San Francisco Estuary & Watershed SCIENCE

Peer Reviewed

Title:

Long-Term Trends in Summertime Habitat Suitability for Delta Smelt (Hypomesus transpacificus)

Journal Issue:

San Francisco Estuary and Watershed Science, 6(1)

Author:

Nobriga, Matthew L., Sommer, Ted R., Feyrer, Frederick, Fleming, Kevin

Publication Date:

02-29-2008

Publication Info:

UC Davis, San Francisco Estuary and Watershed Science, John Muir Institute of the Environment

Permalink:

http://escholarship.org/uc/item/5xd3q8tx

Citation:

Nobriga, Matthew L., Sommer, Ted R., Feyrer, Frederick, & Fleming, Kevin. (2008). Long-Term Trends in Summertime Habitat Suitability for Delta Smelt (Hypomesus transpacificus). San Francisco Estuary and Watershed Science, 6(1), . Retrieved from: http://escholarship.org/uc/item/5xd3q8tx

Keywords:

delta smelt, Hypomesus transpacificus, estuarine habitat, water quality, specific conductance, water clarity, water temperature

Abstract:

<p>The biological productivity of river-dominated estuaries is affected strongly by variation in freshwater inflow, which affects nursery habitat quality. Previous research has shown this is generally true in the upper San Francisco Estuary, California, USA; however, one endemic species of high management importance, delta smelt (Hypomesus transpacificus), has shown ambiguous population responses to river inflow variation. We hypothesized that population-level associations with abiotic habitat metrics have not been apparent because the effects occur seasonally, and at spatial scales smaller than the entire upper San Francisco Estuary. We tested this hypothesis by applying regression techniques and principal components analysis (PCA) to a long-term data-set (1970–2004) of summertime fish catch, and concurrently measured water quality (specific conductance, Secchi disk depth, and water temperature). We found that all three water quality variables predicted delta smelt occurrence, and we identified three distinct geographic regions that had similar long-term trends in delta smelt capture probabilities. The primary habitat region was centered on the confluence of the Sacramento and San Joaquin

rivers; delta smelt relative abundance was typically highest in the Confluence region throughout the study period. There were two marginal habitat regions—including one centered on Suisun Bay—where specific conductance was highest and delta smelt relative abundance varied with specific conductance. The second marginal habitat region was centered on the San Joaquin River and southern Sacramento-San Joaquin Delta. The San Joaquin region had the warmest water temperatures and the highest water clarity, which increased strongly in this region during 1970–2004. In the San Joaquin region, where delta smelt relative abundance was correlated with water clarity, catches declined rapidly to zero from 1970–1978 and remained consistently near zero thereafter. However, when we combined these regional results into estuary-wide means, there were no significant relationships between any of the water quality variables and delta smelt relative abundance. Our findings support the hypothesis that basic water quality parameters are predictors of delta smelt relative abundance, but only at regional spatial scales.</p>

variable that changed significantly at either spatial scale.

Delta smelt relative abundance was typically highest in the Confluence region throughout the study period, though the 1982 step–change (Kimmerer 2002a) is a prominent feature of the Confluence trend (Figure 6). Another prominent trend was that in the San Joaquin region, delta smelt catches declined rapidly to zero from 1970–1978 and have remained consistently near zero ever since. In the Suisun region, there were two periods of increasing and decreasing relative abundance. Relative abundance was correlated with water clarity in each region (Suisun, Spearman ρ = -0.59; n = 32; P = 0.0004; Confluence, Spearman ρ = -0.51; n = 32; P = 0.003; San Joaquin, Spearman ρ = -0.65; n = 32; P = 0.00005). Relative abundance also varied in the Suisun region in association with specific conductance (Spearman ρ = -0.65; n = 32; P = 0.00005), but specific conductance was not correlated with abundance in the other regions (Confluence Spearman ρ = 0.26; n = 32; P = 0.15 and San Joaquin Spearman ρ = 0.094; n = 32; P = 0.61). At the scale of the entire upper estuary, the water quality variables were not correlated with juvenile delta smelt relative abundance indices calculated from the TNS (F = 2.19; P = 0.11; multiple R^2 = 0.10; n = 32; P-values for individual parameters of > 0.05).

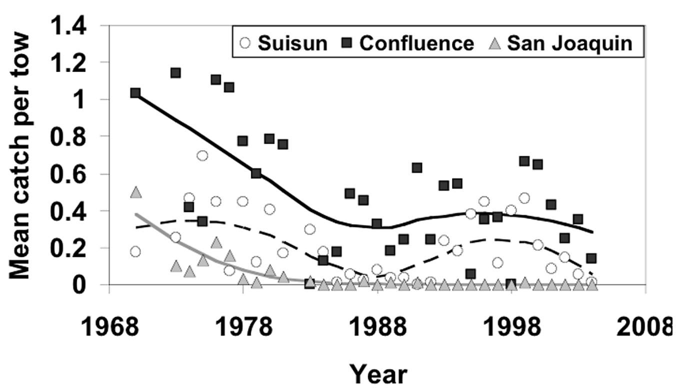

Figure 6. Time series of mean delta smelt catch · tow^{-1} (log_{10} + 1 transformed) in three regions defined by principal components analysis (see Figure 1). The splines are loess regression line.

