## Title

Suisun Marsh Fish Study trends in fish and invertebrate populations January 2014 - December 2014.



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# SUISUN MARSH FISH STUDY

## Trends in Fish and Invertebrate Populations of Suisun Marsh

## January 2014 - December 2014

## Annual Report for the

## California Department of Water Resources

## Sacramento, California


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# SUMMARY


Suisun Marsh, at the geographic center of the San Francisco Estuary, is important habitat for non-native and 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 water in Suisun Marsh in 2014 was generally salty, well-oxygenated, warm, and clear. Delta outflows were well below average compared to a typical year, corresponding to comparatively high salinities in Suisun Marsh. With the exception of one reach in one slough, oxygen concentrations were hospitable for most marsh fishes in all months of 2014. Water temperatures were about average through the first half of the year but were then much warmer than usual in the last four months of 2014. Consistent with low Delta outflows, the water in Suisun Marsh was more transparent than usual, particularly during summer and autumn.

Abundances of common invertebrates in 2014 reflected, in part, the dry year. Overbite clams (*Potamocorbula* amurensis) were extremely abundant, likely due to favorable salinities for recruitment occurring in Suisun Marsh for much of the year; Black Sea jellyfish (*Maeotias marginata*) were also caught in high numbers. Conversely, numbers of both California bay shrimp (*Crangon franciscorum*) and Siberian prawn (*Exopalaemon modestus*) were down, a pattern that has been observed in previous years of low Delta outflow.

Fish abundance in otter trawls was below average though not as low as has been seen in some other dry years (*e.g.*, 2008), while fish abundance in beach seines was higher than average. The lower otter trawl value in 2014 was mainly due to fewer non-native fish, especially striped bass (*Morone saxatilis*). In contrast, native fishes such as Sacramento splittail (*Pogonichthys macrolepidotus*) and tule perch (*Hysterocarpus traski*) were remarkably abundant in otter trawls in 2014 and contributed to a higher-than-average trawl abundance for native fishes despite a precipitous drop in longfin smelt (*Spirinchus thaleichthys*) numbers from 2013 to 2014. Although not caught in enough numbers to offset the relatively low striped bass abundance, non-native black crappie (*Pomoxis nigromaculatus*) and white catfish (*Ameiurus catus*) were surprisingly abundant in otter trawls given their intolerance of moderately salty water. In beach seines, Mississippi silversides (*Menidia audens*) were more abundant than usual, a common observation in warm years. Nevertheless, abundance of native fishes was higher than average in beach seines, partially due to a rise in numbers of threespine stickleback (*Gasterosteus aculeatus*) and staghorn sculpin (*Leptocottus armatus*) but especially Sacramento splittail; the latter is unusual given the species' positive relationship to Delta outflow. These patterns in catch suggest that the suboptimal hydrologic conditions in Suisun Marsh in 2014 for fishes such as Sacramento splittail and white catfish may have been mitigated by other beneficial marsh conditions (*e.g.*, food abundance).

## TABLE OF CONTENTS

**Introduction……………………………………………………………………………..….….…..….…4**

**Methods…………………………………………………………………………….….……….….….…5**

**Results and Discussion…………………………………………………………...……….......10**

**Abiotic Conditions...........................................................................................................………...10**

**Trends in Invertebrate Distribution and Abundance.......................................….....…...16**

**Trends in Fish Distribution and Abundance...................................................………...19**

**Conclusion..…………………………………………………………………………………....31**

**Acknowledgements..........................................................................................................….…..…31**

**References……………………………………………………………………………….…..32**

**Appendices……………………………………………………………………………………..35**

# 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 uninterrupted estuarine marsh 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 remaining acreage consisting of tidal sloughs, marsh plains, and grasslands (DWR 2001). The marsh's central location in the San Francisco Estuary makes it an important nursery for salt-tolerant-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 (*e.g.*, O'Rear 2012). 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.*, Blacklock Island and Luco Pond); contributing to the general understanding of estuarine systems through publication of peer-reviewed papers (*e.g.*, 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, but 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 curtailed 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 both drought and high salinity reduced native fish abundance. 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 both bolstered previous findings and enhanced understanding of the aquatic ecosystem's food web. O'Rear and Moyle (2014*a*, *b*, 2010, 2009) found that the timing, variability, and magnitude of Delta outflow continued to be important factors affecting abundance of fishes recruiting into the marsh from upstream and downstream areas [*e.g.*, striped bass, yellowfin goby (*Acanthogobius flavimanus*), respectively]. Additionally, a limitation in pelagic food appeared to occur sometime in summer that resulted in an inshore movement of fishes (O'Rear and Moyle 2014*c*). Studies on non-native jellyfish found a high likelihood of competition for food between the jellyfish and two pelagic fishes [threadfin shad (*Dorosoma petenense*) and delta smelt (*Hypomesus transpacificus*); Wintzer *et al.* 2011*b*]. O'Rear (2012) discovered that white catfish mostly ate food from managed wetlands from autumn through spring while subsisting on bay-produced or slough-produced food during summer; unlike previous studies in the Sacramento-San Joaquin Delta (Turner 1966), white catfish in Suisun Marsh never ate at-risk fishes. Isotope studies by Schroeter *et al*. (in press) found that many consumers in the marsh are generalists and that submerged aquatic vegetation may be a significant carbon source to upper trophic levels. Data animations showed novel patterns in the seasonality and distribution of diverse fish species (Manfree 2014). Finally, data accumulating from an ongoing companion study (the "Arc Project"), utilizing in part the same sampling methods as the Suisun Marsh Fish Study, have been 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 2014 and typical conditions in Suisun Marsh; (2) compare abundances of important invertebrates and important fishes in 2014 to study averages, noting abundance changes between 2013 and 2014; (3) describe the pattern in monthly abundance of notable fishes and invertebrates in 2014, 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. There are two major subtidal channels in the marsh: Montezuma and Suisun sloughs (Figure 1). Major tributary sloughs to Montezuma are Denverton and Nurse; Cutoff Slough and Hunter Cut connect Suisun and Montezuma sloughs (Figure 1). Major 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).

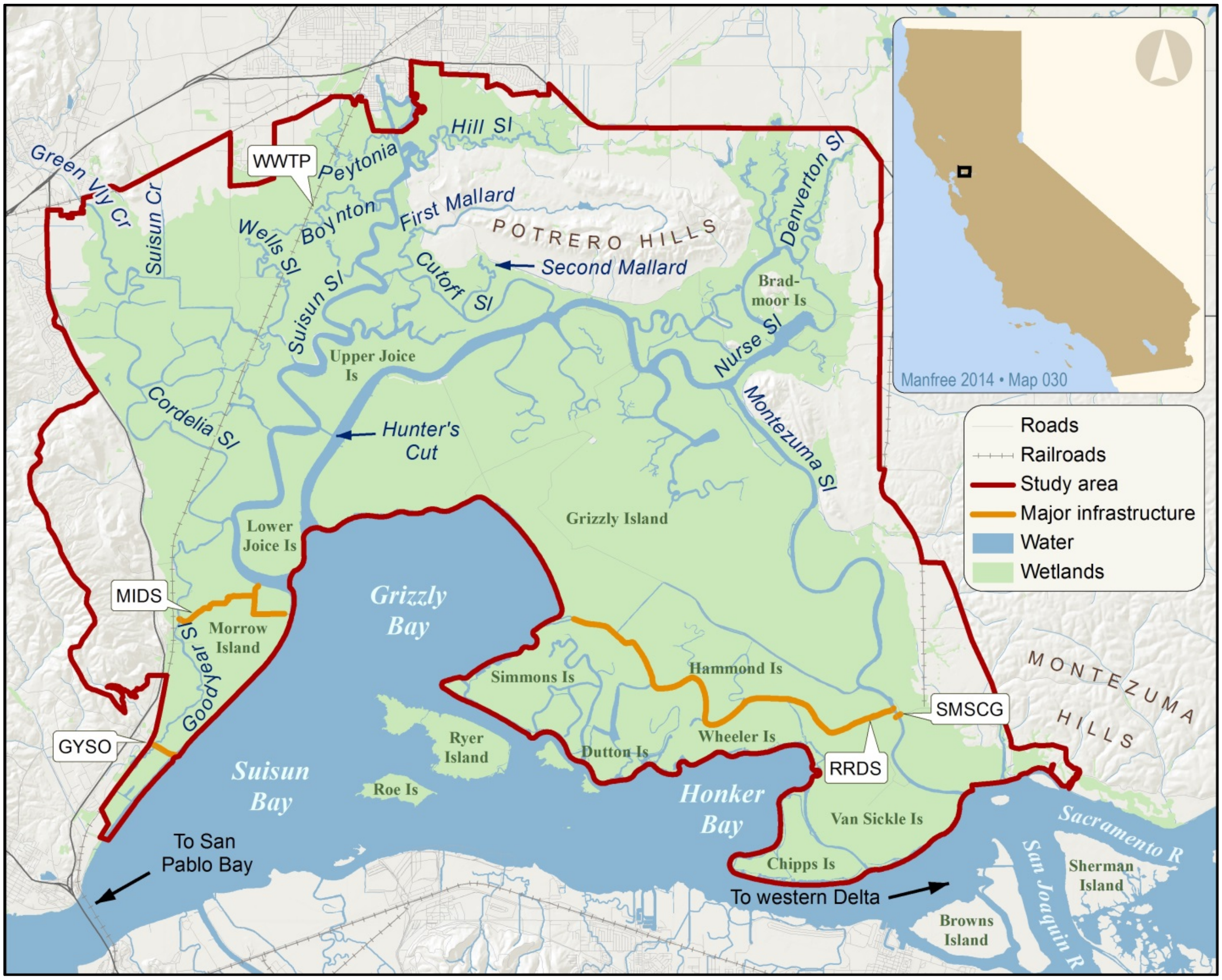


**Figure 1.** Suisun Marsh study area ("GYSO" = Goodyear Slough Outfall, "MIDS" = Morrow Island Distribution System, "RRDS" = Roaring River Distribution System, "SMSCG" = Suisun Marsh Salinity Control Gates, and "WWTP" = the Fairfield-Suisun Sanitation District's wastewater treatment plant discharge 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; fringed with common reed (*Phragmites australis*) and tules (*Schoenoplectus* spp.); and have very little riprap. 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 freshwater flow determines the salinity of Suisun Marsh's sloughs. 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. 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 and less so 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.

A number of 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 food plants for waterfowl (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). Two additional sites in Montezuma Slough - one historical (MZ6) and one new (MZN3; Figure 2) - were sampled throughout 2014 as part of the Arc Project; their data were included in this report. Several additional sites were sampled intermittently in 2014 for other projects, but their data were not included in monthly or slough-to-slough comparisons due to the infrequent sampling.

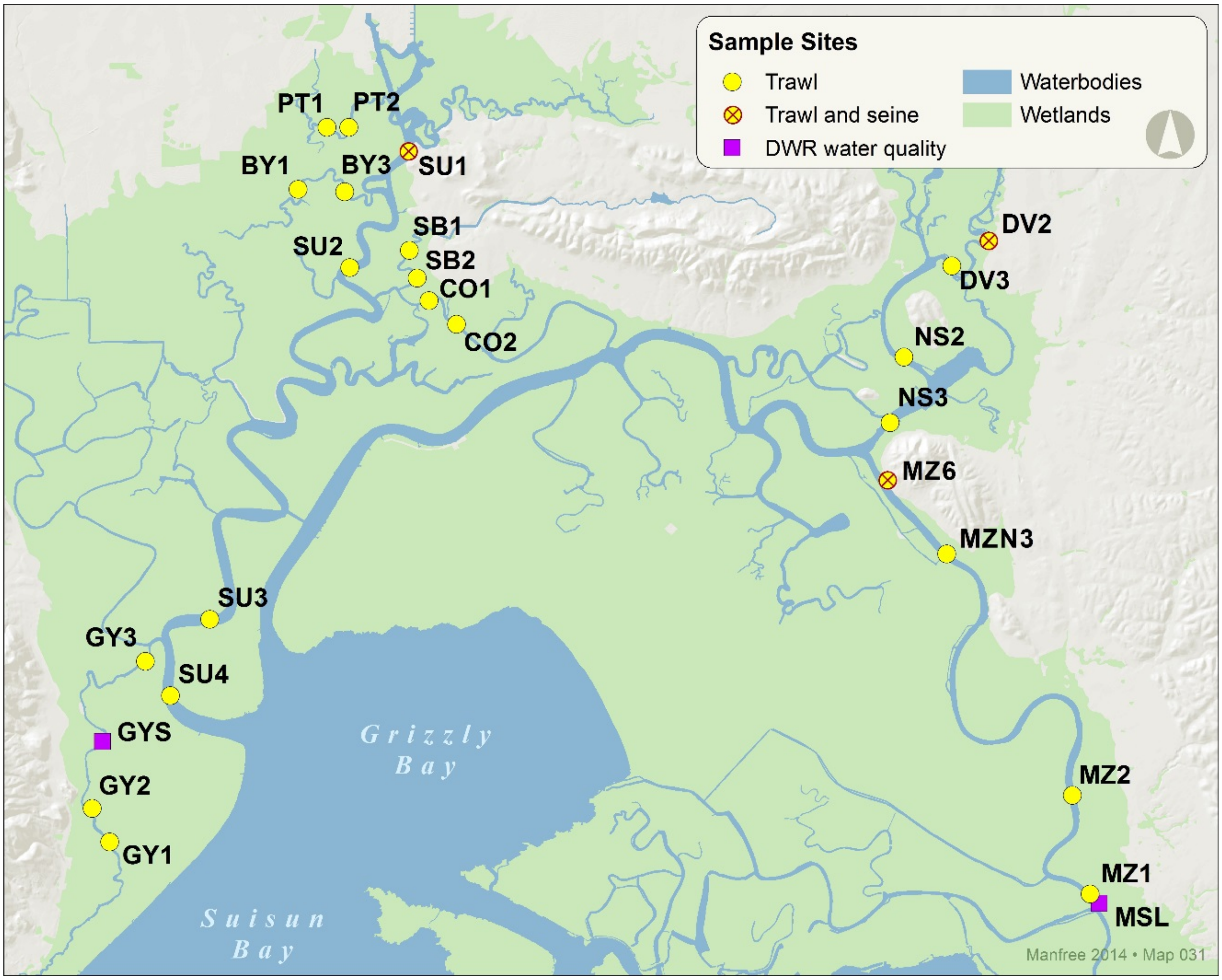


**Figure 2.** Current Suisun Marsh Fish Study sampling sites and DWR water-quality monitoring stations used in this report (map by Amber Manfree).

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. Fish were identified, measured to the nearest mm standard length (mm SL), and returned to the slough where captured. Sensitive native species were processed first and immediately released. Numbers of Black Sea jellyfish, Siberian prawn, oriental shrimp (*Palaemon macrodactylus*), California bay shrimp, Harris mud crab (*Rhithropanopeus harrisii*), overbite clam, Asian clam (*Corbicula fluminea*), and other rare Suisun Marsh clam 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

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

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

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

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 2014 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 in 2014 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." X2, the distance in kilometers from the Golden Gate Bridge along the thalweg to the near-bed water with salinity of 2 ppt, was calculated following Jassby (1995). The Net Delta Outflow Index ("Delta outflow"), a proxy for water leaving the Delta, was obtained from the DWR's Dayflow website (DWR 2015).

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 2014 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 served as useful bookends.

Catch of all fishes and by each method from 1979 to 2014 are found in Appendix A; annual catch of each slough and number of trawls/seines in each slough in 2014 are found in Appendix B and C.

