■ Interagency Ecological Program for the San Francisco Estuary ■

IEP NEWSLETTER

VOLUME 28, NUMBER 2, 2015

Of Interest to Managers

Louise Conrad (DWR), Louise.Conrad@water.ca.gov
Brian Schreier (DWR), Brian.Schreier@water.ca.gov

This issue of the Interagency Ecological Program (IEP) Newsletter provides four status and trends pieces highlighting different aspects of the San Francisco Bay-Delta ecosystem, as well as an article presenting modeled estimates of recent White Sturgeon abundance.

Felipe La Luz and **Randy Baxter** (CDFW) provide the 2014 status and trends report for pelagic fishes, providing abundance indices and long-term trends for American Shad, Threadfin Shad, Delta Smelt, Longfin Smelt, Sacramento Splittail, and age-0 Striped Bass from major IEP fisheries surveys. Indices for all six species declined from previous years, or remained at near-record low levels. However, the authors note that many of the species of interest were caught in the Cache Slough and Sacramento Deepwater Ship Channel region, evidence for the importance of this area for a number of pelagic fishes.

Jason Azat (CDFW) reports on trends in the Central Valley Chinook Salmon harvest and escapement, 1975-2014, using a suite of data sources that composes the GrandTab database. The 2014 combined ocean harvest and recreational fishery was well below the 40-year average, as were escapement estimates for both Winter-run and Spring-run Chinook Salmon. Winter-run escapement, in particular, was only 48% of the long-term average. Late-fall and Fall-run, in contrast, were either on par with the 40-year average, or only slightly below.

Naoaki Ikemiyagi and co-authors (DWR) provide an annual report for Yolo Bypass fisheries monitoring, covering water year 2014. The drought conditions resulted in record-low flows for the Yolo Bypass since the monitoring program began in 1998. In fact, peak flows actually occurred in the summer during agricultural drainage, rather than the more typical pattern with peak flows occurring with winter storm pulses. Low flow conditions were favorable to invasive aquatic vegetation, which was so extensive that it occasionally restricted rotary screw trap operation and beach seining activities. Both Chinook Salmon and Delta Smelt continued to show a strong presence relative to previous sampling years. In this update, the authors also present a multivariate analysis of the beach seine data, covering 2011-2014. This analysis highlighted 2011 as an outstanding year compared with the drought years of 2012-2014, with increased catch of native species in the wet year of 2011.

Betsy Wells (DWR) provides the 2014 update for IEP's Environmental Monitoring Program for benthic species. She summarizes the phyla observed at each of 10 sampling sites as well as their densities, and the variation over the course of the year. While the program sampled 187 different species, the 10 most abundant species composed 82% of all individuals collected. Betsy Wells also reports observations of how 2014 differed from previous years; interestingly, the species composition at sites at and above the confluence area did not appear to change with interannual differences in hydrology. In contrast, there was a strong signal of wet years vs. dry years in the species composition at Suisun Bay and San Pablo Bay sites.

Finally, **Marty Gingras** and **Jason DuBois** (CDFW) present a modeling effort to estimate the abundance of White Sturgeon in a juvenile size class (85-116 cm) as well as harvestable fish (≥ 169 cm). The juvenile size class is currently under-studied and while estimates exist for the larger size class, they are imprecise because of low sample sizes. Their results provide size-class specific estimates for 2007-2012, showing a consistently low abundance of White Sturgeon ≥ 169 cm. The result is not a surprise given that these fish come largely from year classes that had low abundance indices and were not well protected relative to current regulations. The authors plan to continue working on the precision of their abundance estimates in order to inform fishing regulations.

Status and Trends

2014 Status and Trends Report for Pelagic Fishes of the Upper San Francisco Estuary

Felipe La Luz (CDFW), felipe.laluz@wildlife.ca.gov
Randy Baxter (CDFW), randy.baxter@wildlife.ca.gov

Introduction

The 2014 Pelagic Fishes Status and Trends Report uses data from four of the Interagency Ecological Program's (IEP) long-term fish monitoring surveys: (1) the 20-mm Survey, (2) the Summer Townet Survey (STN), (3) the Fall Midwater Trawl (FMWT), and (4) the US Fish and Wildlife Service (USFWS) Beach Seine Survey (Honey et al. 2004). Abundance indices, as well as long-term trends in abundance and distributional information are presented for six species: American Shad (*Alosa sapidissima*), Threadfin Shad (*Dorosoma petenense*), Delta Smelt (*Hypomesus transpacificus*), Longfin Smelt (*Spirinchus thaleichthys*), Splittail (*Pogonichthys macrolepidotus*) and age-0 Striped Bass (*Morone saxatilis*). Four of these species, Threadfin Shad, Delta Smelt, Longfin Smelt and age-0 Stripped Bass, rely on the upper estuary for spawning and rearing, and have recently undergone significant population declines (Sommer et al. 2007).

Methods

Sampling Background

The California Department of Fish and Wildlife (CDFW) 20-mm Survey monitors distribution and relative abundance of larval and juvenile Delta Smelt throughout its historical spring range (Figure 1). This includes the entire Delta, downstream to eastern San Pablo Bay and the Napa River. The survey name refers to the size of Delta Smelt that the survey gear targets, which corresponds with the size at which Delta Smelt are readily identifiable and counted at the State Water Project and Central Valley Project fish salvage facilities. Since 1995, the 20-mm Survey has conducted surveys on alternate weeks from early March through early July, completing nine surveys per year since 2009. Three tows are conducted at each of the 47 stations (Figure 1) using a fixed-mouth, 1,600-µm mesh net (Dege and Brown 2004). The survey added five Napa River stations in 1996. In 2008, two stations each were added in Lindsey Slough, Miner Slough, and the Sacramento River Deep Water Ship Channel (SRDWSC). A < 60-mm FL length criterion is used to select length data for age-0 Delta Smelt, which are then averaged by survey for all stations sampled to determine when mean fork length (FL) reaches or surpasses 20 mm. The four surveys whose mean FL bounds 20 mm are used to calculate the annual abundance index. From this subset of surveys, Delta Smelt catch-per-unit-effort (CPUE) is calculated for each of the 41 index stations. CPUE for each tow is calculated by dividing catch by the volume (m^3) filtered during the sample and multiplying by 10,000 to obtain a whole number. CPUE is then averaged across tows for each index station. The resulting mean station CPUE values are incremented by one and then $\log_{10}$ transformed (i.e., $\log_{10}(x+1)$). These transformed values are averaged within each survey and then the mean values back transformed (i.e., 10^x), to return them to their original scale. Finally, one is subtracted from each

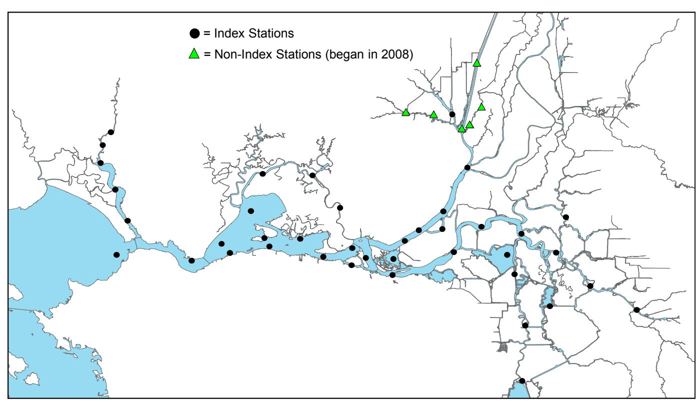

Figure 1 Map of 20-mm Survey stations. Index stations have been sampled since survey inception in 1995. Data collected at index stations are used to calculate survey and annual abundance indices. Non-Index stations were added to the survey in 2008 to better assess the distribution of Delta Smelt and other pelagic fishes.

value and then these values are summed across the four surveys, which bracket the date when mean Delta Smelt FL reached 20 mm to obtain the 20-mm Survey annual abundance index.

The Summer Townet Survey (STN) began in 1959 and its data have been used to calculate age-0 Striped Bass indices for all years since except 1966, 1983, 1995, and 2002. Delta Smelt indices have also been calculated for the period of record, except for 1966 through 1968. Historically, STN conducted two to five surveys annually, depending on when the mean FL of age-0 Striped Bass exceeded 38.1 mm, at which time the index could be set and sampling terminated for the year. In 2003, CDFW standardized sampling to six surveys per year, beginning in early June and continuing every other week into August (Hieb et al. 2005). STN samples 32 historic stations, one of which is located in the Napa River and is excluded from index calculations due to historically infrequent sampling. Index stations are distributed from eastern San Pablo Bay to Rio Vista on the Sacramento River, and to Stockton on the San Joaquin River (Figure 2). In 2011, STN added eight supplemental stations in the Cache Slough-SRDWSC region to increase spatial coverage and better describe Delta Smelt range and habitat (Figure 2). A minimum of two tows are completed at historic stations, and a third is conducted if any fish are caught during the first two tows. One tow is completed at the supplemental stations with a second conducted only if the Delta Smelt catch during the first tow is less than 10.

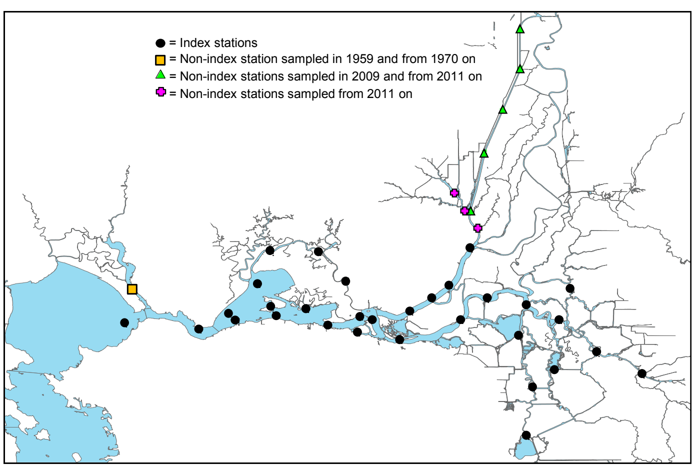

Figure 2 Map of the Summer Townet Survey stations. Index stations have been sampled since survey inception in 1959 and their data are used for calculating survey and annual abundance indices. Non-index stations were added as indicated to better assess the distribution of Delta Smelt and other pelagic fishes.

Catch per tow data from the 31 index stations are used to calculate annual abundance indices for age-0 Striped Bass and Delta Smelt. First, catch of a species is summed across tows at each station and then this sum is multiplied by a volume-weighting factor (i.e., the estimated volume (m^3) represented by each station) (Chadwick 1964). These products are then summed across all 31 index stations within a survey to produce the survey abundance index. The annual abundance index for age-0 Striped Bass is interpolated using the abundance indices from the two surveys that bound the date when mean FL reached 38.1 mm (Chadwick 1964; Turner and Chadwick 1972). STN did not consistently measure Delta Smelt FL until 1973, so no length criterion is used for the Delta Smelt index calculation. Instead, the annual index for Delta Smelt is the average of the first two survey indices of each year; however, in 1996 the first survey was cut short due to an equipment malfunction, so the index was calculated as the average of the indices for the second and third surveys.

The Fall Midwater Trawl (FMWT) survey began in 1967 and has been conducted in all years except 1974 and 1979. CDFW established the FMWT survey to examine age-0 Striped Bass relative abundance and distribution in the upper estuary (Stevens 1977). Later, FMWT developed abundance and distribution information for other upper-estuary pelagic fishes, including American Shad, Threadfin Shad, Delta Smelt, Longfin Smelt, and Splittail. The FMWT survey currently samples 122 stations monthly from September to December. Trawl sampling ranges from western San Pablo Bay to Hood on the Sacramento River, and from Sherman Lake to Stockton on the San Joaquin River (Figure 3). The annual abundance index calculation uses catch data from 100 of the 122 stations (Stevens 1977). The remaining 22 stations were added in 1990, 1991, 2009, and 2010 to improve our understanding of Delta Smelt distribution and habitat use (Figure 3). To calculate survey abundance indices, the 100 index stations are grouped into 17 regions. Monthly indices are calculated by averaging index station catch in each region, multiplying these regional means by their respective weighting factors (Chadwick 1964), and summing these products. Annual abundance indices are the sum of the four (September-December) monthly indices.

Since 1994, USFWS has conducted beach seine sampling weekly at approximately 40 stations in the Delta and in the lower Sacramento and San Joaquin rivers

(Brandes and McLain 2001). Data from 33 stations are used to calculate the annual age-0 Splittail abundance index (Figure 4). These stations range from Sherman Lake to Ord Bend on the Sacramento River (not pictured), to just downstream of the Tuolumne River confluence on the San Joaquin River (Figure 4). Hereafter, we refer to the confluence of the of the Sacramento and San Joaquin rivers at Sherman Lake as the Confluence, and the Tuolumne River confluence with the San Joaquin River as the Tuolumne confluence. All Splittail < 25-mm FL (measured individuals and proportions resulting from plus counts) are removed from calculations. The 33 index stations are grouped into 10 regions, and the annual index is calculated as the grand average of regional mean catch per m³ for seine hauls conducted in May and June.

FMWT data were used to describe abundance trends and distribution patterns of all six fish species listed in the introduction. STN data described trends for Delta Smelt and Striped Bass. Two studies only provided single species information: the 20-mm Survey for the abundance and distribution of larval and small juvenile Delta Smelt, and the USFWS beach seine data for age-0 Splittail abundance and distribution.

Results

American Shad

The American Shad was introduced into the Sacramento River in 1871 (Dill and Cordone 1997). This anadromous species spawns in the Sacramento, Feather, and American rivers from April through June. Juveniles can be found in freshwater areas within the Delta from late May through summer. From summer through fall, juveniles migrate to the ocean where they mature. Males reach maturity at 3 to 5 years with females maturing slightly later at 4 to 6 years (Able 1998). A large proportion of the spawning population in the Delta succumbs to natural mortality shortly after spawning; however, spent females have been observed downstream of spawning sites indicating some survival (Stevens 1966). Surveys conducted in the Susquehanna River, in the Northeastern United States, suggest that mortality is higher among spawning females than males (Walburg 1960).

The 2014 FMWT index for American Shad was 278, the second lowest index on record and only slightly higher than the record low 2008 index (Figure 5). American Shad abundance peaked at 9,360 in 2003. No index after 2003 has exceeded 25% of that year's index, and the majority failed to exceed 10% of the record high.

Throughout the FMWT sampling season, 233 American Shad were collected at index stations from San Pablo Bay through the lower Sacramento and San Joaquin rivers, including the confluence and the South Delta. In September, American Shad were collected from San Pablo Bay to the confluence of the Sacramento and San Joaquin rivers as well as in the South Delta and Lower San Joaquin River (n = 39). In October, they were collected from Carquinez Strait upstream to the lower Sacramento River (n = 16). In November, they were collected in the

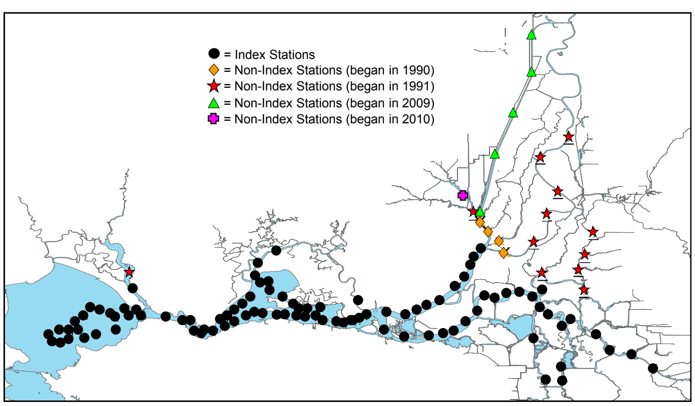

Figure 3 Map of the Fall Midwater Trawl Survey stations. Index stations have been sampled since survey inception in 1967 and their data are used for calculating survey and annual abundance indices. Non-index stations were added as indicated to better assess the distribution of Delta Smelt and other pelagic fishes.

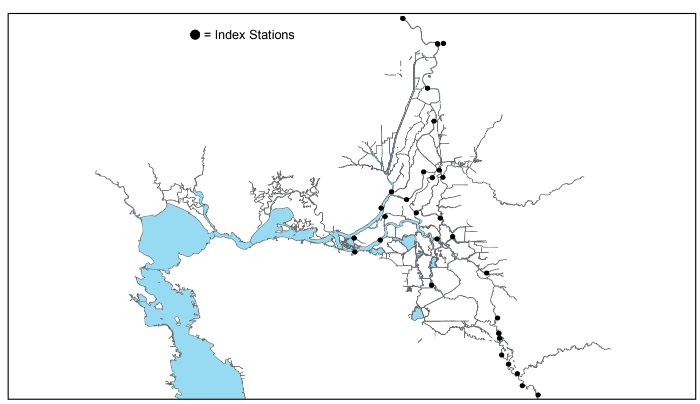

Figure 4 Map of USFWS beach seine survey stations. Data from all pictured and eight non-pictured stations are used for annual abundance indices. Locations for eight stations on the Sacramento River are not pictured.

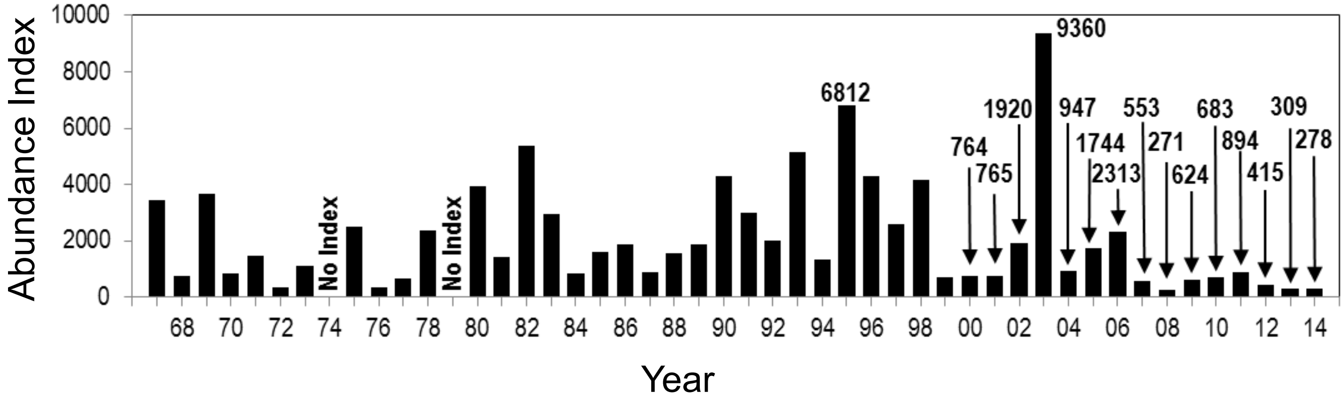

Figure 5 Annual abundance indices for American shad (all sizes) from the Fall Midwater Trawl Survey, 1967-2014.

same regions as September, including the lower San Joaquin River and South Delta (n = 61). The greatest numbers were collected in December (n = 117) and were found throughout the upper estuary, including San Pablo Bay. American Shad were also collected at non-index stations in the Sacramento River above Isleton (n = 1), Cache Slough (n = 5), SRDWSC (n = 65), and the lower San Joaquin River (n = 4). In 2011, a higher proportion of catch (78.4%) occurred downstream of the Confluence. Since then, American Shad catch has been concentrated in non-index stations in the SRDWSC. Little or no catch has occurred in the San Joaquin and South Delta regions since 2009.

