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).

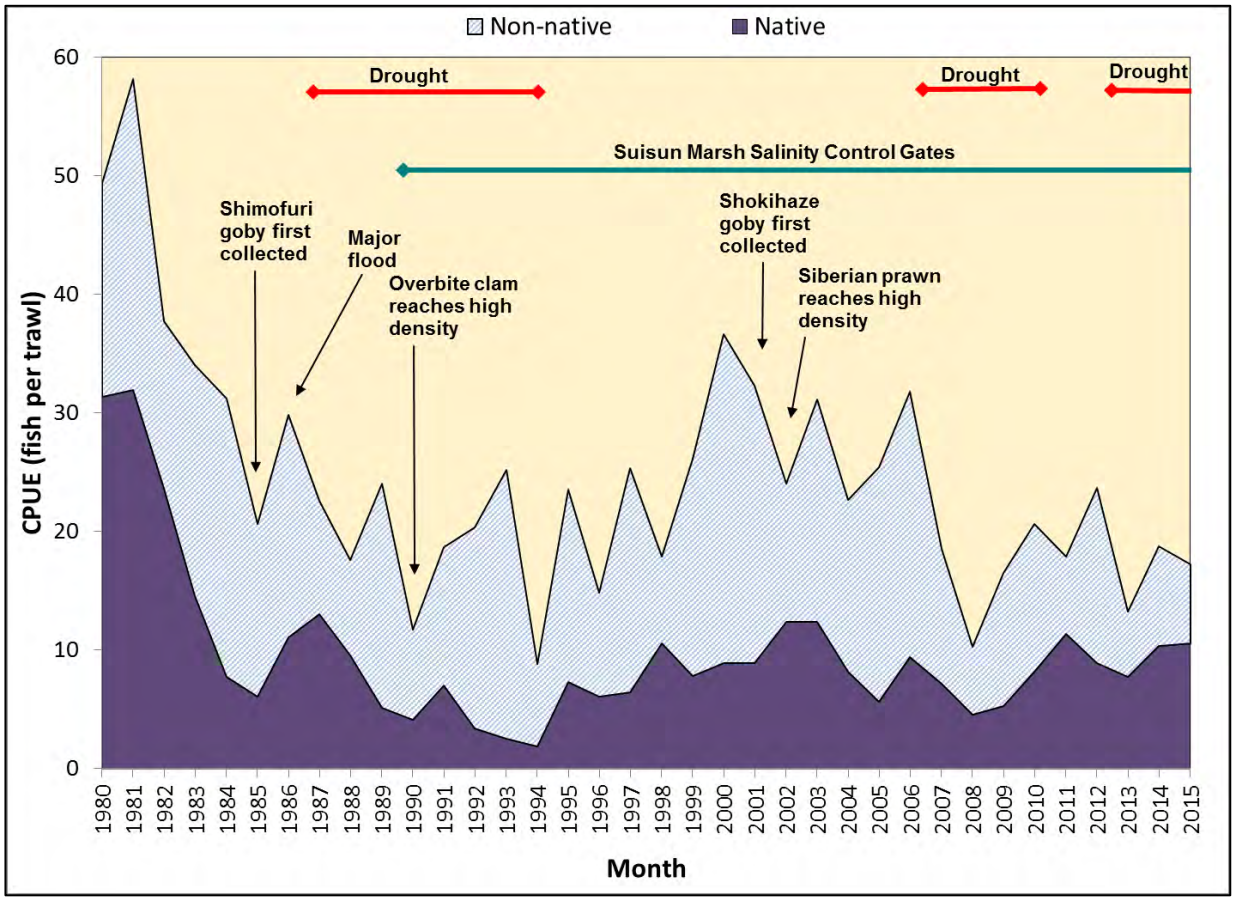

Figure 14. Annual otter trawl CPUE of native and non-native fishes, with important events highlighted.

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).