# RESULTS AND DISCUSSION

## Abiotic Conditions

### *Delta Outflow*

Delta outflow in 2014 was below the all-years (*i.e.*, 1980 - 2014) average for nearly the entire year (Figure 3), consistent with DWR's "Critical" water-year classification for the

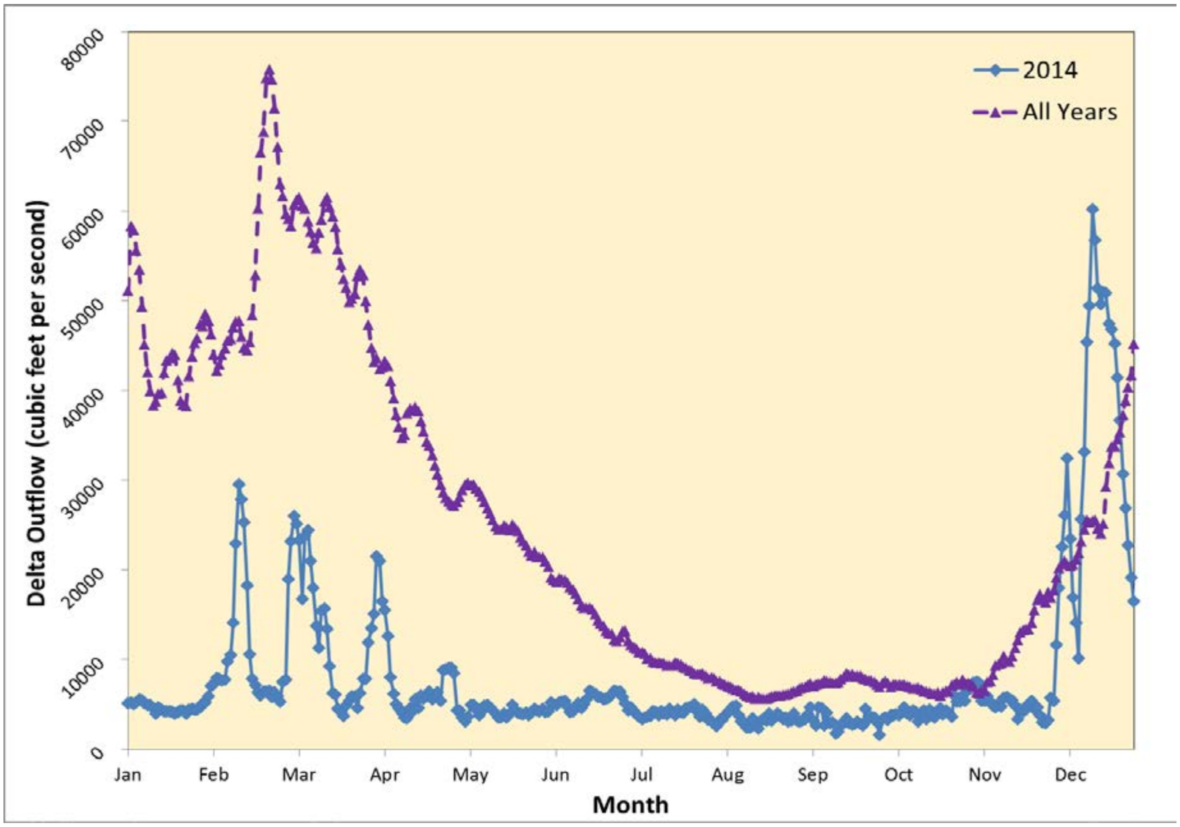


**Figure 3.** Daily Delta outflow in 2014 and the average for all years of the study (1980 – 2014; DWR 2015).

Sacramento River. Delta outflow spiked four times from late winter through spring coincident with storms, but the maximum flows of those spikes were well below the average values for all years of the study. From May to late November, Delta outflow was low and varied only mildly (Figure 3). A cut-off low that entrained a tropical-moisture plume resulted in heavy rain that raised Delta outflow substantially in late November and in December, the only times in 2014 when Delta outflow exceeded the all-years average.

*Salinity*

Consistent with low Delta outflow in 2014, salinities in the marsh were higher than normal for all months (Figure 4). Average Suisun Marsh Fish Study salinities were usually within bounds of the two fixed stations, although the study's average salinities were invariably closer to the MSL gauge's salinities (Figure 5). The fish study's salinities during May and June were notably at the low end of the MSL gauge's salinities, which was due to relatively low values in Peytonia and Boynton sloughs. The disparity in average salinity between 2014 and all years increased from April to August. Salinities remained higher than average for all months after August, although December's value was much closer to the average value than the other months, mainly due to much lower salinities measured in Peytonia, Boynton, and Denverton sloughs just after heavy rainfall. The fish study's average salinity in September 2014 was curiously lower than salinities in adjacent months; data from the GYS gauge also showed a similar pattern (Figure 5).

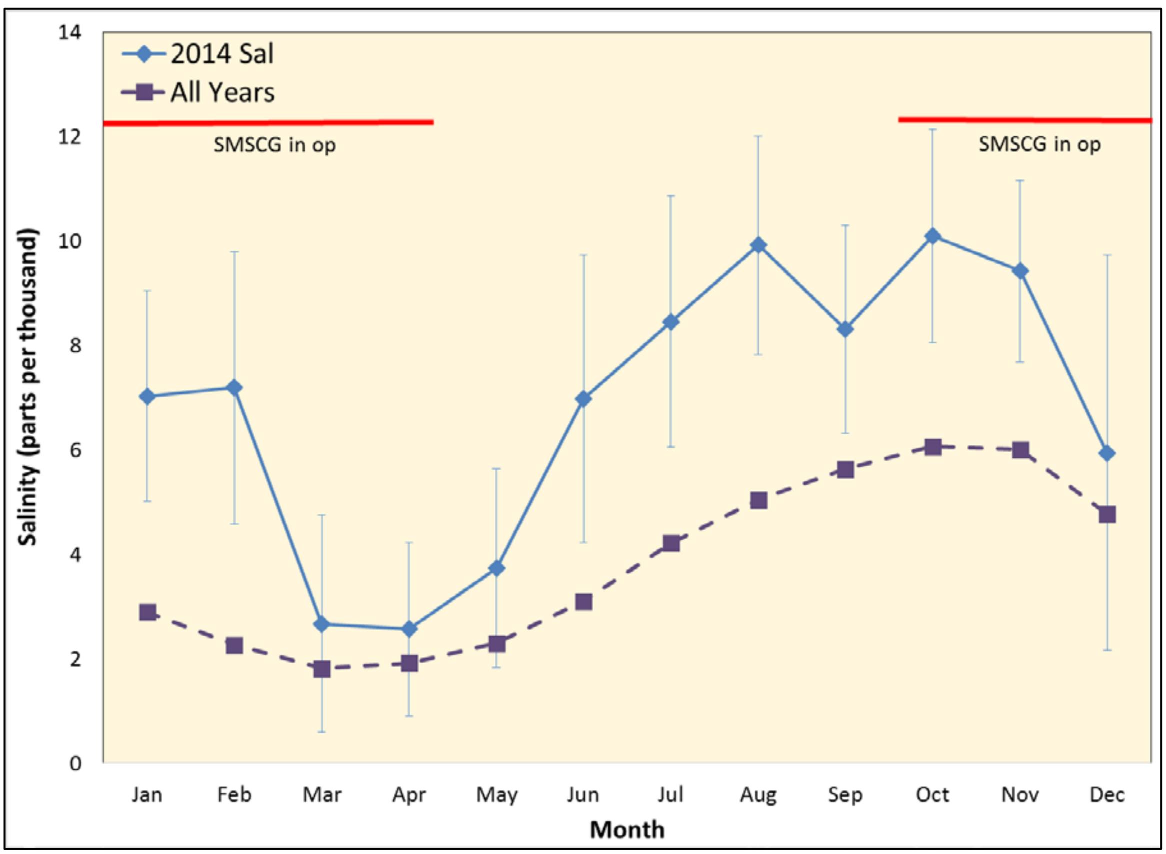


**Figure 4.** Monthly average salinity in 2014 and for all years of the study (1980 - 2014); error bars are standard deviations in 2014. Red bars show when the SMSCG were operating in 2014.

Geographically, highest monthly salinities were always in the southwest marsh in either Goodyear Slough or, in May and June, lower Suisun Slough (*i.e.*, the SU3 and SU4 stations; Figure 2). Lowest salinities were in Peytonia, Boynton, and Montezuma sloughs. The relatively high salinities resulted in operation of the Suisun Marsh Salinity Control Gates throughout much of the control season (January - May and October - December); X2 was within Suisun Bay for only the second week of March and for the last two weeks of December.

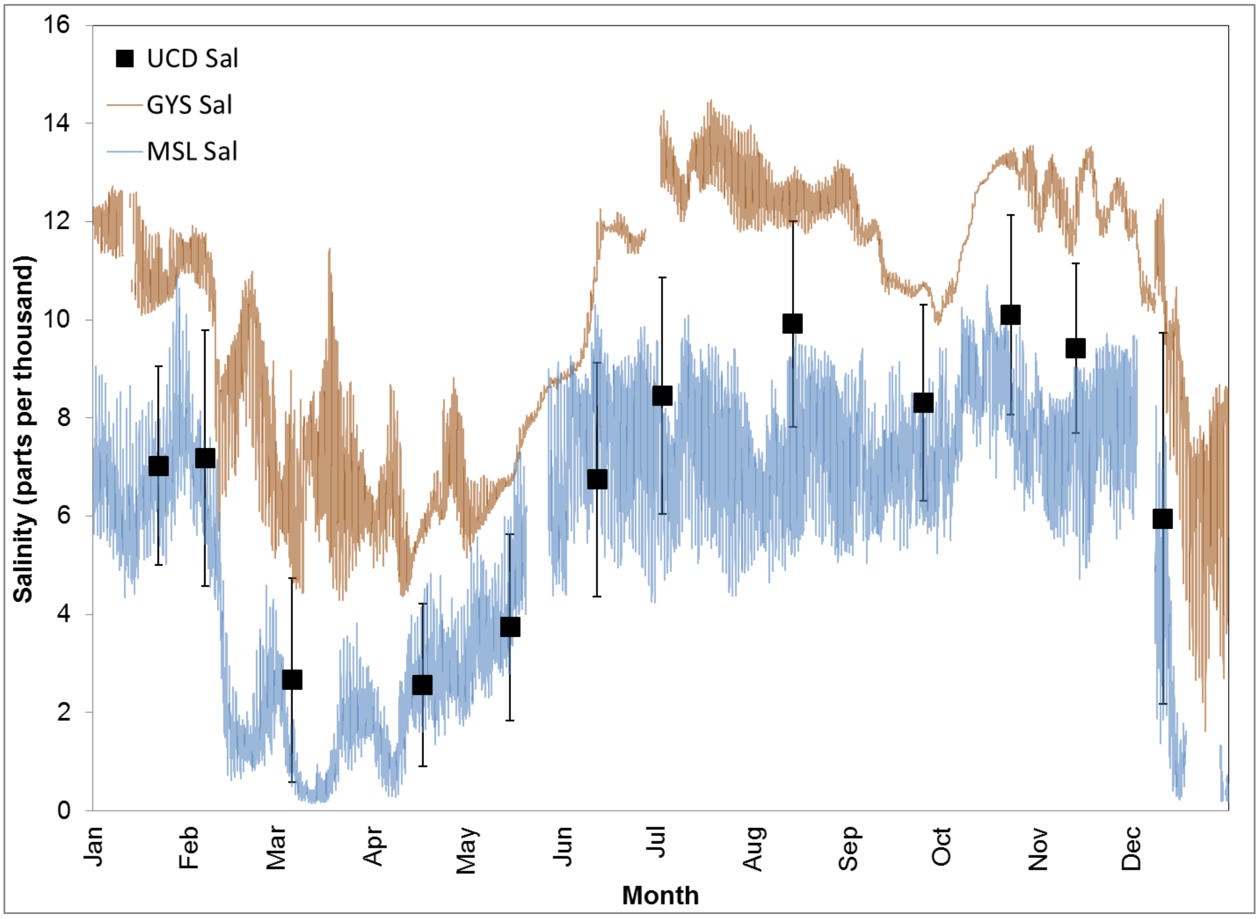


**Figure 5.** Fifteen-minute salinity from fixed stations in Goodyear Slough (GYS) and Montezuma Slough (MSL), with average monthly salinities and standard deviations from the Suisun Marsh Fish Study ("UCD Sal").

*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 duck ponds 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.

Average DO concentrations in 2014 were relatively consistent through the year, with January and February, as is common, having the highest values (Figure 6). Maximum DO in 2014 paralleled fairly well 2014's average DO concentrations and similarly were relatively consistent though exhibited a slight downward trend from January to December. A drop in minimum DO concentration accompanied the decline in average DO in 2014 from January to March, but minimum DO concentration then gradually increased from March to November before reaching the year's low point in December. Highest DO concentrations were always in eastern Montezuma Slough except in January and December, when they were recorded in Denverton and Nurse sloughs, respectively. Except in January and February, the lowest DO concentrations were always in Goodyear Slough at either the GY1 or GY2 site (Figure 2).

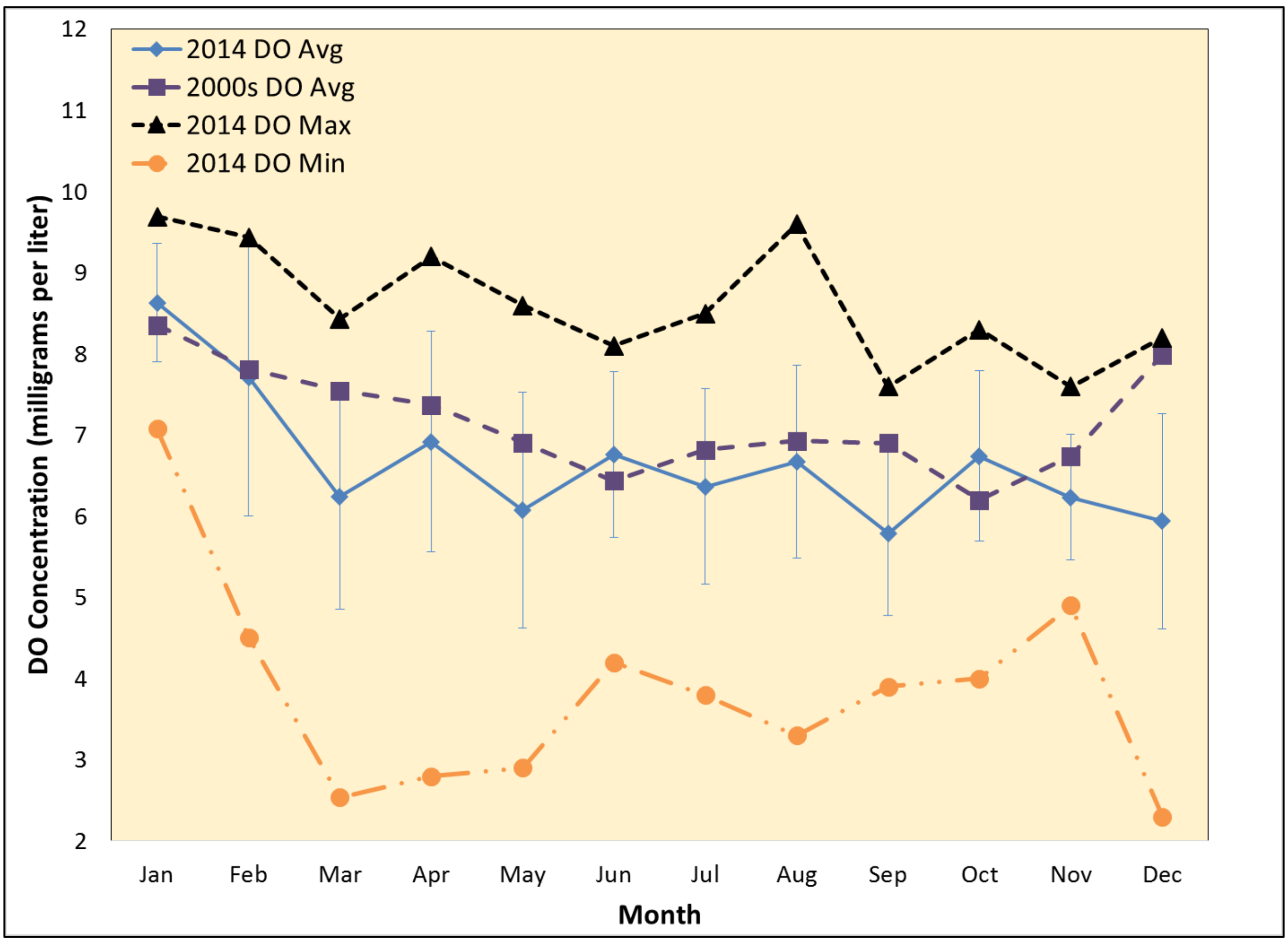


**Figure 6.** Monthly average DO concentration in 2014 and for the 2000s (2000 - 2014), maximum DO concentration in 2014, and minimum DO concentration in 2014. Error bars are standard deviations in 2014.

