Food Web Fuel: Differences across Space and Time, with Implications for Restoration

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Estuarine food webs are fueled by a variety of different primary producers. However, in complex, heterogeneous environments it is difficult to identify the relative importance of these producers, particularly to fishes, which typically integrate multiple sources due to their mobility and generally high trophic levels. Through a series of studies within the San Francisco Bay and Delta we have identified the importance of primary producer contributions to local food webs, and noted dramatic spatial and seasonal differences. These dissimilarities exist both on large and small spatial scales, suggesting the impact of restoration efforts on local food webs will be high. Although relative contributions differed, fishes were consistently reliant on a diversity of primary sources, suggesting that restoration efforts should emphasize a wide variety of primary producers to support consumers. In this talk we summarize recent research on Bay-Delta tidal marsh food webs within the context of restoration goals.

Keywords: food webs, fish, restoration
Session Title: Adaptive Management in the Delta: Learning from Habitat Projects
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Advancing Tidal Wetland Restoration in a Regional Adaptive Management Framework

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Key objectives of large-scale tidal wetland restoration in the Delta and Suisun Marsh are to support the habitat requirements of several threatened and endangered fish species, and aid in the recovery of those species. However, substantial uncertainty exists regarding the most effective approach to meeting these objectives. Based on over 20 years of tidal wetland restoration implementation and research, we ask how key uncertainties can be addressed by incorporating adaptive management experiments in restoration designs. We use the designs of recent projects as examples of how key uncertainties can be investigated experimentally. The design of DWR's Dutch Slough Tidal Marsh Restoration Project, for instance, allows for the assessment of how native fish utilize different tidal wetland scales and marshplain elevations. Examples of other design elements that could be experimentally manipulated are size, depth and residence time of artificial tidal pannes, and the slope and length of constructed wetland – upland ecotones. We assess how monitoring results from multiple restoration projects could be used within the coordinated regional framework of an overall adaptive management program to improve the future success of tidal wetland restoration. Lastly, we discuss the potential institutional and regulatory impediments to this approach and suggest programmatic solutions that would likely provide superior results compared to the current project-by-project approach to adaptive management. Our findings show the benefits of a regional adaptive management approach that includes adaptive management experiments that are coordinated among individual projects. Regional coordination within one adaptive management framework would be the most efficient approach to resolve key uncertainties in tidal wetland restoration designs and would help to improve the contribution of tidal marsh restoration to native fish species recovery in the Delta and Suisun Marsh.

Keywords: adaptive management, tidal marsh restoration, delta smelt, monitoring, regulatory permitting
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The Importance of Emergent Vegetation Dynamics in Post-Restoration Outcomes of the Novel Freshwater Marshes

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The dynamics of emergent vegetation affect multiple ecosystem services of restored wetlands in the Delta estuary, including sequestration of carbon, regulation of greenhouse gas fluxes, counteraction to land subsidence and provision of wildlife habitat. However, it is not well understood how specific restoration outcomes may depend on the initial objectives and site designs. This study assessed the differences in canopy structure and landscape configuration of vegetation among different-aged restored freshwater marshes with similar species composition in the western Delta using 2013-2014 field surveys and remote sensing image analysis. The key post-restoration transformations of these sites included colonization and lateral expansion of emergent vegetation (*Typha* spp. and *Schoenoplectus acutus*) and accumulation of standing litter (dead biomass) within plant canopies. These processes affected the heterogeneity in vertical canopy structure and leaf area index (LAI; green leaf area per ground area) that differed among older and younger wetland sites. The contrasts between higher-litter patch interior and low-litter green edge were more pronounced in larger-sized patches, indicating the increasing importance of shading and constraints on plant density with time and litter build-up. Major changes in landscape-scale wetland structure included increases in vegetation cover and high-litter patch interior and decreases in open water extent. Collectively, these outcomes point to potential post-restoration homogenization of vegetation structure, landscape composition and habitat, which may be slower in sites with more complex configuration where water depth and disturbance constrain vegetation colonization and expansion. Because open water, green vegetation and litter contribute differently to ecosystem function and habitat properties, these observed dynamics have multiple important implications for restoration objectives and emerging management needs. The important future task is to quantify specific feedbacks between local plant canopy processes and landscape site structure and to develop a spatially explicit modeling framework to simulate vegetation composition and restoration outcomes under different site configurations.

Keywords: Restoration, vegetation, freshwater, marsh, canopy, LAI, litter, habitat, patches, homogenization
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Geospatial Initiatives to Support Adaptive Management in the Delta and the Watershed

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Is data management important for Bay-Delta habitat restoration? Are geospatial datasets integrated into project planning, post-project monitoring and regional assessments? Data and information are key component of an adaptive management process, from planning to modeling, to monitoring and analyses, to assessment and evaluation. Remote sensing and large-scale datasets, terrain datasets and earth and ocean observation data system are increasingly sophisticated and available. Tidal wetland restoration planning success is dependent on site elevation mapping. Fine topographic details are needed for hydrological modeling, restoration evaluation and planning. The National Map initiative lead by US Geological Survey National Geospatial Program includes the 3D Elevation Program to respond to growing need for high quality topographic data and for a wide range of other three-dimensional representations of the natural and constructed features. The 3D Elevation Program systematically collects enhanced elevation data in the form of high-quality light detection and ranging (lidar) data. New lidar data, along with updated, high resolution surface water network data (The National Hydrography Dataset), currently in collection for the Bay-Delta will provide an integrated detailed terrain and surface water flow framework for understanding the complexity, availability, and movement of water within the Bay-Delta. This unique high resolution data will further the understanding and monitoring of subsidence in the Bay-Delta, the integrity and settlement of existing levees, the viability and cost effectiveness of intertidal habitat restoration, identifying critical fish passage alternatives, and focus protection of vital farming areas. Similar data that surrounds the Bay-Delta (foothills, San Francisco Bay Area, northern and southern Central Valley) provides critical contextual information about the conditions and volume of water entering and exiting the Bay-Delta system.

Keywords: geospatial, elevation, lidar, hydrography
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Human Use of Restored and Naturalized Delta Landscapes

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Current legislation and plans for the Delta call for large-scale restoration of aquatic and terrestrial habitats, which will require significant changes in land uses and cultural patterns.
These rewilded landscapes will be subject to a variety of new human uses, which Delta planning and adaptive management literature has yet to adequately consider. Failing to account for human uses can lead to diminished performance and public support for Delta restoration efforts.

Our one year empirical study examined restored and naturalized Delta landscapes from an integrative human--environment perspective; adopting a landscape planning approach that seeks to reconcile multiple goals and land use agendas spanning ecological, social, economic and political domains. Research was conducted through a combination of surveys and interviews with approximately 100 land managers, scientists, landowners, law enforcement personnel, agency representatives and Delta residents; review of existing delta planning literature; extensive field work, and specific case studies.

Initial findings have shown that human uses of the Delta's restored landscapes are diverse and pervasive. They are subject to multiple and sometimes conflicting uses and values. Therefore, reconciling human uses with ecological restoration will require a more inclusive and multifunctional approach to designing and adaptively managing these landscapes. Case studies revealed that more participatory and proactive planning for human uses is a sound investment in the long term, as it helps to discourage undesirable activity while also building constituency and public support for these projects. The general public has the potential to be an asset in restoration through citizen science and civic ecology programs, which are currently almost non-existent in the Delta. Thus we propose that human uses of restored landscapes be integrated into adaptive management efforts and that more resources and research be dedicated to planning for human uses of these expanding lands.

Keywords: human use, adaptive management, restored landscapes, rewilding, integrative planning
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