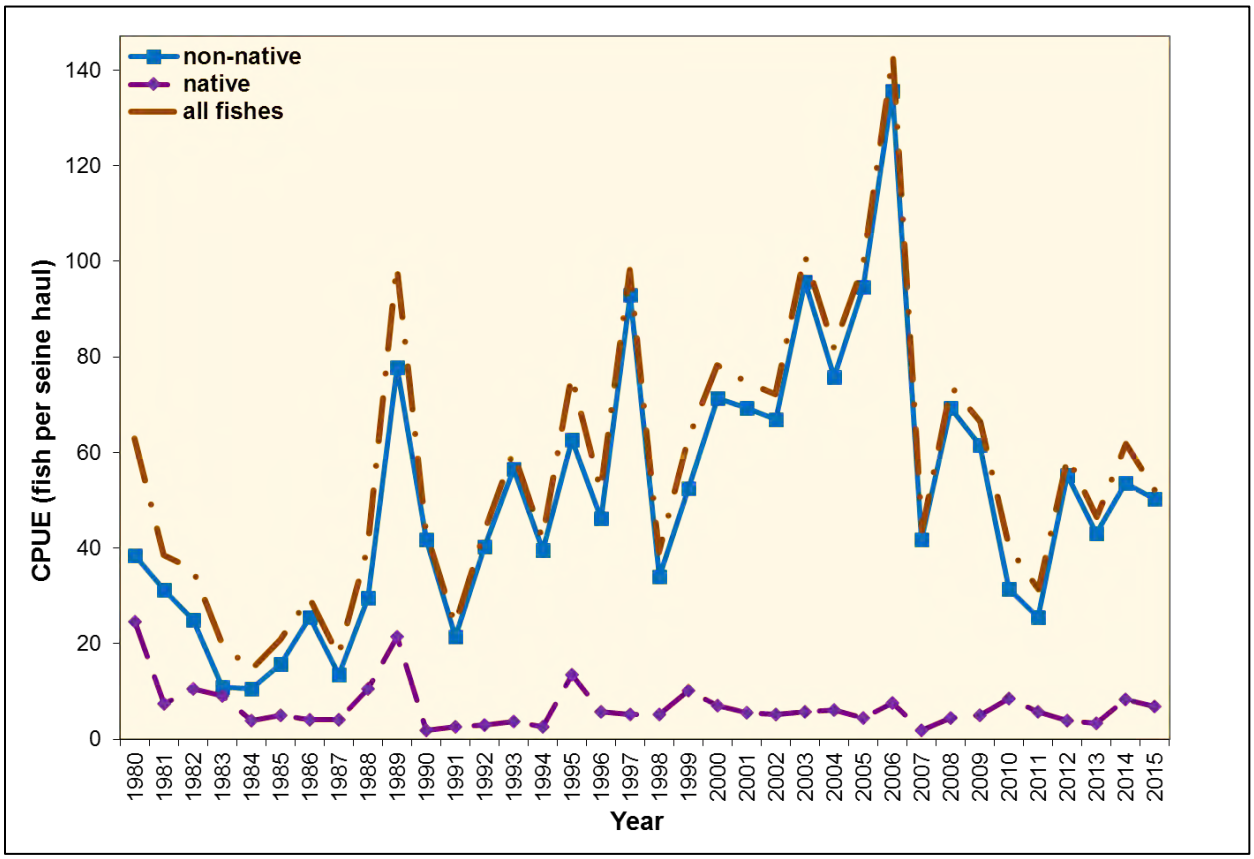

Figure 15. Annual beach seine CPUE of non-native, native, and both categories of fishes combined ("All Fishes").

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.

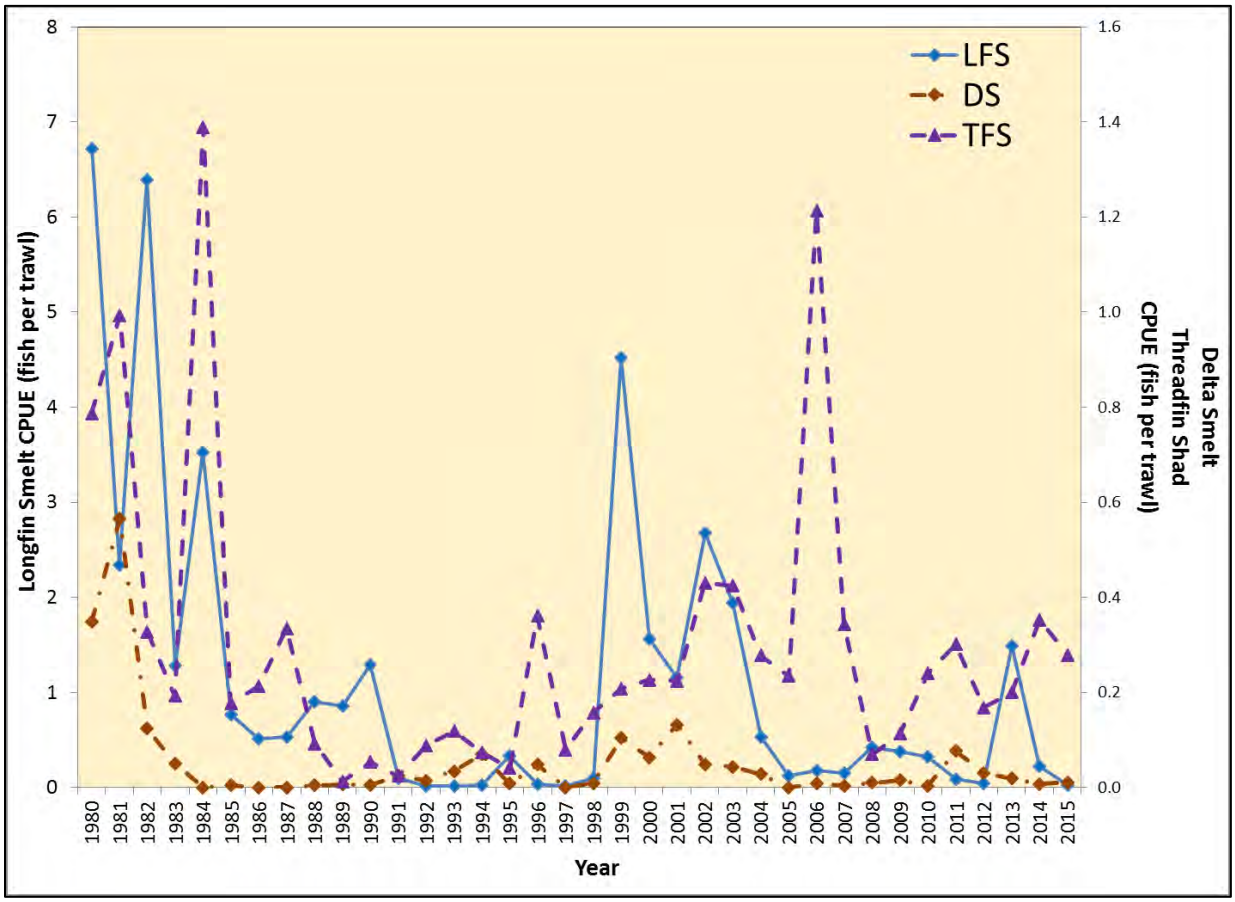

Figure 16. Annual otter trawl CPUE of three fishes of the Pelagic Organism Decline ("DS" = delta smelt, "TFS" = threadfin shad, and "LFS" = longfin smelt).

