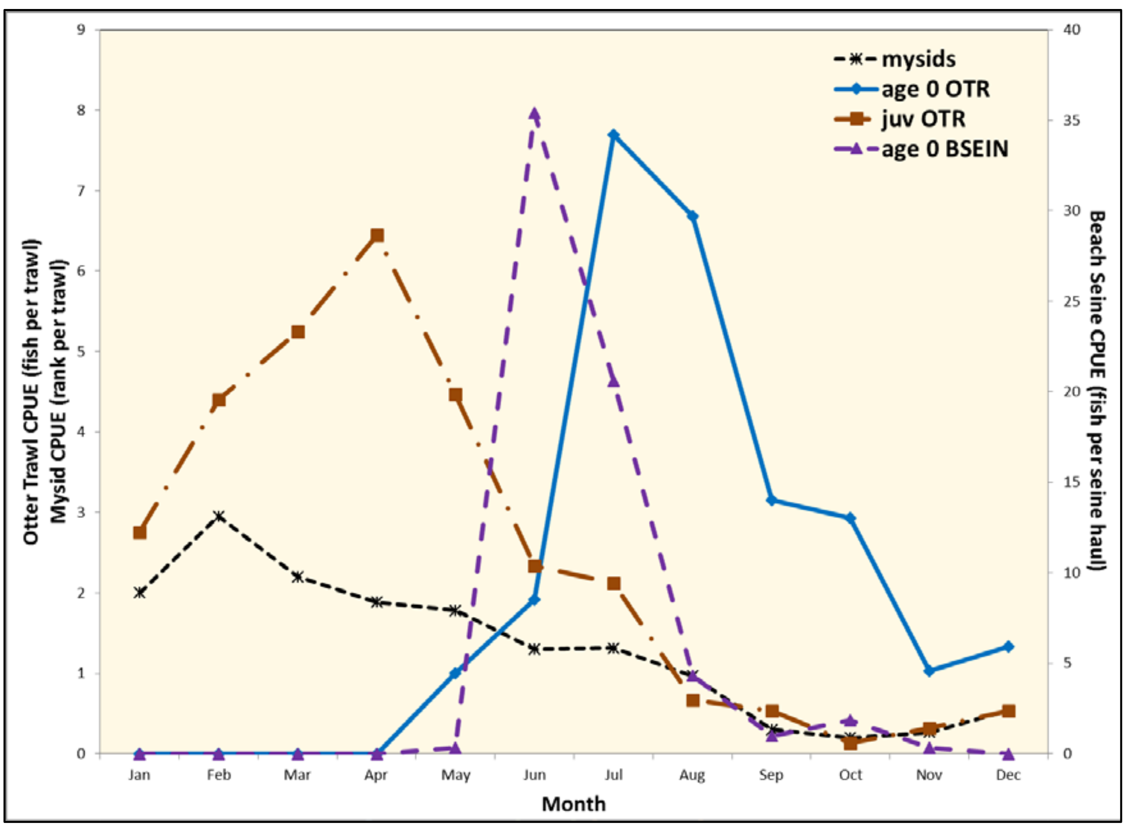

Figure 18. Monthly average CPUE of striped bass age classes and mysids ("Juv" = juvenile; other codes as in Figure 17) in 2015.