*Water Temperature*

Water temperatures in 2014 were relatively normal except for (1) cooler-than-average water in February and (2) increasingly warmer water relative to the all-years average from September to December (Figure 7). Average water temperatures from the fish study in 2014 were within the ranges of the two fixed monitoring stations (Figure 8). The most extreme water temperatures from the fish study were generally recorded in the smaller sloughs; for example, summer high temperatures in June were in Cutoff Slough, while coldest temperatures were recorded in First Mallard and upper Nurse sloughs in January and December, respectively. This was consistent with water temperature varying more in Goodyear Slough than in Montezuma Slough, with Goodyear attaining higher summer temperatures and lower winter temperatures than Montezuma (Figure 8). Nevertheless, highest water temperatures in July and August where recorded in larger sloughs: lower Suisun Slough and eastern Montezuma Slough, respectively.

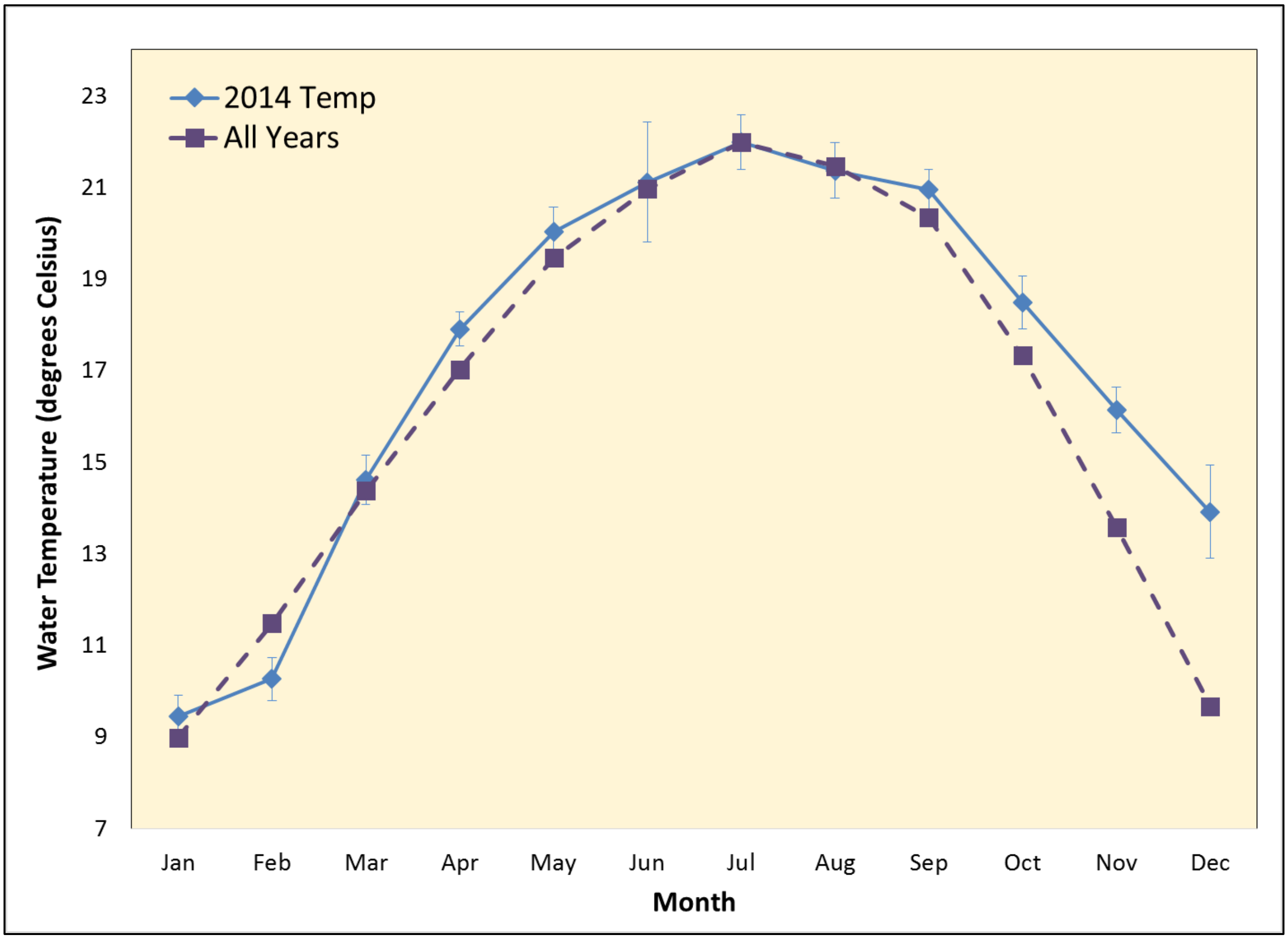


**Figure 7.** Monthly average water temperature in 2014 and for all years of the study (1980 - 2014); error bars are standard deviations in 2014.

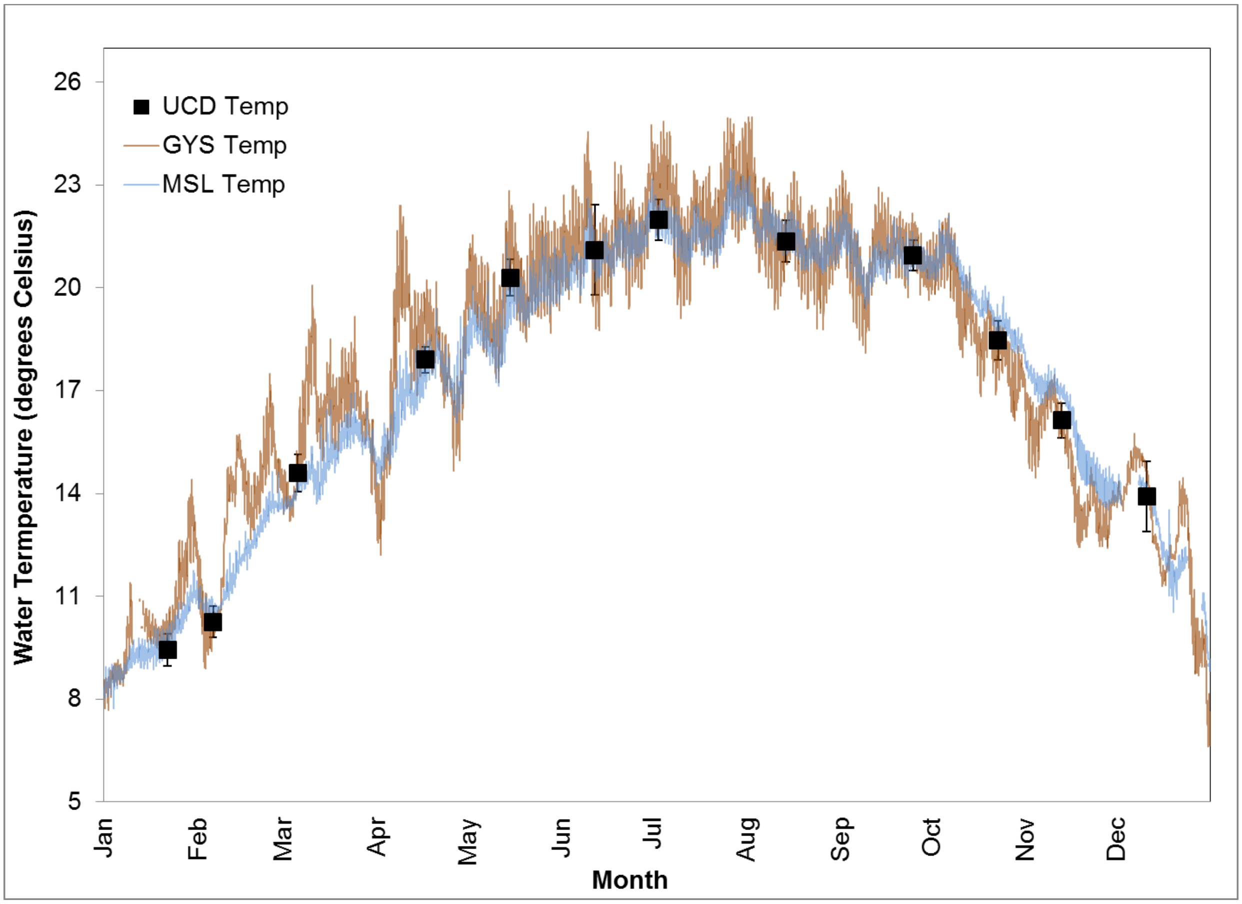


**Figure 8.** Fifteen-minute water temperatures from fixed stations in Goodyear Slough (GYS) and Montezuma Slough (MSL), with monthly average temperatures and standard deviations from the Suisun Marsh Fish Study ("UCD Temp").

*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 2014 followed this trend, with all months in 2014 exhibiting higher-than-average transparencies. Transparencies in 2014 were lowest during spring, concomitant with higher Delta outflow; highest transparencies were observed during autumn (Figure 9). Except during September, when the lowest transparency was measured in Suisun Slough, lowest monthly transparencies in 2014 were in small sloughs (Boynton, Peytonia, and upper Goodyear sloughs) far from larger sloughs; eastern Montezuma had the clearest water of the sites sampled in all but two months (February and April). Variability in transparency was similar among months except (1) in April, when transparencies were generally lower and more even among the sloughs (Figure 9); and (2) in December, when transparencies varied widely, mainly due to very low values in Denverton and Peytonia sloughs, coincident with heavy precipitation and drastically reduced salinities.

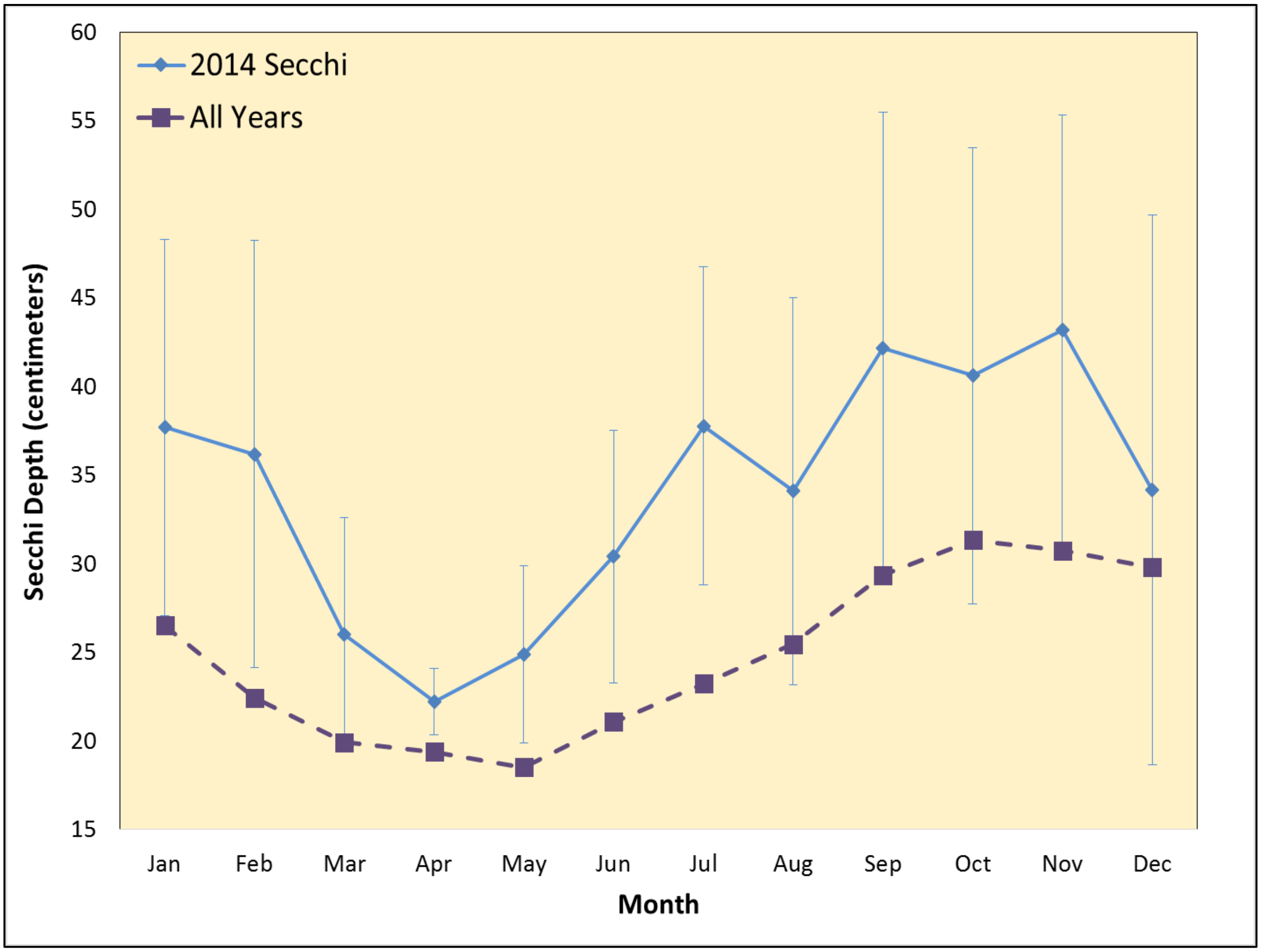


**Figure 9.** Monthly average water transparency in 2014 and for all years of the study (1980 - 2014); error bars are standard deviations in 2014.