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.

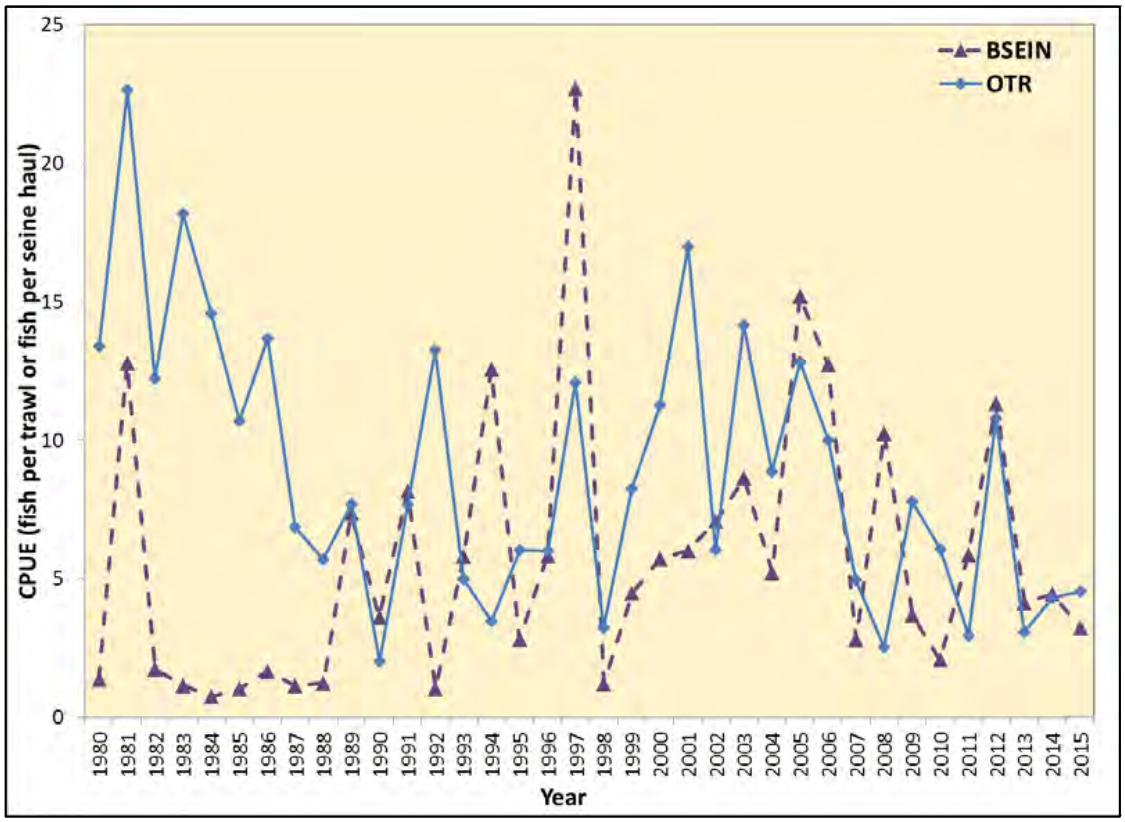

Figure 17. Annual otter trawl and beach seine CPUE of striped bass ("OTR" = otter trawl, "BSEIN" = beach seine).