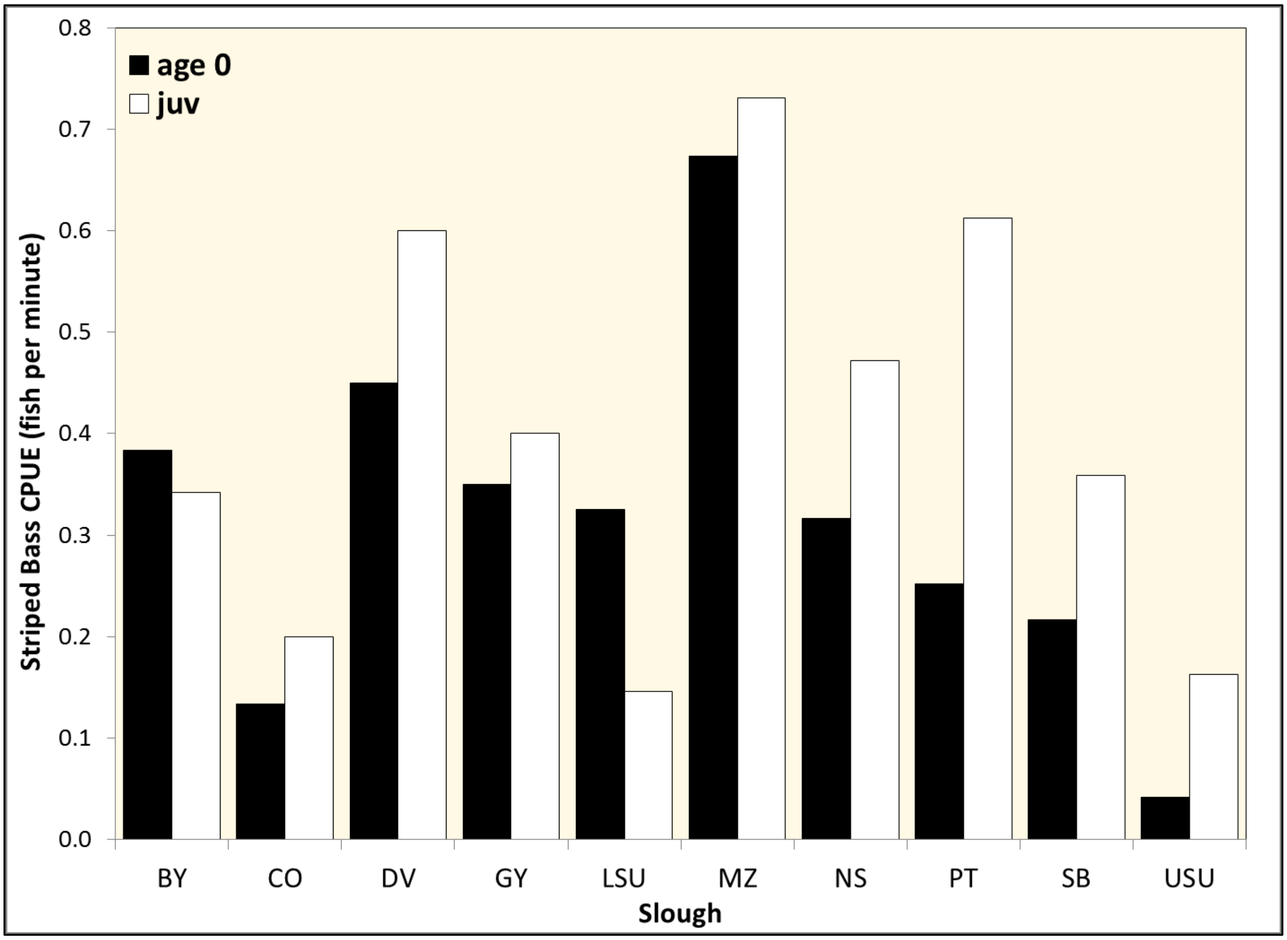

Figure 19. Average otter trawl CPUE of age classes of striped bass in 2015 ("BY" = Boynton Slough, "CO" = Cutoff Slough, "DV" = Denverton Slough, "GY" = Goodyear Slough, "LSU" = lower Suisun Slough, "MZ" = Montezuma Slough, "NS" = Nurse Slough, "PT" = Peytonia Slough, "SB" = First Mallard Slough, and "USU" = upper Suisun Slough).

<u>Other Species of Interest</u>

SACRAMENTO SPLITTAIL

Sacramento splittail were remarkably abundant in 2015 (Figure 20). Annual otter trawl CPUE in 2015 was the second highest in the study's history, being 40% higher than 2014's CPUE and more than double the value for all years of the study. The increase from 2014 to 2015 was mainly due to a marked rise in age-1 CPUE (*i.e.*, 2014 year-class fish) from 0.6 to 3.8 fish per trawl, respectively (Figure 20). Age-2+ CPUE remained stable from 2014 to 2015, while age-0 CPUE in 2015 dropped substantially from 2014 (0.4 and 2.2 fish per trawl, respectively) and was well below the all-years study average (1.1 fish per trawl). Low recruitment of 2015 age-0 fish was typical of such a dry year since splittail reproduction and subsequent recruitment in the marsh has been greatly enhanced in wet years (Moyle *et al.* 2004, Sommer *et al.* 1997). Unlike in 2014 when the Cosumnes River floodplain inundated three times and was accompanied by presence of ripe adults, the Cosumnes River spilled onto its floodplain only once in 2015 (February), limiting the number of floodplain spawning events.