## 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)].

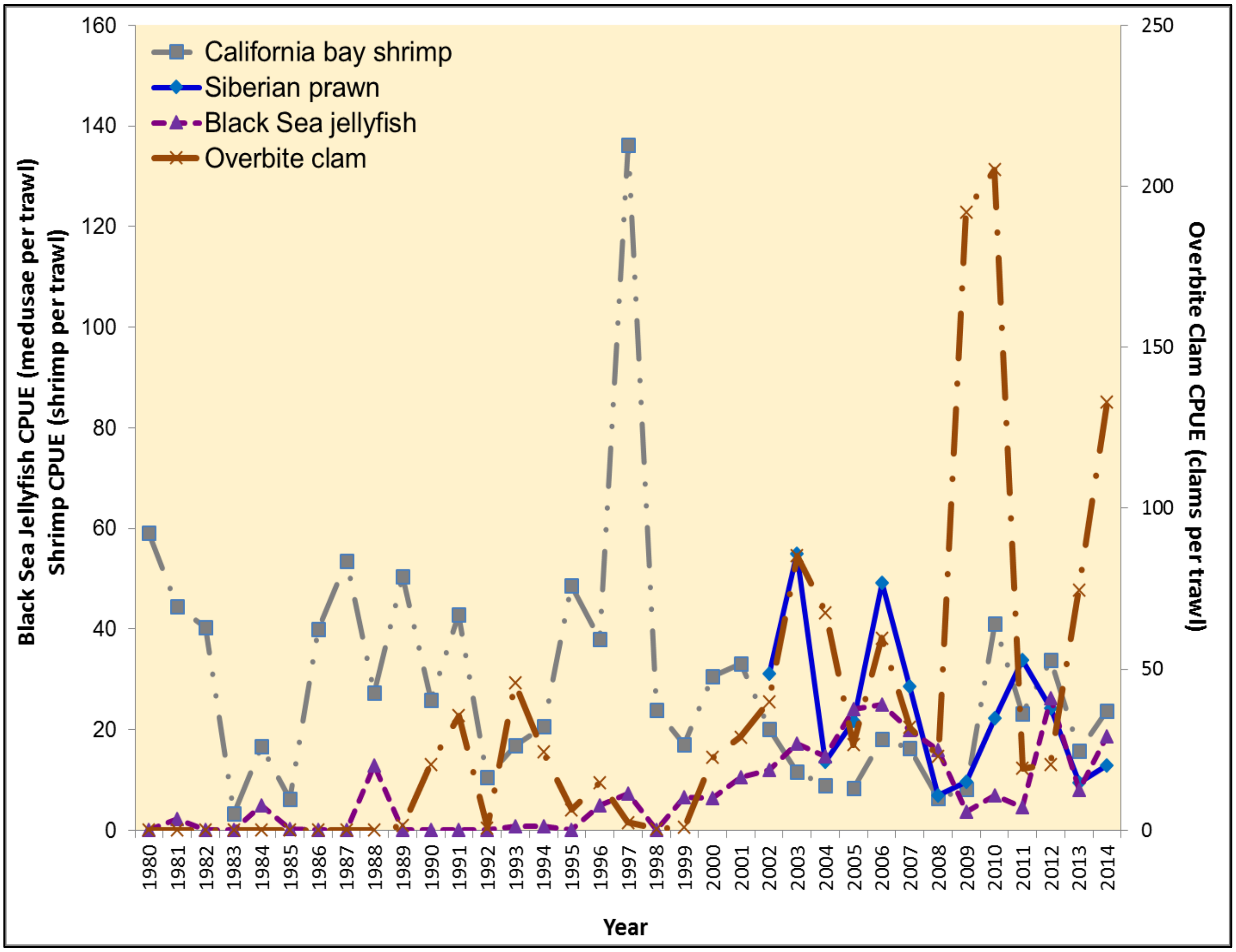

**Figure 10.** Annual otter trawl CPUE of four common macroinvertebrates.

*Black Sea Jellyfish*

Black Sea jellyfish annual CPUE more than doubled from 2013 to 2014 (8 to 19 medusae per trawl; Figure 10), with the 2014 CPUE nearly triple the average for the entire study period (19 and 7 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). Black Sea jellyfish were especially abundant in sloughs of the northwestern marsh (Peytonia, Boynton, and upper Suisun [*i.e.*, the SU1 and SU2 sites; Figure 2) sloughs], where nearly two-thirds of 2014's catch was made. Black Sea jellyfish were least abundant in Goodyear and Denverton sloughs, both of which hosted only 1% of 2014's annual catch.

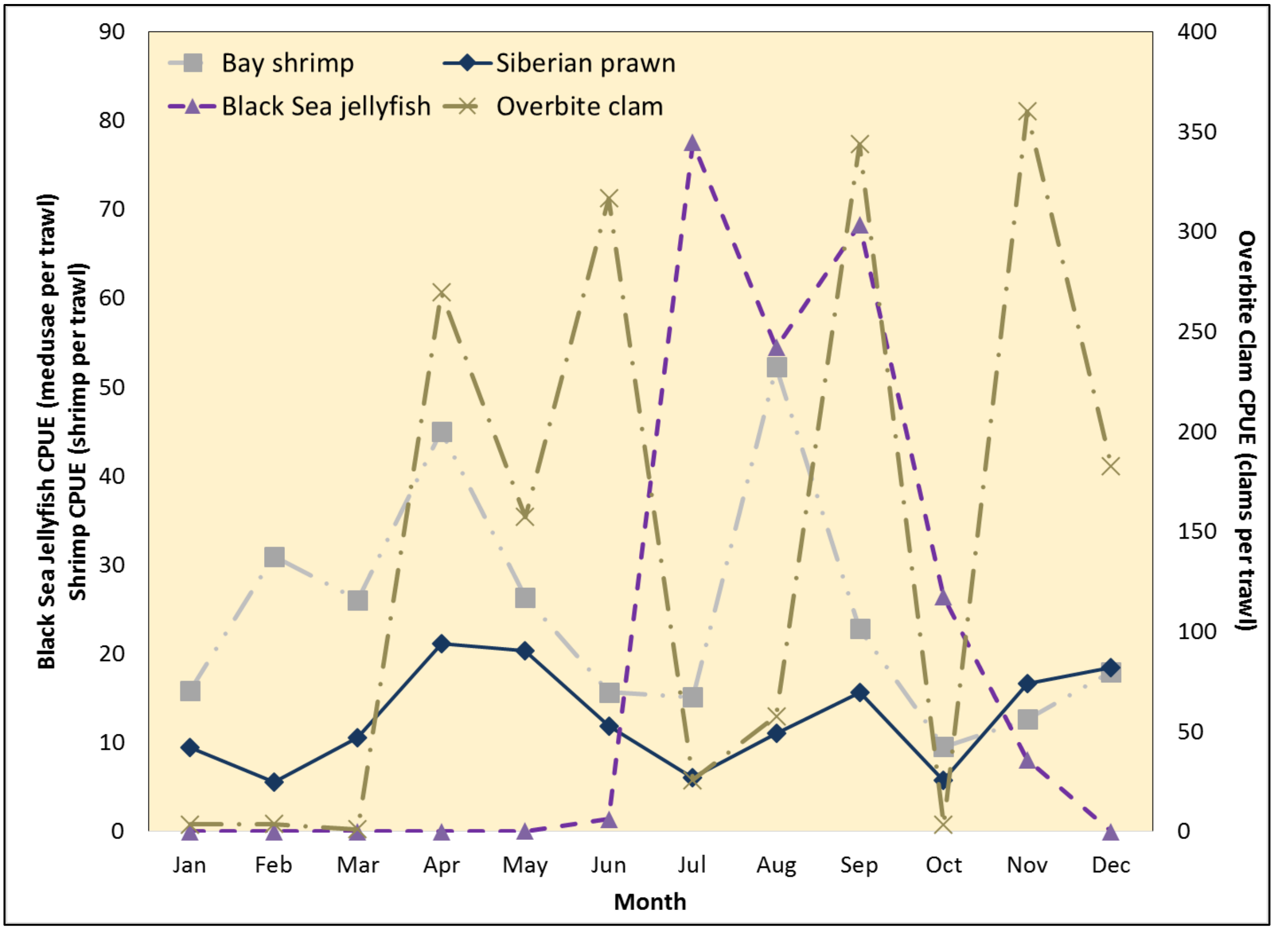


**Figure 11.** Monthly average CPUE of four common macroinvertebrates in Suisun Marsh in 2014.

*Overbite Clam*

Annual overbite clam CPUE in 2014 increased tremendously from 2013 (133 and 75 clams per trawl, respectively) and was well above the average (40 clams per trawl) since 1988, the first year overbite clams were captured in the marsh. While monthly overbite clam CPUE was highly variable in 2014, large numbers were commonly observed in all seasons except winter, likely due to favorable salinities being present somewhere in the marsh for all of 2014 (Miller and Stillman 2013, Schroeter 2011, Nicolini and Penry 2000). As in 2013, nearly all overbite clams in 2014 - 99% - were captured in Suisun Slough , with the catch in Suisun Slough split evenly between the upper (*i.e.*, SU1 and SU2; Figure 2) and lower reaches (*i.e.*, SU3 and SU4). This is the fifth year in a row in which a substantial proportion of the overbite clam catch came from upper Suisun Slough. Of the 38,002 overbite clams captured in 2014, only 22 came from Denverton, Boynton, or First Mallard sloughs, further supporting previous patterns that smaller sloughs in the marsh are inhospitable to the clam (O'Rear and Moyle 2014*a*, Schroeter 2011).

*California Bay Shrimp*

California bay shrimp annual CPUE increased from 2013 to 2014 (16 and 24 shrimp per trawl, respectively) but remained below the average for the entire study period (29 shrimp per trawl; Figure 10). Monthly CPUE about tripled from January to April and then, with the exception of a high value in August, declined and stayed relatively low through the rest of the year (Figure 11). Both the comparatively high CPUE early in the year (*i.e.*, April) and the relatively low maximum monthly CPUE were consistent with effects of the dry, salty year: earlier recruitment and lower abundances in years of low Delta ouflows have been observed throughout the estuary (O'Rear and Moyle 2014*b*, *c*, Hatfield 1985, Siegfried 1980). Most of the bay shrimp in 2014 were caught in the large sloughs, with Suisun and Montezuma sloughs comprising 45% and 24% of the annual catch, respectively, while four of the fresher, smaller interior sloughs - Denverton, First Mallard, Boynton, and Cutoff - 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).

*Siberian Prawn*

Annual CPUE of Siberian prawn increased from 2013 to 2014 (9 and 13 shrimp per trawl, respectively), although 2014's annual CPUE was still well below the average annual value (24 shrimp per trawl) since the prawn's introduction in 2002 (Figure 10). Monthly CPUE was relatively low and fairly consistent throughout 2014 (Figure 11), reflecting low recruitment similar to previous dry years (O'Rear and Moyle 2008). The monthly CPUE peaked in April concurrent with the lowest salinities of the year, which was probably because of elevated Delta outflows transporting more prawns from upstream areas into Suisun Marsh (Brown and Hieb 2014). Siberian prawns were relatively ubiquitous in the marsh, being most abundant in, but not overwhelmingly so, in Denverton and Boynton sloughs (14% and 13% of 2014's catch, respectively).

## Trends in Fish Distribution and Abundance

*Otter Trawls*

Annual otter trawl CPUE increased from 13.3 fish per trawl in 2013 to 18.6 fish per trawl in 2014 (Figure 12), although 2014's value was still below the average for the whole study period (24.8 fish per trawl). The below-average CPUE in 2014 was due to non-native fishes, the CPUE of which was little more than half that of the all-years average (8.4 and 14.9 fish per trawl, respectively). In contrast, the native fish CPUE in 2014 was actually higher than the average for the whole study (10.3 and 9.7 fish per trawl, respectively). The increase from 2013 to 2014 was greater for non-native fishes, the CPUE of which rose by 41% while native-fish CPUE increased by 33% (Figure 12). American shad, striped bass, black crappie, and white catfish were the fishes most responsible for the rise in non-native CPUE from 2013 to 2014 (Table 1). Native fishes that contributed most to 2014's higher value were Sacramento splittal and tule perch, which offset a drastic reduction in longfin smelt CPUE from 2013 to 2014 (Table 1).

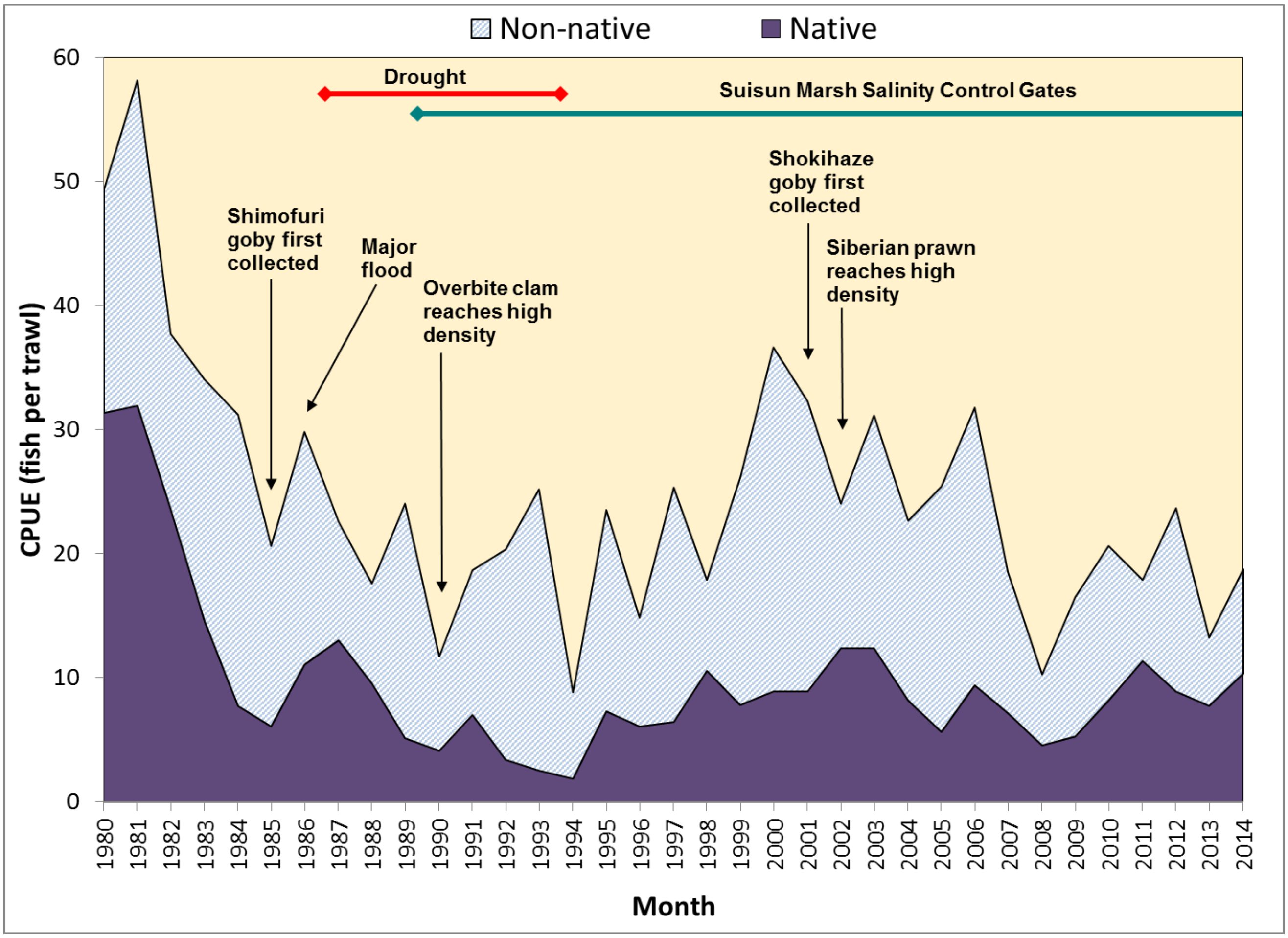


**Figure 12.** Annual otter trawl CPUE of native and non-native fishes, with important events highlighted.

**Table 1.** Percent change in annual otter trawl CPUE of seven 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 - 2014).

| Species | All Years CPUE | 2013 CPUE | 2014 CPUE | 2014/2013 % Change |
|---|---|---|---|---|
| **Sacramento splittial** | **2.7** | **3.5** | **5.2** | **+48%** |
| **longfin smelt** | **1.2** | **1.5** | **0.2** | **-87%** |
| **tule perch** | **2.1** | **1.7** | **3.4** | **+100%** |
| American shad | 0.1 | 0.1 | 0.7 | +600% |
| white catfish | 0.6 | 0.7 | 0.9 | +29% |
| striped bass | 9.0 | 3.1 | 4.3 | +39% |
| black crappie | 0.2 | 0.1 | 0.5 | +400% |

### *Beach Seines*

Annual beach seine CPUE in 2014 rose mildly relative to 2013 (61.8 and 46.4 fish per seine, respectively), with 2014's value similar to the average from 1980 to 2014 (57.0 fish per seine; Figure 13). CPUE increased for both non-native and native fishes from 2013 to 2014, with non-native CPUE rising moderately while native CPUE more than doubled (Figure 13); nevertheless, non-native fish were far more abundant in seine hauls than native fish.