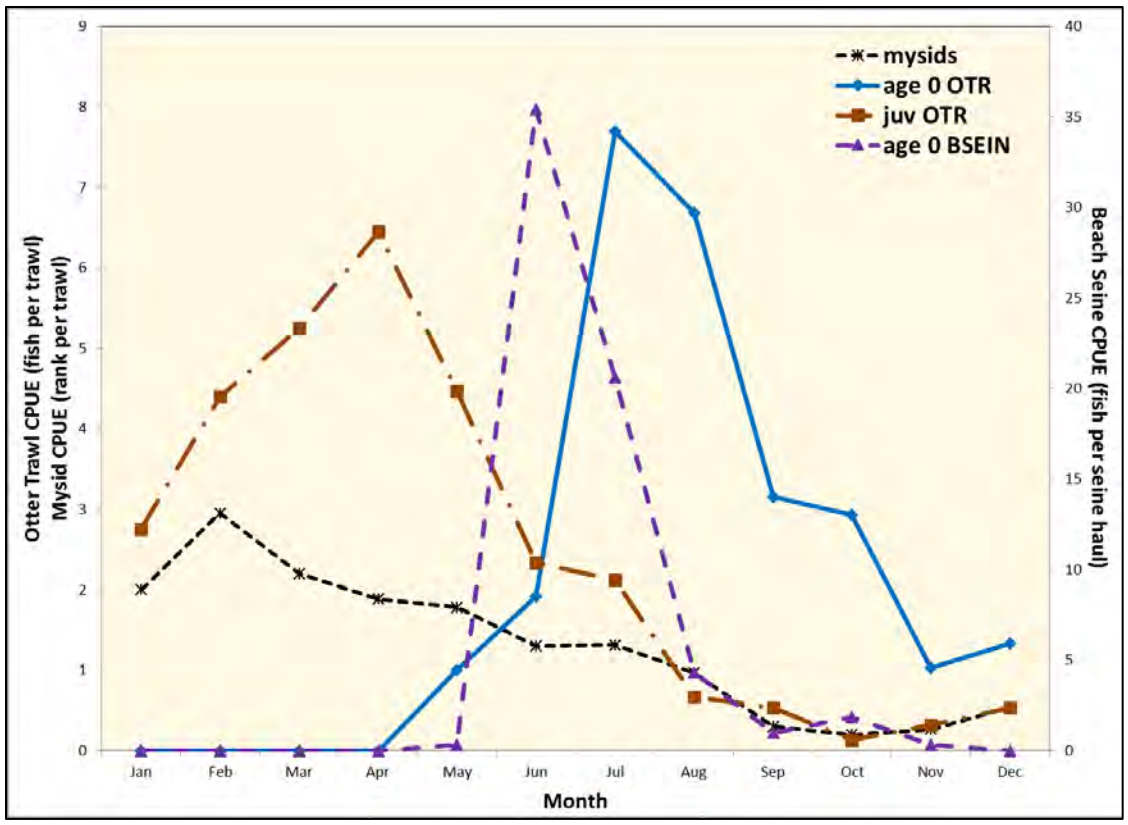

Figure 18. Monthly average CPUE of striped bass age classes and mysids ("Juv" = juvenile; other codes as in Figure 17) in 2015.