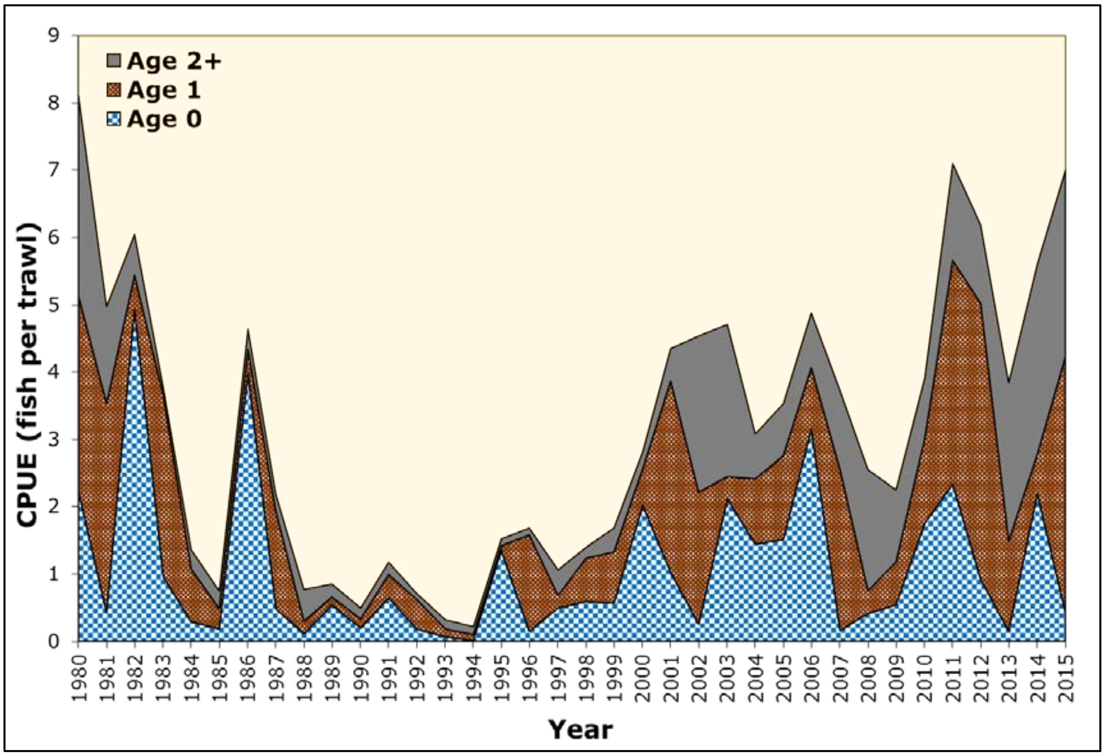

Figure 20. Annual otter trawl CPUE of three age classes of Sacramento splittail.

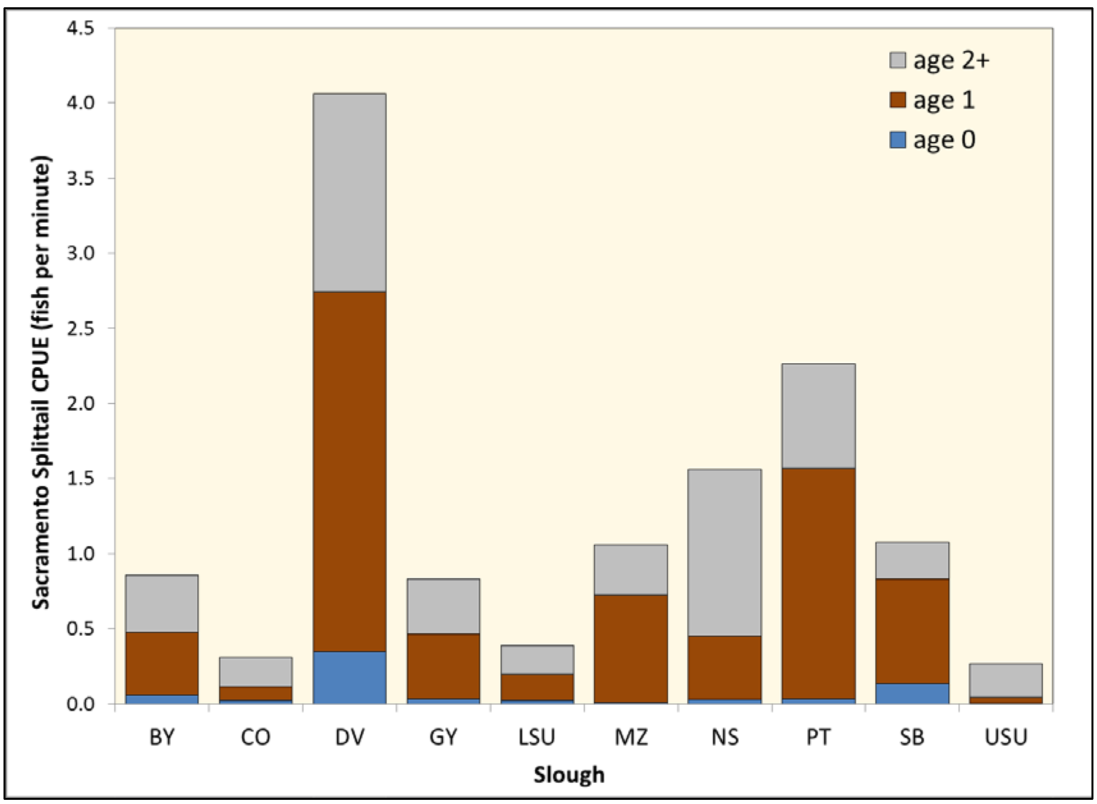

Figure 21. Average otter trawl CPUE of age classes of splittail in 2015 (codes as in Figure 19).

All three Sacramento splittail age classes were most abundant in Denverton Slough (Figure 21). Age-2+ fish were also notably abundant in Nurse Slough; Peytonia Slough contained many age-1 fish. Aside from Denverton Slough, First Mallard was the only slough that had more-than-negligible numbers of age-0 fish.

WHITE CATFISH

White catfish otter trawl CPUE fell substantially from 2014 to 2015, with 2015's value being the lowest recorded since 2004 (Table 1; Figure 22). Recruitment of age-0 white catfish has been poor in dry years and has often resulted in lower annual otter trawl CPUE values (O'Rear and Moyle 2014*a*). This pattern was followed in 2015, during which no age-0 white catfish were captured.

