How Do Edaphic Characteristics Influence Native Pacific Cordgrass (Spartina foliosa) Restoration Success across Tidal Elevations?

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Restoring native cordgrass (*Spartina foliosa*) is a critical step in reestablishing important ecosystem functions following eradication of invasive hybrid cordgrass in the San Francisco Bay. Among the most essential functions is providing foraging and nesting habitat for the federally endangered California Clapper Rail (*Rallus longirostris obsoletus*) as well as supporting numerous species as part of the benthic food web. We investigated the effects of tidal elevation (inundation), herbivory, sediment conditions, porewater salinity and porewater sulfide on the success of restoring native *S. foliosa.* Large-scale outplanting occurred at three sites with dissimilar hydrology. Planting occurred along an elevation gradient to test inundation limits to survivorship. Native cordgrass was planted in paired caged and uncaged plots to test the effect of herbivory. Growth and edaphic characteristics were monitored on a quarterly basis. Preliminary results indicated inundation time and caging are significant factors in survivorship at two sites, but did not explain variation in survivorship at the third site. Sulfide and salinity varied across elevations and among sites; however, neither of these factors were associated with initial survivorship rates. Continued sampling will test the influence of salinity and sulfide by the end of summer 2013, since pilot plots in August 2012 had large spikes in mortality of plants associated with field soil conditions. Mean survivorship and the parameters that limited growth varied among marshes, and inundation and herbivory played an important role in survival. Understanding the limits on native cordgrass survival will aid the large-scale restoration efforts underway in San Francisco Bay.

Keywords: Cordgrass, Spartina, Foliosa, Salinity, Inundation, Pore Water

Poster Topic: Habitat Restoration: Climate Change

When Will the Bay Reach Highway 37?

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Reclamation and conversion for agriculture, urban development, and salt production over the past 150 years led to the loss of approximately 82% of historic marshes in the San Pablo Baylands. During the past decade the US Fish and Wildlife Service (Service), Ducks Unlimited (DU), the State of California, and a coalition of partners have made significant progress towards acquiring and restoring a large proportion of these lands. Cullinan Ranch is among the few large remaining publicly-owned tracts between the Napa River and Sonoma Creek still requiring restoration. Cullinan Ranch Restoration Project broke ground in 2011 and will restore over 1,500 acres of former diked and farmed baylands back to tidal habitat. Once complete, a sea of blue will be visible along the north side of Highway 37, extending for 3.3 miles.

Originally acquired in 1991 with intention of immediate tidal restoration, implementation was delayed by the recognition that breaching levees would result in flooding nearly one mile of Highway 37 under combined high wind and high tide events. The Service and DU worked together on a project design to maintain the current level of protection for Highway 37 once the levees are breached.

Two major challenges must be overcome prior to breaching levees:

- Obtaining a Caltrans encroachment permit to build acceleration and deceleration lanes to access the site along Pond 1 levee; and
- Optimizing ability to import dredged sediments to raise the elevation of a portion of the site to jumpstart wetland habitat development.

DU engineers continue to work with Caltrans to obtain an encroachment permit while minimizing construction costs. Concurrently DU is implementing a novel approach to importing dredged sediments for beneficial reuse by permitting an offloading facility on the Napa River, and is seeking ways to ensure that if they build it, the sediments will come.

Keywords: Estuarine, Tidal Wetland Restoration, Beneficial Reuse, Endangered Species, Baylands

Poster Topic: Habitat Restoration: Climate Change

Evolution of Community-Based Restoration Techniques for Transition Zone Habitat at Eden Landing Ecological Reserve

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The transition zones between the coastal marshes and upland areas of San Francisco Bay are critical habitat for hundreds of species, some of which are threatened or endangered. Transition zones are integral habitat for wildlife as they move between marshes and uplands during high tides and storm surges. These areas provide a food source for insects, birds, reptiles, and small mammals. A vast majority of coastal marshes have been filled in for development or converted into salt ponds and agricultural lands, and adjacent transition zones have become severely degraded and condensed into fragments of their historic ranges.

Save The Bay has used community volunteers to remove non-native and invasive species and to restore transition zone habitat on narrow levees slopes of the Bay for over 13 years. Using Eden Landing Ecological Reserve as a model, we demonstrate how our restoration approach has adapted over time to meet restoration goals to increase transition zone habitat in the Bay. Save The Bay managed three separate transition zone projects over a six-year period at Eden Landing Ecological Reserve. Over the six-year period, Save The Bay has expanded our strategy from restoring narrow levee slopes to include restoring transition zone habitat on broad, gentle slopes and shifting to an emphasis on site-specific plant diversity. We use a mix of native annual and perennial grasses and native plants to create a dense habitat mosaic. This recent work can be applied to existing and future transition zone restoration designs.

Keywords: Transition Zone, Native Plants, Tidal Marsh, Restored Levee

Poster Topic: Habitat Restoration: Climate Change

Up-scaling Wetland CO2 and CH4 Exchange in the Sacramento-San Joaquin River Delta

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Returning land in the Sacramento-San Joaquin River Delta to wetlands can help reverse land subsidence by maintaining plant productivity while drastically reducing the rapid peat decomposition that has occurred since this region was drained for agricultural use in the 1850s. Rebuilding peat soils will help to both protect California's water supply and mitigate globally rising atmospheric CO_2 concentrations. The more anaerobic soil environment of wetlands, however, promotes methane (CH_4) production, a 25x more potent greenhouse gas than CO_2. It is therefore important to understand the impact of wetland restoration on both these gases to evaluate both subsidence reversal and climate change mitigation goals. To this end, measurements of wetland gas exchange via the eddy covariance method can quantify ecosystem-scale sequestration or emission of CO_2 and CH_4. The ultimate goal of these measurements is to predict the effects of wetland restoration on Delta-wide fluxes of these important greenhouse gases. Wetlands, however, are spatially variable ecosystems, varying in substrate, plant species, plant density, and open water fraction, to name a few. Extending site-level measurements to other areas therefore requires attributing spatial variability in CO_2 and CH_4 exchange to respective sources and identifying spatially available indicators of this change. This poster presents preliminary results evaluating the spatial variability of CO_2 and CH_4 fluxes in two restored Delta wetlands and how this variability can be up-scaled to region-wide estimates using remotely sensed indicators.

