Insights into Colonization and Expansion Dynamics of *Schoenoplectus californicus* at Liberty Island, California

Mark Hester, University of Louisiana, mhester@louisiana.edu
Jonathan Willis, University of Louisiana, jmwcoastal@gmail.com
Taylor Sloey, University of Louisiana, taylorsloey@gmail.com

Understanding plant colonization and expansion dynamics is an essential component in the development of sustainable restoration plans. As part of a larger, multidisciplinary collaboration at Liberty Island, we conducted both observational and manipulative studies that focused on colonization and expansion dynamics of vegetation at the site, particularly *Schoenoplectus californicus* (tule). Our approach had multiple components, including: 1) a seed-bank assay, 2) a field transplant study of *S. californicus, S. acutus, and Typha latifolia*, and 3) a field transect study in areas that are currently dominated by *S. californicus.* Results of the seed-bank assay revealed greater species richness of viable seeds than is currently displayed in the emergent wetland plant community at the site, suggesting that environmental conditions limit the successful germination and persistence of many of these species. Transplant establishment success was greatest in adult transplants (versus rhizomes),and although all three species assessed were able to establish both adjacent to the existing marsh edge and in slightly deeper open water areas, *S. californicus* rapidly became the dominant species and exhibited high rates of vegetative expansion. The transect study revealed interesting differences between the east and west sides of Liberty Island with *S. californicus* growing at lower elevations on the east side where plant height and stem densities were also generally lower than on the west side. Additionally, west-side transects exhibited a trend of soils becoming more compacted and displaying higher bulk densities along a gradient from the marsh platform interior to adjacent open water areas, whereas east-side transects displayed an abrupt increase in unconsolidated sediments in adjacent open water areas and less soil organic matter accumulation in the vegetated marsh platform. Our findings illustrate the importance of recognizing multiple factors and dynamic interactions between the plant community and the abiotic environment when considering restoration thresholds.

Keywords: Liberty Island, wetland restoration, *Schoenoplectus*, Typha, colonization, expansion, elevation

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Restored Marshes in Liberty Island: How 'Deltaic' are the New Wetlands?

Denise Reed, The Water Institute of the Gulf, djreed@uno.edu
Ross Del Rio, University of New Orleans, rdelrio@uno.edu
Lindsay Dunaj, University of New Orleans, ldunaj@my.uno.edu

All plans for ecosystem restoration in the Bay-Delta call for increasing the area of tidal marsh and the question of how and where tidal marsh restoration is feasible must be addressed. Sites with relatively little subsidence and a supply of riverine sediment are often viewed as more suitable and the 'restoration' of some tule marshes on Liberty Island following levee breach provides an opportunity to explore the dynamics of the new wetlands.

As part of the BREACH III study, measurements of surface elevation change, grain size, and gravimetric and volumetric contributions of organic and mineral material are being made at Liberty. Data collection includes the transition from mudflat to marsh, and sites with varying exposure to wind waves. In addition, the character of these 'new' marsh soils was compared with growing deltaic wetlands in Louisiana to elucidate the applicability of traditional delta building concepts to marsh restoration in the Delta.

Results show 'protected' areas had higher rates of elevation increase than exposed sites independent of absolute elevation. Over the almost 2 years of data the mean rate of elevation change exceeded 1 cm/yr at protected sites. Soil development is dominated by the mineral fraction both gravimetrically and volumetrically. In contract to Louisiana deltaic marshes, where a strong relationship between elevation change and seasonal water level has been established, elevation change at Liberty does not seem to be controlled by stage.

This study supports the finding of previous work on natural and restored marshes in the Delta - that despite the traditional view of delta wetlands as being peat dominated systems, mineral sediment is an essential component of soil development and vertical building. Plans to restore marshes in the Delta must account not only for areas where subsidence is low but also for the supply of sediment for continued marsh growth.