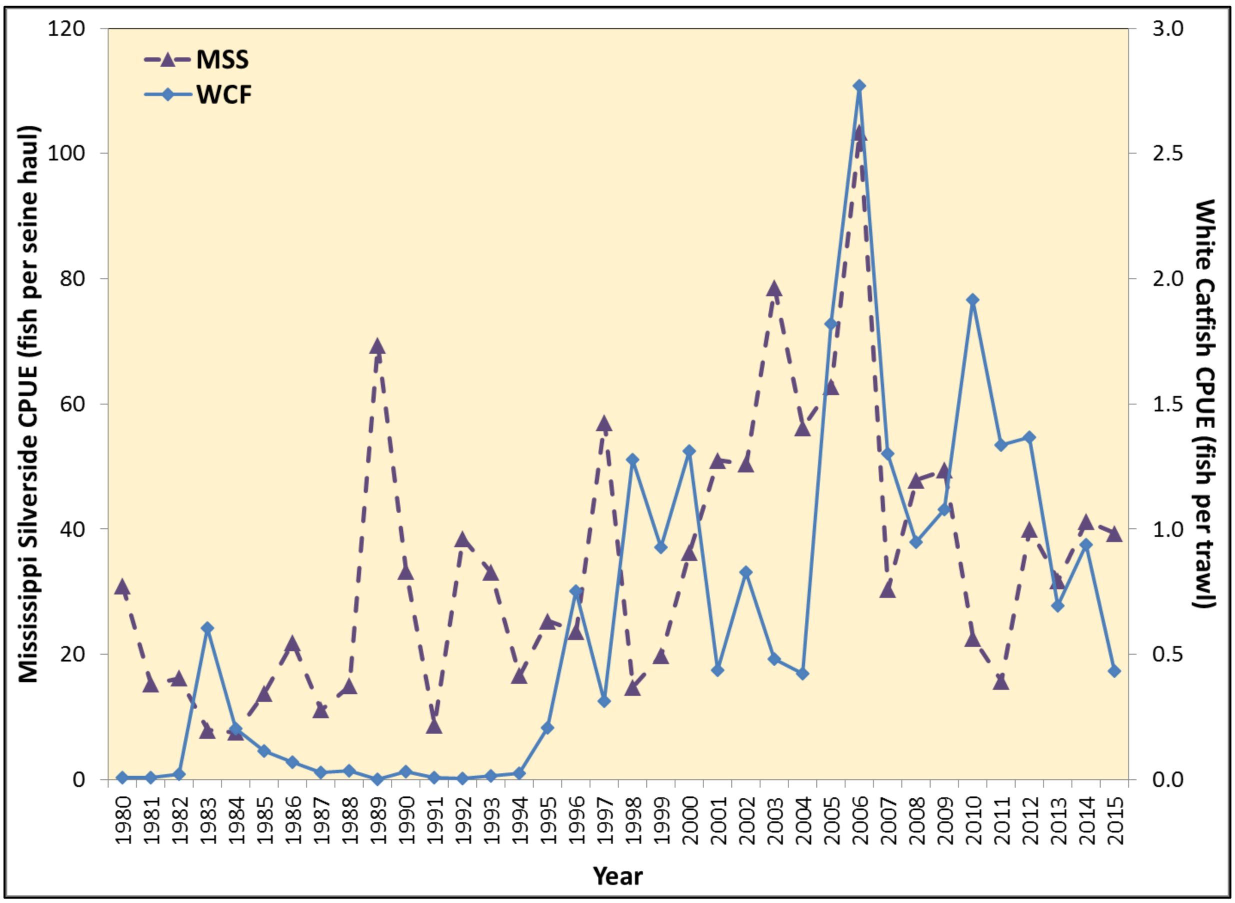

Figure 22. Annual CPUE of white catfish ("WCF") and Mississippi silverside ("MSS").

White catfish are intolerant of moderate and high salinities (Markle 1976, Allen and Avault, Jr. 1971, Kendall and Schwartz 1968) and so have generally been less common in the saltier regions of the marsh. This pattern was especially prevalent in 2015, in which 44% of the catch came from just Denverton Slough while no fish were caught in the saltier sloughs of Goodyear and lower Suisun in the southwestern marsh. Small numbers of white catfish were also taken in Boynton and Peytonia sloughs (25 and 14 fish, respectively). Unlike the usual pattern of CPUE increasing in spring, peaking in summer, and then declining moderately through autumn to the year's end (O'Rear and Moyle 2008, 2009), white catfish CPUE in 2015 plummeted drastically after July when average marsh salinities hovered around 12 ppt (Figure 23). Ancillary hook-and-line surveys only captured white catfish after July in Boynton Slough approximately 200 meters downstream of the wastewater treatment plant's discharge pipe where salinity was 5.5 ppt. Such patterns suggest white catfish suffered considerably from the higher-than-average salinities in 2015.

