Community Patterns and Environmental Associations for Fish-Dominated Assemblages in the Upper San Francisco Estuary

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INTRODUCTION - OBJECTIVES

Understanding how species are interrelated and respond to environmental and spatio-temporal variation are central ecological and management questions in the upper San Francisco Estuary (SFE). The California Department of Fish and Wildlife long-term monitoring survey, the Spring Kodiak Trawl (SKT) provides an extensive record of species and environmental data in the USFE (Figure 1).
We evaluated: 1) species composition and relative abundance, 2) association patterns for stations and species (H_0: No differences between groups of stations or species), and 3) community structure in relation to environmental and temporal-spatial variability.

Figure 1. Spring Kodiak trawl being towed (left) and retrieved (right).

METHODS

As sample units we used stations (n=39) and areas (n=10; Figure 1). We used available SKT surveys 1-5 conducted from January to May, 2002-2014 . Catch data was standardized to individuals per 10^4 m^3. We conducted Multi-response Permutation Procedures (MRPP) for our Null Hypotheses. We used two-way cluster analysis to evaluate station and species groups and Canonical Correspondence Analysis (CCA) to evaluate community response to covariates. We excluded rare species (with less than 3 occurrences in cluster analyses) and those collected in less than 5% of the sample units (CCA). We considered the following covariates: depth; salinity; turbidity; water temperature; latitude; longitude; month; year and month-year.

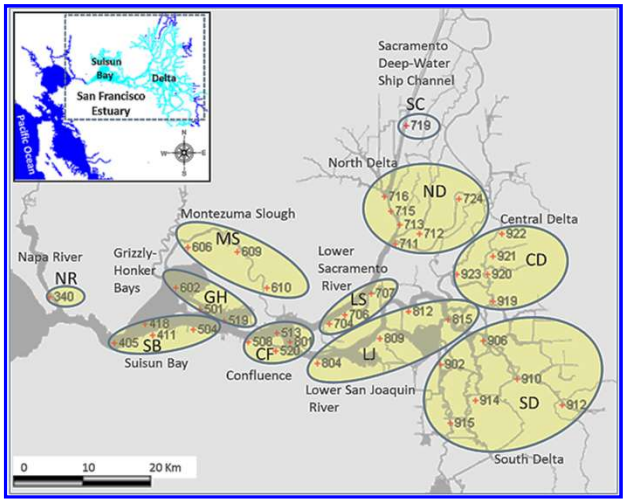

Figure 2. Location of Spring Kodiak Trawl stations and areas in the USFE (station 719 = area SC, was excluded from analyses due to lack of data prior to 2005).

RESULTS

Objective 1: Catch was comprised of fish (22 native and 21 introduced species), decapods (2 introduced species and 1 of genus of unknown origin), and jellyfish (1 introduced species plus jellyfish of unknown origin). Mean relative abundance was similar between native and introduced species. The species with the highest catch included Threadfin Shad; Delta Smelt; Silverside; Pacific Herring; and Chinook Salmon, and they were mainly found at salinities < 5 (Figure 3).

Objective 2: We found significant differences among areas (Figure 2, MRPP, P < 0.001) and species groups (Figure 4, MRPP, P < 0.001). Six alternative groups of stations were suggested by cluster analysis (Figure 4, MRPP, P < 0.001). Most species were found at stations near and downstream of the confluence (Figure 3) and no broad spatial segregation among species was observed in the USFE.

Objective 3: Five covariates accounted for 30.1% of the community variation, with about half of such variation explained by the first axis (Figure 5).

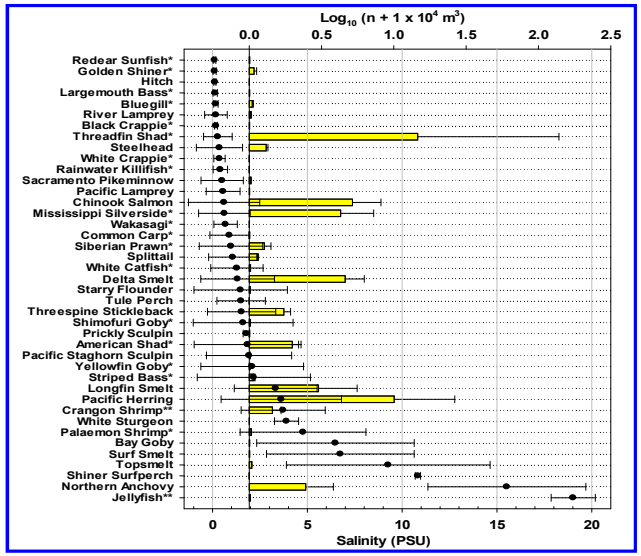

Figure 3. Distribution of fishes and invertebrates by salinity (dot-mean ± SD) and their relative abundance (bar-mean ± SE) in SKT surveys. Taxa represented by only one individual were excluded. One or two asterisks after the species name denote respectively species that are introduced or of unknown origin.