Threadfin Shad

The Threadfin Shad was introduced to California reservoirs in the late 1950s and quickly spread downstream into the Sacramento and San Joaquin rivers (Dill and Cordone 1997). It has become established throughout the Delta and is most common in slow moving, fresh to oligohaline water found in dead-end sloughs (Wang 1986). Threadfin Shad are planktivorous throughout life (Holanov and Tash 1978). Spawning peaks from May to July and occurs from late spring through summer (Wang 1986). Individuals can reach maturity in their first year and live up to four years.

The FMWT Threadfin Shad index for 2014 was 282, making it the sixth lowest on record (Figure 6). This index was consistent with a seven-year pattern of low abundance indices beginning in 2008. Abundance was highest during the late 1990s and early 2000s, with the two highest indices occurring in 1997 and 2001. In 2002, the index dropped to 12% of the previous year and remained relatively low until another dramatic decrease in 2008 (Figure 6).

During the four survey months, 227 Threadfin Shad were collected at index stations from San Pablo Bay through the lower Sacramento and San Joaquin rivers as well as in the South Delta. Collections in the lower Sacramento River peaked in November (n = 125), while collections in the San Joaquin River peaked in December (n = 29). Throughout 2014 sampling, Threadfin Shad were more abundant at non-index stations in Cache Slough (n = 69) and SRDWSC (n = 865), similar to catch patterns observed since 2009 and 2010 when sampling began in these regions.

Delta Smelt

The Delta Smelt is a small (< 90 mm FL) osmerid endemic to the San Francisco Estuary. In the 1980s, Delta Smelt underwent a severe population decline (Figure 7C) and in 1993 was listed as a threatened species by state and federal agencies. It is considered environmentally sensitive because it has an annual life cycle, dependence on a spatially-limited, oligohaline to freshwater habitat and low fecundity (1,200 to 2,600 eggs on average) (Moyle et al. 1992). Low fecundity may be partially offset by the ability of females to produce multiple clutches in a single spawning season (Bennett 2005, California Department of Fish and Wildlife unpublished data).

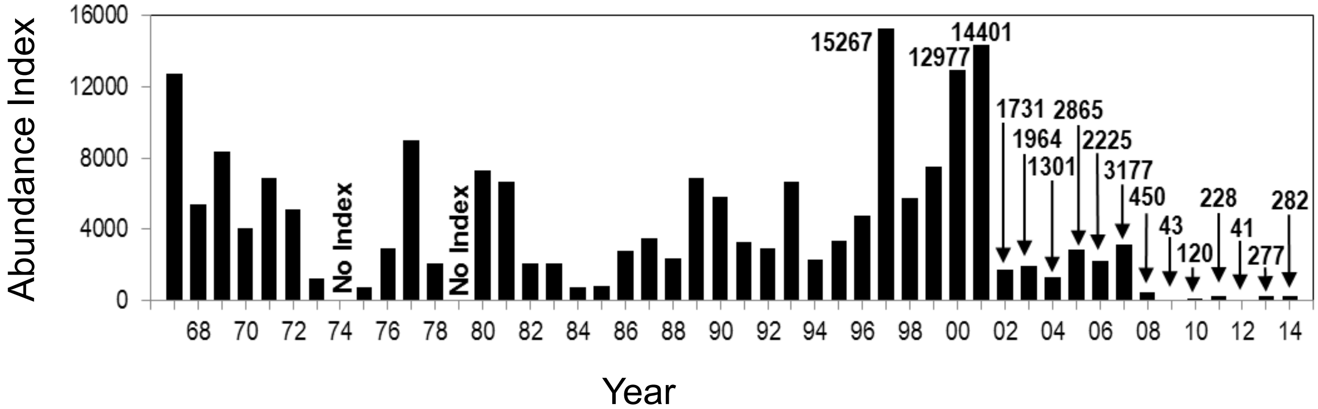

Figure 6 Annual abundance indices for Threadfin Shad (all sizes) from the Fall Midwater Trawl Survey, 1967-2014.

The 2014 20-mm index for Delta Smelt was 1.1, the second lowest after an index of 1.0 reported for 2007 (Figure 7A). It was only 14% of the previous year's index of 7.8 and similar to low indices reported from 2007 to 2010. Larval Delta Smelt catches were low in March. A single fish was collected in each of the Suisun, lower San Joaquin River, lower Sacramento River, and Cache Slough regions. Catches were lower for the first survey in April, with only one fish collected in the South Delta. Later in the month catches were higher, with a total of 48 fish collected throughout the Delta; however, none were collected from areas west of the confluence. Catch increased sharply in May when 160 Delta Smelt were captured during the two surveys within the month, of which 127 were captured in the SRDWSC. They were also detected in Cache Slough (n = 9), the lower Sacramento River (n = 12), the Confluence (n = 2) and the lower San Joaquin River (n = 10) regions. Catch declined in June to 42 fish. Twenty fish remained in the SRDWSC in June, and 19 were collected in the lower Sacramento River, and three fish captured in Suisun Marsh/Suisun Bay region. The final 20-mm survey of 2014 occurred in early July and only collected two fish in Sherman Lake within the lower Sacramento River region.

The STN Delta Smelt index for 2014 was 0.5, making it the fifth lowest on record and similar to most indices reported from 2005 to present, with the exception of 2011 (Figure 7B). Catch in the two June surveys consisted of 26 fish captured in the Lower Sacramento River and an additional 23 fish at non-index stations in the SRDWSC. In July, three surveys resulted in eight Delta Smelt caught at index stations in Suisun Bay and nine from the Lower Sacramento River; three more were caught at non-index stations in the SRDWSC. During the single August survey, a single Delta Smelt was captured at an index station in Suisun Bay and another seven in the lower Sacramento River region. Also in August, a single Delta Smelt was caught at a non-index station in the SRDWSC.

The FMWT Delta Smelt index for 2014 was nine, only half that of the previous year's index (Figure 7C). This was the lowest Delta Smelt index in the history of FMWT and only 53% of the next lowest index in 2009. Throughout the survey, only eight Delta Smelt were collected at index stations from Suisun Bay in September and the Confluence in December (n = 1, each), the lower Sacramento River in September and October (n = 6). Delta Smelt were also collected at non-index stations in Cache Slough (n = 1) in December and in the SRDWSC (n = 2) in September and December.

Longfin Smelt

The Longfin Smelt is a short-lived, anadromous fish that spawns in freshwater to slightly brackish water in winter and spring. It rears primarily in brackish water with some young-of-the-year and year 1+ fish migrating to the ocean in summer and fall. Adults typically return to the estuary as water temperatures drop in late fall and winter. Most reach maturity in their second year, but some individuals appear capable of spawning in their first year and others appear to wait until the end of their third year. A few individuals may survive to spawn a second time (Wang 1986).

The 2014 FMWT Longfin Smelt index was 16, the second lowest index on record and less than 10% of the index for 2013 (Figure 8). Longfin Smelt abundance was highest in the late 1960s and peaked again in the early 1980s. After a brief increase in the late 1990s, abundance dropped again and has remained relatively low for most recent years (Figure 8).

Throughout the survey, 11 Longfin Smelt were collected at index stations from San Pablo Bay through the lower Sacramento River. In September, single fish were collected in Carquinez Strait, Suisun Bay, the Confluence, and the Lower Sacramento River. In October, one each was collected in San Pablo Bay and the lower Sacramento River. In November, one fish was collected in San Pablo Bay (n = 1) and three in Suisun Bay. Only one Longfin Smelt was collected during December sampling, from San Pablo Bay. No Longfin Smelt were collected at non-index stations in 2014.

Splittail

The Splittail is a large cyprinid endemic to the San Francisco Estuary and its watersheds. Adults migrate from brackish to fresh water from late fall to early spring as river flows increase. During this time, they forage and eventually spawn on inundated floodplains and river margins (Sommer et al 1997, Moyle et al 2004). Spawning migrations occur in the Sacramento, San Joaquin, Cosumnes, Napa, and Petaluma rivers, as well as in Butte Creek and other small tributaries (Moyle et al. 2004). The majority of spawning takes place March through May, and the resulting larvae and small juveniles disperse downstream in late spring and summer. This outmigration coincides with reduced river flows that decrease available backwater and edge-water habitats. Year-class strength is influenced by timing and duration of floodplain inundation. Moderate to strong cohorts are associated with periods of springtime inundation lasting 30 days or more. (Sommer et al. 1997; Moyle et al. 2004).

The 2014 USFWS Beach Seine index for age-0 Splittail was 0.2, which was higher than the 2013 index, despite persistent drought conditions (Figure 9A). Regional abundance was highest within the Sacramento River and lowest in the San Joaquin River, a typical pattern for relatively dry years.

The 2014 FMWT Splittail index for all ages was 1, and represents a single age-0 fish collected in Montezuma Slough during December. A single adult Splittail was collected at a non-index station in the SRDWSC as well. The Splittail index tends to be low or zero except

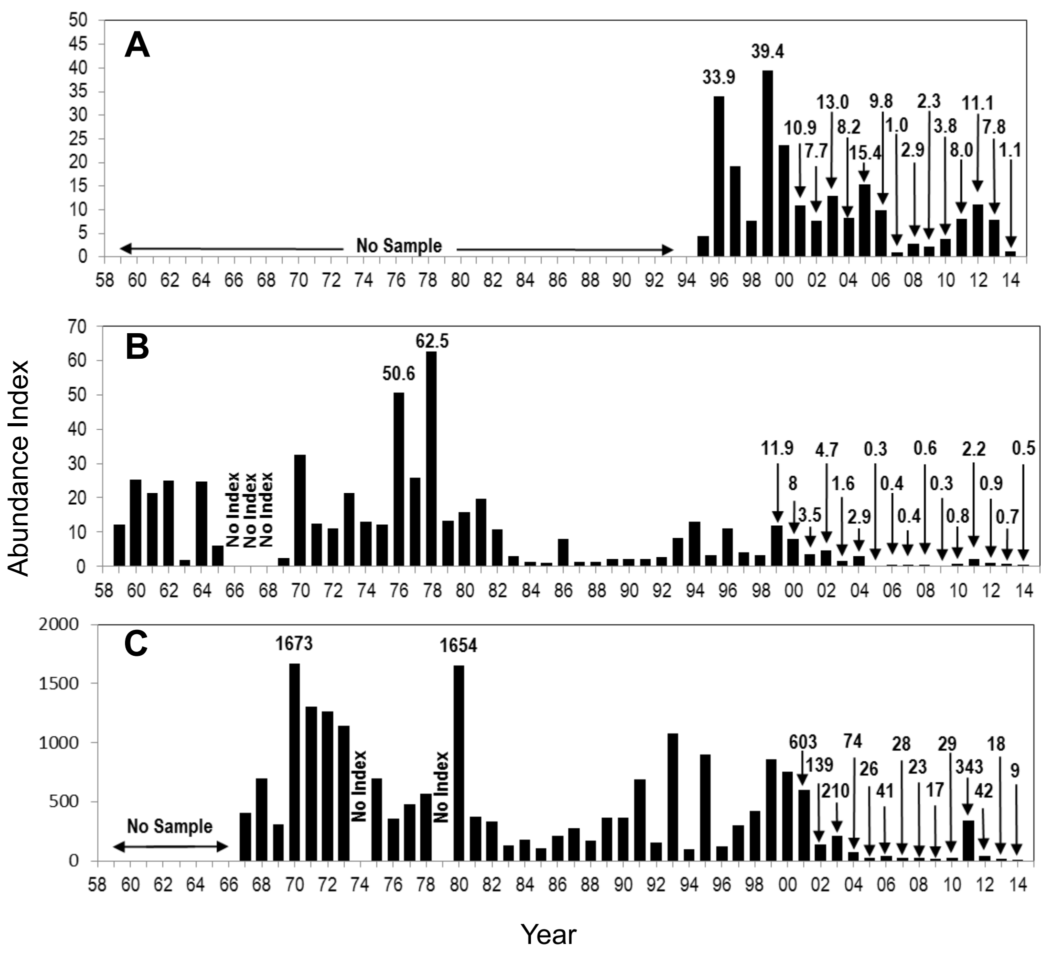

Figure 7 Annual abundance indices for Delta Smelt from: A) 20-mm Survey (larvae and juveniles, 1995-2014), B) Summer Townet Survey (juveniles, 1959-2014), C) Fall Midwater Trawl Survey (sub-adults, 1967-2014).

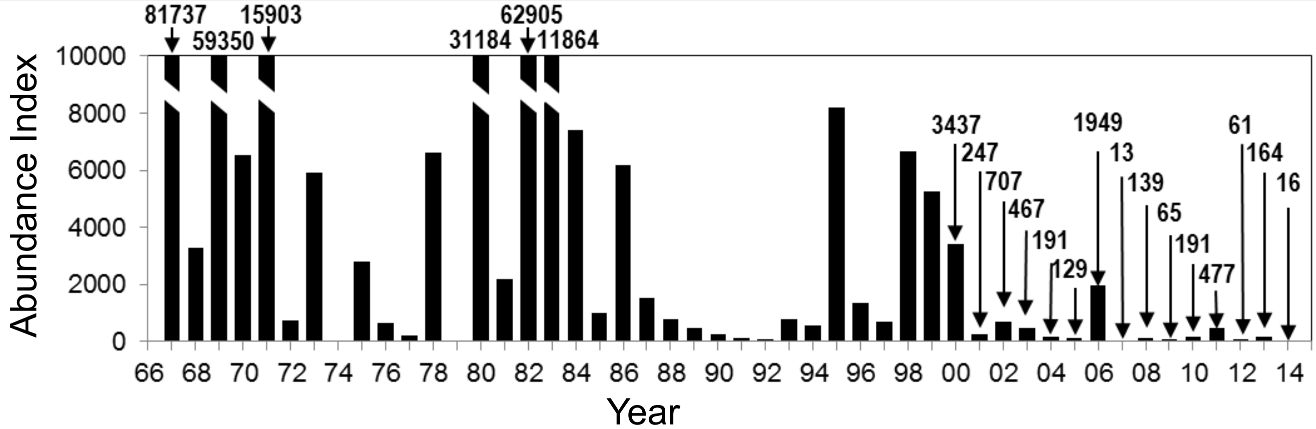

Figure 8 Annual abundance indices for Longfin Smelt (all sizes) from the Fall Midwater Trawl Survey, 1967-2014.

in relatively wet years, such as 2011, when age-0 fish tend to be abundant. FMWT operates in water > 2 m deep, whereas Splittail, particularly age-0 fish, appear to primarily inhabit water < 2 m deep. Thus, during most years, FMWT data probably does not accurately reflect trends in Splittail abundance. However, FMWT does effectively detect strong year classes, such as the one in 1998 (Figure 9B).

Age-0 Striped Bass

The Striped Bass is a long-lived, anadromous fish first introduced to the San Francisco Estuary in 1879 (Dill and Cordone 1997). Mature individuals forage in near-shore marine habitats, including coastal bays and estuaries. Many adults migrate to the Delta in fall and early winter, and remain there until they migrate upstream in spring to spawn. Spawning takes place in the water column, and both eggs and larvae rely on river and tidal currents to keep them suspended during early development. Eventually larvae are transported to rearing areas in fresh and brackish waters.

Both the STN and FMWT indices showed declines in age-0 Striped Bass abundance in the mid-1970s (Figure 10). Abundance dropped two more times, in the late 1980s and '90s, and has not approached historic numbers for the past 15 years. Stevens et al. (1985), hypothesized that four factors were responsible for the low abundance: (1) the adult population was too low to maintain adequate egg production, (2) planktonic food production has decreased to a point that is too low to sustain historic population levels, (3) losses due to entrainment in water diversions, and (4) pollution in the form of pesticides, petrochemicals, and other toxic substances. More recently, Sommer et al. (2011) argued that age-0 Striped Bass distribution had shifted almost exclusively to shoal areas, which were under-sampled by CDFW trawl surveys. While a shift of this nature would reduce catch and thus reduce abundance indices, Sommer et al. (2011) cautioned against attributing low values solely to a change in habitat use.

The 2014 STN index for age-0 Striped Bass was 0.3, or half of the previous year's index and tied with 2007 for the lowest index on record (Figure 10A). In 2014, age-0 Striped Bass reached an average fork length of 38.1 mm on July 3rd; data collected during the two surveys bracketing that date were used to calculate the annual index.

Catch was highest among index stations during the first two surveys in June (n = 149) when fish were broadly distributed from Suisun Bay (n = 5) upstream, but the majority were captured in the lower Sacramento River (n = 109). For the three surveys conducted in July, age-0 Striped Bass catch declined sharply to 24 total: 16 in Suisun Bay, a single fish in the Confluence region, five in the lower Sacramento River region, and two fish in the lower San Joaquin River region. Both of the fish captured in August were collected in the Suisun Bay region. Fish were also collected at non-index sites in the SRDWSC (n = 35), with the bulk of them (n = 31) taken in the two June surveys.