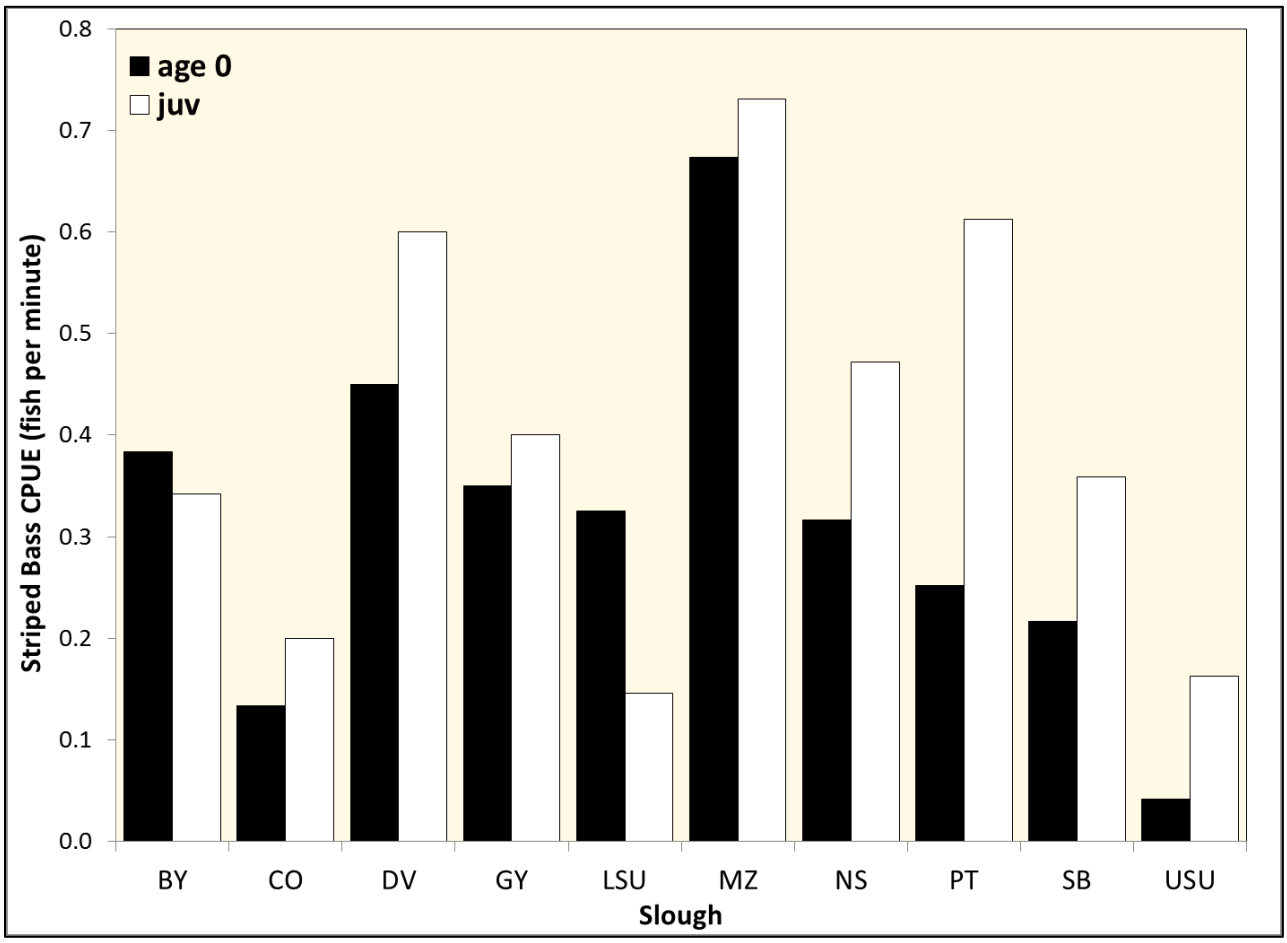

Figure 19. Average otter trawl CPUE of age classes of striped bass in 2015 ("BY" = Boynton Slough, "CO" = Cutoff Slough, "DV" = Denverton Slough, "GY" = Goodyear Slough, "LSU" = lower Suisun Slough, "MZ" = Montezuma Slough, "NS" = Nurse Slough, "PT" = Peytonia Slough, "SB" = First Mallard Slough, and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

Other Species of Interest

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.

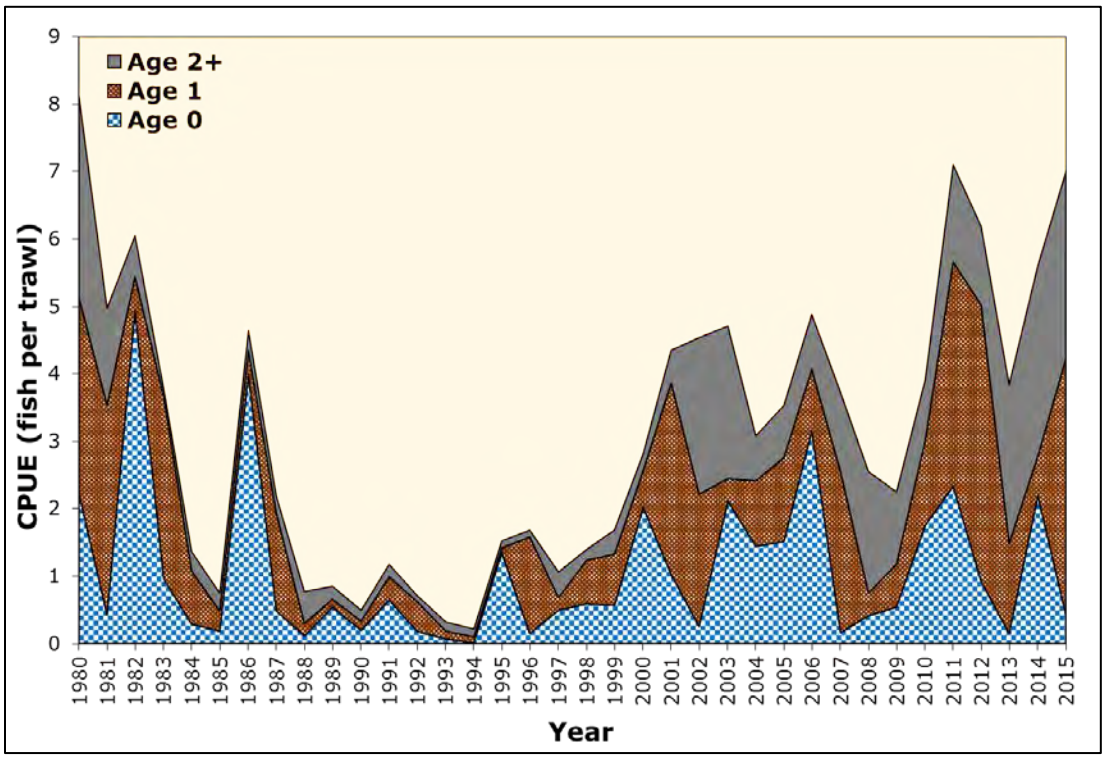

Figure 20. Annual otter trawl CPUE of three age classes of Sacramento splittail.