Keywords: Subsidence Reversal, Wetland Restoration, Climate Change Feedbacks, Greenhouse Gas Flux

Poster Topic: Habitat Restoration: Climate Change

Direct Measurements of Wind-Water Momentum Coupling in a Tule Marsh

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Wetland restoration is already underway in many parts of the California Delta. Among the numerous ecological benefits of restoration is carbon sequestration. As emergent vegetation (like tule) thrive, carbon dioxide in the atmosphere is removed and converted into biomass that gradually replenish the soils. Forecasts and management strategies, however, rely on accurate knowledge of gas exchange between the atmosphere and the wetland ecosystem. Our previous work show the rate of gas transfer across the air-water interface is affected by the amount of water column mixing caused by winds penetrating through the plant canopy. Here, we present the first direct measurements of this within a wetland. This work in Twitchell Island shows that under the conditions measured, momentum is imparted into the water from wind stress and that this wind stress interacts with the surface waters in an interesting way. By correlating three-component velocity signals from a sonic anemometer placed within the plant canopy and from a novel Volumetric Particle Imager (VoPI) placed in the water, we measure how much kinetic energy actually makes it through the canopy and into stirring the water column.

Keywords: Delta, Wetland, Gas Exchange, Measurements, VoPI

Poster Topic: Habitat Restoration: Climate Change

Modeling Suspended Sediment Transport and Geomorphic Processes at a Breached Delta Island

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This poster presents modeling work investigating the physical processes which drive the transport of suspended sediment at Liberty Island, a former agricultural island which has been allowed to evolve naturally following a catastrophic levee failure in 1998. Sediment transport processes play a major role in shaping estuarine ecosystems. Sediment deposition contributes to the growth and expansion of mudflat and vegetated marsh habitats, and elevated suspended sediment concentrations are thought to play an important role in creating habitat for threatened native fish species such as delta smelt.

The Cache Slough region and Liberty Island in particular have been observed to have elevated suspended sediment concentrations relative to the rest of the Delta. In order to better understand the processes driving these elevated suspended sediment concentrations, we have developed a coupled 2D-hydrodynamic (Delft3D) and wind-wave (SWAN) model representing the northwest portion of the Delta, encompassing Liberty Island and surrounding channels. The model is used to predict the re-suspension, transport, and deposition of suspended sediment. The model is forced with a range of inputs, including tides, wind, Sacramento River discharges, and flows down the Yolo Bypass. The model has been run for several representative time periods allowing us to explore both seasonal variations and long term trends at the site.

The model results provide insight into the relative importance of wind-waves, tidal currents, and river discharges in driving the deposition, transport, and re-suspension of suspended sediments, helping us better understand the expected patterns of landscape and habitat evolution in this important part of the Delta.

Keywords: Freshwater Tidal Marsh Restoration, Liberty Island, Suspended Sediment

Poster Topic: Habitat Restoration: Climate Change

Interactions Between Waves, Sediment, and Turbulence on a Shallow San Pablo Bay Mudflat

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Observations of tides, turbulence, and wind-waves on a shallow mudflat in northern San Francisco Bay illustrate the mechanisms that control shear stresses on the bed and drive sediment resuspension in this estuarine environment. Measurements spanning the transition from intertidal to subtidal mudflat were collected in the spring of 2011 in San Pablo Bay. During wind events, wave-driven bed shear stresses elevated concentrations of suspended sediment near the bed such that stable density stratification was induced. Density variations were attributed to suspended sediment concentration since salinity and temperature were largely uniform throughout the water column. Direct measurements of the buoyancy flux were provided by each of five ADVs on three instrument frames and demonstrated the dynamical relevance of the stratification to the turbulence field with values 1-10% of shear production. Contrary to expectations, increased near-bed turbulent shear stresses were observed during these stratification events, and shear production was heightened in particular. The observed increases in velocity shear in the lowest 30 cm of the water column during wind events were attributed to return flows generated by set-up at the coast from wind shear and Stokes transport, which enhanced the offshore flows on ebb tides. The increased shear production resulting from event-scale wave dynamics augmented bed shear stresses, reinforcing the impact of waves on sediment resuspension. The data illustrate that there were layered feedbacks between wind waves, sediment resuspension, and turbulent motions, and that wave events lead to stable stratification and a very energetic turbulence field in which the buoyancy flux became an important factor in the balance of turbulent kinetic energy.

Keywords: Waves, Turbulence, Sediment, Stratification, Mudflat, Intertidal, Stokes Drift

Poster Topic: Habitat Restoration: Climate Change

Restoration Progress Toward Regional Goals in the San Francisco Baylands

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Fifteen years after the publication of the Bayland Ecosystem Habitat Goals Project (1999) and as part of the Bayland Ecosystem Habitat Goals Update (BEHGU, 2014) project, the San Francisco Estuary Institute has analyzed the net losses and gains in bayland habitats since c. 1800, highlighting contributions due to restoration and enhancement activities. The Goals Project established amounts and types of habitats needed to establish a healthy and vibrant Bay ecosystem. These goals were based on the historical (c.1800) and the current (1998) extent of tidal habitats, opportunities and constraints for restoration, and wildlife requirements, among others. Bay Area restoration/enhancement activities began to not only meet these goals, but also provide beneficial uses such as cleaner water, flood protection, more wildlife, and beautiful places to be in nature in the heart of our urban region. More than 190 restoration/ enhancement projects have been planned or implemented around the Bay. By 2009 over 20,000 acres of restored or enhanced habitat had been completed. It is projected that the Bay Area will see an additional 48,000 acres of restored or enhanced tidal marsh due to future restoration efforts.