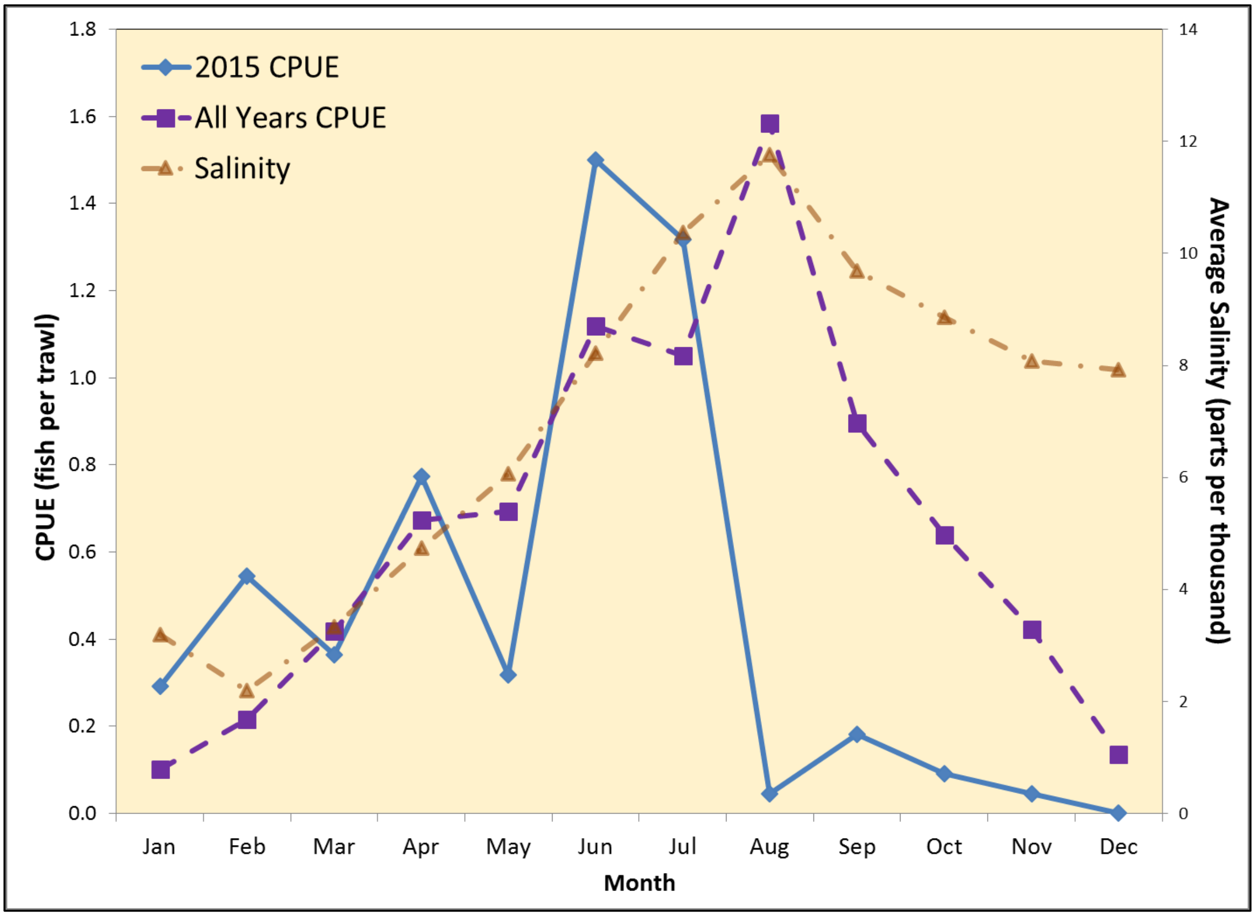

Figure 23. Monthly CPUE of white catfish in 2015 and all years of the study (1980 – 2015), with average monthly salinity in 2015.

MISSISSIPPI SILVERSIDE

Mississippi silverside annual beach seine CPUE in 2015 was nearly the same as in 2014 (39 and 42 fish per seine, respectively) and was moderately above the all-years average (34 fish per seine; Figure 22). Monthly CPUE was moderate and stable from January to March, thereafter declined to lower levels through summer, and then peaked and reached its maximum during September (Figure 24). Fish smaller than 30 mm SL, which are likely two months old and younger (Gleason and Bengston 1996, Hubbs 1982), were present in July and August and then again in October and November, suggesting reproduction from April through October with a lull during mid-summer (Figure 25). This was a longer spawning period than seen in cooler, wetter years such as 2011 (O'Rear and Moyle 2014*b*).