The increase in native fish CPUE was mainly due to elevated numbers of Sacramento splittail, staghorn sculpin, and threespine stickleback (Table 2). For non-native fishes, striped bass and Mississippi silverside CPUE values increased notably and mitigated the drop in threadfin shad CPUE (Table 2).

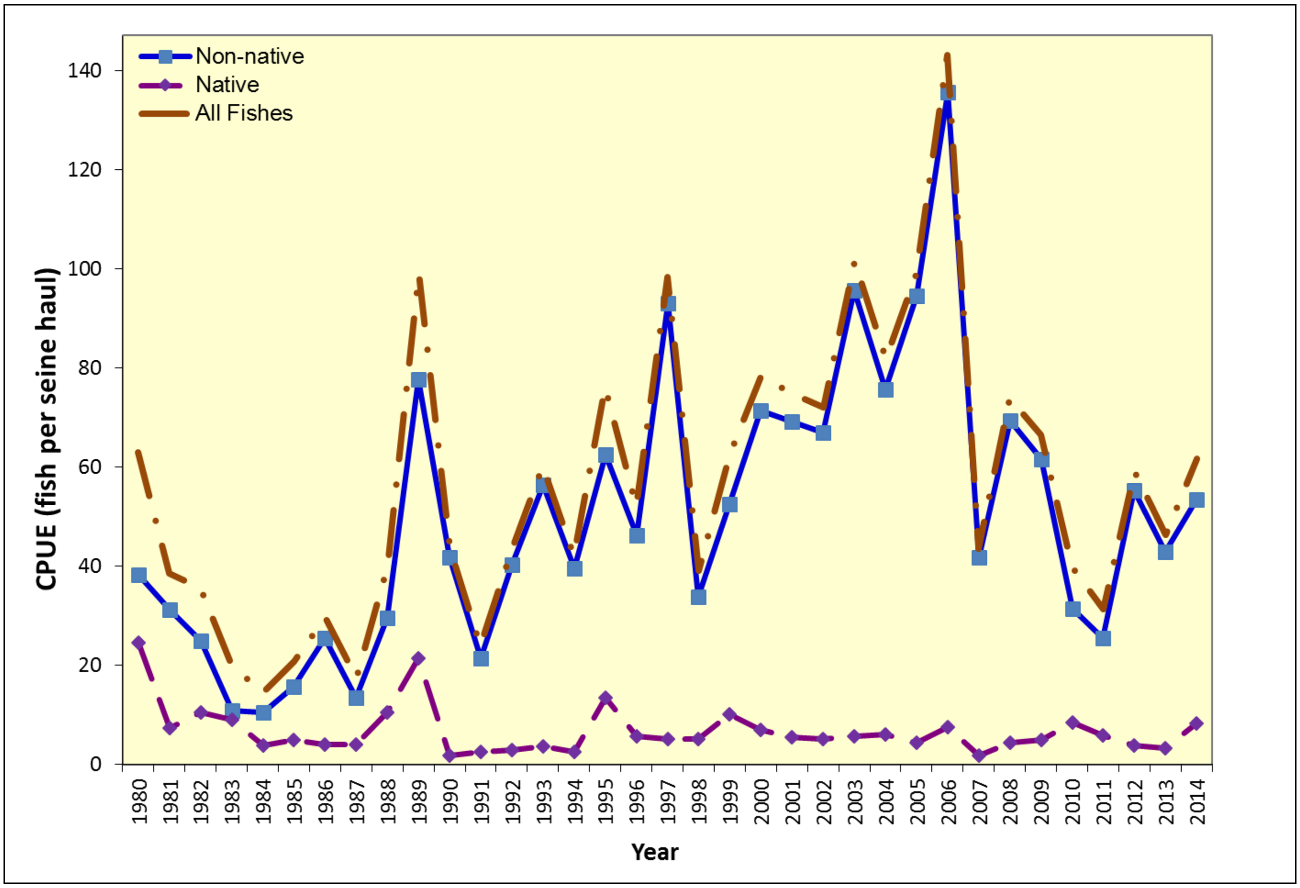


**Figure 13.** Annual beach seine CPUE of non-native, native, and both categories of fishes combined ("All Fishes").

**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 | 2013 CPUE | 2014 CPUE | 2014/2013 %Change |
|---|---|---|---|---|
| **Sacramento splittail** | **1.4** | **1.6** | **4.1** | **+156%** |
| **staghorn sculpin** | **1.9** | **0.2** | **0.9** | **+350%** |
| **threespine stickleback** | **1.8** | **0.7** | **2.1** | **+200%** |
| threadfin shad | 2.0 | 1.5 | 0.7 | -53% |
| Mississippi silverside | 34.2 | 31.8 | 41.3 | +30% |
| striped bass | 5.8 | 3.2 | 4.5 | +41% |

*Fish Species of Interest*

Fishes of the Pelagic Organism Decline

**LONGFIN SMELT**

Otter trawl CPUE in 2014 (0.2 fish per trawl) returned to a value more typical of the last 10 years after 2013's anomalously high number (1.5 fish per trawl; Figure 14; Table 1) and was considerably lower than the average CPUE for the entire study period (1.2 fish per trawl). Of the 65 longfin smelt captured by otter trawl, all but six individuals were age-0 fish. Consistent with trends in previous years, most age-0 fish (78%) were caught during spring, with a second, much smaller peak in CPUE occurring in autumn (Figure 15; O'Rear and Moyle 2014*c*,*d*, Rosenfield and Baxter 2007). Age-1+ fish were only caught in the coldest months: January, February, and December (Figure 15). Half of the age-1+ fish were captured in lower Suisun Slough; age-0 longfin smelt were also more abundant in lower Suisun Slough, which hosted 41% of 2014's catch. Age-0 fish were widely distributed, however, being caught in all sampled sloughs except Denverton.

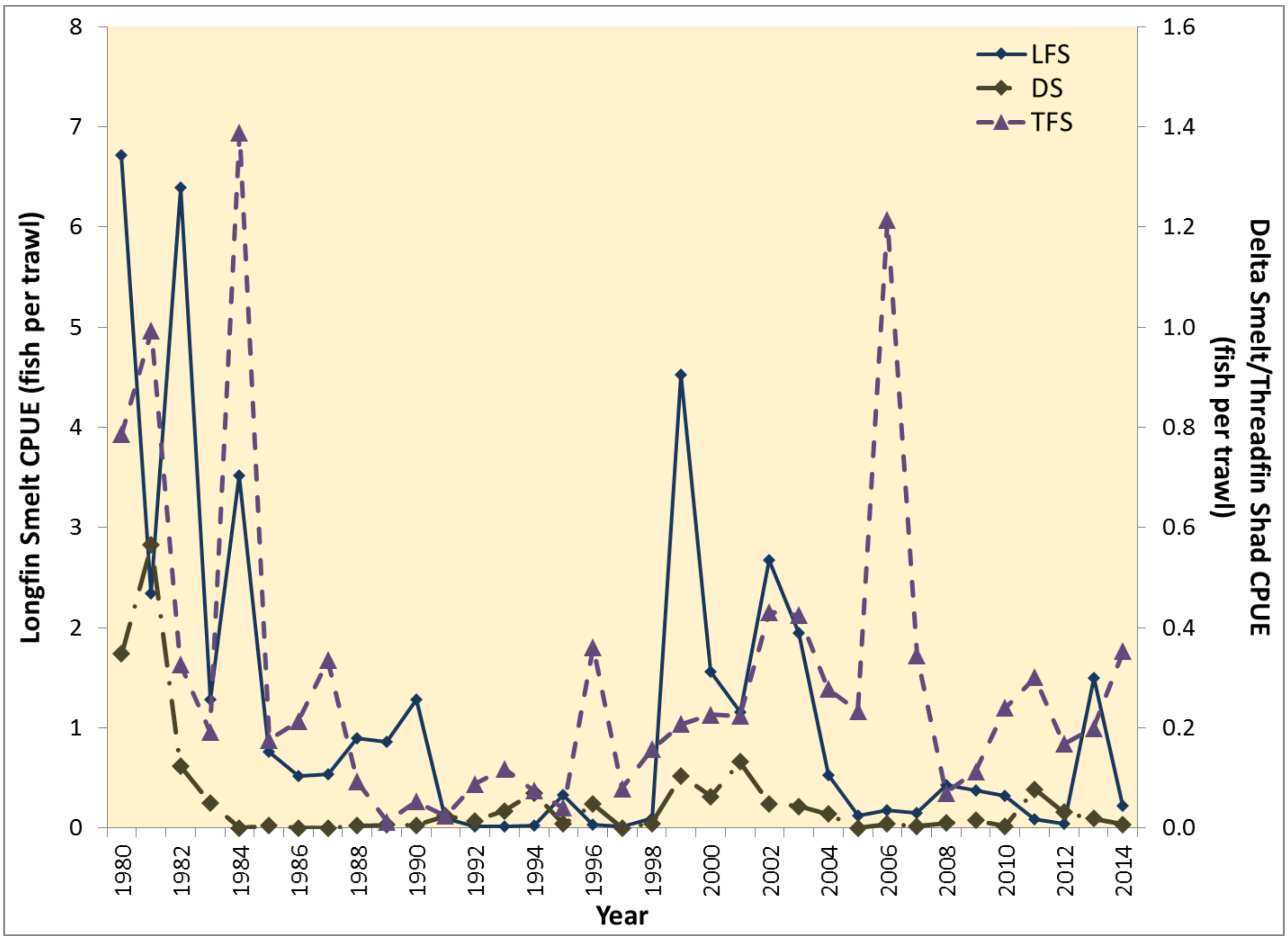


**Figure 14.** Annual otter trawl CPUE of three fishes of the Pelagic Organism Decline ("DS" = delta smelt, "TFS" = threadfin shad, and "LFS" = longfin smelt).

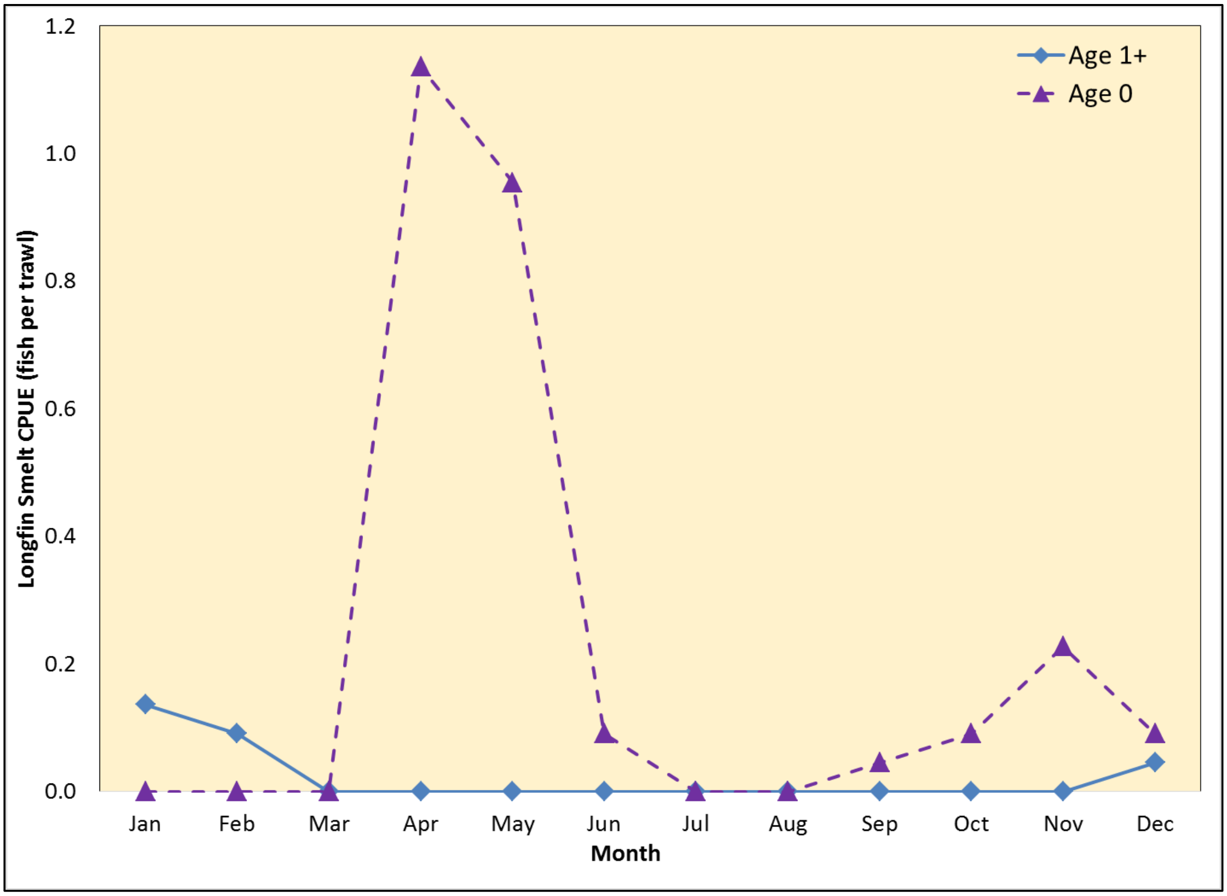


**Figure 15.** Monthly average otter trawl CPUE of two age classes of longfin smelt in 2014.

## DELTA SMELT

Delta smelt otter trawl CPUE in 2014 was very low, similar to most years of the 2000s after 2001 (Figure 14) and well below the average for all study years (0.01 and 0.05 fish per trawl for 2014 and all years, respectively). Otter trawls caught two delta smelt in 2014: one from the 2013 cohort captured in January, and one from the 2014 cohort caught in December 2014. Both fish were caught in lower Suisun Slough, where salinity averaged 9.5 ppt; the two fish measured about 61 mm SL. Four delta smelt were seined in Montezuma Slough in March at a salinity of 0.9 ppt; these fish averaged 63 mm SL and ranged from 58 to 70 mm SL. One final fish that was 51 mm SL was seined in Montezuma Slough during November 2014 when salinity was 9.1 ppt.