Performing a Region-wide net habitat change analysis allows us to better understand how these numbers compare to the Region's 1999 goals and provides a planning tool for identification of areas with additional enhancement/restoration potential. Time stamps for the net change analysis include circa c.1800, 1997, 2009 as well as a Post-restoration estimate that considers all known restoration projects with a high likelihood of implementation in the next 5-30 years. Datasets and information used in the net habitat change analysis include the Historical Baylands, Modern Baylands , the Bay Area Aquatic Resource Inventory (BAARI), and a combination of EcoAtlas Projects, San Francisco Joint Venture Project Tracking, and restoration expert narratives.

Keywords: Bayland, Restoration, Habitat, Tidal, Landscape Change, Planning, Enhancement, Marsh

Poster Topic: Habitat Restoration: Climate Change

Current Status of Olympia Oyster Populations in the San Francisco Estuary

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The Olympia oyster, *Ostrea lurida*, is a target of restoration efforts in the San Francisco Estuary. A better understanding of population fluctuations could significantly aid restoration outcomes and improve resilience to future climatic changes. As part of a project connecting applied science and restoration efforts, we generated a snapshot of the current status of oyster populations in the estuary, comparing it to previous snapshots under different environmental conditions.

We investigated oyster population dynamics using surveys at sites from San Pablo Bay to the South Bay over a five year period spanning recent dry and wet extremes, including the end of a three-year drought in 2009 and higher flow conditions in 2011.

Over five years, oyster abundance and sizes differed significantly along the salinity gradient, with maximum densities usually occurring in the northern-central portion of the estuary. After a three-year drought, maximum oyster densities in 2009 occurred in brackish waters near China Camp State Park. Two years later, high winter freshwater flow coincided with complete mortality of the oysters in this region, with maximum density of living oysters thereafter occurring downstream of China Camp.

Regional temperature and salinity variation correlated with the timing of the onset and peaks in fecundity and settlement. Juvenile oyster settlement varied geographically, with greatest settlement in upstream areas, coinciding with maximum adult densities during warmer periods. Following die-offs upstream in 2011, settlement began later and maximum settlement rates were halved. Maximum settlement was highest on the west side of the estuary, though maximum fecundity occurred in the east.

Great fluctuations in North Bay population densities occurred as high settlement was balanced against the inability of local populations to survive wetter winters. In contrast, South Bay populations had steady demographic rates, possibly making this area an important buffer against fluctuations in freshwater flow and other environmental changes.

Keywords: Oysters, *Ostrea lurida*, Salinity, Temperature, Demography, Freshwater Flow

Poster Topic: Habitat Restoration: Living Shorelines

Effects of an Environmental Stressor on Oysters: Using a Scientific Approach to Restoration Planning

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The Olympia oyster, *Ostrea lurida*, is a species of restoration interest in San Francisco Bay, Elkhorn Slough, and other estuaries along this same coast. Our goal is to produce science-based planning tools so that restoration practitioners can best select sites for successful oyster restoration that will be resilient to climate change. Here, we present targeted scientific research that will be incorporated into these tools. We investigated oyster threshold response to a specific climate related stressor, salinity, using laboratory mesocosms. Realistic treatment levels of both low salinity intensity and duration of exposure were chosen based on historical outflow volume and frequency records from San Francisco Bay and encompass both current conditions and more extreme conditions. Adult oysters were collected from a central and a north San Francisco Bay site that have different salinity regimes. Both oyster survival and food intake varied with respect to low salinity intensity and duration of exposure, and also between source populations. These results indicate that climate change effects on salinity are likely to impact oyster performance and should be incorporated into restoration planning. Next, we will combine these data with information we are collecting about oyster responses to other stressors in the laboratory and in the field to generate predictions about which sites and source populations are best suited for restoration efforts. Using this information along with stakeholder input, we will then produce restoration planning tools to aid practitioners and policy-makers in selecting sites for oyster restoration now and under projected future conditions.

Keywords: Climate Change, Environmental Stressors, *Ostrea lurida*, Restoration Planning

Poster Topic: Habitat Restoration: Living Shorelines

Managing for Resilience in the Face of Climate Change: A Collaborative Approach to Oyster-Restoration Research in San Francisco Bay and Elkhorn Slough, CA

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Coastal managers and decision-makers are faced with the challenge of designing conservation and restoration strategies that enhance the resilience of coastal resources to climate change. To design effective strategies, they need restoration-planning tools based on robust science. In two Central California estuaries, we are engaged in a collaborative, joint fact-finding approach to understand the responses of native oysters (*Ostrea lurida*) to climate-change and other anthropogenic stressors. We used an online questionnaire, one-on-one interviews, and focused workshops to ensure that our research informs decisions made by restoration practitioners and resource managers and that work products are understandable and easy to use. End-user partners are also engaged in data collection at three field sites. Across 11 field sites in San Francisco Bay and 9 sites in Elkhorn Slough (Monterey County), we are collecting data on a suite of physical and biological parameters and on oyster performance. Our study sites span a wide range of environmental conditions, allowing us to examine the effects of multiple real-life factors on oyster recruitment, growth, fecundity, and survival. Laboratory experiments are being used to measure oyster response at various life stages to stressors expected to become more extreme as a result of climate change: higher air and water temperatures, lowered salinity, lower dissolved oxygen and sediment burial. Field and lab data indicate that adult and juvenile oysters are particularly vulnerable to lowered salinity; low dissolved oxygen reduced growth but did not result in higher mortality. In the field, oyster density and recruitment were negatively correlated with very high water and air temperatures, and summer and fall recruitment were positively associated with high chlorophyll a (a proxy for food supply) in the spring. These results will be used to construct a “score card” for site selection and a practitioners’ guide for oyster restoration/conservation now and into the future.

