Seed Ecology and Transplant Success of *Schoenoplectus acutus*, *S. californicus*, and *Typha latifolia* at Liberty Island, California: Applications to Restoration

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Current wetland restoration techniques proposed for the Sacramento-San Joaquin Bay Delta include the consideration of intentionally breaching constructed levees, thus returning land that had been reclaimed for agriculture back to a tidal marsh hydrology. Liberty Island, a post levee-breach freshwater tidal marsh restoration site, is a model area for understanding challenges to successful wetland restoration in California. Understanding the environmental constraints on vegetation establishment, survival, and expansion is necessary to maximize the efficiency and success of future wetland restoration efforts. This study examined hydrologic and edaphic constraints on plant establishment, survival, and expansion at Liberty Island through the implementation of a seed-bank assay and transplant study. The seed-bank sampling and transplant study were conducted in several areas at Liberty Island that varied in hydrology, edaphic characteristics, and elevation. Seed-bank samples were collected over three seasons and allowed to germinate under favorable greenhouse conditions at the University of Louisiana at Lafayette. Over two years the survival success and degree of expansion of three transplant species (and two life stages) was monitored. The seed-bank assay elucidated that a rich species pool of germinable seeds are present at Liberty Island, however, field observations suggest environmental conditions limit seed germination and seedling establishment.

The transplant study revealed strongly significant differences ($P < 0.01$) between species and life history stages regarding survival and expansion, with *S. californicus* and adult transplants (compared to rhizome transplants) performing most successfully. Furthermore, overall vegetative expansion was 2.5 times greater in areas of lesser compacted soils, indicating that historic soil compaction may be a limiting factor on plant establishment in this system. The information gained from these studies will enhance our understanding of marsh restoration processes and plant species responses, which should prove valuable when setting ecosystem restoration goals and trajectories.

Keywords: seed-bank, Liberty Island, soil compaction, vegetative expansion

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Relationship between Elevation, Edaphic Characteristics, and Patterns of *Schoenoplectus californicus* Abundance and Distribution at Liberty Island, California

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The upper Delta wetlands are a dynamic system whose long-term management depends on a greater understanding of the colonization and subsequent expansion of key wetland plant species, including *Schoenoplectus californicus* (tule). To provide a greater knowledge base for local environmental managers, we are conducting an observational field study to determine environmental factors associated with marsh vegetation colonization dynamics as a component of a large, interdisciplinary collaboration. Plots (1-m^2) were established along transects in interior marsh, vegetated marsh edge, unvegetated marsh edge, and unvegetated mudflat habitats in both protected and more exposed areas of the east and west sides of Liberty Island. All transects were established in marshes dominated by *S. californicus*. Within each plot, *S. californicus* stem heights and density were determined, as well as soil bulk density, organic matter, nutrient concentration, and soil penetration resistance. Additionally, soil redox potential and elevation were quantified in all plots. Data analysis thus far indicates that lower soil bulk densities and higher plot elevations are correlated with greater *S. californicus* stem densities and heights on the west side of Liberty Island. A general trend towards higher soil nutrient concentrations is discernible in areas that were either recently colonized (<1 year) or not yet colonized by *S. californicus*. Expansion of *S. californicus* in certain areas is occurring at a relatively rapid rate (> 1 m yr^{-1}). We anticipate that expansion of *S. californicus* marshes in Liberty Island may proceed at a slower rate when expanding edges reach a low elevation limit or encounter highly compacted soils, at which time feedbacks between the vegetation and sediment supply will become increasingly important in modulating elevation and soil bulk density. Additional field work to more fully characterize the rooting depth and root morphology at the transect sites in this area is planned for Summer of 2012.

Keywords: Liberty Island, *Schoenoplectus californicus*, tule, vegetation colonization dynamics, elevation

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The Importance of Vegetated Ponds to Water Quality and Phytoplankton Carbon Production in Liberty Island, California

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Liberty Island is a freshwater tidal wetland that is thought to provide habitat and food resources for the endangered delta smelt. However, little is known about the mechanisms that control environmental conditions and carbon production in the wetland. This study was designed to address the question: Do the small vegetated ponds in the upper portion of Liberty Island contribute significantly to the overall water quality and phytoplankton production of the wetland? To address this question, a suite of physical, chemical and biological variables were measured at four locations in three wetland ponds between 2010 and 2011. Continuous measurements of water temperature, pH, specific conductance, dissolved oxygen, turbidity and chlorophyll *a* fluorescence with YSI 6600 water quality sondes provided information on water quality conditions. Continuous phytoplankton carbon production was predicted from continuous Turner Phytoflash photometers, Li-COR underwater light measurements and chlorophyll *a* fluorescence. Continuous and discrete monthly measurements provided baseline information on nutrient availability. Calibration data were collected semi-monthly to monthly throughout the study. Chlorophyll *a* concentration, water temperature, specific conductance and turbidity were greater in the vegetated ponds. On average, phytoplankton cells were growing at 45% to 48% of their maximum potential yield (Fv/Fm) throughout the ponds. Average daily yield was similar among the three ponds at 0.38 $\pm$ 0.10 to 0.41 $\pm$ 0.11 Fv/Fm and ranged from 70% to 10% of the maximum potential yield. In situ 24 hr light and dark bottle dissolved oxygen incubation studies indicated both the net primary productivity and maximum photosynthetic potential were greater in the vegetated ponds. Phytoplankton production was supported by elevated nitrate, ammonium, soluble reactive phosphorus and silica concentrations that were often greater in the vegetated ponds. Initial findings suggest vegetated ponds are a potential source of suspended solids, salt and phytoplankton carbon to the wetland.