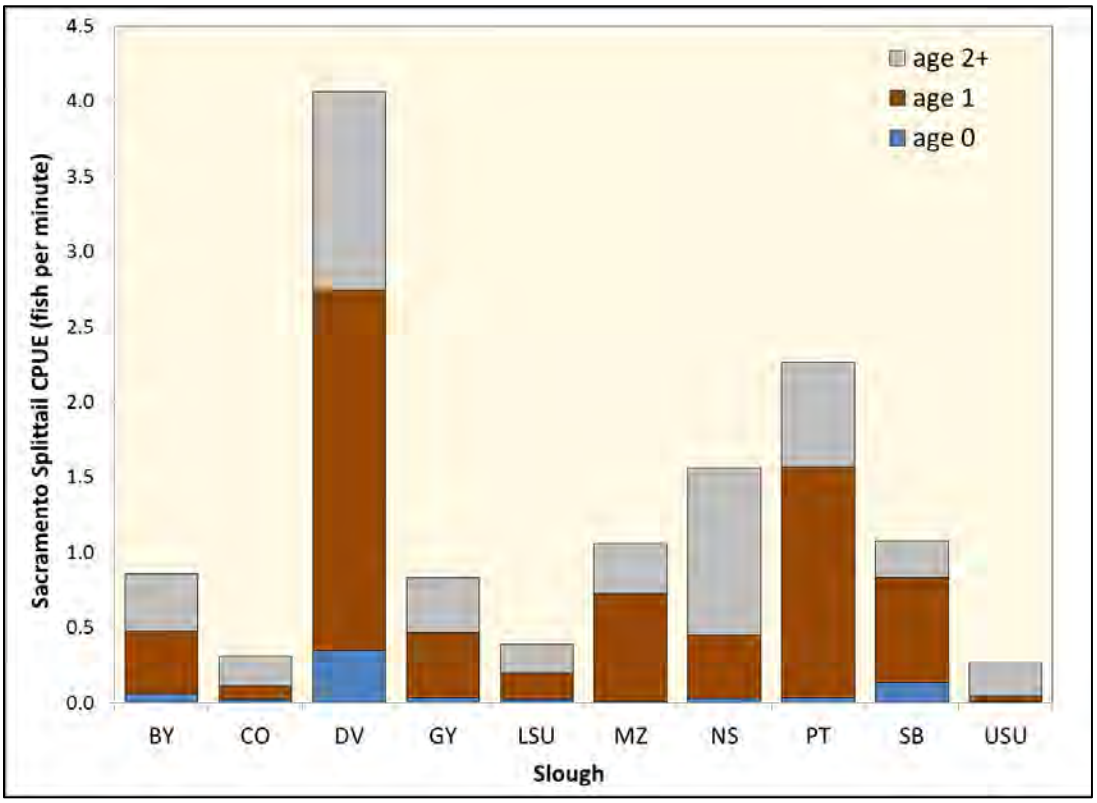

Figure 21. Average otter trawl CPUE of age classes of splittail in 2015 (codes as in Figure 19).

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.

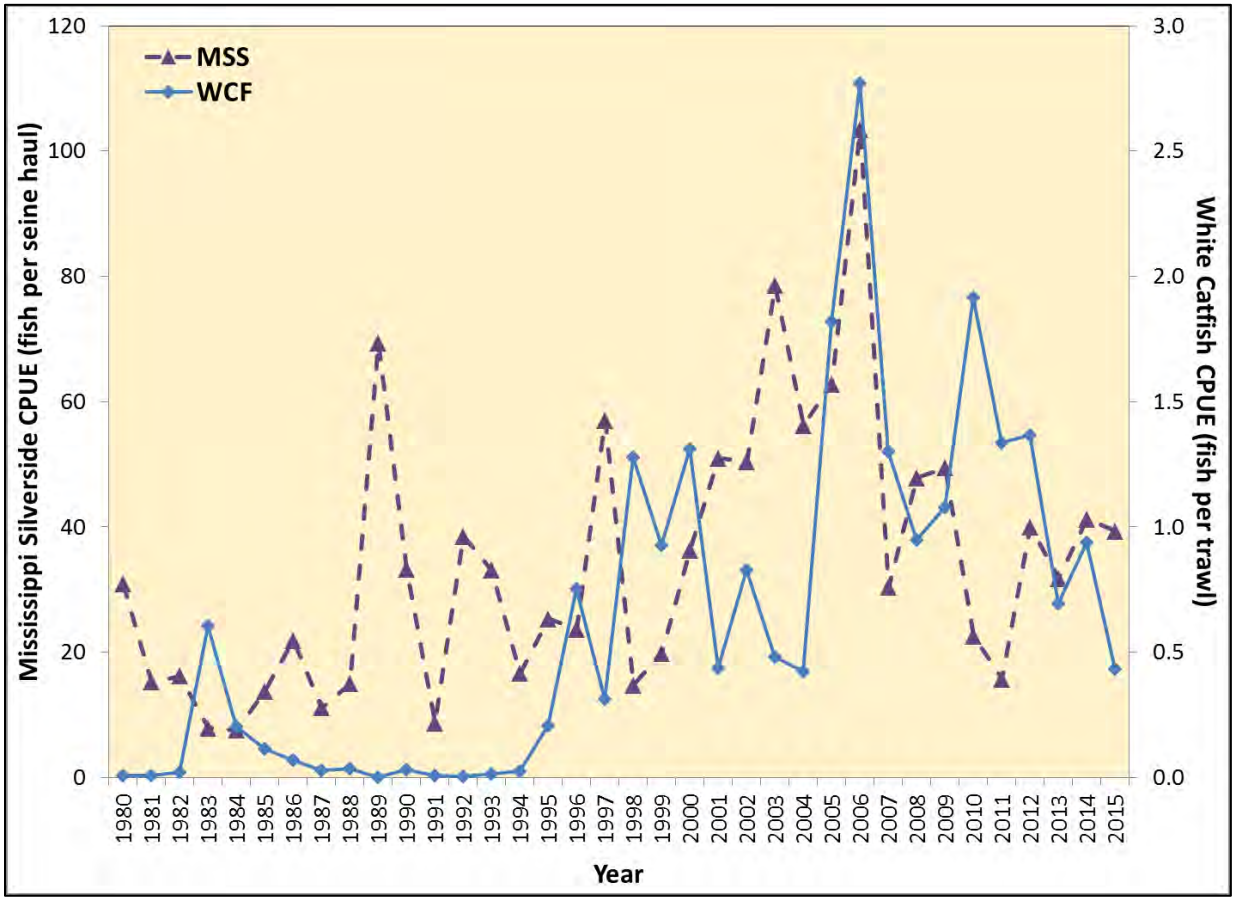

Figure 22. Annual CPUE of white catfish ("WCF") and Mississippi silverside ("MSS").