The 2014 FMWT index for age-0 Striped Bass was 59, the third lowest on record, and consistent with the low abundances reported since the early 2000s (Figure 10B). The index was highest at the inception of the survey in

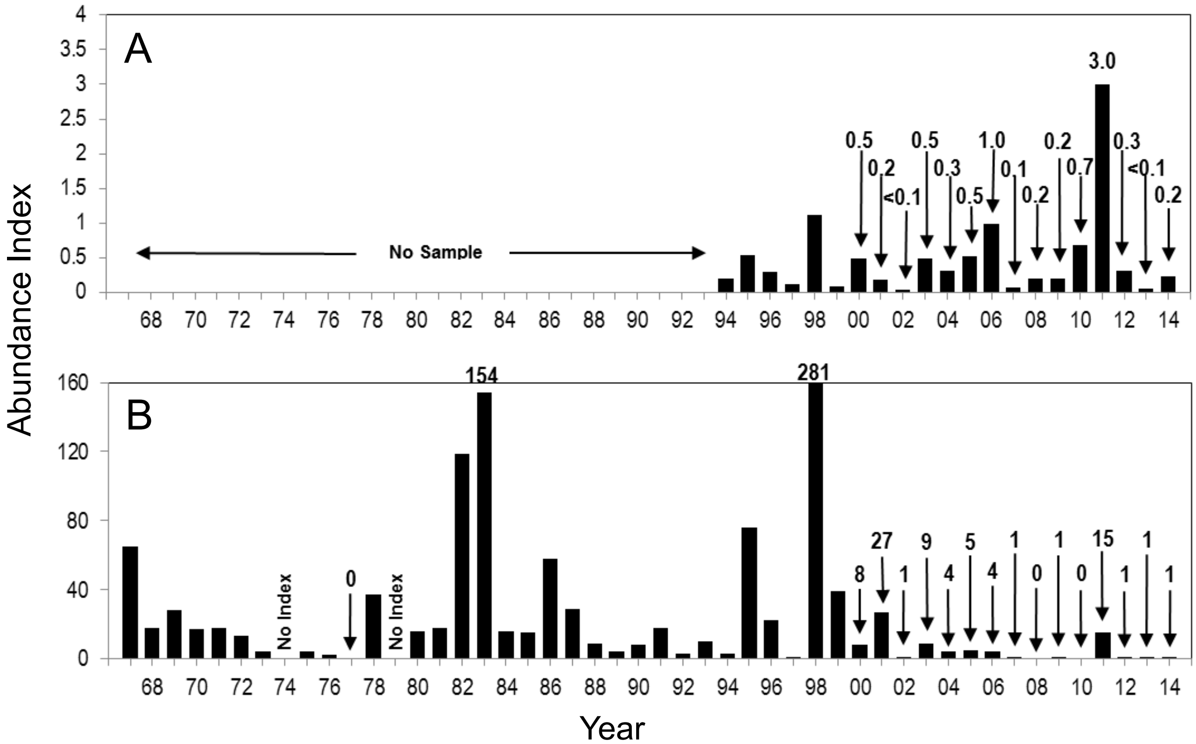

Figure 9 Annual abundance indices for Splittail from: A) USFWS Beach Seine Survey (juveniles ≥ 25mm), 1994-2014; B) Fall Midwater Trawl Survey (all sizes), 1967-2014.

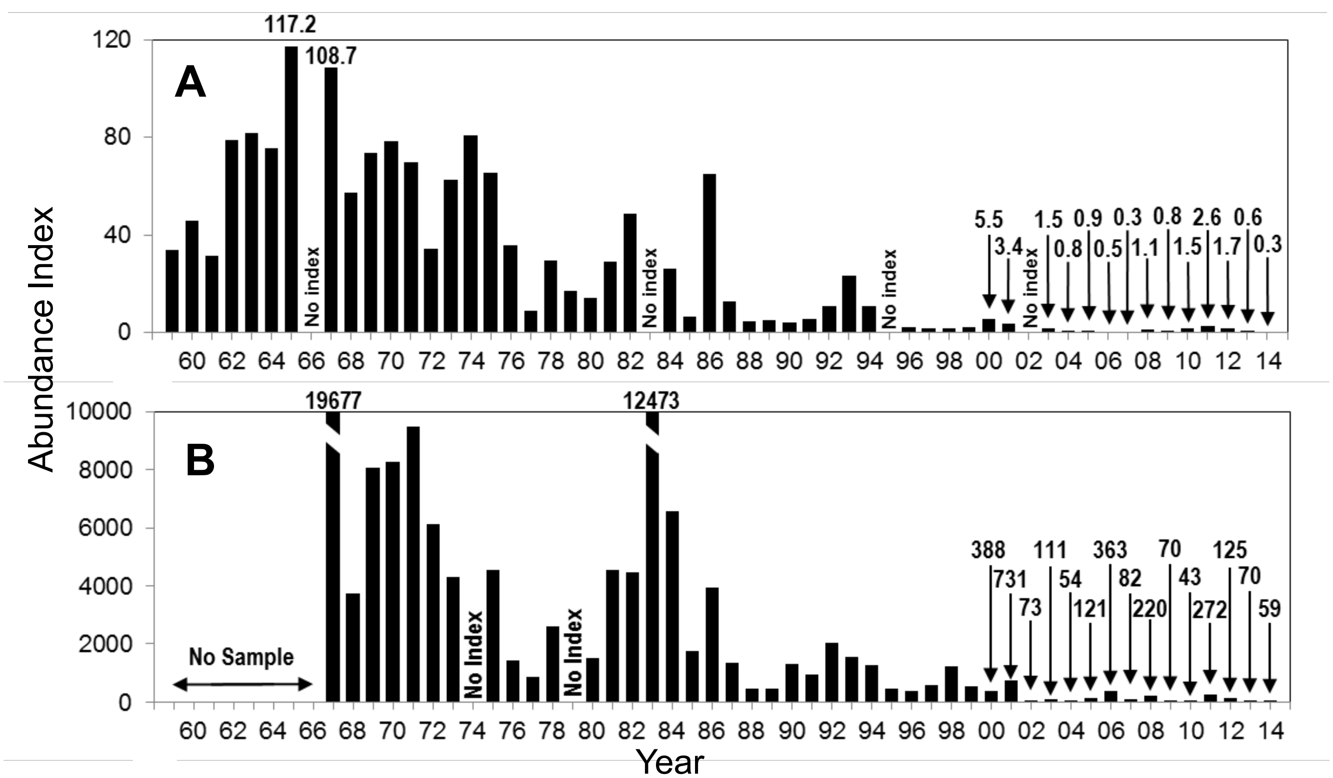

Figure 10 Annual abundance indices of age-0 Striped Bass from: A) Summer Townet, 1959-2014; B) Fall Midwater Trawl Survey, 1967-2014.

1967, peaked again in 1971, and a third time in 1983. In the later 1980s, age-0 Striped Bass abundance declined, and in the early 2000s it dropped and has remained low since then (Figure 10B). Forty-seven age-0 Striped Bass were collected at index stations in 2014: two from Carquinez Strait and six from Suisun Bay for September and October; a single fish at the Confluence, and two in the south Delta in November; and 36 spread from San Pablo Bay through the lower Sacramento and San Joaquin rivers in December, but 26 were collected in the lower Sacramento River. For non-index stations, age-0 Striped Bass were collected in the SRDWSC during October (n = 1) and December (n = 4), but most came from Cache Slough (n = 44) sampling during December.

Conclusion

Annual abundance indices continued to decline, or remained low, for all six fish species monitored. During recent surveys, catch of Delta Smelt, Longfin Smelt, and Age-0 Striped Bass have declined to several fish per survey or less, which is approaching the minimum threshold of detection. During four months of FMWT sampling at index stations, Delta Smelt were present in 4 tows, Longfin Smelt were present in 9 tows, and Age-0 Striped Bass were present in 22. Future declines in catch of rare species, such as Delta Smelt and Longfin Smelt, may fall below the threshold of detection and limit our ability to detect variation among years. Splittail FMWT indices have been near the threshold of detection more often than not for the past 15 years. Splittail catch in the FMWT ranged from 0 to 6 detections during this time, except for wet years, resulting in little variation among indices. Conversely, Beach Seine indices for Splittail continue to show modest variation and continued recruitment from most low outflow years (e.g., 2001, 2002, 2007, 2008, 2009, 2010, 2012, 2013, and 2014).

One bright spot from the trawl survey data might be the broad species use of the Cache Slough and SRDWSC region. We expanded STN sampling into this region in summer 2009 and FMWT sampling in fall 2010. Based on FMWT sampling, a majority of the Threadfin Shad catch and large fractions of the American Shad, age-0 Striped Bass, and Delta Smelt catches came from the region. The importance of Cache Slough and the SRDWSC as habitat is becoming evident from consistent and in some cases large catches across seasons and years.

Conversely, the south Delta continues to provide few if any collections of pelagic fishes from mid-way through STN through most FMWT sampling. Even for Threadfin Shad, once frequently caught in very high numbers, the south Delta does not appear to support anywhere near historical densities, at least within the trawl-surveyed reaches.

References

Able KW and Fahay MP. 1998. "*Alosa Sapidissima* (Wilson) American Shad." First Year in the Life of Estuarine Fishes in the Middle Atlantic Bight. Pages 55-57. Rutgers University Press.

Bennett W. 2005. "Critical Assessment of the Delta Smelt Population in the San Francisco Estuary." California San Francisco Estuary and Watershed Science. 3(2): Article 1

Brandes PL and McLain JS. 2001. "Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary." In: Contributions to the Biology of Central Valley Salmonids, R.L. Brown, editor. California Department of Fish and Game Fish Bulletin 179, Volume 2, 39-136.

Chadwick HK. 1964. "Annual abundance of young Striped Bass,*Roccus saxatilis*, in the Sacramento-San Joaquin Delta, California." California Fish and Game 50(2):69-99.

Dege M and Brown LR. 2004. "Effect of outflow on spring and summertime distribution and abundance of larval and juvenile fishes in the upper San Francisco Estuary." Pages 49-65. In: Early Life History of Fishes in the San Francisco Estuary and Watershed, Feyrer F, Brown LR, Brown RL, and Orsi JJ, editors. American Fisheries Society, Symposium 39, Bethesda, Maryland, 295 pp.

Dill WA and Cordone AJ. 1997. "History and the status of introduced fishes in California, 1871-1996." California Department of Fish and Game. Fish Bulletin 178.

Hieb K, Bryant M, Dege M, Greiner T, Souza K, and Slater S. 2005. "Fishes in the San Francisco Estuary." Status and Trends. IEP Newsletter 18(2):19-36.

Holanov SH and Tash JC. 1978. "Particulate and filter feeding in Threadfin Shad, *Dorosoma petenense*, at different light intensities." Journal of Fish Biology 13(5):619-625.

Honey K, Baxter R, Hymanson Z, Sommer T, Gingras M, and Cadrett P. 2004. "IEP long-term fish monitoring program element review." Interagency Ecological Program for the San Francisco Estuary Technical Report 78: 67 pages plus appendices.

Moyle PB, Baxter RD, Sommer T, Foin TC, and Matern SA. 2004. "Biology and population dynamics of the Sacramento Splittail (*Pogonichthys macrolepidotus*) in the San Francisco Estuary: A review." San Francisco Estuary and Watershed Science 2(2):1-47.

Moyle PB, Herbold B, Stevens DE, and Miller LW. 1992. "Life history and status of Delta Smelt in the Sacramento-San Joaquin Estuary, California." Transactions of the American Fisheries Society 77:67-77.
Sommer T, Baxter R, and Herbold B. 1997. "Resilience of Splittail in the Sacramento-San Joaquin Estuary." Transactions of the American Fisheries Society 126:961-976.
Sommer T, Armor C, Baxter R, Breuer R, Brown L, Chotkowski M, Culberson S, Feyrer F, Gingras M, Herbold B, Kimmerer W, Mueller-Solger A, Nobriga M, and Souza K. 2007. "The collapse of pelagic fishes in the upper San Francisco Estuary." Fisheries 32(6):270-277.
Sommer T, Mejia F, Hieb K, Baxter R, Loboschefsky E, and Loge F. 2011. "Long-term shifts in the lateral distribution of age-0 Striped Bass in the San Francisco Estuary." Transactions of the American Fisheries Society 140:1451-1459.
Stevens DE. 1966. "Distribution and food habits of the American Shad, *Alosa sapidissima*, in the Sacramento-San Joaquin Estuary." Pages 37-107. In: Ecological studies of the Sacramento-San Joaquin Delta, Part II, Turner JL and Kelley DW, compilers. California Department of Fish and Game Fish Bulletin 136.
Stevens DE. 1977. "Striped Bass (*Morone saxatilis*) monitoring techniques in the Sacramento-San Joaquin Estuary." Pages 91-109. In: Proceedings of the conference on assessing the effects of power-plant-induced mortality on fish populations. Van Winkle W, editor. Pergamon Press, New York, New York. http://www.dfg.ca.gov/delta/data/fmwt/bibliography.asp.
Stevens DE, Kohlhorst DW, Miller LW, and Kelley DW. 1985. "The decline of Striped Bass in the Sacramento-San Joaquin Estuary, California." Transactions of the American Fisheries Society 114:12-30.
Turner JL and Chadwick HK. 1972. "Distribution and abundance of young-of-the-year Striped Bass, *Morone saxatilis*, in relation to river flow in the Sacramento-San Joaquin Estuary." Transactions of the American Fisheries Society 101(3):442-52.
Walburg CH and Nichols PR. 1967. "Biology and Management of the American Shad and Status of the Fisheries, Atlantic Coast of the United States, 1960." United States Fish and Wildlife Service Special Scientific Report. Fisheries No. 550.
Wang JCS. 1986. "Fishes of the Sacramento-San Joaquin Estuary and adjacent waters, California: A guide to the early life histories." Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary Technical Report 9.

Central Valley Chinook Salmon Harvest and Escapement: 1975-2014

Jason Azat (CDFW, Fisheries Branch), jason.azat@wildlife.ca.gov

This paper presents available Chinook Salmon escapement and harvest estimates through 2014, with a focus on the California Central Valley. The California Central Valley contains the Sacramento and San Joaquin river systems. The Sacramento River System is made up of the mainstem Sacramento River and the many tributaries that flow into it. Likewise, the San Joaquin River also has many tributaries. Available estimates were compared with estimates from earlier years and the data were plotted to show abundance trends over time. The data were collected from the Pacific Fisheries Management Council (PFMC) Annual Fisheries Review, biologists throughout the Sacramento and San Joaquin river systems, and from the GrandTab database output developed by the California Department of Fish and Wildlife (CDFW). The GrandTab database output is a compilation of abundance estimates made for Chinook Salmon utilizing natural spawning areas in the Central Valley, as well as counts of Chinook that enter associated hatcheries. The GrandTab database output can be accessed at http://www.dfg.ca.gov/fish/Resources/Chinook/CValleyAssessment.asp.

California Ocean Harvest

Each year, the CDFW Ocean Salmon Project estimates recreational and commercial ocean harvest through monitoring of approximately 20 California ports, with a goal of sampling 20% of all salmon landed (Palmer-Zwahlen and Kormos 2013). The estimated combined recreational and commercial harvest of Chinook Salmon in California ocean waters was 241,232 Chinook Salmon in 2014, 58% of the 413,701 harvest in 2013 (Pacific Fisheries Management Council 2015). The harvest in 2014 was 45% of the 40-year-mean ocean harvest of 530,601 (Figure 1).

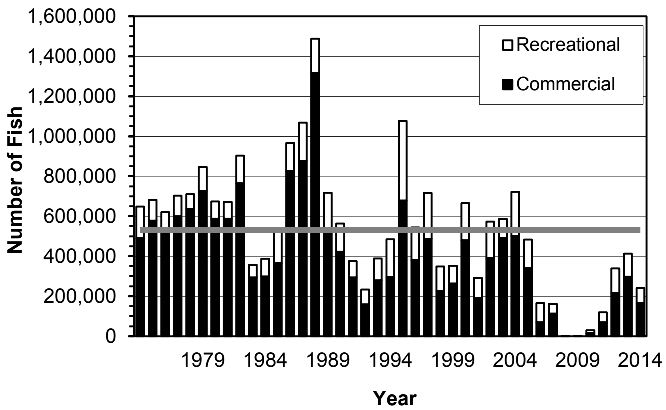

Figure 1 California commercial and recreational Chinook Salmon ocean catch from 1975 to 2014 and 40-year mean (gray line).

California Central Valley Harvest

Each year, the CDFW Central Valley Angler Survey estimates Chinook Salmon fishing effort, catch, and harvest for the entire Sacramento River system, from the Carquinez Strait to Keswick Dam and including the lowermost Mokelumne River. These estimates are made by counting and surveying anglers and their catch using a stratified random sampling design. A total harvest estimate is calculated by expanding the survey data for each survey section and month. The estimated harvest in Central Valley waters was 41,181 Chinook Salmon in 2014, 62% of the harvest of 66,555 in the previous year. The harvest of late-fall-run was 371 in 2014, just 17% of the 2,164 in the previous year. There was no winter-run harvest in 2014, due to selective fishing regulations put into effect in 2010. The harvest of spring run was 753 in 2014, 144% of the 523 in the previous year. The harvest of Sacramento River fall run was 35,381 in 2014, 57% of the 61,672 in the previous year. The harvest of San Joaquin Basin fall run was 4,676 in 2014, 213% of the 2,196 in the previous year.

California Central Valley Escapement

Each year, escapement estimates are made for Chinook Salmon that return to spawn in natural areas and for those that return to hatcheries within these river systems. Among the methods used to derive these estimates are such diverse methodologies as hatchery spawning counts, mark recapture surveys, snorkel surveys, and video passage counts. These estimates are in addition to the inland harvest estimates.

In 2014, the escapement estimate for Chinook Salmon returning to hatcheries and natural areas of California's Central Valley was 281,863 fish (Azat 2015). This estimate includes late-fall, winter, spring, and fall-run Chinook Salmon. This is 58% of the 486,649 estimate for the previous year, and 89% of the 40-year mean of 315,705 (Figure 2). The late-fall-run escapement was 13,050, the winter-run escapement was 3,015, the spring-run escapement was 9,901, and the fall-run escapement was 255,897 Chinook Salmon. Compared with the previous year, late-fall escapement increased, while winter, spring, and fall escapements all decreased.

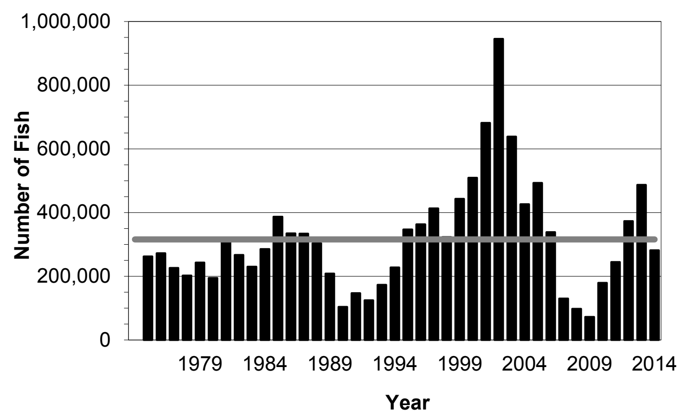

Figure 2 Annual Chinook Salmon escapement to the California Central Valley from 1975 to 2014 and 40-year mean (gray line).

Late-fall-run Escapement to the Sacramento River System

The estimated escapement of late-fall-run Chinook Salmon to the Sacramento River and its tributaries was 13,050 in 2014. This is 146% of the 8,966 of the previous year, and is 107% of the 40-year mean of 12,156 (Figure 3). This is the highest since the 18,843 estimate of 2007. Escapement to the Sacramento River was 7,989. Escapement to Battle Creek was 4,989. Most of the late-fall run in Battle Creek were counted at Coleman National Fish Hatchery, where the fish are propagated.

Winter-run Escapement to the Sacramento River

The estimated escapement of winter-run Chinook Salmon to the Sacramento River in 2014 was 3,015. This is 50% of the 6,084 of the previous year, and 48% of the 40-year mean of 6,226 (Figure 4).

Spring-run Escapement to the Sacramento River System

The estimated escapement of spring-run Chinook Salmon to the Sacramento River and its tributaries was 9,901 in 2014. This is 42% of the 23,696 of the previous year, and 68% of the 40-year mean of 14,542 (Figure 5).