Keywords: freshwater tidal wetland, primary productivity, carbon and material flux, hydrology

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Fish Community Composition and Abundance across a Vegetation Gradient in a Restoring Tidal Freshwater Wetland

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The Sacramento-San Joaquin Delta of the San Francisco Estuary is a highly manipulated ecosystem with structural impacts including levees and water diversions that have occurred over the last century. Several restoration efforts are underway, including at Liberty Island, a breached levee island once used for agriculture that is thought to provide good habitat for fish, particularly species of concern (i.e. Chinook salmon and delta smelt). We evaluated the seasonal and spatial variation of fish community composition and abundance across a habitat gradient. Field sampling occurred at six sites extending across three primary habitat types based on vegetation density and wind exposure. Fish were collected using gill nets in spring 2010, summer 2011 and winter 2012. We collected 388 individual fish representing 21 species, eight of which were native to California. The most abundant species were inland silverside, common carp, bigscale logperch and striped bass. The highest abundances occurred in spring 2010 and summer 2011 and the lowest abundances occurred in winter 2012. In spring, fish abundance was higher in moderately vegetated habitat, while in summer and winter fish abundance was higher in less vegetated, open-water habitat near a levee breach. Non-metric multidimensional scaling indicated that the fish community composition was largely correlated with seasonal (water temperature and specific conductance) and spatial variables (vegetation and distance from a levee breach). Based on our results, we recommend that (i) open water habitat containing low to moderately dense vegetation (which fish may use for spawning and rearing) and (ii) connectivity with adjacent rivers and sloughs (which reintroduces tidal inundation and allows increased access for fish) be considered in designing and managing tidal marsh restoration.

Keywords: Wetland restoration; Tidal marsh; Vegetation gradient; Fish ecology; Community composition

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Spatial and Temporal Patterns in the Diet of Fishes in a Restoring Tidal Freshwater Wetland

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Several restoration efforts are underway in the Sacramento-San Joaquin Delta of the San Francisco Estuary to restore functional ecosystems, especially marshes. Marsh habitat provides structural heterogeneity and has been shown to influence resource use by many fish species. We investigated fish diet across a vegetation gradient at Liberty Island. Field sampling occurred at six sites extending across three primary habitat types based on vegetation density and wind exposure. Fish were collected using gill nets and fyke nets in spring 2010, summer 2011, and winter 2012. Gut contents of 463 individual fish, representing 23 species, were examined. Preliminary results from a two-way analysis of similarities (ANOSIM) based on percent prey biomass showed significant biological differences in diet composition among the five most abundant fish species across seasons. During the spring, inland silversides and delta smelt consumed similar prey items, consisting mainly of chironomids, *Corophium* sp. and calanoid copepods, however during summer, inland silversides consumed mostly insects. Catfish and Carp were the primary demersal species caught in all habitat types and consumed mainly plant detritus and clams, respectively, in all seasons. Striped bass stomachs were fuller in the summer, when they consumed more fish prey, compared to stomachs from spring and winter. Understanding fish habitat use and food resources will allow researchers and managers to gain insight into ecosystem dynamics and habitat quality within this restoring wetland.

Keywords: Wetland restoration; Tidal marsh; Vegetation gradient; Diet; Fish ecology

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BREACH III: Evaluating 'Restoration Thresholds' of Liberty Island

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The purpose of the Breach III study is to provide a predictive level of understanding about how abiotic and biotic factors control vegetation colonization and expansion in a restoring freshwater tidal wetland and how vegetation subsequently affects fish and wildlife populations. The research in this cluster examined vegetation colonization, productivity and water quality, and fish diet and community composition.

Habitat structure is an important factor affecting fish abundance and distribution at multiple spatial scales. Understanding fishes occupy habitats to fulfill one or more life history requirements (e.g., survival, foraging, and reproduction), Breach III researchers hypothesized that fishes within Liberty Island would occur in areas providing predation refuge, food, and/or spawning habitat. Willis, Sloey, and Hester demonstrated expansion and colonization of emergent aquatic vegetation within Liberty Island was positively correlated with lesser compacted soils and higher plot elevations. Lehman et al. showed vegetated ponds within the wetland was a likely source of suspended sediments and phytoplankton to the wetland. We predicted that increases in turbidity and phytoplankton densities could increase food availability of planktivorous and herbivorous fishes and increases in the presence of aquatic vegetation could provide spawning habitat, structural cover, and food for fishes at various life stages. Therefore, we hypothesize there would be discernible relationships between aquatic vegetation and fish composition diet. Whitley and Bollens demonstrated total fish abundance was higher in moderately vegetated habitats during the spring, which can be a result of both spawning and rearing, and non-piscivorous fishes were generally consuming plant detritus and zooplankton. As a result, it is clear freshwater tidally influenced wetlands can provide essential habitat for the survival, foraging, or reproduction of native fishes. Fish abundance can be increased by restoration projects targeting habitats with minimal historical agricultural land use and higher plot elevations allowing for relatively fast vegetation expansion and colonization.

Keywords: Breach III, wetland, restoration, plants colonization, elevation, modeling, fish diet,

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