Keywords: Climate Change, Anthropogenic Stressors, *Ostrea lurida*, Restoration Planning, Collaboration

Poster Topic: Habitat Restoration: Living Shorelines

Avian and Benthic Invertebrate Responses to Eelgrass and Native Oyster Restoration for the Living Shorelines Near-shore Linkages Project

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The San Francisco Bay Living Shorelines Near-shore Linkages Project is a multi-objective habitat restoration pilot project with the overarching goal to create biologically rich and diverse subtidal and low intertidal habitats, including eelgrass and oyster reefs, as part of a self-sustaining estuary system that restores ecological function and is resilient to changing environmental conditions. Phase I includes using a pilot-scale, experimental approach to establish native oysters and eelgrass at sites in Hayward and San Rafael. The USGS WERC San Francisco Bay Estuary Field Station conducted avian and benthic invertebrate pre-project monitoring at each site from Nov 2011-April 2012, and post-project monitoring from September 2012-April 2013. Our primary objective was to determine species and guild specific responses to restored habitat relative to control areas and pre-treatment conditions using a Before-After Control-Impact (BACI) design. We conducted high and low tide avian surveys twice monthly to record avian densities, instantaneous behavioral scans, and focal behavioral observations. To relate waterbird densities and behaviors to prey availability, we sampled invertebrates by taking 3 replicate benthic cores every 150-m along transects running perpendicular to shore. Both pre- and post-project avian densities were highest at Hayward treatment and control sites where small shorebirds predominated and reached densities of >2300 birds/ha during peak periods in January of both years. At San Rafael, densities of black oystercatcher and several wader species increased significantly at treatment plots in comparison to pre-treatment and control densities. Bivalves predominated at Hayward and more than doubled in the treatment area during the post-project period. The number of unique taxa at the San Rafael site increased from 14 representing 6 classes to 22 representing 8 classes. Our preliminary results suggest that some avian and invertebrate species may be responding to oyster and eelgrass habitat restoration.

Keywords: Benthic Invertebrates, Eelgrass, Native Oysters, Living Shorelines, Restoration

Poster Topic: Habitat Restoration: Living Shorelines

Invertebrate and Fish Responses to Eelgrass and Oyster Restoration in a San Francisco Estuary Living Shorelines Project

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The San Francisco Estuary has historically supported a high diversity of fish and aquatic invertebrates. Intertidal habitats with complex physical structure are considered especially productive, providing foraging and shelter opportunities for multiple life stages. This research is being conducted to monitor the response of these populations to the restoration of intertidal habitat including eelgrass (*Zostera marina*) and native oyster (*Ostrea lurida*) in the Estuary. The CA Coastal Conservancy's San Francisco Bay Living Shorelines: Nearshore Linkages project (LSP) is the first project in the Estuary to implement these intertidal habitat restoration techniques at a scale large enough (30m x 10m plots) to provide quantifiable physical results in addition to biological results. Living shorelines have been used throughout the world to reduce physical impacts on shorelines, while simultaneously providing habitat to intertidal invertebrate and fish species. Quarterly invertebrate and fish monitoring was conducted in the restoration plots for four rounds prior to oyster restoration (Oct 2011-July 2012) and has continued after restoration (July 2012-current). Quarterly monitoring has been conducted for seven rounds prior to eelgrass restoration (Oct 2011-Apr 2013) and has continued after restoration (April 2013-current). Monitoring is conducted using a series of traps, seines, and vacuum sampling. Preliminary results have shown a trend of increase in species richness and abundance within the restoration plots compared to the control plots. We have observed a shift from a predominance of mudflat species (e.g., mud-flat crab, *Hemigrapsus oregonensis*) to species that have been shown to use eelgrass and oyster habitats as nursery or foraging grounds (e.g., juvenile Dungeness crab, *Metacarcinus magister*). This monitoring will further help to determine the relative and interactive effects of adding eelgrass and oyster reefs to restore habitat structure.

Keywords: Eelgrass, Oysters, Living Shorelines, Habitat Restoration, San Francisco Estuary, Invertebrates

Poster Topic: Habitat Restoration: Living Shorelines

Acoustic Fish Telemetry at the San Rafael Living Shorelines Oyster Reef

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Creating habitat for fishes is a chief goal of oyster reef restoration projects in the San Francisco Estuary. Oyster restoration reefs, such as the SF Bay's Living Shorelines Project's reef near San Rafael, provide physical structure that supports a robust local food web offering foraging opportunities for many fish species. The nooks and crannies of the reef can provide nursery and refuge habitat for fishes. Determining which fish species are utilizing this restoration site and quantifying their use of the site is the problem that we are investigating.

To approach this problem we have applied the tools of hydroacoustic telemetry. In December, 2012, we installed an array of 25 VEMCO VR2W acoustic receivers (69 kHz and 180 kHz frequencies) around the oyster reef to detect and quantify the presence of tagged fish. Receivers were arranged in such a way that any tagged fish would likely be detected by at least three receivers. Detections at multiple receivers allow the calculation of the fish's position within the reef. Receivers were also installed at a smaller reef near the Marin Rod and Gun club for comparisons.