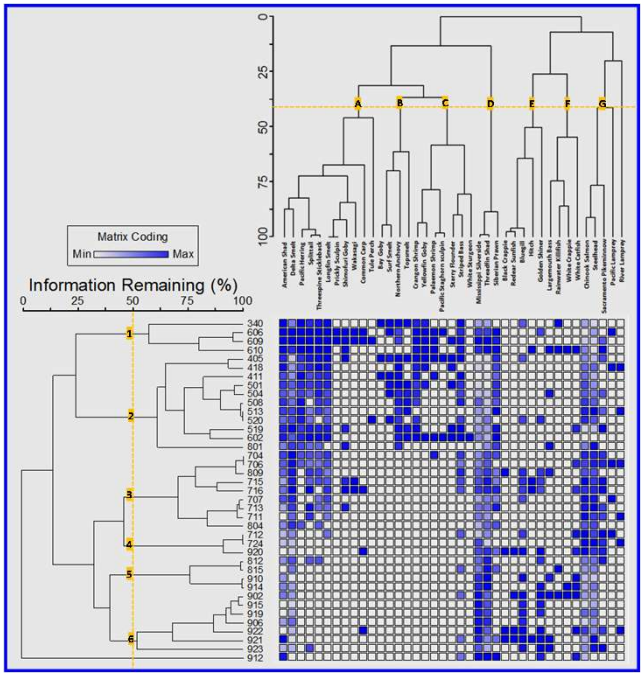

Figure 4. Clustering of 39 SKT stations x 39 fish and invertebrates occurring in the USFE.

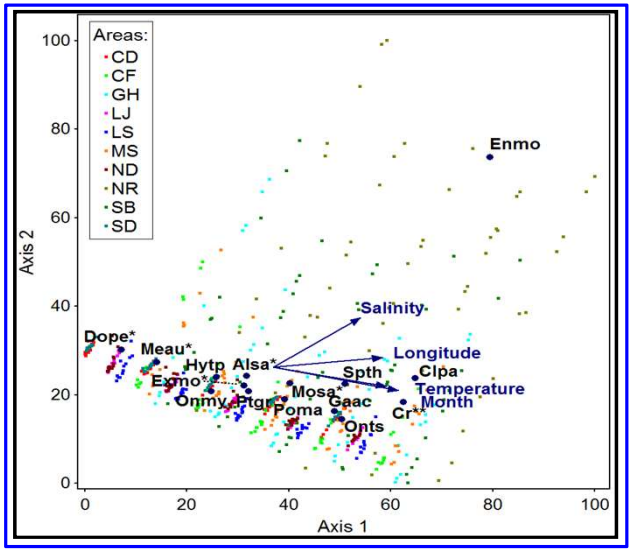

Figure 5. Area-based CCA ordination for the 15 most common species across environmental and spatio-temporal gradients in the USFE. Turbidity (not shown) was important in axes 2-3. Species codes: Dope: Threadfin Shad; Meau: Mississippi Silverside; Exmo: Siberian Prawn; Hytp: Delta Smelt, Onmy: Steelhead; Ptgr: Sacramento Pikeminnow; Alsa: American Shad; Poma: Splittail; Mosa: Striped Bass; Gaac: Threespine Stickleback; Spth: Longfin Smelt; Onts: Chinook Salmon; Cr: Crangon Shrimp; Clpa: Pacific Herring; Enmo: Northern Anchovy (asterisks as in Figure 3).

DISCUSSION

Our SKT analyses showed a community dominated by a few species of native and introduced fish. Yet, relative abundances for many pelagic species have dramatically declined since the early 2000s. Because area-based sample units increased species occurrence relative to stations, the ordination resulting from areas was a useful approach to describe community gradients explained by covariates. Interpretation of area-based ordinations were supported by station-based ordinations (Castillo and Damon, in progress). The temperature-month and salinity-longitude gradients highlighted the need to consider the inter-dependence of abiotic factors and spatio-temporal scales when interpreting estuarine community patterns.
Abiotic and biotic factors for which no concurrent data was collected in SKT surveys could further influence community structure. Superimposed on the inferred community patterns are long-term human-induced ecosystem changes. The effects of such impacts on community structure and sustainability could be greatly aggravated by droughts, particularly in profoundly altered systems such as the USFE.

CONCLUSIONS

1. **Community analyses support the presence of heterogeneous and non-coevolved fish dominated assemblages with similar overall relative abundance of native and introduced species in the USFE.**

2. **Groups of stations inferred from cluster analysis and from geographically close SKT stations (areas) seemed both statistically justified, with the latter providing a more practical spatial classification.**

3. **Community structure for fish and invertebrate species occurring in at least 5% of the SKT areas was significantly related to abiotic factors (salinity, water temperature, turbidity) and spatio-temporal scales (longitude, month) and accounted for 30.1% of the community variation.**

ACNOWLEDGEMENTS

We thank CDFW staff who participated in the field and those who coordinated SKT surveys[1]. Matt Dekar (USFWS) provided useful suggestions. Community analyses funded by USBR under agreement R15PG00046.
[1] https://www.wildlife.ca.gov/Conservation/Delta/Spring-Kodiak-Traw