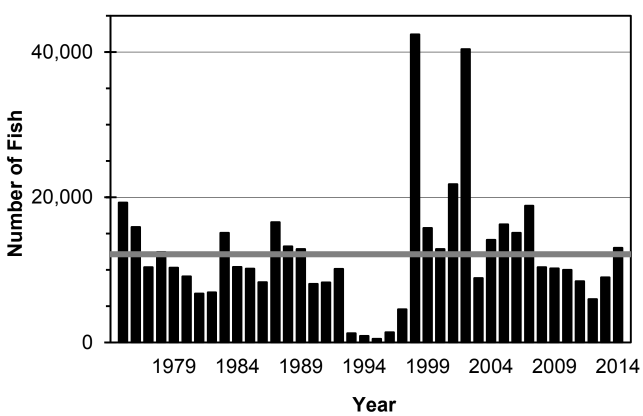

Figure 3 Annual late-fall-run Chinook Salmon escapement to the Sacramento River System from 1975 to 2014 and 40-year mean (gray line).

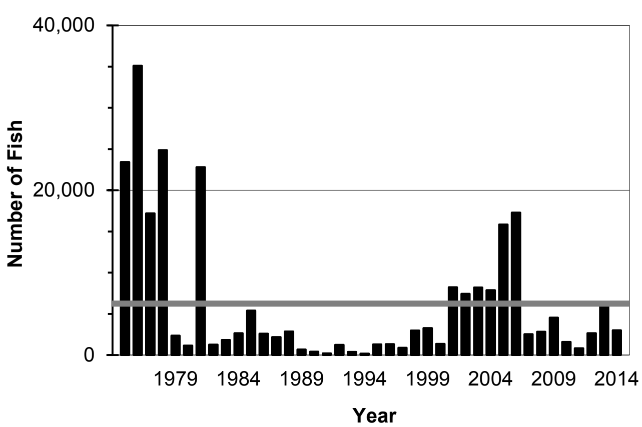

Figure 4 Annual winter-run Chinook Salmon escapement to the Sacramento River from 1975 to 2014 and 40-year mean (gray line).

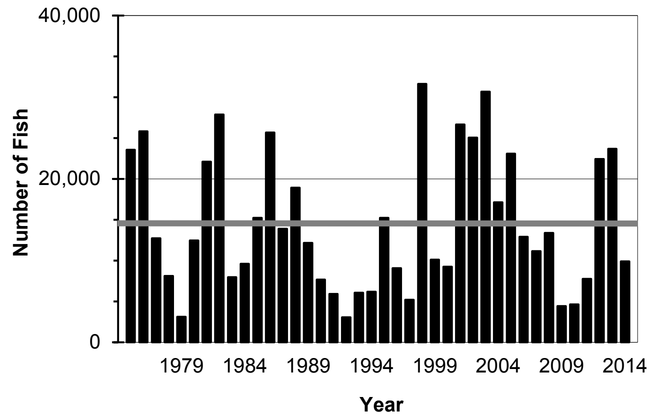

Figure 5 Annual spring-run Chinook Salmon escapement to Sacramento River Tributaries from 1975 to 2014 and 40-year mean (gray line).

The majority of these fish were from Butte Creek with an estimate of 5,083 Chinook Salmon. It should be noted that carcass survey estimates have replaced the snorkel survey estimates in GrandTab as the official CDFW estimate. Clint Garman's work on Butte Creek shows that the mean snorkel survey estimate has been roughly 55% of the mean carcass survey estimate over the last 12 years. The 2014 snorkel survey data indicated an estimate of 3,616 fish.

Fall-run Escapement to the Sacramento River System

The estimated escapement of fall-run Chinook Salmon to the Sacramento River and its tributaries was 238,176 in 2014. This is 56% of the 426,956 of the previous year, and 90% of the 40-year mean of 263,547 (Figure 6).

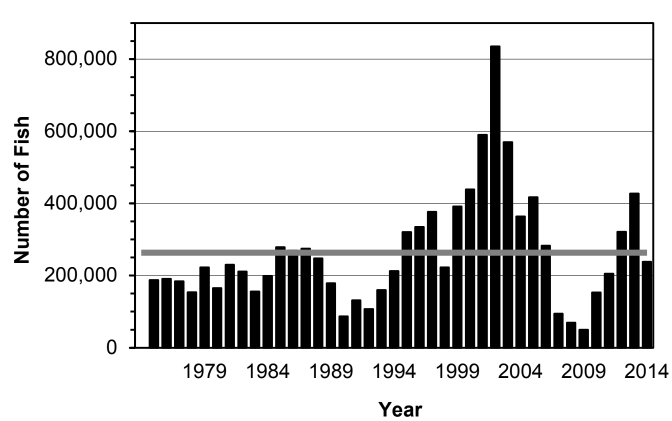

Figure 6 Annual fall-run Chinook Salmon escapement to the Sacramento River System from 1975 to 2014 and 40-year mean (gray line).

Escapement to the Sacramento River and its tributaries upstream of Red Bluff Diversion Dam (RBDD) was 97,321 in 2014. This is 89% of the 40-year mean of 109,897 Chinook Salmon. Escapement to the Sacramento River and its tributaries between RBDD and Princeton Ferry was 8,390 in 2014. This is 39% of the 40-year mean of 21,503 Chinook Salmon. Escapement to Sacramento River tributaries between Princeton Ferry and Sacramento was 132,465 in 2014. This is roughly the same as the 40-year mean of 132,147 Chinook Salmon.

Fall-run Escapement to the San Joaquin River System

The estimated escapement of fall-run Chinook Salmon to the San Joaquin River and its tributaries was 17,721 in 2014. This is 85% of the 20,947 from the previous year, and 92% of the 40-year mean of 19,204 (Figure 7).

The Chinook Salmon escapement and harvest estimates presented in this paper do not attempt to give a total Chinook Salmon population estimate, but rather the data from those areas where estimates are made are presented for comparison with previous years to examine general trends. The GrandTab database is a collection of these estimates in the Central Valley. The estimates are reviewed, recalculated, and finalized by CDFW, and though they cannot give a complete accounting of the Chinook Salmon population, they represent the best available data.

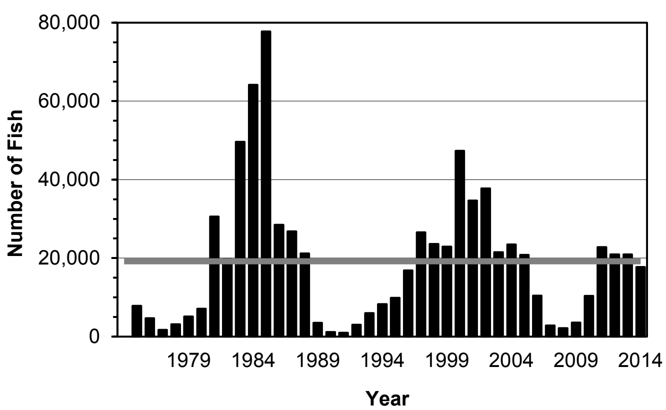

Figure 7 Annual fall-run Chinook Salmon escapement to the San Joaquin River system from 1975 to 2014 and 40-year mean (gray line).

References

Azat J. 2015. GrandTab 2015.05.15: California Central Valley Chinook Population Database Report. CDFW. Available at http://www.dfg.ca.gov/fish/Resources/Chinook/CValleyAssessment.asp.

Palmer-Zwahlen M and Kormos B. *Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement and Ocean Harvest in 2011*. CDFW. Available at https://nrm.dfg.ca.gov/documents/Default.aspx.

Pacific Fishery Management Council. 2015. *Review of 2014 Ocean Salmon Fisheries*. Prepared for the Council and its advisory entities, 7700 NE Ambassador Place, Suite 101, Portland, Oregon, 97220-1384. Available at http://www.pcouncil.org.

Acknowledgements

The author would like to thank **Dr. R. Titus** of the CDFW Fisheries Branch for oversight and editing.

The inland data in GrandTab and presented in this article were compiled from discussions with the following individuals:

Anderson, R. CDFW, North Coast Region (NCR)
Brown, M. United States Fish and Wildlife Service (USFWS), Red Bluff Fish and Wildlife Office (RBFWO)
Brown, M. CDFW, Fisheries Branch.
Burkes, R. CDFW, NCR.
Burr, K. Fishery Foundation of California (FFC).
DelReal, C. East Bay Municipal Utilities District. Fisheries and Wildlife Division.
Ferguson, E. CDFW, Fisheries Branch.
Garman, C. CDFW, Sacramento Valley and Central Sierra Region (SVCSR), Chico Office.
Gallagher, S. USFWS, RBFWO.
Hartwigsen, K. California Department of Water Resources, Division of Environmental Services.
Heyne, T. CDFW, San Joaquin Valley and Southern Sierra Region (SJVSSR).
Hoover, Paula. CDFW, NCR.
Killam, D. CDFW, NCR, Sacramento River Salmon and Steelhead Assessment Project (SRSSAP).
Kastner, A. CDFW, SVCSR, Feather River Hatchery.
Kennedy, T. FFC.
Krueger, D. CDFW, Information Technology Branch.
Mahoney, L. USFWS, RBFWO.

Massa, D. Pacific States Marine Fisheries Commission, Yuba River Accord Monitoring and Evaluation.
Null, R. USFWS, RBFWO.
Offill, K. USFWS, RBFWO.
Philips, J.CDFW, NCR.
Titus, R. CDFW, Fisheries Branch.
Tsao, S. CDFW, SJVSSR.

2013-2014 Yolo Bypass Fisheries Monitoring Status and Trends Report

Naoaki Ikemiyagi (DWR) Naoaki.Ikemiyagi@water.ca.gov, Alice Tung (DWR) Alice.Tung@water.ca.gov, Jared Frantzich (DWR) Jared.Frantzich@water.ca.gov, Brian Mahardja (DWR) Brian.Mahardja@water.ca.gov, and Brian Schreier (DWR) Brian.Schreier@water.ca.gov

Introduction

Largely supported by IEP, the Department of Water Resources (DWR) has operated the Yolo Bypass Fish Monitoring Program (YBFMP) since 1998. The project has provided a wealth of information regarding the significance of seasonal floodplain habitat to native fishes. The objectives of the project are to collect baseline data on lower trophic metrics (phytoplankton, zooplankton, and aquatic insects), juvenile and adult fish, hydrology, and water quality conditions. As the Yolo Bypass has been identified as a high restoration-priority by the National Marine Fisheries Service (NMFS) Biological Opinion for winter and spring-run Chinook Salmon (*Oncorhynchus tshawytscha*) and by California EcoRestore, these baseline data are critical for evaluating the success of future restoration projects. In addition, results from this monitoring have already served to increase our understanding of the role of the Yolo Bypass in the life history of native fishes, and the ecological function the bypass plays in the San Francisco Estuary. Key findings from previous analyses include: (1) Yolo Bypass is a major factor regulating year class strength of Sacramento Splittail, *Pogonichthys macrolepidotus* (Sommer et al. 1997; Feyrer et al. 2006; Sommer et al. 2007a), (2) Yolo Bypass is a key migration corridor for the adults of several listed and sport fish species (Harrell and Sommer 2003), (3) Yolo Bypass is one of the most important regional rearing areas for juvenile Chinook Salmon (Sommer et al. 2001a; Sommer et al. 2005), and (4) Yolo Bypass can be an important source of phytoplankton to the food web of the San Francisco Estuary (Jassby and Cloern 2000; Schemel et al. 2004; Sommer et al. 2004; Lehman et al. 2007; Frantzich et al. 2015).

This report describes fisheries' sampling effort for the 2014 water year (October 1, 2013-September 30, 2014), including a summary of fisheries' catch by species and gear type. Our sampling mainly occurred in the Toe Drain, a perennial riparian channel on the eastern edge of the Yolo Bypass. During drier months, the tidally influenced Toe Drain channel is the primary water body in the Yolo Bypass, linking a complex network of canals and ditches. In the 2013-14 sampling period, we continued to observe the higher numbers of Delta Smelt and juvenile Chinook Salmon seen in previous years (Ikemiyagi et al. 2014). However, water year 2014 also saw relatively lower occurrences of adult Chinook Salmon and other native fish species such as White Sturgeon (*Acipenser transmontanus*) and Sacramento Splittail compared with previous years.

Methods

Since 1998, small adult (e.g. Delta Smelt) and juvenile fish have been sampled with an 8-foot diameter rotary screw trap located in the Toe Drain of the Yolo Bypass, approximately nine miles south of the Lisbon Weir (Figure 1), for up to seven days a week during the months of January-June. In water year 2014, the rotary screw trap was consistently operated five days a week for the entire sampling period without any restrictions from high flows or heavy debris (Figure 2). For the rotary screw trap, the sampling time (total hours based on set and pull times) is used to calculate catch per unit effort (CPUE) as the volume of water sampled is unknown as a result of tidal variation in flows.

We supplemented the collection of small adult and juvenile fish in the Yolo Bypass by conducting biweekly beach seine surveys at various site locations within the Toe Drain and in a perennial pond on the west side of the Yolo Bypass (Figure 1 and Figure 2). During inundation events, weekly sampling is conducted (such as in water year 2011) at four distinct site locations only accessible during flood conditions (Figure 1), though none of these sites were sampled in 2014 due to a lack of any substantial inundation. In the summer of 2010, the non-inundation beach seine survey was increased to include seven additional stations, distributed above and below Lisbon Weir, to capture the fish assemblage along the axis of the Toe Drain at a higher resolution.

Upstream-migrating, large adult fish in the Toe Drain are monitored using a 10-foot diameter fyke trap, designed after the California Department of Fish and Wildlife's (DFW) fyke traps used for sampling sturgeon and Striped Bass in the Sacramento River. The fyke trap is operated up to seven days a week during the months of October-June (Figure 2). The trap is located three-quarters of a mile below Lisbon Weir and thirteen miles north of the terminus of the Toe Drain (Figure 1).

Additionally, starting in 1999, we have conducted a survey for the general composition and timing of larval fishes in the Toe Drain, with a comparison site in the mainstem Sacramento River at Sherwood Harbor (SHR). During the months of January-June, sampling is conducted by towing a 4-meter long 500-micron mesh net with a 0.65 meters diameter opening for 10 minutes. Samples are taken biweekly under normal conditions and weekly during inundation periods.

To provide data on ambient water quality conditions, field crews concurrently collected data on several water quality parameters during all sampling, including water temperature, electrical conductivity, dissolved oxygen, pH, turbidity, and secchi depth. Data loggers also recorded water temperature at 15-minute intervals at the rotary screw trap (January-June only) and Lisbon Weir (year-round) in the Toe Drain, and for comparison purposes, in the Sacramento River at Sherwood Harbor (year-round). In addition, to monitor lower trophic parameters in the Yolo Bypass, chlorophyll-a grab samples (to estimate phytoplankton biomass), zooplankton, and drift invertebrate samples are collected on a bi-weekly basis (weekly during inundation) at the rotary screw trap site with paired sampling at Sherwood Harbor on the Sacramento River.

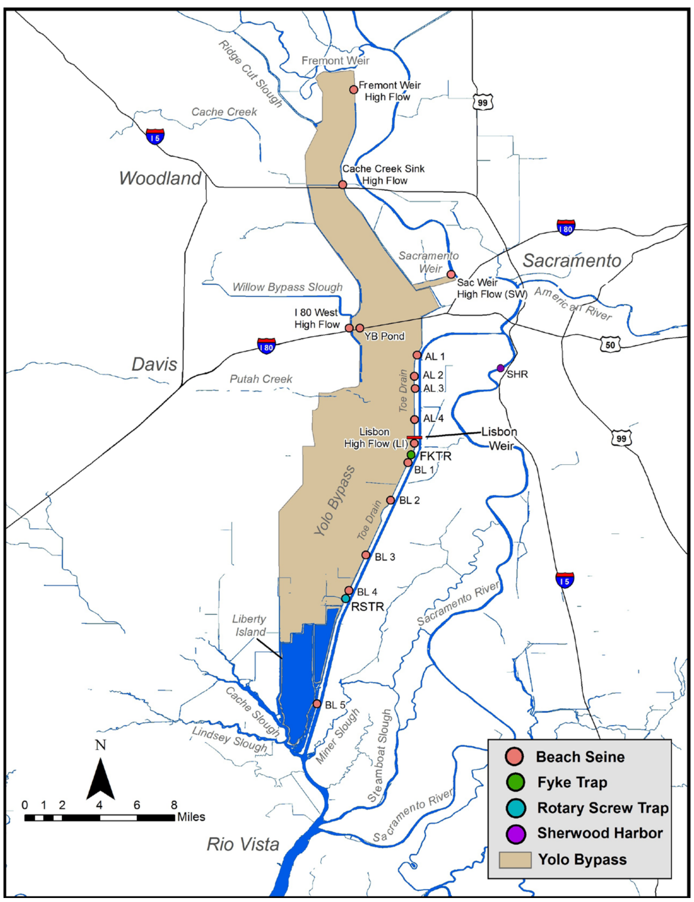

Figure 1 Map of Yolo Bypass.