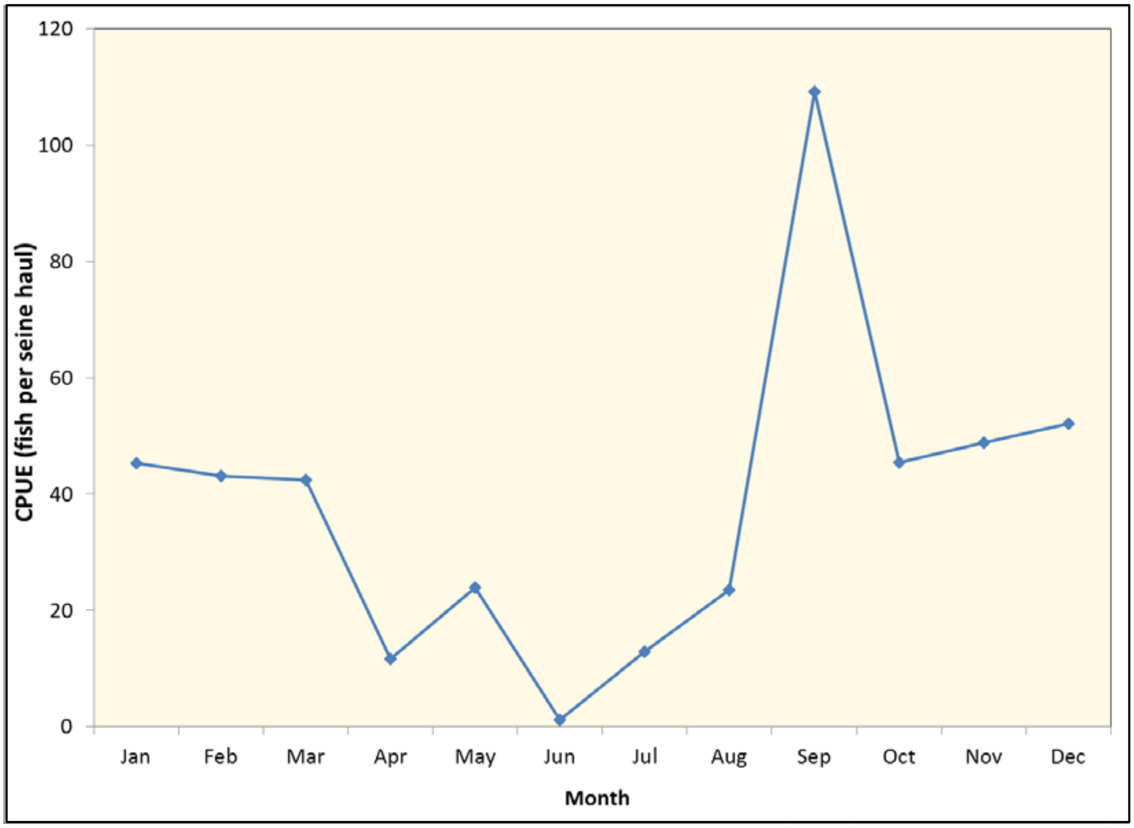

Figure 24. Monthly average beach seine CPUE of Mississippi silverside in 2015.

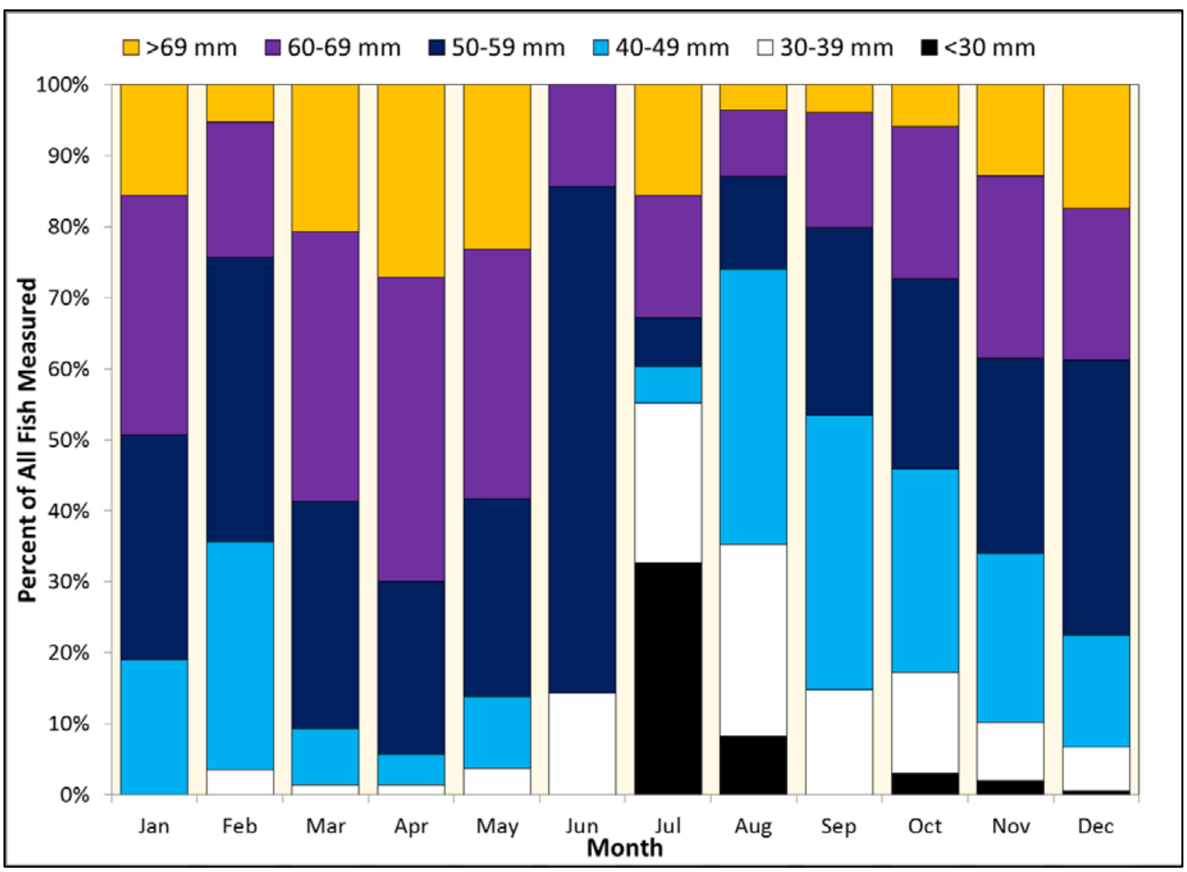

Figure 25. Monthly average beach seine CPUE of size classes (mm SL) of Mississippi silverside in 2015.