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.

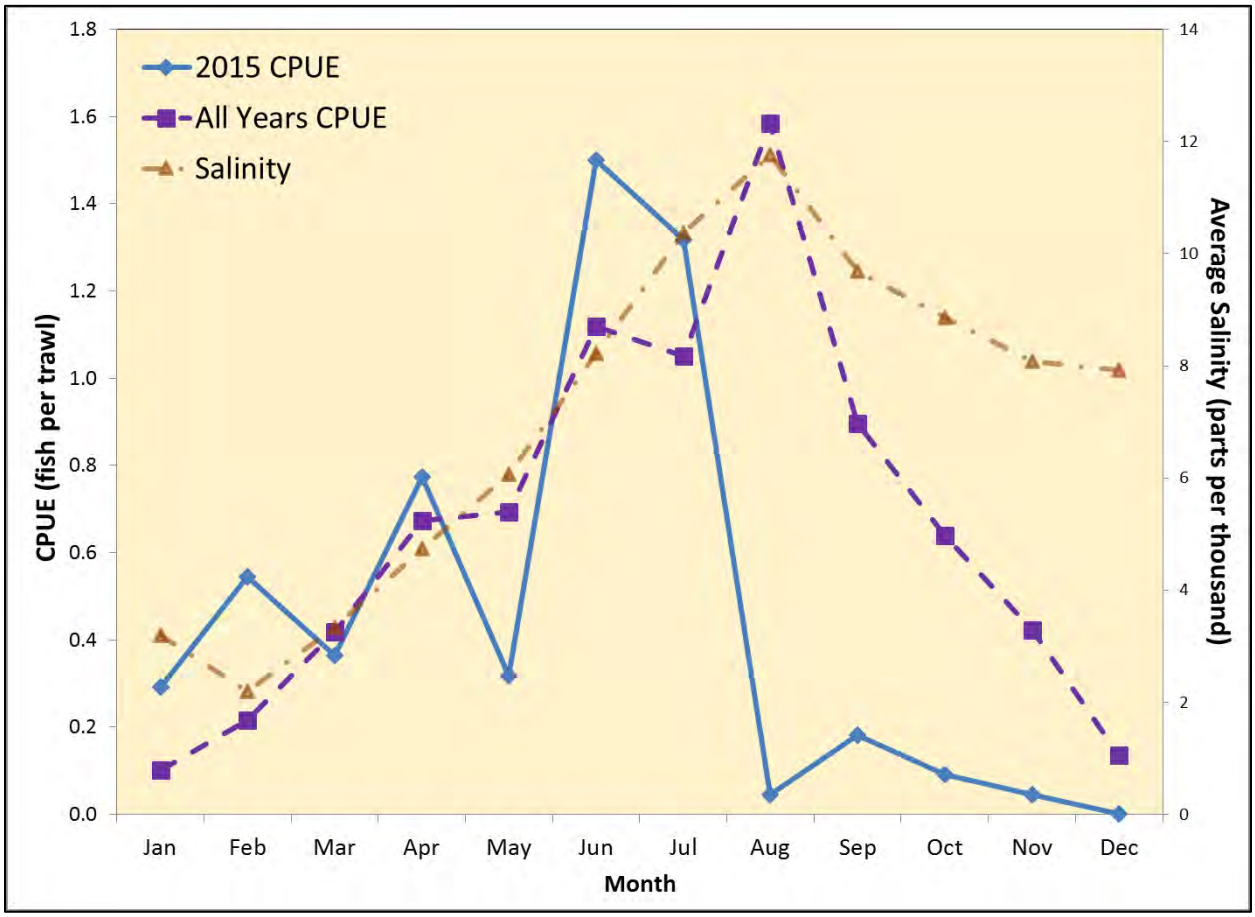

Figure 23. Monthly CPUE of white catfish in 2015 and all years of the study (1980 – 2015), with average monthly salinity in 2015.

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*).