Fish are tagged by multiple academic researchers and agencies so that their movements within and beyond San Francisco Estuary can be tracked. Out-migrating salmonids (chinook and steelhead) and other species of concern such as green sturgeon, white sturgeon, striped bass and cow sharks are implanted with acoustic transmitters.

In June, 2013, we downloaded data from all of our receivers. Our preliminary results show that at least eight tagged fish visited this oyster reef over the study period. Our analysis will determine which specific fish used the reef and provide a track of their position within the reef structures.

Our results will help guide future oyster reef restoration projects to maximize benefits to important fish species.

Keywords: Acoustic Telemetry, Receivers, Transmitters, Tagged, Chinook, Steelhead, Sturgeon, Living Shorelines

Poster Topic: Habitat Restoration: Living Shorelines

Evaluating Oyster-Restoration Substrate Performance Between and Within Two Restoration Sites in San Francisco Bay

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Most restoration efforts for native oysters (*Ostrea lurida)* in California involve the provision of hard substrates to increase natural larval recruitment. Different types, sizes, and configurations of such substrate have been used, but have not been compared in a rigorous study design. In the ideal, substrates should encourage oyster recruitment, growth, and survival, while remaining relatively free of non-native foulers and sediment. As part of a larger "living shoreline" project, we compared the performance of native oysters across five substrate types at two restoration sites in San Francisco Bay. Four substrate types constructed from "baycrete" (cement and locally dredged shell)—modular interlocking oyster blocks, stacks of small oyster domes (Oyster Reef Balls), large oyster domes (Bay Reef Balls), and large segmented oyster domes (Layer Cakes)—and stacks of Pacific oyster shell in mesh bags were deployed at the sites in summer 2012. Data collected show large variation in oyster recruitment between the two sites. Within each site, there is little difference in oyster density across the substrate types, but oyster numbers are consistently highest on north and vertical faces, and at lower tidal elevations, suggesting that thermal stress is a factor in oyster recruitment and/or survival at these sites. We also compared oyster growth and longer-term survival, measured sediment accumulation, and enumerated other species that have recruited to the deployed substrates, including small fish, algae, and sessile and mobile invertebrates. We tested for interactions between oysters and native eelgrass, which was planted as part of this restoration project, examined effects of the restoration project on the natural oyster populations at each site, and looked for community-level effects such as fish use of the restored sites. This project adds to our understanding of restoration methods both in terms of increasing oyster populations and habitat creation.

Keywords: Oysters, Habitat Restoration, Living Shorelines, Eelgrass, Substrate, Methods

Poster Topic: Habitat Restoration: Living Shorelines

Evolving the Bed: Physical and Geomorphic Processes of the San Francisco Bay Living Shorelines Nearshore Linkages Project

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Mitigating shoreline erosion with biologically self-sustaining habitats would lessen the need for intrusive shoreline protection infrastructure in bays and estuaries. The San Francisco Bay Living Shorelines Near-shore Linkages Project is a multi-objective habitat restoration pilot project with the overarching goal to create biologically rich and diverse subtidal and low intertidal habitats, including eelgrass and oyster reefs, as part of a self-sustaining estuary system that restores ecological function and is resilient to changing environmental conditions. Understanding changes to the physical and geomorphic processes in the project area is key to evaluating the impacts to shoreline and mudflat habitats. Waves, currents, and the resultant sediment transport will cause a geomorphic response on the shoreline and bed while the morphology of the bed will affect wave shoaling and sedimentation rates.

Waves, currents, sedimentation/erosion, and substrate composition are being investigated at four experimental 32 m x 10 m plots in San Rafael Bay. Turbidity of the water column is also being measured. The plots consist of an oyster reef, an eelgrass planting, a combination of oyster-eelgrass elements, and a control plot of native mudflat. Wave and current monitoring instruments were deployed for 6 weeks in spring 2013 to provide data for a Boussinesq wave model that examines wave attenuation by the reef structures. Sedimentation rates and substrate stability were calculated from high-resolution topographic surveys of the bed. The wave model and sedimentation rates provide guidance for future designs of reefs on how they attenuate waves and impact sediment trapping.

Keywords: Wave Attenuation, Mudflat, San Rafael Bay, Sedimentation, Living Shorelines

Poster Topic: Habitat Restoration: Living Shorelines

How Do Transplant Source, Restoration Site Constraints, and Herbivory Interact in Reintroduction Efforts of Native Pacific Cordgrass (*Spartina foliosa*) in the San Francisco Bay?

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Planting native cordgrass (*Spartina foliosa*) is an essential part of restoring tidal marsh vegetation to the central portions of San Francisco Bay. In this region, native cordgrass was extirpated by the highly invasive *Spartina alterniflora* and its hybrids with S*. foliosa*. Restoration of native cordgrass follows highly successful control of non-native *Spartina*. However, revegetation attempts have been complicated by three factors: (i) a paucity of native cordgrass populations available for transplant, (ii) altered marsh characteristics following hybrid invasion and removal, and (iii) Canada Goose herbivory. In 2011-2012, we explored the relationship between restoration site characteristics, parental source of *S. foliosa* transplants, and plant caging. We transplanted plugs from four donor marshes into five restoration sites, pairing caged and uncaged material, and monitoring growth responses monthly. After one year, it was clear that herbivory pressure varies greatly between restoration marshes. Marshes with resident geese had low survivorship of uncaged plots (<7%), but caged plots had high survivorship (>75%). In marshes with limited grazing pressure, caging did not hinder survivorship, but did decrease plant performance. The source of transplants had strong effects within some of the restoration sites. In 2012-2013, we further explored the interaction between source of transplant material and edaphic conditions. Plants were collected from eight widespread marshes, genetically tested using microsatellites, and grown in identical nursery conditions. Despite the fact that we did not detect genetic variation between source populations, plants from different sources varied greatly in growth characteristics after 10 months of nursery growth. Preliminary monitoring after planting in the field further suggests that the source of transplant material strongly influences survivorship, although this was not predictable from patterns in the nursery beds. We conclude that both goose exclusion and transplant source selection should play an important role in ongoing native cordgrass restoration.