Metric multidimensional scaling

Because continuous biweekly beach seine survey at Yolo Bypass has been ongoing since 2011, we had sufficient data to evaluate how community composition has varied among sites across the four years of sampling. We calculated the mean catch per cubic meter (m^3) of the most common 24 species in our beach seine survey (Table 1) for each site between the months of March and June of each year, and summarized their similarities by using metric multidimensional scaling (mMDS). The period between March and June was chosen because juvenile fish abundance in the Sacramento-San Joaquin Delta seems to be the highest during these months (Feyrer and Healey 2003; Grimaldo et al. 2004) and our beach seine catch data for the fall and winter months tend to not vary by much year to year. To downweight the effect of a single dominant species, we applied square-root transformation on the catch data. A similarity matrix was constructed using the Bray-Curtis similarity index, and an mMDS plot was built with a non-zero Shepard diagram intercept allowed in Primer 7 (Clarke et al. 2015). We calculated the Pearson correlations between the square-root transformed data and the mMDS axes, and vectors for species with

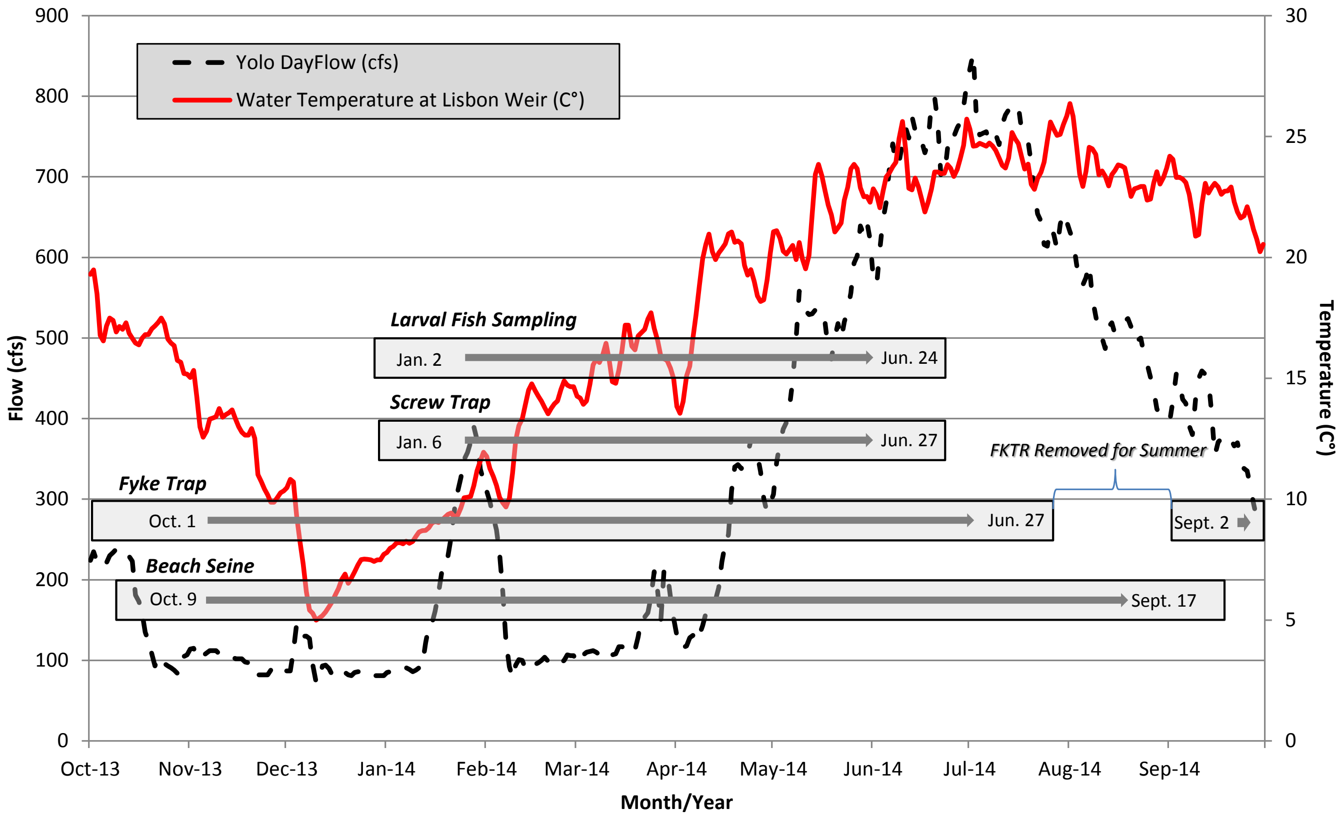

Figure 2 Fishing effort for every gear type summarized against average daily flow (source: Yolo Dayflow) and water temperature.

Pearson correlation at > 0.6 were subsequently plotted on the mMDS to show the directionality and relative influence of these select species.

Results and Discussion

Drought Effects

The water year 2014 constituted the second consecutive critically dry water year in the Sacramento Valley (based on the Sacramento Valley 40-30-30 water year index) (California Data Exchange Center 2015). Long periods of low precipitation have reduced flows and floodplain habitat availability, altering the water quality conditions and fish species assemblage. Drought conditions also promoted higher levels of floating aquatic vegetation in the Toe Drain. During parts of the water year, high densities of floating, matted Water Hyacinth (*Eichhomia crassipes*) covered up entire portions of the Toe Drain above and below Lisbon Weir. In addition, increased densities of Water Primrose (*Ludwigia* spp.) resulted in the partial blockage of some beach seine sites above Lisbon Weir and in the perennial pond site. Occasionally, this aquatic vegetation reduced the overall efficiency of our fish sampling (e.g., restricting the ability of the rotary screw trap to turn, reducing length of our beach seine sampling, etc.). Most significantly, it prevented us from sampling the BL5 beach seine site entirely (Figure 1) for most of the 2014 water year. High concentrations of Water Hyacinth have also precluded beach seine sampling at BL5 since August 2013, with respite only during March and April of 2014.

Hydrology

The Sacramento Valley experienced a critically dry water year in 2014 (California Data Exchange Center 2015). Based on the Dayflow estimates (QYOLO; Department of Water Resources 2014), the Yolo Bypass average daily flow in water year 2014 was exceptionally low at 327 cubic feet per second (cfs) with a peak at 854 cfs (July 14th) and a low of 73 cfs (December 10th).

Table 1 Species catch summarized by gear type for water year 2014. Sorted by descending order of abundance. An asterisk indicates that the species was used for the beach seine survey mMDS analysis.

Species	*Screw Trap*	*Fyke Trap*	*Beach Seine*	*Total Catch*
Mississippi Silverside*	3,264 (12.93%)	0	4,123 (29.28%)	7,387
Western Mosquitofish*	23 (0.09%)	0	2,941 (20.89%)	2,964
Threadfin Shad*	686 (2.72%)	59 (6.43%)	1,264 (8.98%)	2,009
American Shad	1,320 (5.23%)	50 (5.45%)	1 (0.01%)	1,371
Bluegill*	0	14 (1.53%)	1,112 (7.90%)	1,126
Bigscale Logperch*	0	0	929 (6.60%)	929
Striped Bass*	685 (2.71%)	94 (10.24%)	54 (0.38%)	833
Chinook Salmon*	403 (1.60%)	17 (1.85%)	38 (0.27%)	458
Black Crappie*	8 (0.03%)	150 (16.34%)	215 (1.53%)	373
White Catfish	100 (0.40%)	267 (29.08%)	1 (0.01%)	368
Largemouth Bass*	3 (0.01%)	8 (0.87%)	252 (1.79%)	263
Shimofuri Goby*	24 (0.10%)	0	124 (0.88%)	148
Sacramento Splittail*	45 (0.18%)	73 (7.95%)	15 (0.11%)	133
Redear Sunfish*	0	1 (0.11%)	84 (0.60%)	85
Prickly Sculpin*	2 (0.01%)	0	79 (0.56%)	81
Channel Catfish	7 (0.03%)	59 (6.43%)	6 (0.04%)	72
Common Carp*	1 (0.00%)	51 (5.56%)	14 (0.10%)	66
Delta Smelt*	61 (0.24%)	0	0	61
White Crappie	0	24 (2.61%)	36 (0.26%)	60
Yellowfin Goby*	19 (0.08%)	0	36 (0.26%)	55
Fathead Minnow*	0	0	44 (0.31%)	44
White Sturgeon	0	26 (2.83%)	0	26
Tule Perch*	3 (0.01%)	0	18 (0.13%)	21
Warmouth*	0	0	21 (0.15%)	21
Black Bullhead	1 (0.00%)	6 (0.65%)	13 (0.09%)	20
Sacramento Blackfish*	0	8 (0.87%)	12 (0.09%)	20
Threespine Stickleback	19 (0.08%)	0	0	19
Golden Shiner*	3 (0.01%)	1 (0.11%)	12 (0.09%)	16
Sacramento Sucker*	0	7 (0.76%)	8 (0.06%)	15
Green Sunfish*	0	0	11 (0.08%)	11
Goldfish	0	2 (0.22%)	2 (0.01%)	4
Hitch	0	0	2 (0.01%)	2
Sacramento Pikeminnow*	0	1 (0.11%)	1 (0.01%)	2
Longfin Smelt	1 (0.00%)	0	0	1
Wakasagi	1 (0.00%)	0	0	1
Grand Total	21501	1,908	22,310	45,719

In comparison, the previous dry water year of 2013 had over twice the average daily flow at 698 cfs. This flow also constitutes the lowest average daily flow in the Yolo Bypass since the monitoring program's inception in 1998. Fremont Weir did not overtop in 2014. The Sacramento River reached a maximum stage of 24.06 feet on March 6th, and Fremont Weir overtops at 33.5 feet (California Data Exchange Center 2015). The maximum stage at Lisbon Weir for water year 2014 was 7.27 feet on July 11th, which means the Toe Drain overbanked at some point in 2014, as the Toe Drain generally begins to overbank when water level at Lisbon Weir goes over 7.16 feet. The lowest measured stage at Lisbon Weir in water year 2014 was 1.59 feet, which occurred on May 12th.

Water Quality

Water Temperature

The extreme hydrologic variability of the Yolo Bypass, along with its susceptibility for floodplain inundation, can cause significant differences in water temperature when compared with the Sacramento River. When the entire Yolo Bypass is inundated, the wetted area of the Sacramento-San Joaquin Delta is doubled (Sommer et al. 2001a), and this floodplain consists of mainly shallow water habitat (< 2 m) with vegetated substrate (Sommer et al. 2004a). The inundation timing and duration in the Yolo Bypass varies annually, but with longer hydraulic residence times the increased surface area of the floodplain habitat allows for warmer water temperatures to persist (Sommer et al. 2004b).

In water year 2014, water temperature in the Sacramento River at Sherwood Harbor and the Yolo Bypass at Lisbon Weir followed typical seasonal trends, with the highest temperatures occurring in the summer and the lowest temperatures in the late fall and winter (Table 2). Despite the ongoing extreme drought, average water temperatures in the Yolo Bypass were not notably high compared with the previous year. However, as is seen in most years, the Yolo

Bypass experienced greater variation in maximum and minimum water temperatures compared with the adjacent Sacramento River. This higher variation in temperature can be attributed to: (1) the presence of shallow inundated floodplain, (2) lower average velocity, and (3) shallower and narrower channel composition of the Toe Drain relative to the Sacramento River. Click to View Table 2

Click to view Table 2 Statistical summary of Yolo Bypass and Sacramento River at Sherwood Harbor water temperature, conductivity, and secchi depth.

Conductivity

Variations in salinity can strongly affect the geographic distribution of several listed and non-listed fishes of the San Francisco Estuary (Bulgar et al. 1993; Nobriga et al. 2008). Conductivity is used as a surrogate measurement for the seasonal variation in salinity for the Yolo Bypass Toe Drain and Sacramento River. Conductivity measurements were highly variable year-round in the Yolo Bypass as compared with the Sacramento River, with measurements peaking primarily in the spring months (Table 2). The lowest conductance values occurred in the Toe Drain during the summer months in water year 2014, which was in contrast to water year 2013 when the lowest values were recorded in winter months. On average, the Toe Drain had a lower conductivity in water year 2014 in comparison to water year 2013 (Ikemiyagi et al. 2014). The greater variation in conductance values observed annually in the Toe Drain as compared with the Sacramento River is likely due to the influence of local tributaries and various agricultural practices, including early summer and fall rice field drainage (Sommer et al. 2004a; Schemel et al. 2004).

Turbidity and Secchi Depth

Turbidity was recorded bi-weekly at the fyke trap site in the Toe Drain and in the Sacramento River at Sherwood Harbor year-round in 2014. The annual average water clarity (turbidity, secchi depth) in the Toe Drain (54.49 NTU, 0.22 m) was significantly more turbid (paired t-test, $P < 0.001$) than the Sacramento River (8.87 NTU, 1.15m) (Table 2). Higher turbidity is typical of a seasonally dynamic and abiotically-driven environment such as the Yolo Bypass (Nobriga et al. 2005). The seasonal hydrologic variability of the Yolo Bypass can cause increased turbidity through increased suspended particle concentrations and higher fluctuating temperatures that can increase algal biomass (Sommer et al. 2004a). Lower water clarity has been shown to be beneficial to key fish species in the Delta such as the Delta Smelt (Nobriga 2008; Sommer and Meija 2013), and this increased turbidity further highlights the importance of Yolo Bypass as a habitat for these native species.

Fish

Thirty-five fish species were sampled during the course of fish sampling activities in water year 2014; 12 of which were native to the San Francisco Estuary region (Table 1). The total fish catch from the Yolo Bypass was dominated by the non-native Mississippi Silversides (*Menidia audens*), with 7,387 fish (16.1 % of total) sampled throughout the water year. The high catch of Mississippi Silversides in the Yolo Bypass followed previously observed trends, as they have become one of the most abundant fishes in the shallow-water habitats throughout the estuary (Moyle 2002). In addition, the high catch of Mississippi Silversides in the beach seine in 2014 (Table 1) was consistent with high CPUEs previously observed for this species in the shallow perennial channels and ponds of the Yolo Bypass (Feyrer et al. 2004; Feyrer et al. 2006a; Nobriga et al. 2005, Ikemiyagi et al. 2014). In the water year 2014, we also continued to observe relatively high numbers of Delta Smelt and juvenile Chinook Salmon in our rotary screw trap catches relative to other years within our study period (1998-present). For further details regarding our increased Delta Smelt and juvenile Chinook Salmon catches in recent years, please refer to Mahardja et al. (2015) and Goertler et al. (2015) respectively.

Fish Egg and Larval sampling

In 2014, we primarily observed Threadfin Shad (*Dorosoma petenense*), Prickly Sculpin (*Cottus asper*), and *Tridentiger* spp. in our fish egg and larval sampling at the Toe Drain, with these three species categories forming 93.9 % of our annual total catch (Table 3). The high numbers of Threadfin Shad and Prickly Sculpin is typical of most years (reflected in the total percentage of catch from 1999-2014, as shown in Table 3); however, the increased catch of *Tridentiger* spp. is fairly unusual relative to other years within the study period. Meanwhile, we observed only two species (Prickly Sculpin and Striped Bass) from our sampling effort at Sherwood Harbor at the Sacramento River (Table 3). Click to View Table 3

Click to view Table 3 Summary of 2014 and the last 15 years (1998-2014) Egg and Larval samples from the Yolo Bypass Toe Drain (STTD) and Sacramento River Sherwood Harbor (SHR).

Metric multidimensional scaling

Our two-dimensional mMDS plot of the four-year spring beach seine dataset (Figure 3) captured a reasonable amount of the spatiotemporal assemblage differences between sites (stress = 0.15). The sample spread on the first MDS axis (x-axis) suggested that the largest differences observed in the dataset were primarily driven by the inter-annual difference between the wet year of 2011 and the following drought years (2012-2014). The second MDS axis (y-axis) on the other hand, seemed to have captured most of the spatially driven, intra-annual differences between sites, with sites above Lisbon Weir clustering at the bottom of the plot and sites below Lisbon Weir generally at the top. Beach seine sites from the wet year of 2011 are characterized mostly by native species such as Sacramento Pikeminnow (*Ptychocheilus grandis*), Sacramento Splittail, and Chinook Salmon; while the three subsequent dry years seemed to be defined by higher numbers of Mississippi Silverside, Threadfin Shad, and Bigscale Logperch. Centrarchid species such as Largemouth Bass, Black Crappie, Bluegill, and Redear Sunfish appear to be associated with sites above Lisbon Weir regardless of water year types. In contrast, both Yellowfin and Shimofuri Gobies are associated with sites below Lisbon Weir, though this seems to be primarily true in dry years.

As previously mentioned, the spread of Water Hyacinth in 2014 prohibited us from sampling our southernmost beach seine site of BL5. This situation could potentially be a great loss of information for our program, as results from our mMDS suggested that sites below Lisbon Weir vary more from each other than those above Lisbon Weir and this appeared to be especially true for site BL5 (as indicated by the mMDS plot, BL5 fish

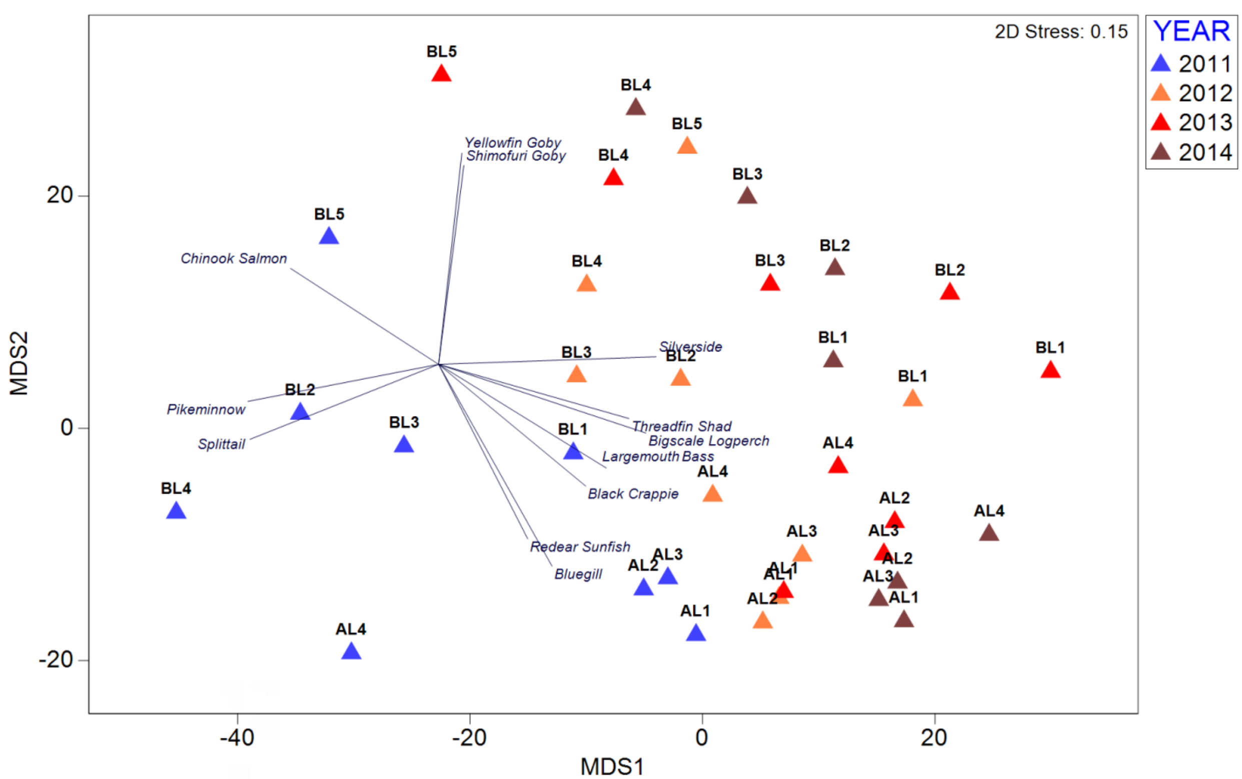

Figure 3 Metric multidimensional scaling plot of fish species assemblages based on square-root transformed catch per m³ numbers from March to June. Each point is labeled by their respective beach seine survey location and is color-coded by year. Square-root transformed species catch data with correlation of >0.6 are shown.

communities are highly variable and often quite distinct from other parts of the Toe Drain). To compensate for the loss of BL5 site from our continuous beach seine survey, we added an alternate site near BL5 in early 2015 as a replacement. We will evaluate how this new alternate site differs from our other permanent beach seine sites in future annual reports.