DISCUSSION

We found that the three water quality variables—specific conductance (salinity), Secchi depth (clarity), and temperature—measured concurrently with fish catches in the CDFG TNS all interact to influence delta smelt occurrence (distribution) in the upper San Francisco Estuary. Thus, they are all indicators of abiotic habitat suitability. Long-term associations of water quality variation and relative abundance were discernable at regional spatial scales, most notably on the perimeter of the species' distribution outside of the Confluence region. Delta smelt relative abundance in the Suisun region varied in association with specific conductance, which is a function of river inflow variation. This is consistent with previous findings for larvae during spring–early summer (Dege et al. 2004) and juveniles and pre-spawning adults during fall (Feyrer et al. 2007). Note that Kimmerer (2002a) reported there was no long-term trend in mean January–June X_2 position. This reflects river inflow conditions during the six months preceding the data used in our study. Thus, it is not surprising that we found no long-term trend in July specific conductance. At the landward edge of the estuary, delta smelt have essentially disappeared during midsummer.

Of the three water quality variables, only water clarity had a long-term trend. Jassby et al. (2002) had reported previously that water clarity in the Sacramento-San Joaquin Delta had increased due to significant long-term reductions in total suspended solids during most months between March and November. Thus, we propose that increased San Joaquin region water clarity has constricted delta smelt habitat, and is a major reason for its regional absence during summer. The possibility of habitat constriction was proposed by Bennett (2005) who suggested it as a possible mechanism for apparent 'density–dependence' between the summer and fall based on stock-recruitment analyses of long-term monitoring data-sets.

Our conclusion that there has been a long-term habitat constriction for delta smelt is also consistent with Feyrer et al. (2007), who analyzed fall abundance data. Feyrer et al. (2007) were able to identify changes both regionally and at the scale of the entire upper estuary. They also found simple statistical associations between fall stock size, fall water quality, and abundance the following summer. We suggest that estuary-wide habitat changes are more apparent in fall than in summer because delta smelt habitat suitability progressively deteriorates over the course of the year. Adult and juvenile delta smelt use the San Joaquin region during winter through early summer, sometimes causing conflicts between water export schedules and Endangered Species Act–mandated take levels (Bennett 2005). Presumably, cooler water temperatures and lower water clarity during winter–spring flow pulses allow delta smelt to occupy the San Joaquin region early in the year. By July, the San Joaquin region is no longer suitable delta smelt habitat, and by fall, habitat suitability declines further due to a separate long-term trend toward elevated salinity in the Suisun region (Feyrer et al. 2007).

We acknowledge that the three water quality variables we analyzed cannot fully define abiotic habitat for delta smelt. For instance, estuarine fish distributions can be influenced by dissolved oxygen (Eby and Crowder 2002). Young delta smelt are also exposed to contaminants (Kuivila and Moon 2004), and some individuals show evidence of sublethal toxic exposure (Bennett 2005); the population-level consequences of contaminant exposures are unknown. However, each of the water quality variables we used has well-known effects on fish ecology. Water clarity strongly affects large river (Quist et al. 2004) and estuarine fish assemblages (Blaber and Blaber 1980). In the cited studies, water clarity was thought to mediate predator–prey interactions; there is experimental evidence for the role of turbidity as a factor influencing piscivore success (Abrahams and Kattenfeld 1997; Gregory and Levins 1998). We suggest that predation on delta smelt may be higher in relatively clear water, or that delta smelt may avoid clear water because it increases their predation risk.

The increased water transparency in the upper estuary appears to be due to the combined effects of decreasing sediment inputs (Wright and Schoellhamer 2004), sediment wash-out from very high inflows during the 1982–1983 El Nino (Jassby et al. 2005), and the proliferation of large beds of submerged freshwater macrophytes, particularly in the San Joaquin region (Nobriga et al. 2005; Brown and Michniuk 2007).These macrophyte beds may act as ‘biological filters’ for sediment. The invasion of aquatic macrophytes has already substantially changed near-shore fish assemblages. The results of the present study and of Feyrer et al. (2007) suggest the macrophyte proliferation may also have restricted pelagic fish distributions.

Specific conductance is a surrogate for salinity, which strongly affects estuarine fish distributions (Bulgar et al. 1993). The influence of salinity on the geographic distribution of young delta smelt has been noted previously (Moyle et al. 1992; Dege and Brown 2004). Swanson et al. (2000) found the upper salinity tolerance of delta smelt was about 19 psu. This corresponds well with the field data in this study; predicted capture probabilities were virtually zero at a specific conductance of 35,000 $\mu S \cdot cm^{-1}$, which roughly corresponds to 20 psu (Figure 4). Similarly, Feyrer et al. (2007) found that delta smelt capture probabilities during fall were essentially zero at specific conductances higher than 25,000 $\mu S \cdot cm^{-1}$ (about 15 psu). The results of the present study, and of Feyrer et al. (2007), provide idealized salinity response curves that bridge previous findings and show the interactive influence of other water quality variables on delta smelt distribution along the estuarine salinity gradient.

Water temperature is an important determinant of fish metabolic and growth rates, so it affects estuarine habitat suitability through a variety of mechanisms (Lankford and Targett 1994; Marine and Cech 2004). Water temperature was the poorest predictor of delta smelt distribution in the present study, accounting for only about 6% of the null deviance in delta smelt occurrence (Table 1). Water temperature also had no significant regional or estuary-wide effects on delta smelt relative abundance. We think the low predictive power of water temperature was due more to the shape of its response curve than to low ecological importance. Essentially, delta smelt occurrence and relative abundance responded to water temperature only when it neared or exceeded the 25°C lethal limit reported by Swanson et al. (2000). Currently, the upper San Francisco Estuary averages more than 20°C during mid-summer, and the San Joaquin region