Keywords: *Spartina foliosa*, Restoration, Cordgrass, Herbivory, Revegetation

Poster Topic: Habitat Restoration: Wetlands

Is Restoration of Salt Marshes Enhanced by Proximity to Established Native *Spartina*?

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Establishing Pacific cordgrass, *Spartina foliosa*, is vital to the success of large scale tidal marsh restoration in the San Francisco Bay. However, since the 1970s, introduced *Spartina alterniflora* and its highly invasive hybrids with *S. foliosa* have established throughout many wetlands baywide. Prior to eradication efforts, restored marshes located near the introduction site in the central bay were typified by a dense monoculture of non-native *Spartina.* As distance from the epicenter increased, higher rates of native recruitment were observed, especially in restoration marshes near established native clones. The importance of localized recruitment is supported by an Invasive *Spartina* Project (ISP) drift card study in which most cards were recovered close to the release location, with only a few cards traveling over 100 km. In this study, we use genetic tools to determine the influence of local populations of established *Spartina* clones on the genotypic identity of recruiting seedlings. In this ongoing study, we are sampling seedlings at four classes of sites: (i) untreated areas dominated by hybrids, (ii) previously treated areas that have been outplanted with nursery-grown *S. foliosa*, (iii) naturally occurring mixed stands of native and hybrid plants, and (iv) stands of naturally occurring *S. foliosa*. We sample populations in 12 distinct geographic locations in the central and southern portion of the San Francisco Bay using a suite of 16 diagnostic microsatellite markers to identify young clones and nearby established clones as hybrid or native. We test for similarity of genetic composition using a Bayesian approach in *Structure*, and with summary statistics in AMOVA. The results demonstrate the potential for active management of nearby *Spartina* hybrids to positively affect the long-term recruitment trajectory of invasive plants in San Francisco Bay wetlands.

Keywords: Hybrid, Invasive, Cordgrass, Spartina, Microsatellites, Genetics, Recruitment, Restoration, Salt Marsh

Poster Topic: Habitat Restoration: Wetlands

South San Francisco Bay Three-Dimensional Sediment Transport Modeling

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The San Francisco District of the US Army Corps of Engineers is considering the beneficial use of dredge material in South San Francisco Bay (South Bay) by investigating sediment dispersal at potential beneficial locations within the South Bay. Beneficial locations include mudflats and breached salt ponds south of Dumbarton Bridge. The UnTRIM Bay-Delta hydrodynamic model has been coupled with the Simulating WAves Nearshore (SWAN) wave model and the SediMorph sediment transport model to evaluate nine dredge material placement scenarios. The UnTRIM-SWAN-SediMorph modeling system has been calibrated and validated throughout San Francisco Bay and the Sacramento-San Joaquin Delta by comparing model runs to available field data. Simulation results from the modeling system show potential benefits for dredge material placement in the South Bay as briefly described herein. The farther south of Dumbarton Bridge that dredge material placements are located, the more deposition of sediment within beached salt ponds occurs. Dredge material placements in the middle of the far South Bay and just north of Pond A6 of the Alviso salt ponds will supply equal amounts of sediment to the combined salt ponds and mudflats. Between 83 and 96% of the dredged material placed south of Dumbarton Bridge was retained in the Far South Bay and nearly all of the sediment was retained in the South Bay. A simulation of future conditions, which includes the breaching of more salt ponds and sea level rise of 0.2 meters, indicates that when more salt ponds are breached the percentage of dredged material deposited within the breached ponds also increases. Results from this modeling work will support the San Francisco District's Regional Dredged Material Management Plan (RDMMP) and the Regional Sediment Management (RSM) program. The RDMMP will identify dredged material placement locations for the San Francisco District's operation and maintenance dredging.

Keywords: Sediment Transport, San Francisco Bay, Hydrodynamic Modeling, Dredge Material

Poster Topic: Habitat Restoration: Wetlands

Seed Dispersal in the Eden Landing Salt Ponds Complex: The Influence of Landscape, Site, and Time on Seed Arrival

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Recently breached tidal marsh restoration sites offer the opportunity to study the factors that contribute to plant community establishment. While channel development and sediment accretion are two of the main factors driving the development of newly breached restoration sites, both interact with seed supply to structure newly emerging plant communities. Seed supply has been studied in the North Bay, but no published studies have explored seed dynamics in restored salt ponds in the South Bay. This study will look at the influence of geographic distance and microtopography on seed dispersal in Whale's Tail, Old Alameda Creek, North Creek, Mt. Eden Creek and E8A marshes. Analysis will focus on two spatial scales: alpha diversity of species within each marsh and beta diversity of species between marshes. Active dispersal will be assessed by collecting seeds deposited by tide and wind using seed collection mats. Similarity indices and distance decay analysis will be used to determine how seed composition is related to standing vegetation community, time since breach, soil seedbank, distance from seed source, tidal influence and topographic heterogeneity. Understanding these dynamics will help land managers plan restoration efforts and assess conditions under which direct application of propagules may be necessary. Seed collection for this project will begin on September 1st, 2013, and this poster describes project design and implementation of initial steps.

Keywords: South Bay Salt Ponds, Seed Dispersal, Wetland Restoration

Poster Topic: Habitat Restoration: Wetlands

Hayward Shoreline: Observations from an Evolving Landscape

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Public access, endangered species habitat, and wetland restoration all intersect on Hayward Shoreline. When planning restoration projects including plans for sea level rise, observations of past landscape level changes can help frame expectations. The time interval necessary to detect landscape level change is variable. The direct effect of the removal of water control structures and levee breaching can take 1-2 days, while the development of ecosystem complexity associated with a given physical change can take years as measured by tidal channel network density and marsh plain revegetation.