Ongoing and Future Work

There are currently several ongoing and future studies involving the Yolo Bypass and the YBFMP. A study of juvenile Chinook Salmon was initiated in 2012 to examine their growth, migration patterns, and diet within the Yolo Bypass. In 2013, DWR initiated a research project to investigate the relationship between the summer and fall phytoplankton production in the Toe Drain of the Yolo Bypass and the timing of downstream export. Lastly, a study to better understand the habitat use of Delta Smelt by using a combination of otolith and genetic data is also under way.

Acknowledgements

The Yolo Bypass Fisheries Program would not be possible without the support and funding from IEP. We owe a particular thanks to all the field assistance by AES staff: Lynn Takata, Pascale Goertler, Haley Carlson, Jasmine Shen, Angie Munguia, Mollie Ogaz, and a special thanks to Ted Sommer for all his scientific research in the Yolo Bypass.

References

Bulgar AJ, Hayden BP, Monaco ME, Nelson DM, and McCormick-Ray MG. 1993. "Biologically-based estuarine salinity zones derived from a multivariate analysis." Estuaries 16:311-322.

Clarke KR, Gorley RN, Somerfield PJ, and Warwick RM. 2015. *PRIMER v7: User Manual/Tutorial*. PRIMER-E, Plymouth.

DWR. 2014. *Dayflow: An Estimate of Daily Average Delta Outflow.* Data Downloaded July 17, 2015. http://www.water.ca.gov/dayflow/output/Output.cfm.

Dege M and Brown LR. 2004. "Effects of outflow on spring and summertime distribution and abundance of larval and juvenile fishes in the upper San Francisco estuary." Feyrer F, Brown LR, Brown RL, Orsi JJ, editors. In: Early Life History of Fishes in the San Francisco Estuary and Estuary and Watershed. Bethesda (MD): American Fisheries Society Symposium 39. P 49-66.

DuBois J and Gingras M. 2007-2012. *Sturgeon Fishing Report Card: Preliminary Data Report*. California Department of Fish and Game.

Feyrer F and Healey MP. 2003. "Fish community structure and environmental correlates in the highly altered southern Sacramento-San Joaquin Delta." Environmental Biology of Fishes. 66: 123-132.

Feyrer F, Sommer TR, Zeug SC, O'Leary G, and Harrell W. 2004. "Fish assemblages of perennial floodplain ponds of the Sacramento River, California (USA), with implications for the conservation of native fishes." Fisheries Management and Ecology 11:335-344.

Feyrer F, Sommer T, and Harrell W. 2006a. "Importance of flood dynamics versus intrinsic physical habitat in structuring fish communities: evidence from two adjacent engineered floodplains on the Sacramento River, California." North American Journal of Fisheries Management 26:408-417.

Feyrer F, Sommer T, and Harrell W. 2006b. "Managing floodplain inundation for native fish: production dynamics of age-0 splittail in California's Yolo Bypass." Hydrobiology 573:213-226.

Frantzich J, Ikemiyagi N, and Conrad J. 2013. "2010-2011 Yolo Bypass Fisheries Monitoring Status and Trends Report." IEP Newsletter Volume 26, Number 1.

Frantzich J, and Sommer T. 2015. "Yolo Bypass as a Fall Food Web Subsidy for the Lower Estuary." IEP Newsletter Volume 28, Number 1.

Goertler P, Frantzich J, Schreier B, and Sommer T. 2015. "Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) occupy the Yolo Bypass in relatively high numbers during an extreme drought." IEP Newsletter Volume 28, Number 1.

Grimaldo LF, Miller RE, Peregrin CM, and Hymanson ZP. 2004. "Spatial and temporal distribution of native and alien ichthyoplankton in three habitat types of the Sacramento-San Joaquin Delta." American Fisheries Society Symposium. 39: 81-96.

Grimaldo LF, Sommer T, Van Ark N, Jones G, Holland E, Moyle PB, Smith P, Herbold B. 2009. "Factors affecting fish entrainment into massive water diversions in a freshwater tidal estuary: Can fish losses be managed?" North American Journal of Fisheries Management 29:1253-1270.

Harrell WC and Sommer TR. 2003. "Patterns of Adult Fish Use on California's Yolo Bypass Floodplain." Faber PM, editor. Pages 88-93 in: California riparian systems: Processes and floodplain management, ecology, and restoration. 2001 Riparian Habitat and Floodplains Conference Proceedings, Riparian Habitat Joint Venture, Sacramento, California.

Ikemiyagi N, Carlson H, Frantzich J, and Schreier B. 2014. "2012-2013 Yolo Bypass Fisheries Monitoring Status and Trends Report." IEP Newsletter Volume 27, Number 1.

Jassby AD and Cloern JE. 2000. "Organic matter sources and rehabilitation of the Sacramento-San Joaquin Delta

(California, USA).” Aquatic Conservation: Marine and Freshwater Ecosystems 10:323-352.
Jassby AD, Cloern JE, and Cole BE. 2002. “Annual primary production: Patterns and mechanisms of change in a nutrient-rich tidal ecosystem.” Limnology Oceanography. 47: 698-712.
Junk WJ, Bayley PB, and Sparks RE. 1989. “The flood pulse concept in river-floodplain systems.” Canadian Special Publication of Fisheries and Aquatic Sciences 106:110-127.
Kohlhorst DW. 1976. “Sturgeon spawning in the Sacramento River in 1973, as determined by distribution of larvae.” California Fish and Game 62:32-40.
Kohlhorst DW. Botsford LW, Brennan JS, and Cailliet GM. 1991. “Aspects of the structure and dynamics of an exploited central California population of white sturgeon (*Acipenser transmontanus*).” Pages 277-293 P. Williot, editor. In: Acipenser: Actes du premier colloque international sur l’esturgeon. CEMAGREF, Bordeaux, France.
Lehman PW, Sommer T, and Rivard L. 2007. “The influence of floodplain habitat on the quantity and quality of riverine phytoplankton carbon produced during the flood season in San Francisco Estuary.” Aquatic Ecology 42:363-378.
Mahardja B, Ikemiyagi N, and Schreier B. 2015. “Evidence for increased utilization of the Yolo Bypass by Delta Smelt.” IEP Newsletter Volume 28, Number 1.
Merz JE, Hamilton S, Bergman PS, Cavallo B. 2011. “Spatial perspective for Delta smelt; a summary of contemporary survey data.” California Fish and Game 97(4):164-189.
Miller LW. 1972. “Migrations of sturgeon tagged in the Sacramento-San Joaquin Estuary.” California Fish and Game 58(2): 102-106.
Montages DJS and Franklin DJ. 2001. “Effect of temperature on diatom volume, growth rate, and carbon and nitrogen content: reconsidering some paradigms.” Limnology and Oceanography 46:2008-2018.
Moyle PB. 2002. “Inland fishes of California: revised and expanded.” The University of California Press, Berkeley.
Mueller-Solger AB, Jassby AD, and Mueller-Navarra DC. 2002. “Nutritional quality for zooplankton (*Daphnia*) in a tidal freshwater system (Sacramento-San Joaquin River Delta, USA).” Limnology and Oceanography 47(5):1468-1476.
Nobriga M. 2002. “Larval delta smelt composition and feeding evidence: environmental and ontogenetic influences.” California Fish and Game 88:149-164
Nobriga M, Feyrer F, Baxter R, and Chotkowski M. 2005. “Fish community ecology in an altered river delta: spatial patterns in species composition, life history strategies, and biomass.” Estuaries 28:776-785.
Nobriga M, Sommer T, Feyrer F, and Fleming K. 2008. “Long-term trends in summertime habitat suitability for delta smelt, *Hypomesus transpacificus*.” San Francisco Estuary and Watershed Science. Vol. 6, Issue 1 (February), Article 1.
Ribeiro F, Crain PK, and Moyle PB. 2004. “Variation in condition factor and growth in young-of year fishes in floodplain and riverine habitats of the Consumnes River, California.” Hydrobiologia 527: 77-84.
Schafter RG. 1997. “White sturgeon spawning migrations and location of spawning habitat in the Sacramento River, California.” California Fish and Game 83:1-20
Schemel LE, Sommer TR, Muller-Solger AB, and Harrell WC. 2004. “Hydrologic variability, water chemistry, and phytoplankton biomass in a large floodplain of the Sacramento River, CA, USA.” Hydrobiologia 513:129-139.
Sommer T, Baxter R, and Herbold B. 1997. “The resilience of splittail in the Sacramento-San Joaquin Estuary.” Transactions of the American Fisheries Society 126: 961-976.
Sommer TR, Harrell WC, Nobriga M, Brown R, Moyle PB, Kimmerer WJ, and Schemel L. 2001a. “California’s Yolo Bypass: evidence that flood control can be compatible with fish, wetlands, wildlife and agriculture.” Fisheries 26(8):6-16.
TR Sommer, Nobriga ML, Harrell WC, Batham W, and Kimmerer WJ. 2001b. “Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth and survival.” Canadian Journal of Fisheries and Aquatic Sciences 58(2):325-333.
Sommer TR, Harrell WC, Mueller-Solger A, Tom B, and Kimmerer W. 2004a. “Effects of flow variation on channel and floodplain biota and habitats of the Sacramento River, California, USA.” Aquatic Conservation: Marine and Freshwater Ecosystems 14:247-261.
Sommer TR, Harrell WC, Kurth R, Feyrer F, Zeug SC, and O’Leary G. 2004b. “Ecological patterns of early life stages of fishes in a river-floodplain of the San Francisco Estuary.” Pages 111-123in F. Feyrer, L.R. Brown, R.L. Brown, and J.J. Orsi, editors. Early Life History of Fishes in the San Francisco Estuary and Watershed. American Fisheries Society, Symposium 39, Bethesda, Maryland.
Sommer T, Harrell W, and Nobriga M. 2005. “Habitat use and stranding risk of juvenile Chinook salmon on a seasonal floodplain.” North American Journal of Fisheries Management 25:1493-1504.
Sommer TR, Harrell WC, and Feyrer F. 2014. “Large-bodied fish migration and residency in a flood basin of the Sacramento River, California.” Ecology of Freshwater Fish 23:414-423.
Sommer T, Armor C, Baxter R, Breuer R, Brown L, Chotkowski M, Culberson S, Feyrer F, Gingras M, Herbold B, Kimmerer W, Mueller-Solger A, Nobriga M, and Souza K. 2007. “The collapse of pelagic fishes in the upper San Francisco Estuary.” Fisheries 32:270-277.
Sommer T, Baxter R, and Feyrer F. 2007. “Splittail revisited: how recent population trends and restoration activities led to the “delisting” of this native minnow.” Pages 25-38. Brouder MJ and Scheuer JA, editors. In: Status, distribution, and conservation of freshwater fishes of western North America. American Fisheries Society Symposium 53. Bethesda, Maryland.
Sommer T, Meija F, Nobriga M, Feyrer F, and Grimaldo L.

2011. "The spawning migration of Delta Smelt in the Upper San Francisco Estuary." San Francisco Estuary and Watershed Science [online serial] 9(2):article 2.
Sommer T and Meija F. 2013. "A place to call home: A Synthesis of Delta Smelt habitat in the Upper San Francisco Estuary." San Francisco Estuary and Watershed Science 11(2), 27 p.
Swanson C, Young PS, Cech JJ. 1998. "Swimming performance of delta smelt: maximum performance, and behavior kinematic limitations on swimming at submaximal velocities." Journal of Experimental Biology 201:333-345
Swanson C, Reid T, Young PS, Cech Jr., JJ. 2000. "Comparative environmental tolerances of threatened delta smelt (*Hypomesus transpacificus*) and introduced wakasagi (*H. nipponensis*) in an altered California estuary." Oecologia 123 (3):384-390
[SWRCB] State Water Resources Control Board. 1999. Water Rights Decision 1641 for the Sacramento-San Joaquin Delta and Suisun Marsh (Adopted December 29, 1999, Revised in Accordance with order WR2000-02 March 15, 2000). Sacramento, CA.
Thomas MJ. 2013. "Stranding of Spawning Run Green Sturgeon in the Sacramento River: Post-Rescue Movements and Potential Population-Level Effects." North American Journal of Fisheries Management 33:287-297.

Benthic Monitoring, 2014

Betsy Wells (DWR Bay-Delta Monitoring Section), Elizabeth.Wells@water.ca.gov

Introduction

The benthic monitoring component of the IEP's Environmental Monitoring Program (EMP) documents changes in the composition, abundance, density, and distribution of the macrobenthic biota of the upper San Francisco Estuary. Benthic species respond to changes in physical factors within the system such as freshwater inflows, salinity, and substrate composition. As a result, benthic community data can provide an indication of physical changes occurring within the estuary. Because operation of the State Water Project can impact the flow characteristics of the estuary and subsequently influence the density and distribution of benthic biota, benthic monitoring is an important component of the EMP. The benthic monitoring data are also used to detect and document the presence of species newly introduced into the upper estuary. This article summarizes characteristics of benthic communities at the EMP's monitoring sites in 2014, and places these results in the context of results from the previous decade.

Methods

Benthic monitoring was conducted monthly at 10 sampling sites distributed throughout several estuarine regions from San Pablo Bay upstream through the Sacramento-San Joaquin Delta (Figure 1). EMP staff collected five bottom grab samples at each station using a Ponar dredge with a sampling area of 0.052 m^2. Four replicate grab samples were used for benthic macrofauna analysis and the fifth sample was used for sediment analysis. Benthic macrofauna samples were analyzed by Hydrozoology, a private laboratory under contract with the Department of Water Resources. All organisms were identified to the lowest taxon possible and enumerated. Sediment composition analysis was conducted at the Department of Water Resources' Soils and Concrete Laboratory. Field collection methodology and laboratory analysis of benthic macroinvertebrates and sediment composition are described in detail in the benthic metadata found at: http://www.water.ca.gov/bdma/meta/benthic.cfm.

Prior to analysis, the counts per grab were standardized to individuals/m^2 for each species at each site and sample date. Species were then grouped into phyla, and total densities for individual phyla were then plotted month by month to depict seasonal patterns in benthic communities. Rare phyla (fewer than 20 total individuals seen in the entire year) were omitted from the plots.

The 2014 water year was designated as critically dry for both the Sacramento Valley and the San Joaquin Valley. The benthic communities at many of the monitoring sites in 2014 were expected to differ from the communities of the sites in wetter years such as 2006 and 2011, and to be similar to dry years such as 2013. Differences between 2014 and wetter years were expected both in species composition and in species abundances, particularly at sites in the low salinity zone where the regime switches from a freshwater regime to a more salt-tolerant one.

Results

Three new species were added to the benthic species list in 2014. A single specimen of a native polychaete worm, *Lumbrineris inflata*, was collected for the first time by the EMP benthic survey in February 2014 at station D41 in San Pablo Bay; it is known from San Francisco Bay and commonly found in full-strength seawater. A native isopod, *Uromunna ubiquita* (Order Isopoda, Family Munnidae), was collected for the first time by the EMP survey in August and November 2014 at D41, in counts of one or two at a time. Like *L. inflata*, *U. ubiquita* is known from San Francisco Bay surveys, but is usually found in full-strength seawater. An unidentified species of flatworm (Class Turbellaria, order and family unknown), was collected for the first time in EMP surveys in September 2014 at D28A; it was also found in October at C9 and in November at D28A again, with only a few in each sample.

Eleven phyla were represented in the benthic fauna collected in 2014: Cnidaria (jellyfish, corals, sea anemones, and hydrozoans), Platyhelminthes (flatworms), Nermertea (ribbon worms), Nematoda (roundworms), Annelida (segmented worms, leeches), Arthropoda (crabs, shrimp, insects, mites, amphipods, isopods), Mollusca (snails, univalve mollusks, bivalves), Phoronida (horseshoe worms), Chordata (tunicates and sea squirts), and Echinodermata (sea stars and urchins). Of these phyla, Annelida, Arthropoda, and Mollusca accounted for over 97% of all individuals collected in 2014.

Of the 187 benthic species collected in 2014, the ten most abundant represented 82% of all individuals collected throughout the year. These include four species of amphipod, an ostracod, two Asian clams, and three worms (Table 1). Refer to the Bay-Delta Monitoring and Analysis Section's Benthic BioGuide (http://www.water.ca.gov/bdma/BioGuide/BenthicBioGuide.cfm) or Fields and Messer (1999) for descriptions of the habitat requirements, physical attributes, and feeding methods of most of these 10 abundant species.

In the site descriptions that follow, many species densities are reported as the annual average densities of individuals per m^2, sometimes with a note on any moderately sized seasonal peaks. Some species, especially arthropods, display strongly marked seasonal variability with peak densities several times their annual averages; in these cases, we decided that reporting the timing and magnitude of the peaks was more informative than the annual averages for readers interested in how the sites varied throughout the year. Readers who wish to see the full dataset can access it at: http://www.water.ca.gov/bdma/meta/benthic/data.cfm.

Click to View Table 1

Click to view Table 1 Ten most abundant species collected by the benthic monitoring component of the EMP in 2014, as determined by total number of individuals collected.

North Delta (D24)

D24 is located on the Sacramento River, just south of the Rio Vista Bridge (Figure 1). The sediment at this station was almost entirely sand each month in 2014, and there were a total of 22 species in five phyla at D24. Mollusca was the most abundant phylum for

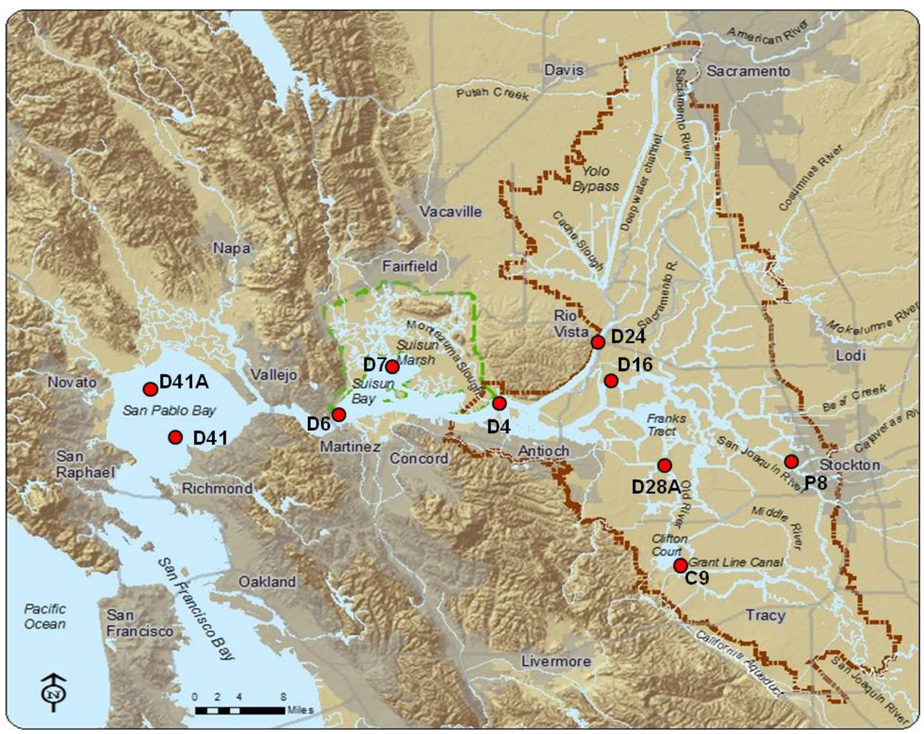

Figure 1 Locations of the Environmental Monitoring Program's (EMP) benthic monitoring stations.

much of the year (Figure 2), accounting for 69% of all individual organisms. Virtually all (99%) of the mollusks found at D24 in 2014 were *Corbicula fluminea*, with an average annual density of 1,305 individuals/m^2. *Gammarus daiberi* made up 93% of all arthropods at D24 in 2014, with an annual average density of 416/m^2. The oligochaete worm *Varichaetadrilus angustipenis* was the most abundant annelid, with a peak density of 284 individuals/m^2 in August, over five times the annual average density. The benthic community found at D24 in 2014 was similar to other dry years (2013, 2012, 2008), but was distinguished by having more *Gammarus daiberi* and *Corbicula fluminea*, and fewer *Americorophium stimpsoni*, than other years in the past decade.