CONCLUSION

Calendar year 2015, the fourth year of a drought, found Suisun Marsh salty, warm, and clear, receiving little outflow from the Delta. Concomitantly, invertebrates and fishes that have exhibited higher abundances in wet years [*e.g.*, yellowfin goby (Feyrer *et al.* 2015)], especially those associated with cooler temperatures [*e.g.*, California bay shrimp (Hatfield 1985), longfin smelt (Nobriga and Rosenfield 2016), staghorn sculpin (Cloern *et al.* 2010)], were relatively few in Suisun Marsh during 2015. The salty water in Suisun Marsh during 2015 appeared to harm freshwater non-native fishes (white catfish and, to a lesser extent, common carp) while facilitating record overbite clam numbers. Although numbers of striped bass and threadfin shad were down relative to marsh averages, they were both comparatively more abundant than in the main axis of the estuary. Sacramento splittail were remarkably abundant, and Siberian prawn numbers were surprisingly high given the shrimp's association with fresher waters. That these species appeared to fare well in such conditions suggests food supply and/or habitat quality was better in Suisun Marsh than elsewhere in the estuary.

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APPENDIX A: CATCHES FOR ENTIRE STUDY PERIOD

Total number of fishes caught in Suisun Marsh by otter trawl, beach seine, midwater trawl, and all methods from 1979 to 2015 (native species in bold).

Common Name	Scientific Name	Otter Trawl	Beach Seine	Midwater Trawl	Total
American shad	*Alosa sapidissima*	1414	284		1698
bay pipefish	***Sygnathus leptorhynchus***	**2**	**0**		**2**
bigscale logperch	*Percina macrolepida*	17	2		19
black bullhead	*Ameiurus melas*	881	3		884
black crappie	*Pomoxis nigromaculatus*	2069	116	1	2186
bluegill	*Lepomis macrochirus*	19	18		37
brown bullhead	*Ameiurus nebulosus*	29	0		29
California halibut	***Paralichthys californicus***	**7**	**3**		**10**
channel catfish	*Ictalurus punctatus*	175	7		182
Chinook salmon	***Oncorhynchus tshawytscha***	**73**	**396**	**1**	**470**
common carp	*Cyprinus carpio*	5288	521	1	5810
delta smelt	***Hypomesus transpacificus***	**664**	**144**	**4**	**812**
fathead minnow	*Pimephales promelas*	36	38		74
golden shiner	*Notemigonus crysoleucas*	9	12		21
goldfish	*Carassius auratus*	304	48		352
green sturgeon	***Acipenser medirostris***	**3**	**0**		**3**
green sunfish	*Lepomis cyanellus*	5	3		8
hardhead	***Mylopharadon conocephalus***	**1**	**0**		**1**
hitch	***Lavinia exilicauda***	**123**	**16**		**139**
largemouth bass	*Micropterus salmoides*	0	3		3
longfin smelt	***Spirinchus thaleichthys***	**11865**	**53**	**5**	**11923**
longjaw mudsucker	***Gillichthys mirabilis***	**1**	**0**		**1**
Mississippi silverside	*Menidia audens*	1242	89501		90743
northern anchovy	***Engraulis mordax***	**322**	**0**	**37**	**359**
Pacific herring	***Clupea harengeus***	**482**	**133**		**615**
Pacific lamprey	***Entosphenus tridentatus***	**43**	**0**		**43**
Pacific sanddab	***Citharichthys sordidas***	**3**	**2**		**5**
plainfin midshipman	***Porichthys notatus***	**19**	**0**		**19**
prickly sculpin	***Cottus asper***	**10766**	**987**	**1**	**11754**
rainbow trout	***Oncorhynchus mykiss***	**9**	**4**		**13**
rainwater killifish	*Lucania parva*	32	122		154
redear sunfish	*Lepomis microlophus*	2	1		3
river lamprey	***Lampetra ayresi***	**3**	**0**		**3**
Sacramento blackfish	***Orthodon macrolepidotus***	**26**	**116**		**142**
Sacramento	***Ptychocheilus grandis***	**152**	**232**		**384**

Common Name	Scientific Name	Otter Trawl	Beach Seine	Midwater Trawl	Total
pikeminnow					
Sacramento splittail	***Pogonichthys macrolepidotus***	**30479**	**4056**	**14**	**34549**
Sacramento sucker	***Catostomus occidentalis***	**3397**	**116**	**5**	**3518**
shimofuri goby	*Tridentiger bifasciatus*	10227	2522	1	12750
shiner perch	***Cymatogaster aggregata***	**17**	**0**		**17**
shokihaze goby	*Tridentiger barbatus*	836	5	6	847
speckled sanddab	***Citharichthys stigmaeus***	**3**	**0**		**3**
staghorn sculpin	***Leptocottus armatus***	**2577**	**3437**		**6014**
starry flounder	***Platichthys stellatus***	**2025**	**272**	**4**	**2301**
striped bass	*Morone saxatilis*	86424	14488	30	100942
surf smelt	***Hypomesus pretiosus***	**5**	**0**		**5**
threadfin shad	*Dorosoma petenense*	2973	5433	1	8407
threespine stickleback	***Gasterosteus aculeatus***	**17616**	**6484**	**6**	**24106**
tule perch	***Hysterocarpus traski***	**20849**	**2282**	**6**	**23137**
wakasagi	*Hypomesus nipponensis*	10	6		16
warmouth	*Lepomis gulosus*	1	0		1
western mosquitofish	*Gambusia affinis*	18	355		373
white catfish	*Ameiurus catus*	5877	164	13	6054
white crappie	*Pomoxis annularis*	112	0		112
white croaker	***Genyonemus lineatus***	**2**	**0**		**2**
white sturgeon	***Acipenser transmontanus***	**117**	**0**	**2**	**119**
yellowfin goby	*Acanthogobius flavimanus*	19726	17224		36950
Total		239377	149609	138	389124