Keywords: restoration; marsh; Liberty Island; sedimentation

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

Peggy Lehman, Division of Environmental Services, California Department of Water Resources, plehman@water.ca.gov
Shawn Mayr, North Central Region Office, CA Department of Water Resources, sdmayr@water.ca.gov
Brett Larsen, North Central Region Office, CA Department of Water Resources, blarsen@water.ca.gov
Mike Dempsey, Division of Environmental Services, California Department of Water Resources, mdempsey@water.ca.gov

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 flux, material flux

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Hydrodynamic, Wind-Wave, and Sediment Transport Modeling to Inform Ecological Response at Liberty Island

Matt Brennan, ESA PWA, mbrennan@esassoc.com
Michelle Orr, ESA PWA, morr@esassoc.com
Eddie Divita, ESA PWA, edivita@esassoc.com
Steve Crooks, ESA PWA, scrooks@esassoc.com

Long-term planning for the Delta has identified habitat restoration as a key element for reconciling human impacts with ecosystem function in the Delta. However, the linkages between physical processes and the resulting habitat evolution are not well understood. As part of the BREACH III project team, we have developed hydrodynamic, wind-wave, and sediment transport models for Liberty Island, a former diked area restored to flow, to understand these linkages.

We have represented the northwest portion of the Delta, encompassing Liberty Island and surrounding channels, with a two-dimensional hydrodynamic model (Delft3D) coupled with a wind-wave model (SWAN). These two hydraulic models are used to predict the re-suspension, transport, and deposition of suspended sediment. The model is forced with a range of inputs, including tides, wind, and river discharge, including the Yolo Bypass. The model, calibrated to water level, discharge, wave, and suspended sediment observations, is used to characterize the spatial and temporal distribution of wave energy, circulation, and sediment transport. By analyzing the predicted response to different forcing conditions and ambient sediment conditions, we assess the relative role of different forcing mechanisms (wind-waves, channel-mudflat connectivity, and the Yolo Bypass) to creating the elevated suspended sediment conditions in the region and the trends in geomorphic change. By paring the modeling with ecosystem data (vegetation, plankton, and fish), we intend to assist in improving understanding of habitat evolution and species use.

This physical-process perspective on ecological response is anticipated to inform projections of habitat evolution as well as potential impacts. Alternative design strategies to enhance the performance of restoration projects can then be evaluated. Finally, this modeling supports the development of ecological modeling tools.

Keywords: Tidal marsh restoration, modeling, suspended sediment, waves, Delta

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Liberty Island Landscape Vegetation Model

Enrique Reyes, Dept. of Biology, East Carolina University, reyese@ecu.edu

A landscape vegetation model was developed to provide a predictive level of understanding about abiotic and biotic controls on vegetation colonization and expansion on Liberty Island, with the goal of investigating how to restore wetlands integrating historical and concurrent environmental data, and assess the evolving wetland features at the landscape scale

The initial conceptual model developed from the BREACH studies was used as base for an evolutionary path from subtidal open water, through emergent mudflats to vegetation colonization and ultimately mature marshes. This conceptual model identified different stages in wetland development and articulated the interactions among these factors for intertidal pioneer and mature tule (*Schoenoplectusacutus*) conditions.

We implemented this conceptual model unto a large-scale dynamic model to understand how hydrologic and geomorphic changes and ecological responses at different scales from local to the entire restoration site, and relationships to the adjoining landscape. The result was a multiple-scale biophysical model for the Liberty Island marshes capable of simulating long-term regional habitat change. This mechanistic process-based ecological landscape model assessed "restoration thresholds" of emerging wetlands. This type of spatial model incorporates location- specific algorithms to allow feedback between the local processes and landscape dynamics. Thus, the biophysical model for Liberty Island compiles physical and biological information at different scales in three modules: hydrodynamic, soil, and macrophyte productivity dynamically coupled via a *unit ecosystem model.* Calibration results show that plant colonization is highly correlated to water depth and wave exposure. Model results could be used to assess how restoration goals can be met using water transport and routing influence changes in habitat composition within the basin.

Keywords: watershed modeling, plant response, long-term simulations

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