Central Delta (D16, D28A)

The benthic monitoring program sampled at two stations in the central Delta. D16 is located in the lower San Joaquin River near Twitchell Island (Figure 1). In 2014, the substrate composition of D16 was mostly clay, with varying proportions of sand. There were a total of 28 species across four phyla at D16 in 2014. Arthropoda was the most abundant phylum, especially in March and April, and made up 48% of all organisms collected through the year (Figure 3). The most abundant arthropods at D16 in 2014 were *Gammarus daiberi* (peaking in March at 1,034 individuals/m^2, over five times its annual average density) and *Americorophium spinicorne* (with a peak in March of 606 individuals/m^2, almost six times its annual average). Mollusks made up 34% of all organisms collected and *Corbicula fluminea* was by far the most abundant, with a peak of 572 individuals/m^2 in March. D16 has been surprisingly stable for the last several years, and its community composition was not markedly different from other years in the past decade.

D28A is located in Old River near Rancho Del Rio (Figure 1). The substrate at this station generally consisted of a high percentage of fine sand with clay or silt, with some months containing large quantities of vegetable material. In 2014, there were 61 species in seven phyla at D28A, and the most abundant phyla were Arthropoda (55% of all individual organisms) and Annelida (40% of all individual organisms) (Figure 4). Of the abundant arthropods, *Cyprideis* species A had an annual average density of 3,417 individuals/m^2 with a peak in March-April, and *Gammarus daiberi* had an annual average density of 1,772/m^2 with peaks in April and July. The most abundant annelids were *Manayunkia speciosa*, which had an annual average density of 2,035/m^2 with

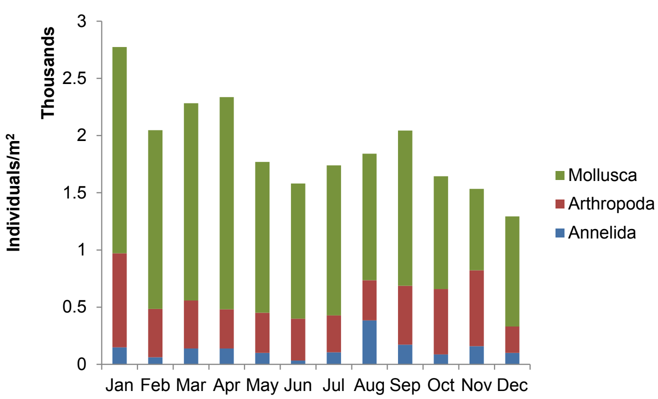

Figure 2 Density of benthic organisms, grouped by phyla, collected at station D24 (Sacramento River at Rio Vista) by month in 2014.

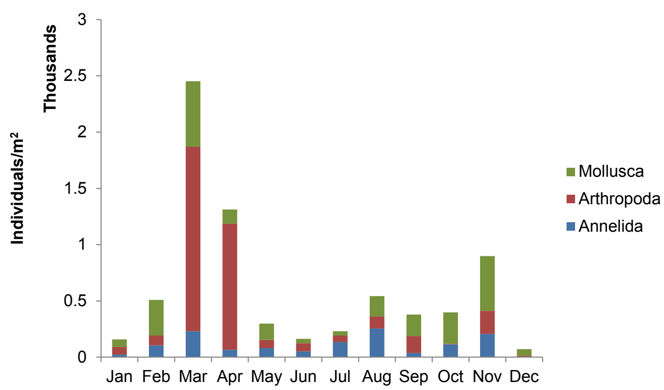

Figure 3 Density of benthic organisms, grouped by phyla, collected at station D16 (San Joaquin River at Twitchell Island) by month in 2014.

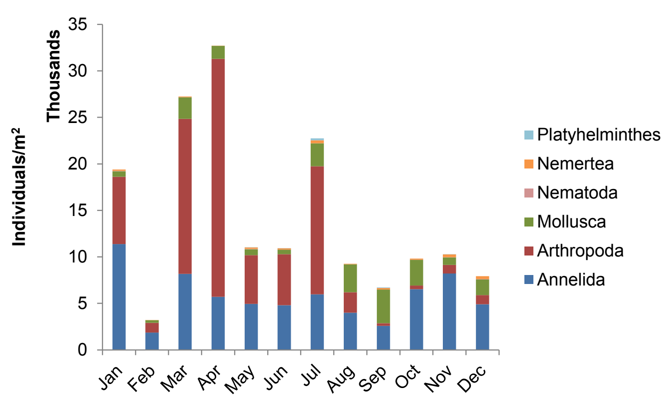

Figure 4 Density of benthic organisms, grouped by phyla, collected at station D28A (Old River) by month in 2014.

peaks in January and November, and *Varichaetadrilus angustipenis*, with an annual average density of 1,406 individuals/m^2 and a peak in October. The species composition at D28A in 2014 had more *Cyprideis* species A, *G. daiberi*, *Americorophium spinicorne*, and *M. speciosa* than in 2004 and 2012, which were the two years most different from 2014 in the past decade. There was no clear grouping of community composition at D28A according to wet or dry years.

South Delta (P8, C9)

The benthic monitoring program sampled at two stations in the southern Delta. P8 is located on the San Joaquin River at Buckley Cove (Figure 1). The substrate was generally made up of clay with some organic material. P8 had a total of 57 species in six phyla, and Annelida was the most abundant phyla at this station for almost all months in 2014, accounting for 71% of all organisms collected (Figure 5). The dominant annelid was *Manayunkia speciosa*, which made up 80% of all annelids in 2014 with a peak density of 36,375 individuals/m^2 in March, which was five times the annual average density and three orders of magnitude larger than its lowest density in June. Within the context of the last decade, the community in 2014 was most different from 2004 and 2005. Driving these differences were higher densities of many species in 2014, of which the most notable were *M. speciosa*, *Cyprideis species A*, the nematode *Dorylaimus species A*, and *Gammarus daiberi*; in contrast, 2014 saw lower levels of annelids *Varichaetadrilus angustipenis* and *Ilyodrilus frantzi*.

C9 is located at the Clifton Court Forebay intake (Figure 1). The substrate at this station was consistently a fairly even mix of sand and either clay or silt, with low levels of peat and organic matter. Data collection at C9 in November and December 2014 was prevented by overgrowth of water hyacinth (*Eichhornia crassipes*). There were 73 species in seven phyla at C9 in 2014. Annelida was the dominant phylum for January through October, accounting for 66% of all organisms collected in 2014 (Figure 6). The most abundant annelids were *Limnodrilus hoffmeisteri* (annual average of 2,258 individuals/m^2), *Aulodrilus pigueti* (annual average of 2,020/m^2 with a peak of 9,272/ m^2 in November), Manayunkia speciosa, (annual average of 2,009/m^2 with a peak in May), and *V. angustipenis* (annual average of 1,741/m^2). The most abundant arthropods were *A. spinicorne* (40% of all arthropods, peak density of 11,504/ m^2 in May), *Cyprideis* species A (peak density of 2,380/ m^2 in April) and *G. daiberi* (peak of 4,447/m^2 in October). Many of the dominant species in 2014 differed from the community composition of 2004-07, but did not appear to vary predictably with respect to wet or dry hydrologic conditions. In 2014, the community had more *Cyprideis* species A, *Limnodrilus hoffmeisteri*, *Pisidium compressa*, *V. angustipenis*, *M. speciosa*, and *A. pigueti*, and fewer *Ilyodrilus frantzi*, and *Corbicula fluminea*, than in 2004-07.

Confluence (D4)

D4 is located near the confluence of the Sacramento and San Joaquin rivers, just above Point Sacramento (Figure 1). In most months the sediment was mostly clay

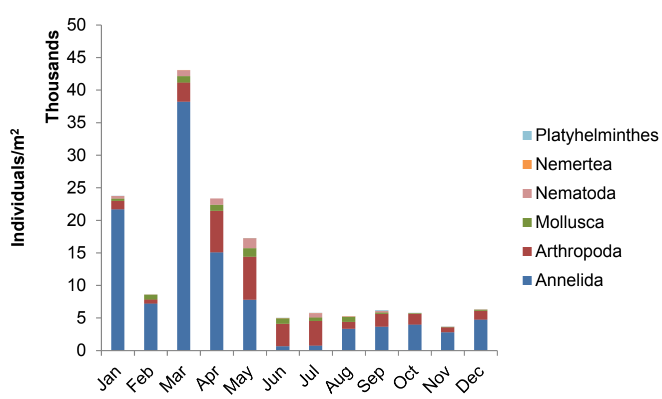

Figure 5 Density of benthic organisms, grouped by phyla, collected at station P8 (San Joaquin River at Buckley Cove) by month in 2014.

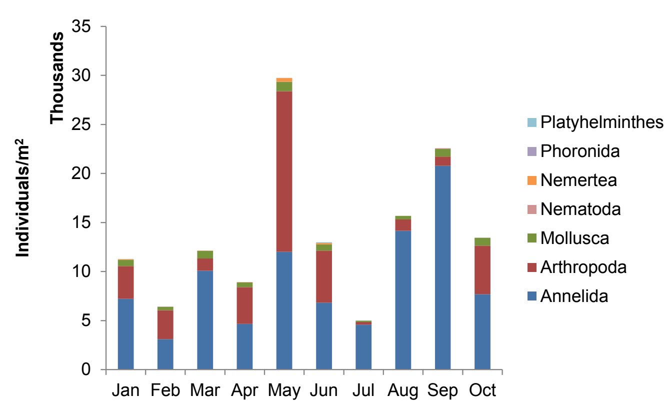

Figure 6 Density of benthic organisms, grouped by phyla, collected at station C9 (Clifton Court) by month in 2014.

or silt with a small proportion of sand, although a few months contained high levels of organic matter (peat), but there was not a clear seasonal trend. There were 44 species in six phyla at D4 in 2014. Annelida (55% of all individual organisms through the year) was the most abundant phylum in all months except February and March when Arthropoda (35% of all organisms through the year) was dominant (Figure 7). *Varichaetadrilus angustipenis* was the most abundant annelid (48% of all annelids, annual average density of 3,177 individuals/m^2) followed by *Limnodrilus hoffmeisteri* (annual average of 1,886/m^2). *Americorophium spinicorne* was the most abundant arthropod at this station in 2014 (average density of 2,020/m^2), with peak density in February and March. *Gammarus daiberi* was the next most abundant, with an annual average density of 1,115/m^2 and peaks in February and November (Figure 7). *Potamocorbula amurensis* made up 78% of all mollusks, with a peak density in August of 1,981/m^2 and an annual average density of 850/m^2. The community in 2014 had more *L. hoffmeisteri*, *Nippoleucon hinumensis*, *P. amurensis*, and *V. angustipenis*, and fewer *Americorophium stimpsoni*, *Mermithid* species A, and *G. daiberi* than in 2006 or 2007, which were the years that differed most from 2014.

Suisun Bay (D6 and D7)

The benthic monitoring program sampled at two stations in the Suisun Bay area. D6 is located in Suisun Bay near Martinez (Figure 1). The substrate at D6 was consistently made up of clay, with a small proportion of sand. Mollusca was by far the dominant phylum in all months at this station (Figure 8), accounting for 96% of all organisms collected. *Potamocorbula amurensis* made up 99.9% of all mollusks collected at D6 in 2014, and was present throughout the year with an annual average density of 9,581 individuals/m^2, with peaks in August and September. Most of the remaining organisms were various species of arthropods. D6 had 38 species in four phyla in 2014. There was a marked difference in the communities seen in wet and dry years, and 2006 (a wet year) was the most different year from 2014 (a critically dry year) in the past decade. Where 2014 had higher levels of *P. amurensis*, *Corophium alienense*, *Balanus improvisus*, *Pseudopolydora kempi*, and *Grandidierella japonica*, 2006 had more *Marenzelleria neglecta* and *Synidotea laevidorsalis.*

D7 is located in Grizzly Bay, near Suisun Slough (Figure 1). The substrate at D7 was uniformly clay or silt through 2013, and there were 34 species in four phyla in 2014 at D7. Mollusks (primarily *P. amurensis*) were the most abundant phylum for much of the year and made up 68% of all organisms in 2014 (Figure 9). *Potamocorbula amurensis* densities demonstrate typical recruitment peaks in spring, reaching a June maximum density of 27,880 /m^2 and comprising over 99% of all mollusks through the year. The amphipod *Corophium alienense* was the dominant arthropod at D7 in 2014, accounting for 89% of arthropods collected with an annual average of 4,976 individuals/m^2. There was a similar strong effect of wet and dry years at D7 as at D6; in 2014, there were higher levels of *P. amurensis*, *Nippoleucon hinumensis*, *Pseudopolydora kempi*, *Grandidierella japonica*, and *C. alienense* than in 2006.

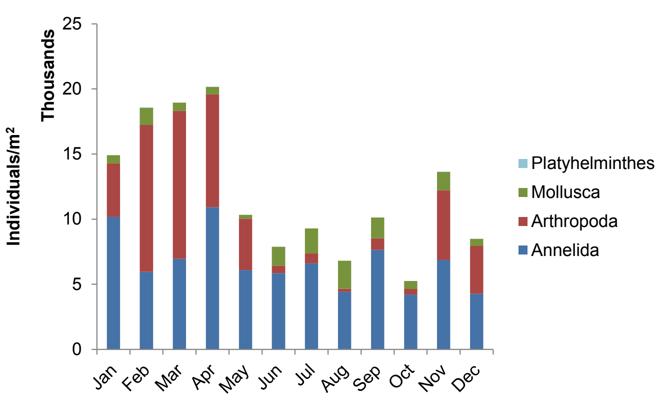

Figure 7 Density of benthic organisms, grouped by phyla, collected at station D4 (Confluence) by month in 2014.

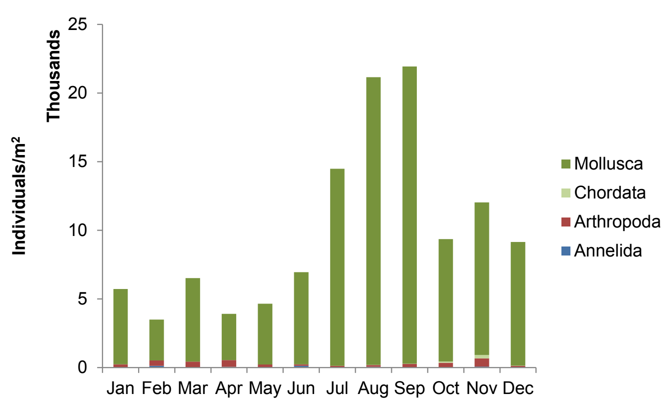

Figure 8 Density of benthic organisms, grouped by phyla, collected at station D6 (Suisun Bay) by month in 2014.

San Pablo Bay (D41, D41A)

The benthic monitoring program sampled at two stations in San Pablo Bay. D41 is located near Pinole Point (Figure 1) and has a benthic community primarily comprised of marine organisms, especially in dry water years. The substrate at this station was consistently silt or clay with varying proportions of sand and organic debris (primarily clamshells). There were 74 species in nine phyla at D41 in 2014, and Annelida and Phoronida were the most abundant phyla at D41 in 2014, each accounting for 29% of organisms collected (Figure 10). The sole species of phoronid, *Phoronopsis harmeri*, had a peak of 6,643 individuals/m^2 in October, which was nine times the annual average. The most common annelid was *Typosillis nipponica*, which had an average annual density of 247 individuals/m^2. The amphipod *Ampelisca abdita* was the most abundant arthropod (63% of all arthropods), with an abrupt peak in abundance of 2,759 individuals/m^2 in June, eight times the annual average. At D41, the critically dry year of 2014 was dramatically different from wet years in the past decade, such as 2006 and 2011. A number of brackish-water species seen in wet years, such as *Potamocorbula amurensis* and *Synidotea laevidorsalis*, were replaced in 2014 with more marine species such as *Typosillis nipponica*, *Theora lubrica*, *Harmothoe imbricata*, *Phoronopsis harmeri*, and *Diadumene* species A.

D41A is located near the mouth of the Petaluma River (Figure 1). The substrate of this station was primarily clay in all months. There were 54 species in six phyla at D41A in 2014, and the most abundant phylum in all months was Arthropoda, constituting 72% of all organisms (Figure 11). The dominant arthropod was *Ampelisca abdita*, which had an August peak of 7,274 individuals/m^2 and accounted for 75% of arthropods collected in 2014. Three other numerically dominant species had strong seasonal signals: the clam *Potamocorbula amurensis* (peak density in April of 4,154 /m^2, over ten times its annual average), the arthropod *Nippoleucon hinumensis* (peak density in February of 1,779/m^2, five times the annual average), and the arthropod *Corophium heteroceratum* (peak density in September of 1,120/m^2, six times the annual average). As at D41, the critically dry 2014 was very different from wet years such as 2006 and 2011. In 2014, the community had fewer brackish water species such as *P. amurensis* than in wet years, and more marine species such as *Theora lubrica* and *Phoronopsis harmeri*, although not all species presence/absence or abundance patterns were perfectly explained by water year.

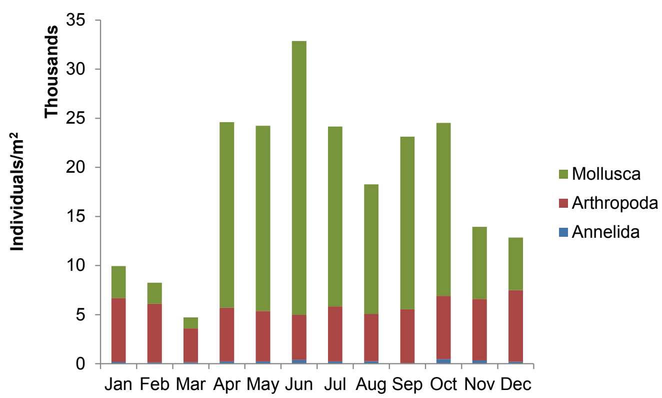

Figure 9 Density of benthic organisms, grouped by phyla, collected at station D7 (Grizzly Bay) by month in 2014.