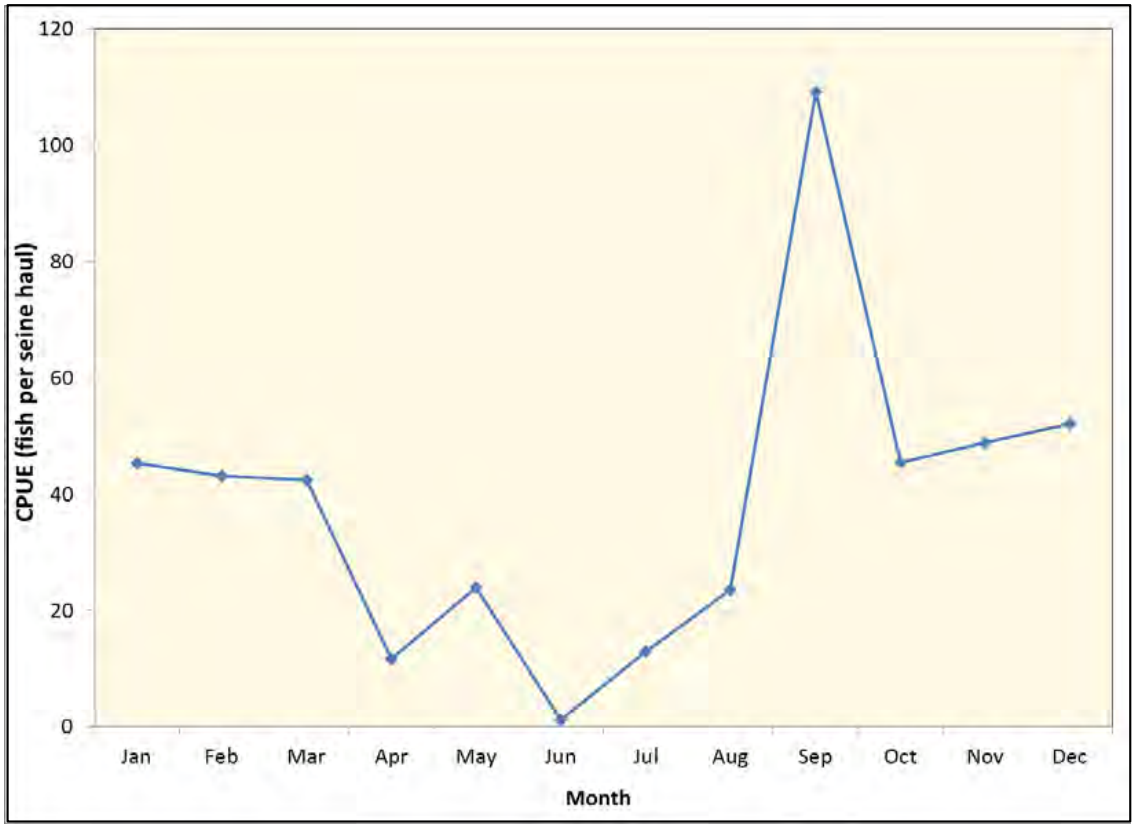

Figure 24. Monthly average beach seine CPUE of Mississippi silverside in 2015.

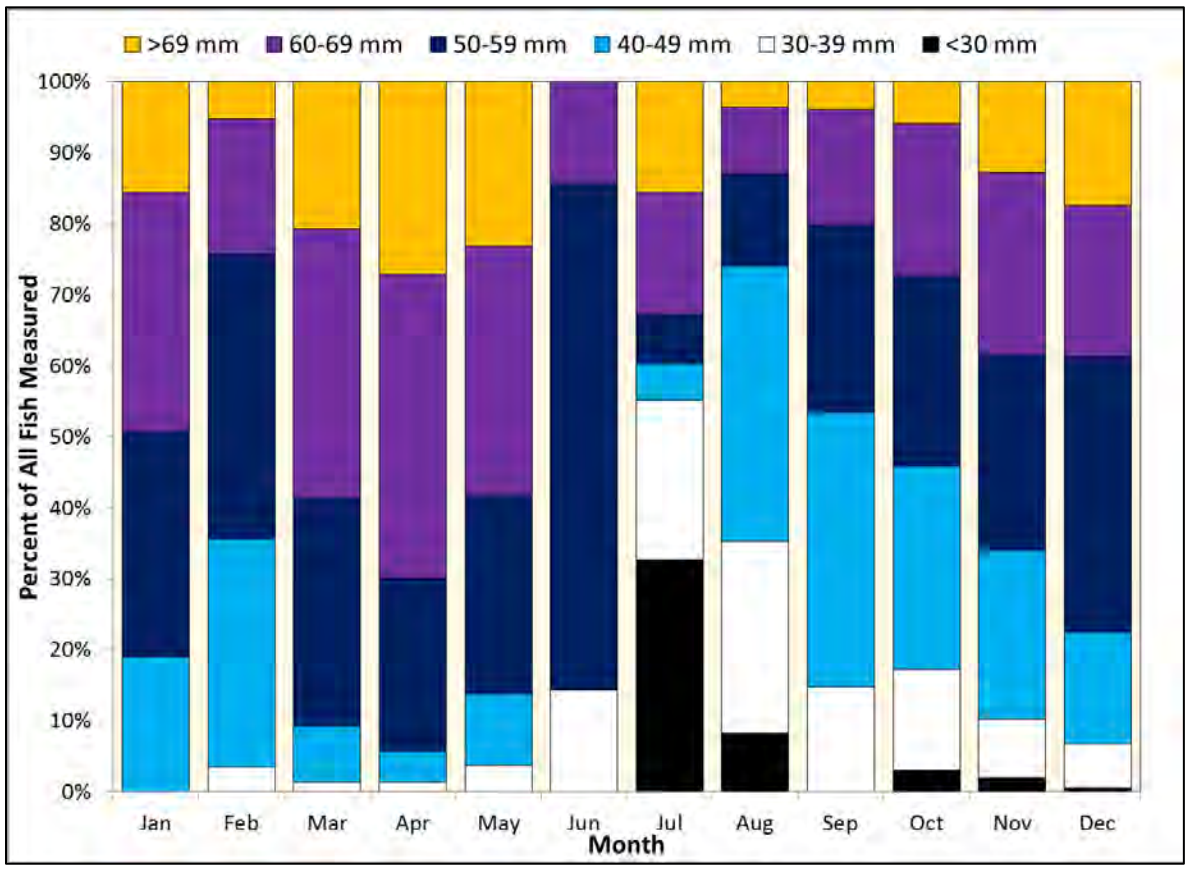

Figure 25. Monthly average beach seine CPUE of size classes (mm SL) of Mississippi silverside in 2015.

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