Describing Invertebrate Diversity Across Wetland Habitat Types

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In the spring of 2016, the Fish Restoration Program (FRP) Monitoring Team sampled macroinvertebrates using a variety of methods to characterize production of fish food resources in tidal wetlands. Sampling occurred in several subregions of the Cache Slough Complex that contained multiple habitat types associated with tidal wetlands. After we identified all invertebrates, we ran non-metric multidimensional scaling which showed differences in community composition between habitat types and between subregions. In some cases, there were also differences between sampler type within a given habitat. Fish dietary diversity and resilience may be enhanced by including multiple habitat types in construction of restoration sites and distributing restoration sites across multiple regions. However, to assess actual benefits, the effect of habitat diversity must be monitored as restoration sites develop. Samplers with the highest catch of invertebrates appearing in listed fish diets will be included in long-term monitoring of FRP tidal wetland restoration sites. We will continue to test the methods we piloted in this study to see if observed patterns in invertebrate diversity continue as restoration progresses in different areas of the of the Sacramento San-Joaquin Delta.

Keywords: invertebrates; wetlands; sampling methods; benthics; vegetation; diversity; restoration; insects
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A High Frequency Solution to Understanding Tidal Wetlands as Fish Habitat

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Major tidal wetland habitat restoration efforts are planned to benefit Delta Smelt and other imperiled species in the Sacramento-San-Joaquin Delta. However, successful implementation of habitat restoration is constrained by a paucity of information on the function and services tidal wetlands provide for fishes. Because of their complicated physical structure and dynamic nature, sampling fishes in tidal wetland habitats is especially challenging. The dynamic nature of tidally influenced habitats requires high frequency data collection in order to accurately depict changing environmental conditions. Similarly, evaluation of fish utilization of tidal wetlands habitat should occur on a commensurate frequency. In this study, physical measurements of wetland environments were collected using continuous flow and water quality monitors. Using acoustic cameras, continuous fish sampling at the entrance to the tidal wetland habitat also occurred simultaneously in an effort to understanding physical-biological coupling mechanisms. The interdisciplinary work presented here is aimed at determining the influence of tidal phase, diel period, lunar cycle, and other relevant factors driving fish movement and habitat use in tidal wetlands. This results of this work will contribute to the knowledge required to implement successful habitat restoration projects.

Keywords: tidal wetland, fish behavior, acoustic camera, high frequency data, continuous
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Ecology of Non-Native Clams and Jellyfish in Suisun Marsh

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Suisun Marsh is important habitat for many native and desirable non-native fishes, and is currently slated for large-scale tidal restoration. However, the marsh is also inhabited by several non-native invertebrates that consume copious phytoplankton and zooplankton, possibly reducing food abundance for imperiled pelagic fishes to which restoration is primarily targeted. Thus understanding factors influencing distribution and abundance of these potentially harmful invertebrates informs restoration design. We used several methods - long-term trawling data, benthic dredges, zooplankton tows - to assess distribution and abundance of three jellyfish species and overbite clam, and then related catches to a suite of environmental variables. In the case of the jellyfish, particularly large-bodied Black Sea jellyfish, warm water and moderate salinities were associated with the largest medusae blooms. For overbite clam, salinity was the most important variable, with saltier years finding clams pushing deeper into Suisun Marsh's interior. However, overbite clam were notably rare in smaller sloughs whether diked or undiked, suggesting softer substrates or limited hydrologic connectivity inhibited recruitment. Because warm, saltier water was generally associated with greater abundances of these non-native invertebrates, then climate-change effects will likely increase the populations of these clams and jellyfish in Suisun Marsh, suggesting future restoration should focus more strongly on limiting hydrologic connectivity, providing fresh water, and promoting softer substrates.

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The Influence of Climate on Vegetation Change Over 15 years at China Camp and Muzzi Marsh

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Understanding temporal trends in plant community composition is an important aspect of interpreting community dynamics and restoration outcomes. Here, we explore the influence of SF Bay salinity and time on plant community trends. From 1990 to 2005, vegetation data was collected along transects at a restoration site (Muzzi Marsh) and a reference site (China Camp) in Marin County, CA. Looking at community change over time using Bray-Curtis similarity metrics, community change was significantly related to SF Bay salinity at China Camp, but not at Muzzi Marsh. Emerging from the drought of the late 1980's and early 1990's, species richness at China Camp was low and began to increase following above average rainfall during the 1994-1995 rain year. These trends were largely driven by the increase in sub-dominant, high marsh species. Community change at Muzzi Marsh was related to time, with sub-dominant species appearing following low salinity conditions in 1994-1995 and increasing steadily through 2005. Overall plant community change at Muzzi Marsh was related to both sub-dominant species and shifts in the co-dominants *Salicornia pacifica* and *Spartina foliosa*. Using Detrended Canonical Analysis to explore these trends, change at Muzzi Marsh followed a directional pattern related to the restoration process while change at China Camp appears to follow a stochastic pattern related to climate. These results highlight the need to consider temporal trends at both reference and restoration sites to understand the dynamic nature of vegetation development. In high variability systems like the SF Bay climate plays an important role in structuring communities and determining restoration trajectories, so funding for long-term project monitoring should be implemented to aid management efforts.

Keywords: Restoration, Drought, El Nino, Plant Community, Climate, Adaptive Management
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Species-specific Plant Responses to Salinity and Inundation in Tidal Wetlands of the San Francisco Bay-Delta Ecosystem

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Anticipated climate change impacts to estuaries include sea-level rise and increasing salinity, factors which may alter wetland plant community structure and function. To better understand how climate change will shape future wetland ecosystems, it is necessary to assess how individual species vary in their functional responses to important climate drivers. To help address these data gaps for tidal marshes in the San Francisco Bay-Delta ecosystem, we are conducting field and laboratory experiments to quantify the effects of tidal inundation and salinity on plant productivity, fecundity, and litter decomposition. Using field mesocosms at Petaluma marsh over a range of tidal inundation conditions, we found different growth responses in major plant species to inundation. The common perennial forb, *Salicornia pacifica,* lost substantial biomass at moderate and elevated levels of flooding, suggesting its greater sensitivity to relative sea-level rise. We are currently assessing inundation and salinity effects on *Juncus balticus*, a high marsh species common in fresher Bay area wetlands. Using complementary greenhouse experiments, we are also determining species-level differences in growth and fecundity with elevated salinity using common species from Suisun marsh. Initial studies of decomposition of plant litter at Petaluma marsh showed that decomposition rates were largely unaffected by variation in tidal flooding, but did differ by species. On-going field and greenhouse studies are addressing salinity and plant root density effects on decomposition. Collectively, these experiments provide insight into functional responses of different species to changing gradients of inundation or salinity as climate change alters physical conditions in San Francisco Bay and the Delta. Our results help inform predictions about how marsh vegetation may change in composition in the future and how functional processes may be affected by sea-level rise and increasing estuarine salinity. Such data will help regional efforts to manage and restore tidal wetlands with impending climate change.

Keywords: climate change, decomposition, productivity, salinity, sea-level rise
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