## THREADFIN SHAD

Threadfin shad CPUE in otter trawls increased from 2013 to 2014 (0.2 to 0.4 fish per trawl, respectively; Figure 14) but decreased in beach seines (Table 2); the 2014 CPUEs were higher than 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 except in Boynton Slough, but they were more abundant in Montezuma Slough near Nurse Slough and in Denverton Slough, which together comprised one-quarter of the 2014 annual catch. The beach seines revealed a similar distribution, with far more threadfin shad captured in Denverton and Montezuma sloughs (1.0 and 0.8 fish per seine haul, respectively) than in upper Suisun Slough (0.2 fish per seine haul). The comparatively high otter trawl CPUE in 2014 in such a dry, salty year was unusual given the association of threadfin shad with fresher waters of the estuary (O'Rear and Moyle 2014*b*, Feyrer *et al*. 2009, Feyrer *et al*.2007, Meng and Matern 2001).

## STRIPED BASS

Both beach seine and otter trawl CPUE for striped bass increased from 2013 to 2014, although 2014's values were below all-year averages for both gear types (Figure 16; Table 1 and 2). Age-0 monthly beach seine CPUE was very high only in July, after which it declined rapidly

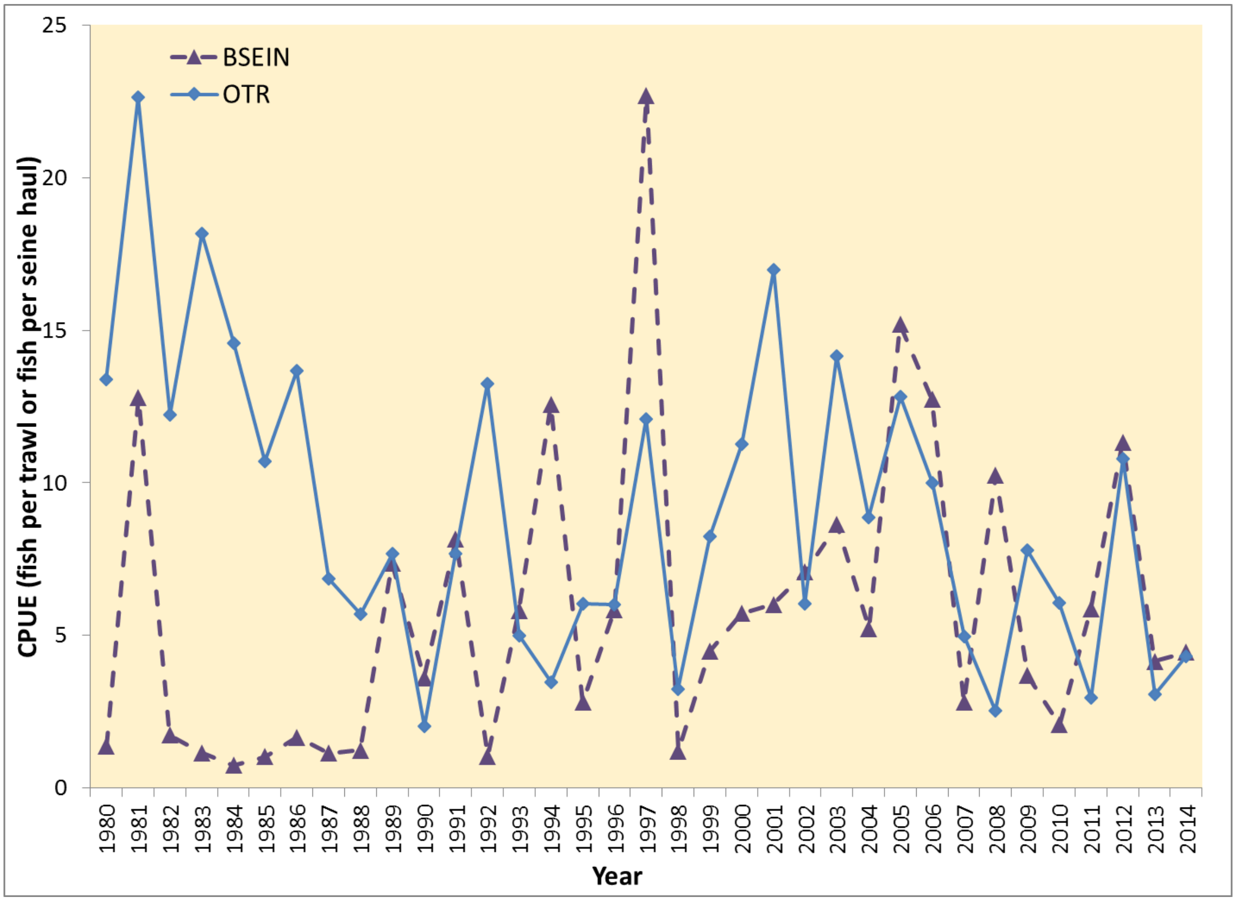


**Figure 16.** Annual otter trawl and beach seine CPUE of striped bass ("OTR" = otter trawl, "BSEIN" = beach seine).

to negligible numbers by the year's end (Figure 17). The pattern was different for age-0 monthly otter trawl CPUE: high numbers of fish were first observed in May, CPUE then increased (except for a lower value in July) until peaking in September, and finally CPUE generally declined through the year's remainder 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, reached peak values during spring, and then declined to lower levels in summer and autumn (Figure 17). Geographic distribution of age-0 striped bass among sampled sloughs was disparate: CPUE in First Mallard Slough was more than double that of the other sampled sloughs (Figure 18), with especially low CPUE values for both eastern Montezuma Slough near the salinity control gates (*i.e.*, the MZ1 and MZ2 sites; Figure 2) and upper Suisun Slough. In contrast, juvenile striped bass were distributed relatively evenly among sloughs (Figure 18).

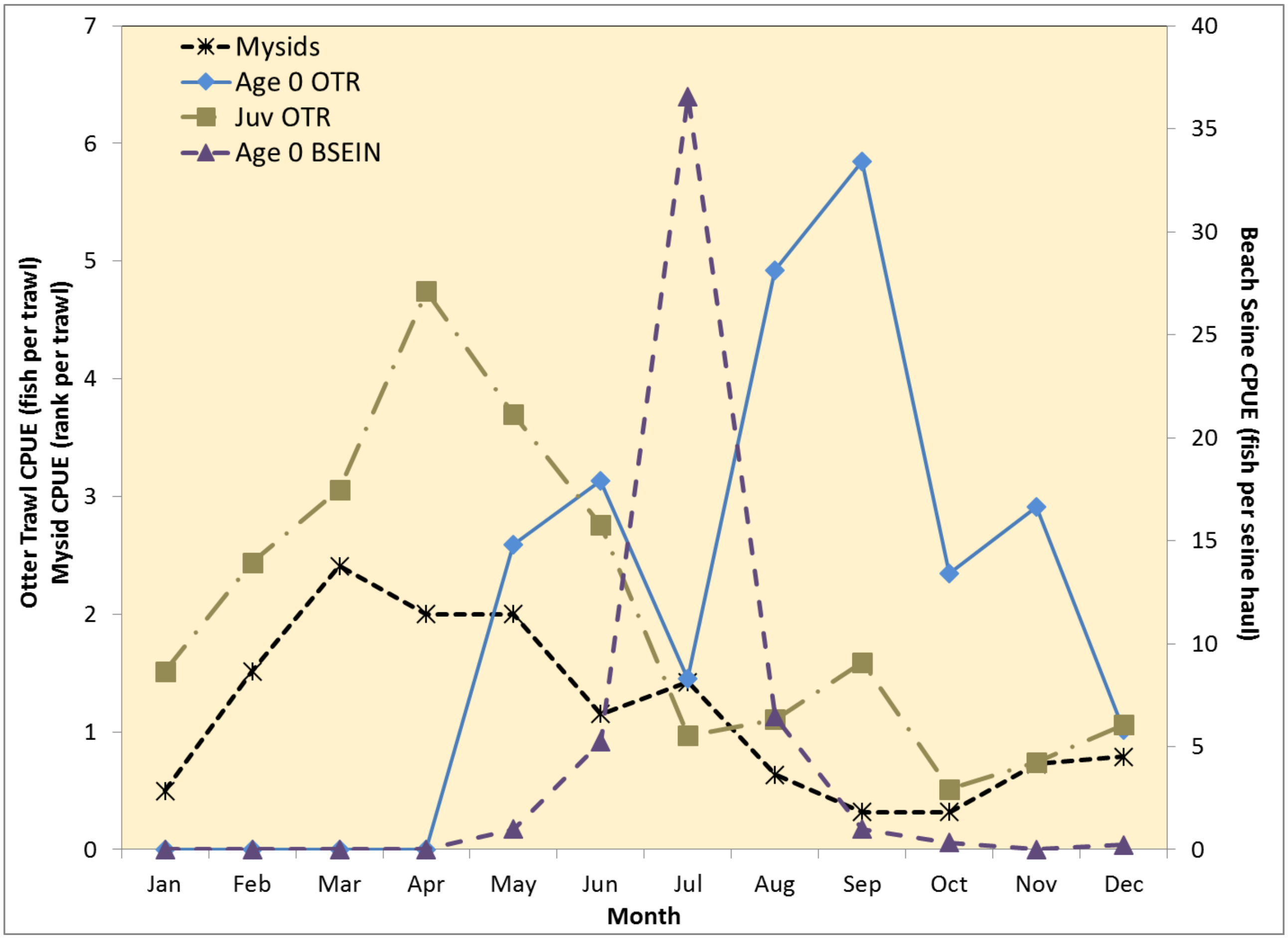


**Figure 17.** Monthly average CPUE of striped bass age classes and mysids ("juv" = juvenile; other codes as in Figure 16) in 2014.

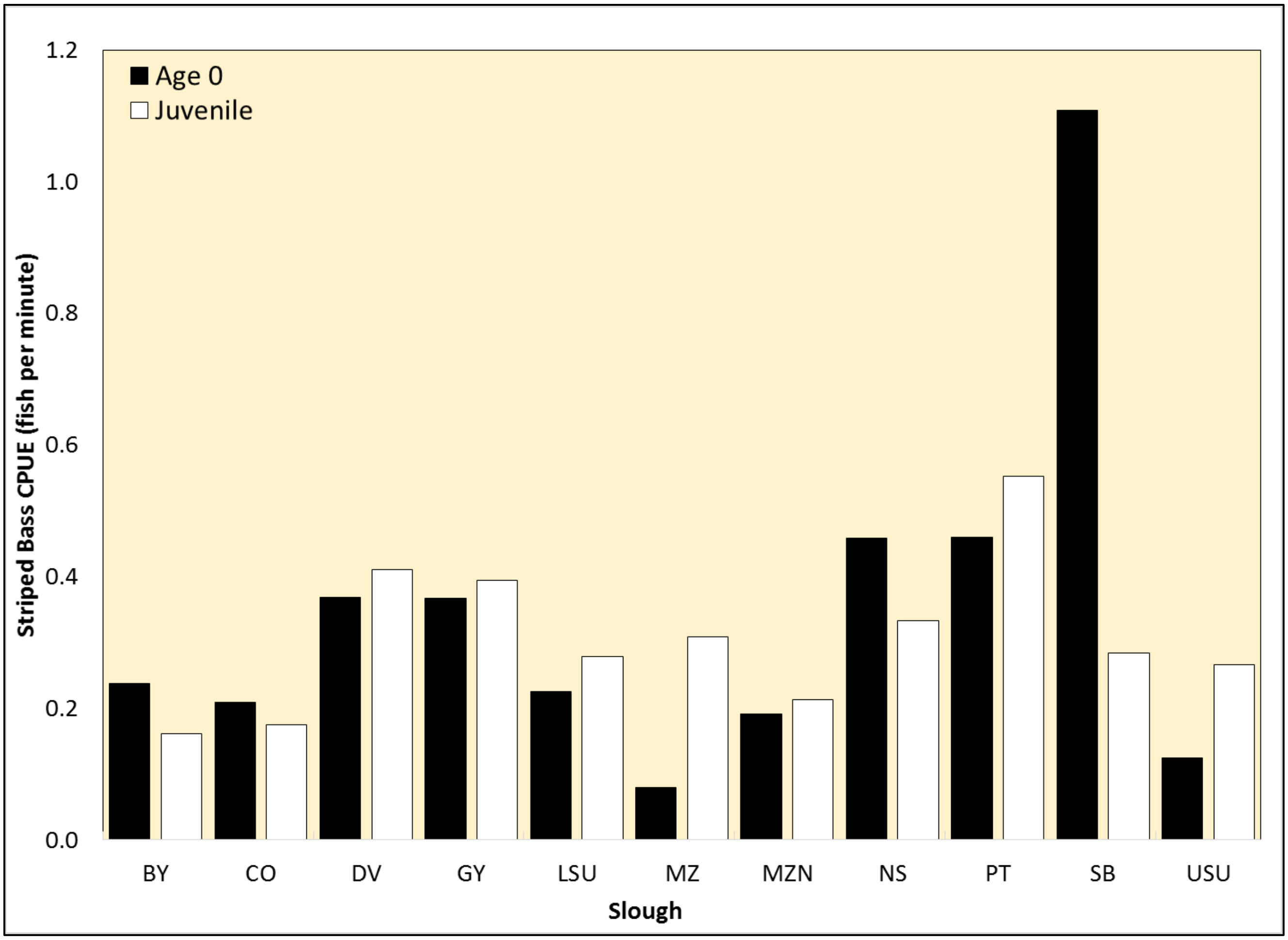


**Figure 18.** Average otter trawl CPUE of age classes of striped bass in 2014 ("BY" = Boynton Slough, "CO" = Cutoff Slough, "DV" = Denverton Slough, "GY" = Goodyear Slough, "LSU" = lower Suisun Slough, "MZ" = Montezuma Slough, "MZN" = Montezuma new, "NS" = Nurse Slough, "PT" = Peytonia Slough, "SB" = First Mallard Slough, and "USU" = upper Suisun Slough).

Sacramento Splittail

Annual otter trawl CPUE in 2014 was the fourth highest in the study's history, being 45% higher than 2013's CPUE and almost double the value for all years of the study (Figure 19, Table 1). The increase from 2013 to 2014 was mainly due to a marked rise in age-0 CPUE from 0.2 to 2.2 fish per trawl, respectively. Changes in the two older age classes contributed little to the change in CPUE between 2013 and 2014, with the CPUE for both age-class groups combined differing by only 0.3 fish per trawl between years (Figure 19). The high 2014 age-0 CPUE was anomalous given the 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).