APPENDIX B: 2015 CATCHES

Total 2015 otter trawl catch of each fish species in each slough of Suisun Marsh (native species in bold).

Species	Slough										Total
	Boynton	Cut-off	Denver-ton	First Mallard	Good-year	lower Suisun	Monte-zuma	Nurse	Pey-tonia	upper Suisun	
American shad	4	3	7	7	11	6	2	1	2	1	44
black bullhead								1			1
black crappie	1	3	134	1			1	2			142
California halibut						**1**	**1**				**2**
common carp	9	13	20	4				9	5	2	62
delta smelt						**3**					**3**
goldfish									1		1
hitch							**2**				**2**
longfin smelt			**1**			**3**	**1**	**2**	**1**		**8**
Mississippi silversides	1		6	15	6						28
northern anchovy					**10**	**44**	**2**				**56**
plainfin midshipman					**2**	**2**					**4**
prickly sculpin	**3**	**4**	**4**	**2**	**33**	**6**	**1**	**2**	**1**		**56**
Sacramento pikeminnow							**1**		**1**		**2**
Sacramento splittail	**103**	**37**	**731**	**129**	**150**	**93**	**276**	**298**	**270**	**64**	**2151**
Sacramento sucker	**4**	**4**		**5**					**20**		**33**
shimofuri goby	13	12	21	11	2	4	1	6	12	6	88
shokihaze goby					3	22	5	3	1	28	62
staghorn sculpin							**1**				**1**
starry flounder		**1**	**1**	**1**		**1**	**5**	**5**	**1**	**6**	**21**
striped bass	88	41	192	69	145	114	365	142	104	49	1309
threadfin shad	3	4	43	20	6	2	17	16	2	3	116
threespine stickleback	**3**	**2**		**5**	**53**	**19**	**18**	**6**	**4**	**9**	**119**
tule perch	**43**	**70**	**125**	**49**	**9**	**18**	**53**	**145**	**180**	**31**	**723**
white catfish	25	11	60	3			3	9	14	1	126
white croaker						**1**					**1**
white sturgeon										**1**	**1**
yellowfin goby	2	3	4	4	9	24	8	8	3	5	70
Total	302	208	1349	325	439	363	763	655	622	206	5232

Total 2015 beach seine catch of each fish species in Denverton and upper Suisun sloughs (native species are in bold).

Species	Slough		Total
	Denverton	upper Suisun	
American shad	13	10	23
black crappie	6		6
California halibut	**1**	**1**	**2**
Chinook salmon	**3**		**3**
common carp	10	11	21
Mississippi silversides	2120	705	2825
prickly sculpin	**21**	**7**	**28**
rainwater killifish	1		1
Sacramento pikeminnow	**1**		**1**
Sacramento splittail	**110**	**45**	**155**
shimofuri goby	123	16	139
staghorn sculpin		**5**	**5**
starry flounder	**2**	**4**	**6**
striped bass	200	103	303
threadfin shad	30	18	48
threespine stickleback	**60**	**26**	**86**
tule perch	**16**	**88**	**104**
western mosquitofish		7	7
yellowfin goby	12	78	90
Total	2729	1124	3853

APPENDIX C: 2015 EFFORT

Number of otter trawls in each slough and each month in 2015.

Slough	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Boynton	2	2	2	2	2	2	2	2	2	2	2	2	24
Cutoff	2	2	2	2	2	2	2	2	2	2	2	2	24
Denverton	3	3	3	3	3	3	3	3	3	3	3	3	36
First Mallard	2	2	2	2	2	2	2	2	2	2	2	2	24
Goodyear	3	3	3	3	3	3	3	3	3	3	3	3	36
lower Suisun	2	2	2	2	2	2	2	2	2	2	2	2	24
Montezuma	4	2	2	2	2	2	2	2	2	2	2	2	26
Montezuma new	1	1	1	1		1	1	1	1	1	1	1	11
Nurse	3	3	3	3	3	3	3	3	3	3	3	3	36
Peytonia	2	2	2	2	2	2	2	2	2	2	2	2	24
Second Mallard				2						1			3
upper Suisun	2	2	2	2	2	2	2	2	2	2	2	2	24
Total	26	24	24	26	23	24	24	24	24	25	24	24	292

Number of beach seines in each slough and each month in 2015.

Slough	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Denverton	3	4	3	3	3	2	2	3	3	3	3	3	35
Montezuma new	3	3	3	3		1	3	3	3	3	3	3	31
upper Suisun	3	3	3	3	3	3	3	3	3	3	3	3	36
Total	9	10	9	9	6	6	8	9	9	9	9	9	102