At the time of the 1856 coast survey, public access on Hayward Shoreline equated to access for hunting, fishing and commerce via deep channels extending to Roberts Landing and Eden Landing. Salt pannes in the back marsh area east of the shoreline were precursors to the formal salt making enterprise that once included using pine boughs to crystallize salt on. Between 1937 and 1982 the Oliver Brothers made salt on a 190 acres bisected by construction of Highway 92 and the bridge. The Hayward Area Recreation and Parks District purchased the northern 153 acres of the Oliver Brothers salt works and implemented a 324 acre restoration project in 2001-03 that included habitat enhancement for nesting western snowy plovers, completion of the Arthur Emmes segment of the Bay Trail, increased tidal flushing by replacing failed culverts with a bridge and added or improved water management options for the Salt Marsh Harvest Mouse Preserve.

The poster maps the development and progression of the tidal channel network and influence of levees, the effects of dredged material reuse on vegetation establishment, the ability to maintain salinities and western snowy plover nesting habitat and the quantity and quality of HARD's public access and education programs.

Keywords: Hayward Shoreline, Wetland Restoration, Planning, Western Snowy Plover, Public Access

Poster Topic: Habitat Restoration: Wetlands

Studying Germination of *Distichlis spicata* for Seeds with South San Francisco Bay Provenance

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Saltgrass (*Distichlis spicata*), a co-dominant species in salt marsh, transitional and alkali grassland habitats is a top candidate in restoration projects because of its high value for wildlife and its grazing tolerance. Saltgrass is an aggressive clonal colonizer but revegetation by direct seeding may be in many occasions more efficient especially when it is combined with other species seeding. However, limited availability of local saltgrass seed stock and low germination rates are challenges associated with the use of direct seeding for this species in the San Francisco Bay area. In 2012, we located four seed producing saltgrass populations in the South Bay and conducted a series of nursery experiments to identify the best conditions for recruitment. Unlike many studies, which found that seed scarification and/or cold stratification may increase germination rates, we found that scarification decreased germination and that constant warm temperatures with no wet cold stratification improved seed germination. Seed germination was also significantly different among the four seed collection sites. Our results support that saltgrass recruitment from direct seeding may be over 70% when temperatures are above 18 degrees Celsius on irrigated fields. A separate series of nursery experiments showed that other salt marsh plant species like Seaside heliotrope (*Heliotropium currasavicum*) and Alkali weed (*Cressa truxilensis*) show the greatest germination rates under similar conditions. Field experiments that will test the effect of seed provenance, seeding time and irrigation regime on seeding success are necessary to determine the most efficient, applicable method for seeding success.

Keywords: *Distichlis spicata*, Germination, San Francisco Bay, Restoration, Nursery, Salt Marsh

Poster Topic: Habitat Restoration: Wetlands

Using Landscape Ecology Metrics to Assess Changes in San Francisco Bay-Delta Estuary Tidal Marsh from Past to Present in Support of Regional Landscape-Scale Restoration

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The San Francisco Bay and the Sacramento-San Joaquin Delta are often studied and managed as distinct entities. However, the Bay and Delta function as a unified and complex estuary, which crosses several ecologically significant gradients (i.e. tidal influence, salinity, and vegetation). These gradients are important when planning for restoration of wildlife corridors and interconnected habitats. While current regional management and restoration efforts emphasize a landscape-scale approach to restoration, few tools are available that illuminate what large, interconnected habitat restoration should look like for the region and Estuary as a whole.

To inform these efforts, the San Francisco Estuary Institute performed multiple landscape ecology analyses of tidal marsh in the Bay and Delta. These analyses—including marsh patch size distribution for clapper and black rails (*Rallus longirostris* and *Laterallus jamaicensis*), nearest neighbor distance, edge-to-core habitat ratio, and habitat adjacency—were performed in parallel on historical and contemporary datasets of the Estuary's aquatic resources. The landscape metrics derived from these analyses allowed us to quantify the extent, distribution, and connectivity of historical tidal marsh, analyze net changes between c. 1800 and 2009, illustrate the current configuration of habitat for key species, and identify areas with enhancement/restoration potential. The Estuary has experienced net decreases in the number of marsh patches > 100 ha (the size below which rail densities are known to decrease) and in the relative proportion of core habitat. Only four of the 35 large marsh patches in the Estuary are within the Delta (representing 6.1% of the Estuary's core marsh habitat). As a whole, this work allows for assessment of the region's progress towards targets established by the Baylands Ecosystem Habitat Goals and Bay Delta Conservation Plan. It is notable for its synthesis of complementary regional datasets and its application across the whole San Francisco Estuary, from Bay to Delta.

Keywords: Landscape, Ecology, GIS, Historical, Estuary, Habitat, Patches, Restoration

Poster Topic: Habitat Restoration: Wetlands

The Sonoma Creek Enhancement Project: Habitat Improvements and Mosquito Source Reduction in a North Bay Centennial Tidal Marsh