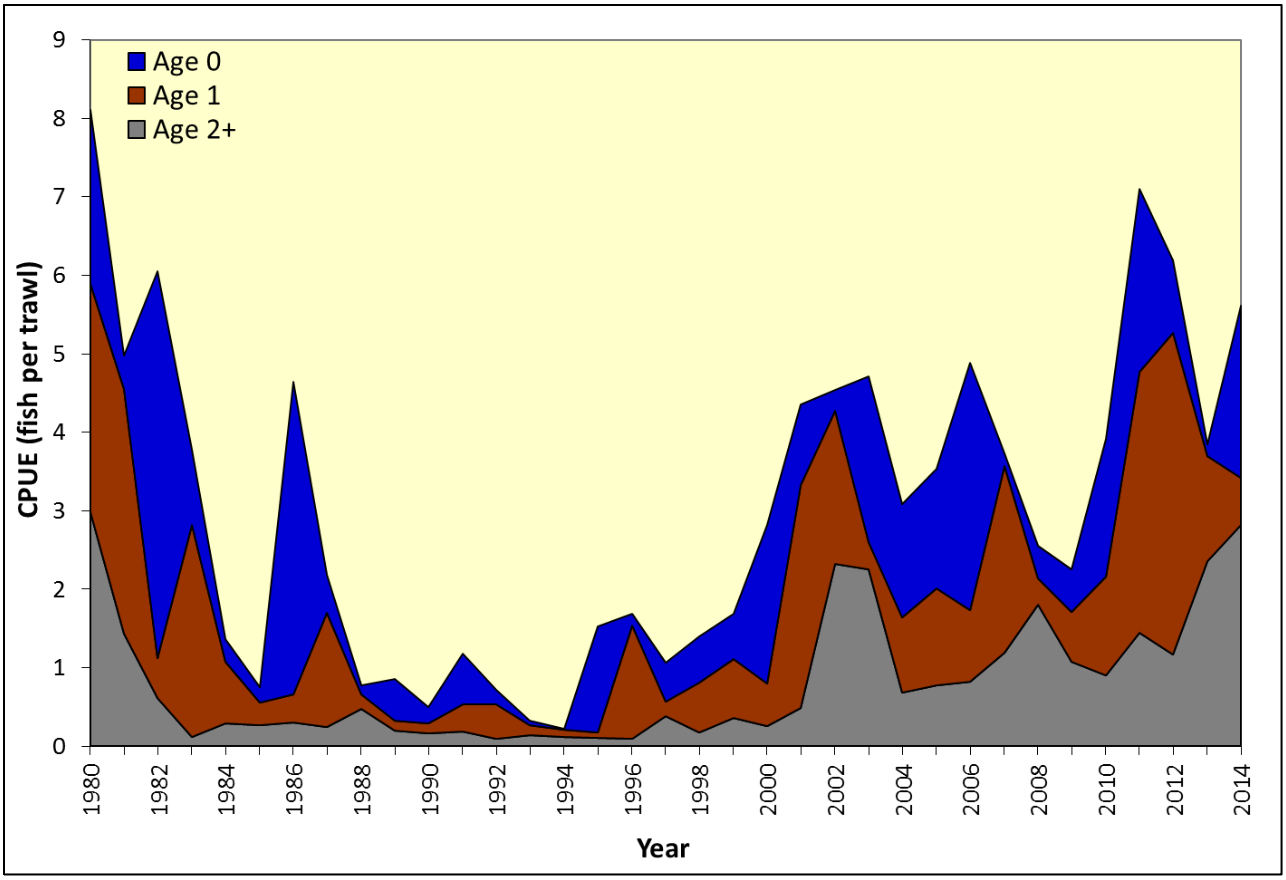

**Figure 19.** Annual otter trawl CPUE of three age classes of Sacramento splittail.

Geographic distribution of Sacramento splittail differed among age classes. Age-2+ fish were especially abundant in Denverton, Nurse, Goodyear, and upper Suisun sloughs but were still common in the remaining sampled sloughs (Figure 20). Age-1 fish were less evenly distributed than age-2+ fish, with larger numbers of age-1 fish in Denverton, Peytonia, and First Mallard sloughs and lower numbers in eastern Montezuma Slough. Age-0 fish were very abundant in Denverton and First Mallard sloughs while being much less abundant in the northwest marsh (*i.e.*, Boynton, Peytonia, and upper Suisun sloughs) and in eastern Montezuma Slough (Figure 20).

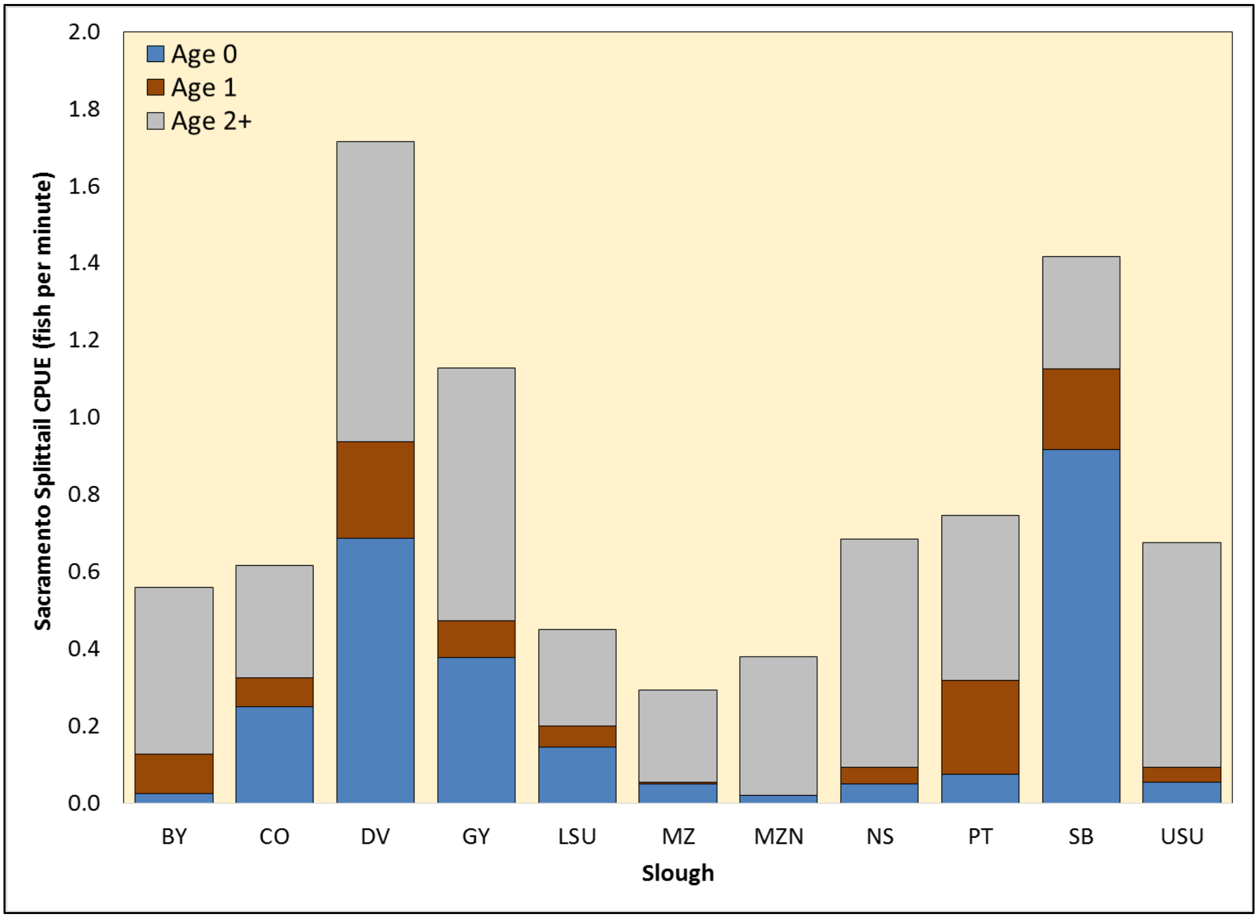


**Figure 20.** Average otter trawl CPUE of age classes of splittail in 2014 (codes as in Figure 18).

<u>White Catfish</u>

White catfish otter trawl CPUE increased by nearly one-third from 2013 to 2014, with 2014's value being higher than the all-years average (Table 1; Figure 21). 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 not followed in 2014, during which no age-0 white catfish were captured but annual otter trawl CPUE was still quite high.

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. As in 2013, this pattern was especially prevalent in 2014, in which 60% of the catch came from just Denverton Slough while only one fish (0.3% of the annual catch) was caught in the saltier sloughs of Goodyear and lower Suisun in the southwestern marsh. Fair numbers of white catfish were also taken in Boynton and Peytonia sloughs (27 and 17 fish, respectively).

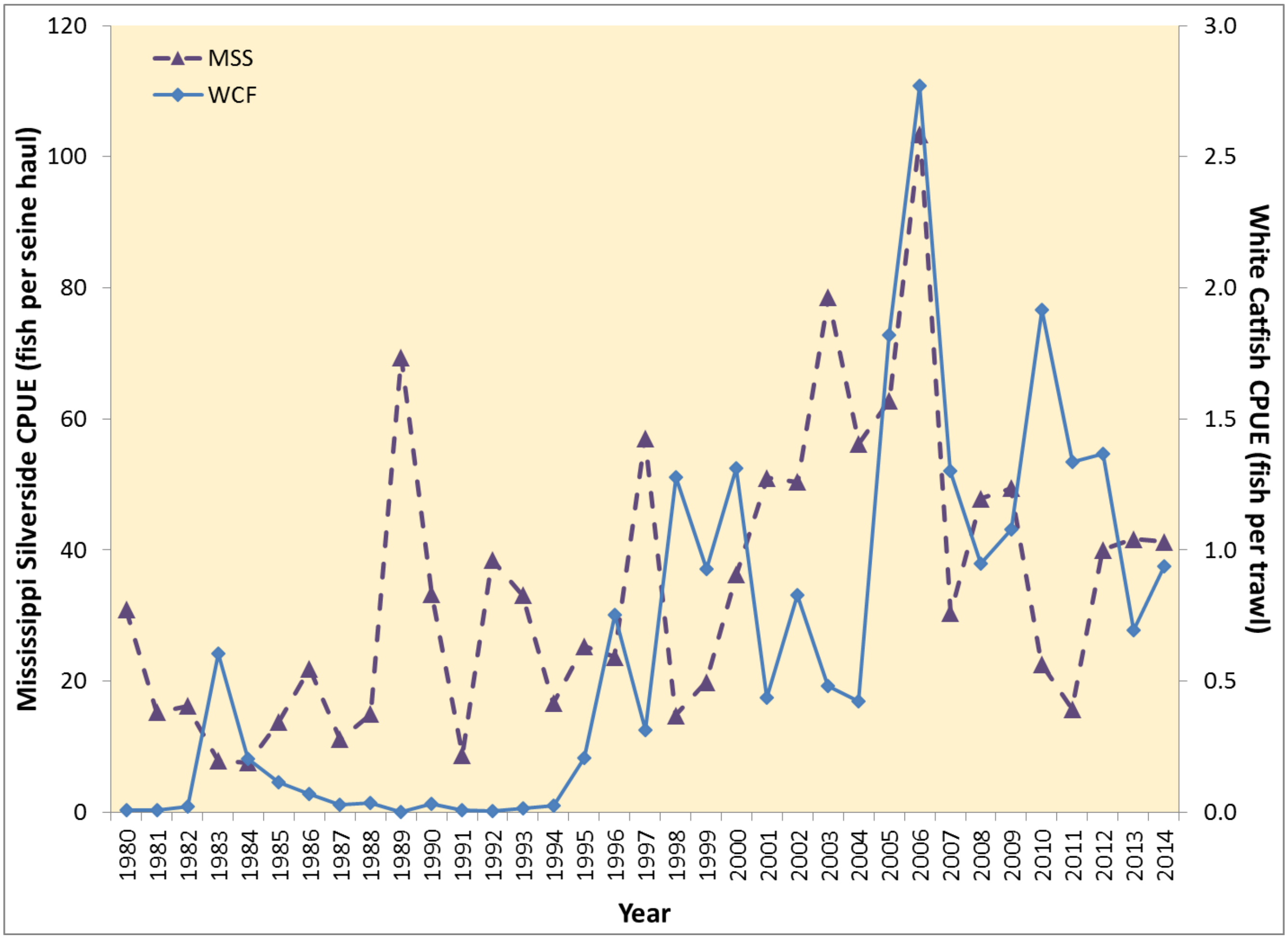


**Figure 21.** Annual CPUE of white catfish ("WCF") and Mississippi silverside ("MSS").

## Mississippi Silverside

Mississippi silverside annual beach seine CPUE in 2014 was 30% higher than in 2013 and was moderately above the all-years average (Figure 21, Table 2). Monthly CPUE spiked in February, thereafter declined to lower levels through summer, and then peaked again and reached its maximum during autumn (Figure 22). Fish smaller than 30 mm SL, which are likely two months old and younger (Gleason and Bengston 1996, Hubbs 1982), were present from June through August and then again in October and November, suggesting reproduction from April through October in 2014 (Figure 23). This was a longer spawning period than seen in cooler, wetter years such as 2011 (O'Rear and Moyle 2014*b*).