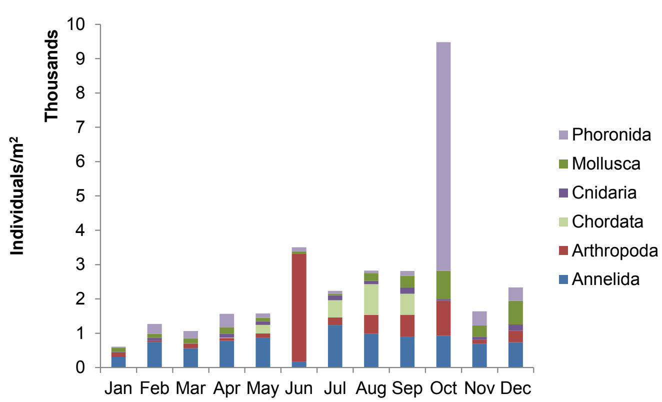

Figure 10 Density of benthic organisms, grouped by phyla, collected at station D41 (San Pablo Bay) by month in 2014.

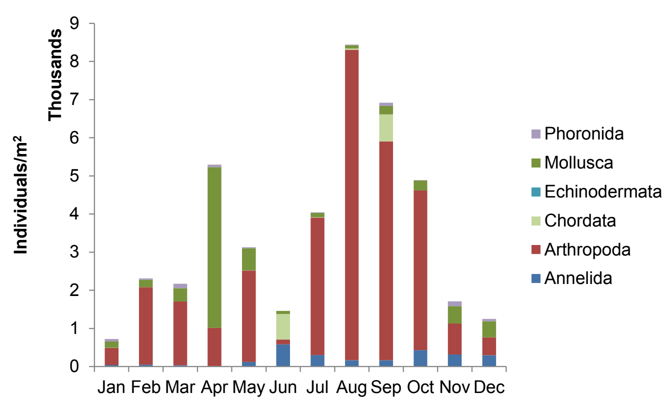

Figure 11 Density of benthic organisms, grouped by phyla, collected at station D41A (San Pablo Bay) by month in 2014.

References

Fields W and Messer C. 1999. "Life on the bottom: Trends in species composition of the IEP-DWR Benthic Monitoring Program." IEP Newsletter 12: 38-41.

Contributed Papers

Estimating Annual Abundance of White Sturgeon 85-116 and ≥ 169 Centimeters Total Length

Marty Gingras (DFW), marty.gingras@wildlife.ca.gov
Jason DuBois (DFW), jason.dubois@wildlife.ca.gov

Introduction

The annual abundance of San Francisco Estuary White Sturgeon less than 102 centimeters total length (cm TL) has not previously been estimated or indexed, because most research focus has been on harvestable fish and for many decades fishing has been prohibited on fish less than 102 centimeters total length. There is now emphasis on making those abundance estimates, because those are needed to simplify forecasts about reasonable expectations for the fishery (e.g., catch per unit effort; acceptable levels of harvest) and to allow a relatively simple assessment of Age-0 White Sturgeon abundance index accuracy. Although the abundance of White Sturgeon ≥ 169 cm TL — a demographic that has been protected by fishing regulations in full or part since the early 1990s — has been estimated using mark-recapture methods, precision of the estimates has been poor due to a paucity of marked fish and recaptured fish. To begin addressing these shortcomings, here we provide some abundance estimates for White Sturgeon 85-116 cm TL and ≥ 169 cm TL, and describe how we made those estimates using (1) estimated abundance of a third White Sturgeon demographic, (2) White Sturgeon lengths from catch in experimental trammel nets during the California Department of Fish and Wildlife (CDFW) White Sturgeon population study, and (3) White Sturgeon relative retention curves for those trammel nets.

Methods and Results

The primary challenge here is use of *catch length frequency distributions* from experimental trammel nets as proxies for *population length frequency distributions*. The issues are selectivity (i.e., one trammel catches fish better than another) and size-dependent availability of fish (i.e., given migratory and other behaviors, are lengths from the catch representative of the population). To begin addressing that challenge, we developed *modeled length frequency distributions* but we accounted only for selectivity.

The CDFW White Sturgeon population study deployed trammel net gangs composed of panels made from 8" stretched-mesh prior to 1990, but thereafter — laying the groundwork for an investigation into selectivity — the study deployed experimental trammel net gangs composed of panels made from 6", 7", and 8" stretched-mesh. Since 1990, the experimental trammel nets have been deployed weekdays in Suisun Bay and San Pablo Bay during either September-October (1990-1991, 1993-1994, 1997-1998, 2005) or August-October (2001-2002, 2006-2014). Length at recruitment to the experimental trammel nets increased with mesh size (Figure 1), which means information on differences in retention rates of the three mesh sizes would help with interpretation and use of the *catch length frequency distributions*.

We used R statistical and graphics software (R Core Team 2014, R version 3.1.1 2014-07-10) for the creation and assessment of relative retention curves (Figure 2) from CDFW White Sturgeon population study catch during 1990-1991, 1993-1994, 1997-1998, 2001-2002, 2005-2013. Models available to us were (1) "norm.loc," which is a normal curve where mean changes with the gear and standard deviation is constant for all gears, (2) "normal.sca," which is a normal curve where mean and standard deviation change with gear, (3) "lognorm," which is a lognormal curve, (4) "binorm.sca," which is the sum of two normals, and (5) "bilognormal," which is the sum of two lognormals.

We used only 2007-2012 length frequency distributions, because that is the longest uninterrupted time series and the findings speak directly to present harvest-management issues. To model 2007-2012 length frequency distributions that should more-closely approximate the *population length frequency distributions*, we used (1) the best-fitted (i.e., smallest model deviance) and most-plausible of the relative retention curves (Bi-Lognormal), and (2) 2007-2012 annual catch by the CDFW White Sturgeon population study.

As expected from relative retention curve shapes, the *modeled length frequency distributions* include a greater fraction of small fish than the corresponding *catch length frequency distributions* (Figure 3). Though not shown here, the *modeled length frequency distributions* also include many implausibly large variations below about 85 cm TL.

We estimated annual abundance of fish 85-116 cm TL and ≥ 169 cm TL (Figure 4) by using (1) estimates of 117-168 cm TL White Sturgeon abundance (as in DuBois and Gingras 2011) from reported harvest and estimated harvest rate (CDFW's "conventional algorithm") (Gingras and DuBois 2014) and (2) the *modeled length frequency distributions*. We constrained the abundance estimates to a minimum of 85 cm TL, because we believe variations in catch of fish less than 85 cm TL do not reliably reflect variations in abundance of that demographic.

Estimating annual abundance of fish 85-116 cm TL and of fish ≥ 169 cm TL is a multi-step process (Box 1). Catch per length is adjusted using relative retention values from the curve. Adjusted catch is then used to complete the final estimates. The abundance and variance calculations for 117-168 cm TL fish are not shown here, but use data from harvest (as reported on Sturgeon Fishing Report Cards) and harvest rate (as estimated from mark-recapture data). Because the algorithm used to estimate harvest rate is pretty-clearly biased low (Gingras and DuBois 2014), the abundance estimates presented here are all likely biased somewhat high.

Click to View Box 1

Click to view Box 1 Stepwise process for estimating annual abundance of White Sturgeon 85-116 cm TL and ≥ 169 cm TL.

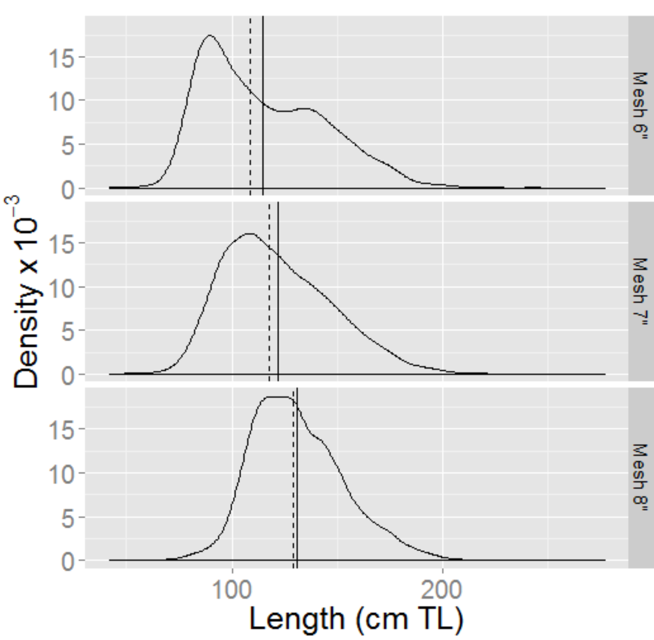

Figure 1 Density plot of White Sturgeon length (centimeters total length [cm TL]) by trammel net mesh size (6", 7", and 8"). Data from 1990-1991, 1993-1994, 1997-1998, 2001-2002, and 2005-2013. The solid vertical line is mean cm TL. The dashed vertical line is median cm TL.

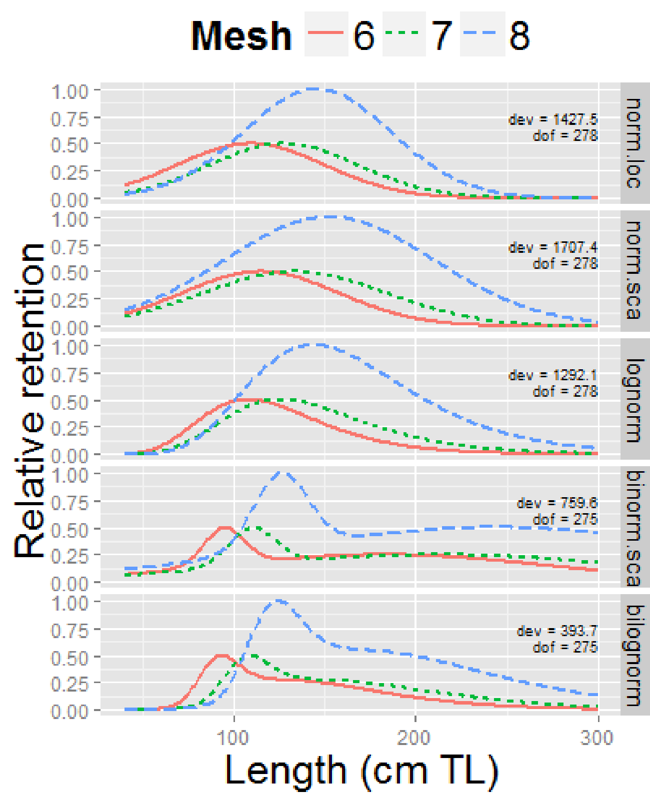

Figure 2 Relative retention curves for White Sturgeon in each trammel net mesh size (6", 7", and 8") for each of the five models over length range of 40-300 centimeters total length (cm TL). Model deviance (dev) and degrees of freedom (dof) displayed in the upper-right corner of each panel.

Discussion

When modeling length frequencies, we did not consider size-dependent availability of fish to the nets because — while recreational and research catch shows that fish in both demographics are ubiquitous in the study area — there are no quantitative distributions or behavior data to work with. Thus, these should be considered estimates of regional abundance that may index and approximate system-wide abundance.

As expected from indices of Age-0 White Sturgeon abundance (California Department of Fish and Wildlife 2014) and presumed growth rates, the trends in estimated 2007-2012 annual abundance of fish 85-116 cm TL reflect growth and protracted recruitment of the modest 2006 cohort to the experimental trammel nets and recruitment of scarcely detectable cohorts for several years prior to 2006. The 2006 cohort is recruiting to legally harvestable size such that catch rate in the fishery has likely begun to increase modestly, but will likely decline rapidly unless harvest is reduced and/or anglers become more efficient.

The estimated 2007-2012 annual abundance of White Sturgeon ≥ 169 cm TL is relatively low and constant, which is expected from the facts that (1) the White Sturgeon fishery has long been popular and is recently highly effective (Gingras and DuBois 2014), (2) these fish are typically from cohorts prior to 1993, (3) a maximum size limit on harvest was first implemented in 1990, and (4) 1984-1994 indices of Age-0 White Sturgeon abundance were negligible. It is particularly important to reliably estimate the abundance of this demographic, because it includes the preponderance of spawning females and — being protected from legal harvest — it is the "insurance policy" (e.g., against drought) for this population. In an effort to improve the rigor of abundance estimates for this demographic, we plan to work with statisticians in an attempt to incorporate adjustments for its migratory behavior.

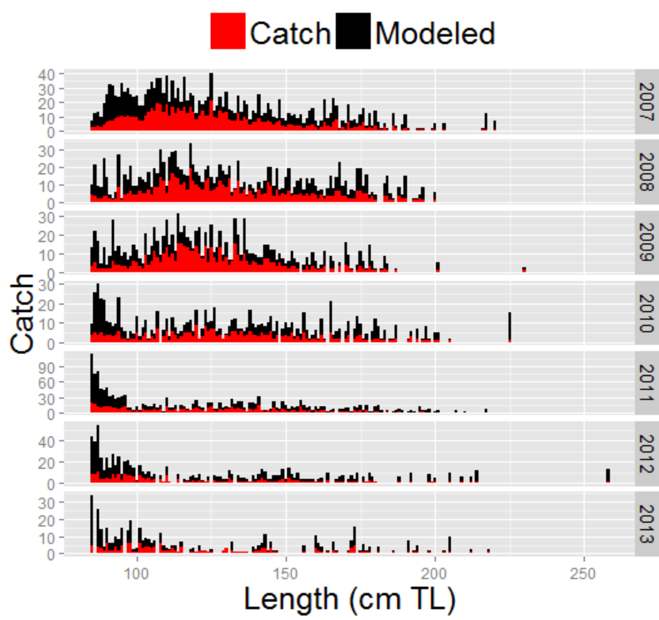

Figure 3 Frequency distributions of White Sturgeon lengths (centimeters total length [cm TL]; ≥ 85) for 2007-2013. Red bars represent catch. Black bars represent modeled (bi-log-normal) catch.

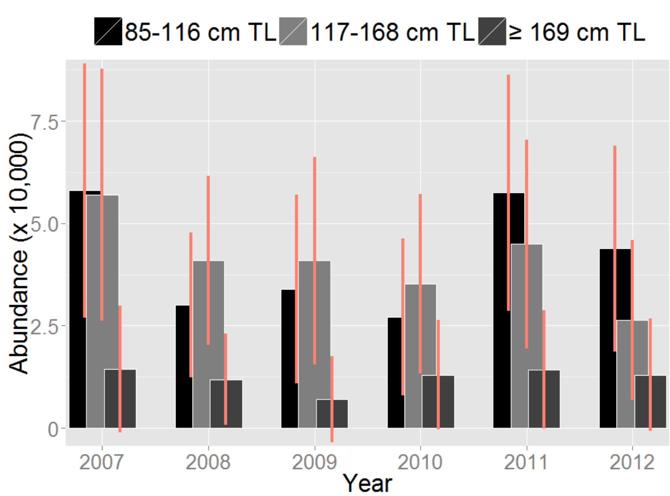

Figure 4 White Sturgeon abundance estimates with 95% confidence intervals for 2007-2012 by size category (85-116 cm TL, 117-168 cm TL, and ≥ 169 cm TL).

Acknowledgments

Russell Millar (https://www.stat.auckland.ac.nz/~millar/selectware/code.html) developed and made available the "R" code we used for the creation and assessment of relative retention curves. U.S. Fish and Wildlife Service statisticians Ken Newman and Lara Mitchell helped us tremendously by pointing us toward Russell Millar's work, coaching us on use of relative retention curves, and developing confidence intervals for these abundance estimates.

References

CDFW. 2014. Figure: Index of Annual Age-0 White Sturgeon Abundance, 1980-2014 https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentId=69133.

DuBois J and Gingras M. 2011. "Using Harvest Rate and Harvest to Estimate White Sturgeon Abundance." Interagency Ecological Program for the San Francisco Estuary Newsletter 24(3): 23-26.

Gingras M. and DuBois J. 2014. "Bias in Estimated Annual Harvest Rates for White Sturgeon of the San Francisco Estuary." Interagency Ecological Program for the San Francisco Estuary Newsletter 27(2): 43-46.

R Core Team (2014). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/.

Did you know that quarterly highlights about current IEP science can be found on the IEP webpage along with a new calendar that displays IEP Project Work Team and other IEP-related public meetings? To view these features see the links below:

http://www.water.ca.gov/iep/activities/calendar.cfm
http://www.water.ca.gov/iep/highlights/index.cfm

The IEP Newsletter is a quarterly publication that provides IEP program and science highlights as well as in-depth articles on important scientific topics for resource managers, scientists, and the public. The spring issue of the IEP Newsletter provides an annual overview of important results from all IEP monitoring programs and associated studies. Articles in the IEP newsletter are intended for rapid communication and do not undergo external peer review; all primary research results should be interpreted with caution.

If you would like to be notified about new issues of the quarterly IEP newsletter, please send an e-mail to Shaun Philippart (DWR), shaun.philippart@water.ca.gov, with the following information:

- Name
- Agency
- E-mail address

Article Submission Deadlines for Calendar Year 2016

Issue	*Article Submission Deadline*
Issue 1 (Winter)	January 15, 2016
Issue 2 (Spring)	April 15, 2016
Issue 3 (Summer)	July 15, 2016
Issue 4 (Fall)	October 15, 2016

Submit articles to Shaun Philippart.

■ Interagency Ecological Program for the San Francisco Estuary ■

IEP NEWSLETTER

3500 Industrial Blvd.
West Sacramento, CA 95691

For information about the Interagency Ecological Program, log on to our Web site at http://www.water.ca.gov/iep/. Readers are encouraged to submit brief articles or ideas for articles. Correspondence—including submissions for publication, requests for copies, and mailing list changes—should be addressed to Frank Keeley, California Department of Water Resources, P.O. Box 942836, Sacramento, CA, 94236-0001. Questions and submissions can also be sent by e-mail to: frank.keeley@water.ca.gov.

■ Interagency Ecological Program for the San Francisco Estuary ■

IEP NEWSLETTER

Louise Conrad, California Department of Water Resources, Lead Editor
Brian Schreier, California Department of Water Resources, Contributing Editor
Shaun Philippart, California Department of Water Resources, Managing Editor
Frank Keeley, California Department of Water Resources, Editor

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

California Department of Water Resources
State Water Resources Control Board
U.S. Bureau of Reclamation
U.S. Army Corps of Engineers

California Department of Fish and Wildlife
U.S. Fish and Wildlife Service
U.S. Geological Survey
U.S. Environmental Protection Agency
National Marine Fisheries Service