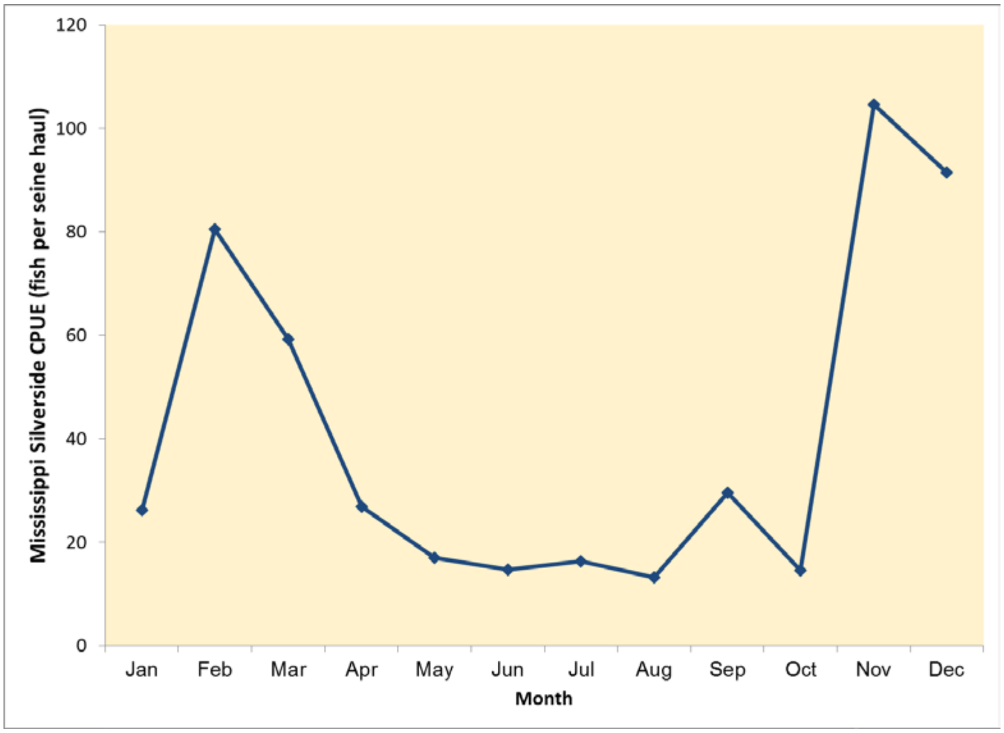


**Figure 22.** Monthly average beach seine CPUE of Mississippi silverside in 2014.

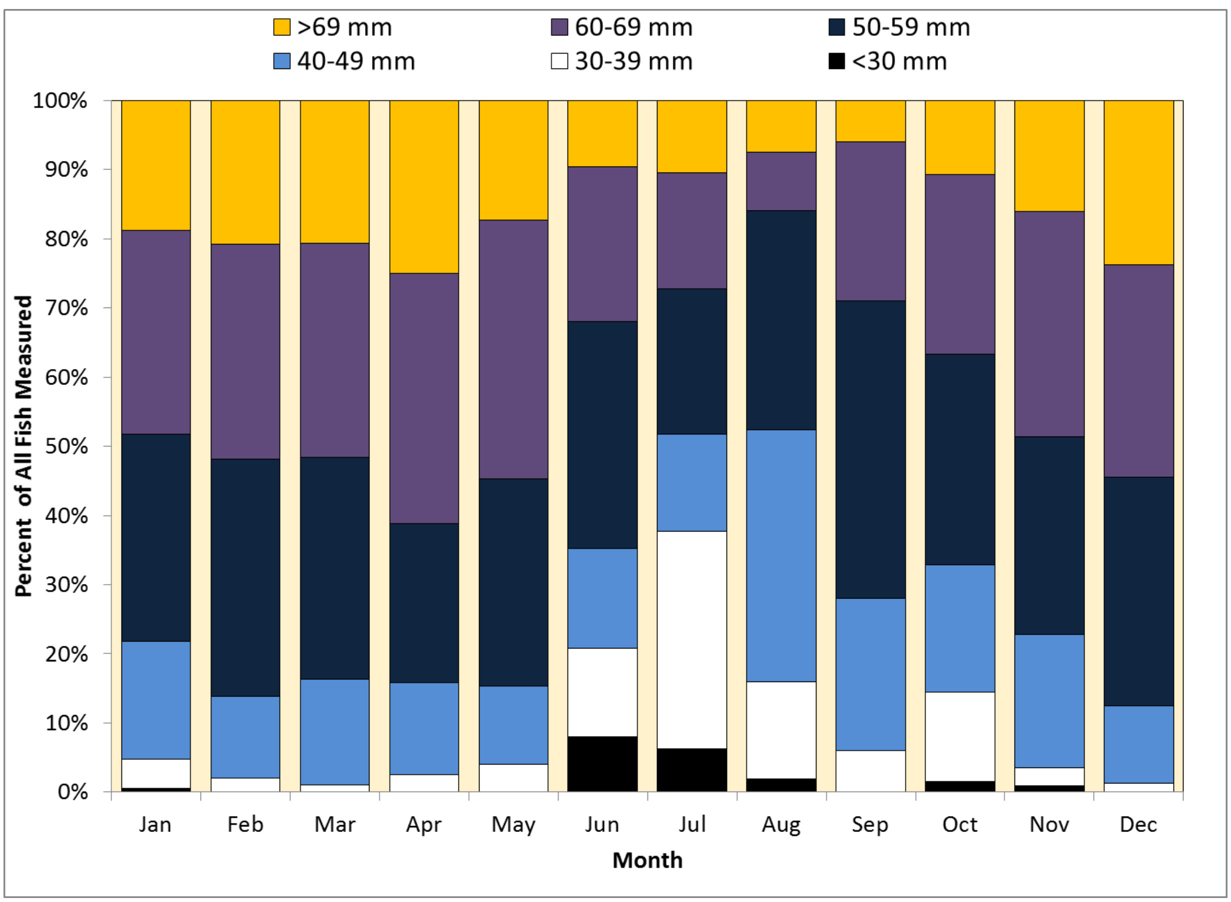


**Figure 23.** Monthly average beach seine CPUE of size classes (mm SL) of Mississippi silverside in 2014.

## CONCLUSION

2014 was a dry, salty, warm year in Suisun Marsh, with clearer-than-normal water during summer and autumn. Catches of common Suisun Marsh shrimps and overbite clams reflected low Delta outflows and high salinities, with lower numbers of shrimp and much higher numbers of the freshwater-intolerant overbite clam (Nicolini and Penry 2000). Numbers of fishes in otter trawls were generally lower than average, in part due to lower influx of age-0 fish from species that spawn primarily upstream of the marsh (*e.g.*, striped bass). Nevertheless, large numbers of age-0 Sacramento splittail were captured in both otter trawls and beach seines, an unusual occurrence for a year as dry as 2014. Fish numbers in beach seines were about average and were dominated by Mississippi silverside, although native fish abundances were higher than normal.

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# APPENDIX A: CATCHES FOR ENTIRE STUDY PERIOD

Total number of fish caught per species in Suisun Marsh by otter trawl, beach seine, midwater trawl, and all methods from 1979 to 2014 (native species in bold).

| Common Name | Scientific Name | Otter Trawl | Beach Seine | Midwater Trawl | Total |
|---|---|---|---|---|---|
| American shad | *Alosa sapidissima* | 1371 | 261 | | 1632 |
| **bay pipefish** | ***Sygnathus leptorhynchus*** | **2** | **0** | | **2** |
| bigscale logperch | *Percina macrolepida* | 17 | 2 | | 19 |
| black bullhead | *Ameiurus melas* | 880 | 3 | | 883 |
| black crappie | *Pomoxis nigromaculatus* | 2013 | 110 | 1 | 2124 |
| bluegill | *Lepomis macrochirus* | 19 | 18 | | 37 |
| brown bullhead | *Ameiurus nebulosus* | 29 | 0 | | 29 |
| **California halibut** | ***Paralichthys californicus*** | **5** | **0** | | **5** |
| channel catfish | *Ictalurus punctatus* | 175 | 7 | | 182 |
| **Chinook salmon** | ***Oncorhynchus tshawytscha*** | **73** | **393** | **1** | **467** |
| common carp | *Cyprinus carpio* | 5236 | 499 | 1 | 5736 |
| **delta smelt** | ***Hypomesus transpacificus*** | **661** | **144** | **4** | **809** |
| fathead minnow | *Pimephales promelas* | 36 | 38 | | 74 |
| golden shiner | *Notemigonus crysoleucas* | 9 | 12 | | 21 |
| goldfish | *Carassius auratus* | 303 | 48 | | 351 |
| **green sturgeon** | ***Acipenser medirostris*** | **3** | **0** | | **3** |
| green sunfish | *Lepomis cyanellus* | 5 | 3 | | 8 |
| **hardhead** | ***Mylopharadon conocephalus*** | **1** | **0** | | **1** |
| **hitch** | ***Lavinia exilicauda*** | **121** | **16** | | **137** |
| largemouth bass | *Micropterus salmoides* | 0 | 3 | | 3 |
| **longfin smelt** | ***Spirinchus thaleichthys*** | **11857** | **53** | **5** | **11915** |
| **longjaw mudsucker** | ***Gillichthys mirabilis*** | **1** | **0** | | **1** |
| Mississippi silverside | *Menidia audens* | 1218 | 85486 | | 86704 |
| **northern anchovy** | ***Engraulis mordax*** | **266** | **0** | **37** | **303** |
| **Pacific herring** | ***Clupea harengeus*** | **482** | **131** | | **613** |
| **Pacific lamprey** | ***Lampetra tridentata*** | **43** | **0** | | **43** |
| **Pacific sanddab** | ***Citharichthys sordidas*** | **3** | **2** | | **5** |
| **plainfin midshipman** | ***Porichthys notatus*** | **14** | **0** | | **14** |
| **prickly sculpin** | ***Cottus asper*** | **10709** | **959** | **1** | **11669** |
| **rainbow trout** | ***Oncorhynchus mykiss*** | **9** | **4** | | **13** |
| rainwater killifish | *Lucania parva* | 32 | 120 | | 152 |
| redear sunfish | *Lepomis microlophus* | 2 | 1 | | 3 |
| **river lamprey** | ***Lampetra ayresi*** | **3** | **0** | | **3** |
| **Sacramento blackfish** | ***Orthodon macrolepidotus*** | **26** | **116** | | **142** |
| **Sacramento pikeminnow** | ***Ptychocheilus grandis*** | **150** | **229** | | **379** |
| **Sacramento splittail** | ***Pogonichthys macrolepidotus*** | **28546** | **3821** | **14** | **32381** |
| **Sacramento sucker** | ***Catostomus occidentalis*** | **3363** | **115** | **5** | **3483** |
| shimofuri goby | *Tridentiger bifasciatus* | 10146 | 2380 | 1 | 12527 |

| | | | | | |
|---|---|---|---|---|---|
| **shiner perch** | ***Cymatogaster aggregata*** | **17** | **0** | | **17** |
| shokihaze goby | *Tridentiger barbatus* | 774 | 5 | 6 | 785 |
| **speckled sanddab** | ***Citharichthys stigmaeus*** | **3** | **0** | | **3** |
| **staghorn sculpin** | ***Leptocottus armatus*** | **2576** | **3428** | | **6004** |
| **starry flounder** | ***Platichthys stellatus*** | **2003** | **262** | **4** | **2269** |
| striped bass | *Morone saxatilis* | 85148 | 14158 | 30 | 99336 |
| **surf smelt** | ***Hypomesus pretiosus*** | **5** | **0** | | **5** |
| threadfin shad | *Dorosoma petenense* | 2895 | 5363 | 1 | 8259 |
| **threespine stickleback** | ***Gasterosteus aculeatus*** | **17491** | **6356** | **6** | **23853** |
| **tule perch** | ***Hysterocarpus traski*** | **20145** | **2161** | **6** | **22312** |
| wakasagi | *Hypomesus nipponensis* | 10 | 6 | | 16 |
| warmouth | *Lepomis gulosus* | 1 | 0 | | 1 |
| western mosquitofish | *Gambusia affinis* | 18 | 347 | | 365 |
| white catfish | *Ameiurus catus* | 5756 | 164 | 13 | 5933 |
| white crappie | *Pomoxis annularis* | 112 | 0 | | 112 |
| **white croaker** | ***Genyonemus lineatus*** | **1** | **0** | | **1** |
| **white sturgeon** | ***Acipenser transmontanus*** | **116** | **0** | **2** | **118** |
| yellowfin goby | *Acanthogobius flavimanus* | 19652 | 17079 | | 36731 |
| Total | | 234552 | 144303 | 138 | 378993 |

## APPENDIX B: 2014 CATCHES

Total 2014 otter trawl catch of each fish species in each slough of Suisun Marsh (native species in bold).

| | Slough | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Boy-nton | Cut-off | Denver-ton | First Mallard | Good-year | lower Suisun | Monte-zuma | Montez-uma new | Nurse | Peyt-onia | upper Suisun | Total |
| American shad | 3 | 11 | 41 | 29 | 32 | 40 | | | | 25 | 4 | 187 |
| black bullhead | | | 1 | | | | | | | | | 1 |
| black crappie | 1 | | 111 | | 1 | | 1 | 1 | 13 | 5 | | 137 |
| brown bullhead | 1 | | | | | | | | | | | 1 |
| common carp | 25 | 13 | 34 | 6 | 4 | 1 | 2 | 3 | 23 | 21 | 7 | 141 |
| **delta smelt** | | | | | | **2** | | | | | | **2** |
| golden shiner | 1 | | 1 | | | | 1 | | | | | 3 |
| goldfish | | 1 | | | | | | | | 4 | | 5 |
| **longfin smelt** | **2** | **2** | | **7** | **3** | **27** | **8** | **5** | **2** | **3** | **6** | **65** |
| Mississippi silverside | | | | 24 | 2 | | | | | 2 | | 28 |
| **northern anchovy** | | | | **1** | **1** | **1** | | | | | **1** | **4** |
| **Pacific herring** | | | **2** | | | **2** | | | | | | **4** |
| **plainfin midshipman** | | | | **1** | | | **1** | **1** | | | | **3** |
| **prickly sculpin** | **25** | **12** | **15** | | **65** | **4** | **3** | **6** | **7** | **14** | **3** | **156** |
| **rainbow trout** | | | | | **1** | | | | | | | **1** |
| **Sacramento blackfish** | | | **1** | | | | | | | | | **1** |
| **Sacramento pikeminnow** | | | | | | | | | | **1** | | **1** |
| **Sacramento splittail** | **66** | **74** | **205** | **176** | **214** | **108** | **70** | **91** | **112** | **89** | **162** | **1473** |
| **Sacramento sucker** | **6** | **6** | **4** | **2** | | | | | | **11** | | **29** |
| shimofuri goby | 25 | 9 | 4 | 4 | 19 | | | 3 | 3 | 42 | 4 | 113 |
| shokihaze goby | 2 | | 1 | | 1 | 4 | 11 | 3 | 15 | 4 | 11 | 52 |
| **staghorn sculpin** | | | **1** | **2** | **8** | **9** | **12** | **7** | **2** | | **5** | **46** |
| **starry flounder** | | | **1** | | | | | **1** | | | | **2** |
| striped bass | 47 | 46 | 93 | 167 | 144 | 125 | 93 | 98 | 95 | 121 | 95 | 1239 |
| threadfin shad | | 9 | 24 | 11 | 4 | 10 | 8 | 20 | 5 | 3 | 3 | 101 |
| **threespine stickleback** | **97** | | **4** | | **22** | **18** | **5** | **1** | **3** | **11** | **11** | **175** |
| **tule perch** | **73** | **128** | **140** | **55** | **67** | **74** | **27** | **47** | **84** | **164** | **75** | **984** |
| white catfish | 27 | 15 | 160 | 10 | 1 | | 16 | 6 | 2 | 17 | 7 | 268 |
| **white sturgeon** | | | | | | **1** | | | | | **2** | **3** |

| Species | Slough | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Boy-nton | Cut-off | Denver-ton | First Mallard | Good-year | lower Suisun | Monte-zuma | Montez-uma new | Nurse | Peyt-onia | upper Suisun | |
| yellowfin goby | 8 | 5 | 5 | 10 | 19 | 22 | 18 | 12 | 6 | 15 | 14 | 134 |
| Total | 409 | 331 | 848 | 505 | 608 | 448 | 276 | 305 | 372 | 552 | 410 | 5359 |

Total 2014 beach seine catch of each fish species in Denverton, Montezuma, and upper Suisun sloughs (native species are in bold).

| Species | Slough | | | Total |
|---|---|---|---|---|
| | Denverton | Montezuma new | upper Suisun | |
| American shad | 5 | 1 | | 6 |
| black crappie | 11 | 1 | | 12 |
| **Chinook salmon** | | **2** | | **2** |
| common carp | 13 | 6 | 5 | 24 |
| **delta smelt** | | **5** | | **5** |
| **longfin smelt** | | **1** | | **1** |
| Mississippi silverside | 1469 | 1490 | 1456 | 4415 |
| **Pacific herring** | **3** | **5** | | **8** |
| **prickly sculpin** | **7** | | **8** | **15** |
| rainwater killifish | 9 | 1 | | 10 |
| **Sacramento splittail** | **93** | **312** | **26** | **431** |
| **Sacramento sucker** | | **2** | | **2** |
| shimofuri goby | 83 | 6 | 15 | 104 |
| shokihaze goby | 1 | 2 | | 3 |
| **staghorn sculpin** | **7** | **24** | **66** | **97** |
| striped bass | 269 | 63 | 144 | 476 |
| threadfin shad | 35 | 27 | 8 | 70 |
| **threespine stickleback** | **61** | **39** | **120** | **220** |
| **tule perch** | **12** | **17** | **72** | **101** |
| western mosquitofish | 3 | | 4 | 7 |
| yellowfin goby | 50 | 272 | 278 | 600 |
| Total | 2131 | 2276 | 2202 | 6609 |

# APPENDIX C: 2014 EFFORT

Number of otter trawls in each slough and each month in 2014.

| | Month | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 24 |
| 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 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 24 |
| Montezuma new | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 24 |
| Nurse | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 24 |
| Peytonia | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 24 |
| upper Suisun | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 24 |
| Total | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 276 |

Number of beach seines in each slough and each month in 2014.

| | Month | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Slough | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
| Denverton | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 35 |
| Montezuma new | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 36 |
| upper Suisun | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 36 |
| Total | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 8 | 107 |