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The Sonoma Creek tidal marsh, which fringes the western bank of Sonoma Creek near the confluence with San Pablo Bay in Sonoma County, routinely ponds water for long periods following spring tides and storm events when high waters become trapped in a large basin in the marsh interior and between a series of abandoned levee alignments along the western marsh boundary. The water that ponds in these areas leads to high mosquito production rates and reduced vigor and cover of marsh vegetation, which reduces habitat quality for the endangered California clapper rail, threatened California black rail, and other marsh-dependent species. The degree of ponding at this site, and the resulting mosquito production and habitat degradation, are exacerbated by the fact that the Sonoma Creek marsh is a centennial tidal marsh (formed over approximately the past 100 years from the Sierra Nevada hydraulic mining sediment load) and lacks the extensive tidal channel networks characteristic of ancient San Francisco Estuary tidal marshes. The San Pablo Bay National Wildlife Refuge, in collaboration with Audubon California, the Marin-Sonoma Mosquito and Vector Control District, and Wetlands and Water Resources, Inc. has developed the proposed Sonoma Creek Enhancement Project to address these issues. The project includes the construction of several enhancement elements to improve conditions at the site by (1) improving tidal exchange within the wetland interior, (2) reducing the extent of continuously ponded areas, (3) providing high-tide refugia within the marsh interior, and (4) creating marsh-upland transitional habitat along the Tubbs Island perimeter levee at the western edge of the project site. The project is currently undergoing regulatory review and construction is planned to begin in summer/fall 2014, pending the receipt of all required permits. The poster presents the current project design, proposed implementation timeline, and updates on the regulatory compliance process and funding status.

Keywords: Wetland Restoration, North Bay, Transition Zone, Tidal Wetlands

Poster Topic: Habitat Restoration: Wetlands

Sonoma Baylands Wetlands Demonstration Project: Lessons Learned Over 15 Years of Monitoring

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Funded in partnership between the U.S. Army Corps of Engineers and the California State Coastal Conservancy, the Sonoma Baylands project was enacted to test the application of dredge material to accelerate tidal wetlands restoration. In all 303 acres of wetland were created. Physical and biological success criteria, established by a review committee, formed the basis of monitoring that is now its 15th year, representing one of the most comprehensive, long term monitoring programs for a tidal wetlands project.

Sonoma Baylands is considered a "second generation" project, designed using lessons learned from smaller previous projects, and is now contributing to the science being used in "third generation" projects such as the restoration at Hamilton, Napa Salt Ponds and South Bay Salt Ponds. Here, strict criteria on the elevation of placed dredge material, to within the colonization zone of tidal wetland vegetation, were specified to accelerate marsh building while maintaining soft sediment conditions to support channel formation. Experimental wave berms were included for their role in reducing wind wave disturbance of vegetation colonizing the mudflat, and to protect the perimeter level from erosion. A channel cut designed to provide full tidal connection to the bay was not constructed over concerns of disturbance to endangered species in natural marsh outboard of the restoration site.

Monitoring demonstrates that the site is following an evolutionary path towards tidal marsh restoration. The evolution of the site was initially stalled, impaired by inadequate capacity of undersized channels to drain tidal waters. Predictions that natural scour would occur were correct, and after a 5 year delay, full tidal connectivity allowed the progressive transition from mudflat to vegetated marsh. Populations of feeding birds have shifted in composition, as the site has evolved from standing water, to increasingly vegetated conditions. Fish counts are in line with data collected bay wide.

Keywords: Restoration, Marsh, Channel, Erosion, Accretion, Colonization, Monitoring, Dredge

Poster Topic: Habitat Restoration: Wetlands

Factors Influencing Vegetation Expansion and Transplant Success at the Liberty Island Restoration Site in the Sacramento/San Joaquin Delta, California

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The development of effective and sustainable wetland restoration approaches is contingent on understanding the colonization and expansion dynamics of the targeted plant species. We employed a combination of observational and manipulative studies at the Liberty Island tidal freshwater marsh restoration site in the Sacramento/San Joaquin Delta to elucidate those factors controlling vegetation dynamics at the site, particularly in regards to *Schoenoplectus californicus* (tule). Our approach had multiple components, including: 1) seed bank assay, 2) field transplant study of *S. californicus, S. acutus*, and *Typha latifolia*, as well as a 3) field transect study and 4) vegetation lateral expansion study at multiple locations. The seed bank at the site included viable seeds for a greater number of species than is currently represented in the emergent wetland plant community, which indicates that environmental conditions limit the successful germination and persistence of many of the species in the seed bank. Transplant establishment using adult transplants was much more successful than with rhizomes, likely because of greater flooding tolerance of adult transplants. All three species assessed were able to establish; however, *S. californicus* displayed the highest transplant survivorship and rapidly became the dominant species, exhibiting high rates of vegetative expansion. The transect study of *S. californicus*-dominated marshes revealed a range of soil conditions, marsh platform and marsh edge elevations, and rates of vegetative lateral expansion across locations at Liberty Island. The history of the site in combination with current hydrologic and exposure gradients appear to be exerting substantial influence on plant community dynamics and rates of expansion. Our findings illustrate the importance of recognizing multiple environmental factors that may exert influence on life history stages to varying degrees, as well as the dynamic interactions between the plant community and the abiotic environment when considering restoration thresholds.

Keywords: Liberty Island, Tules, Restoration, Seed Bank, Plant Establishment, Vegetative Expansion

Poster Topic: Habitat Restoration: Wetlands

Ecosystem-Scale Rates of Primary Production within Wetland Habitats of the Northern San Francisco Estuary

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Salt marsh restoration is hypothesized to provide organic carbon subsidies for estuarine food webs. Organic carbon comes from diverse primary producers that differ in carbon fixation rates as well as areal extent within wetland systems. This study was designed to obtain some of the first estimates of the relative contribution of different primary producers to total organic carbon production within open water and tidally flooded wetlands of the northern San Francisco Estuary (SFE). Carbon fixation rates of phytoplankton, microphytobenthos, and low marsh emergent vegetation were measured in two natural and four restoring estuarine wetlands over the growing season in 2004. Areal (m^2) rates of carbon fixation were the greatest for low marsh vegetation, while phytoplankton and microphytobenthos rates were one and two orders of magnitude lower, respectively. However, when areal production rates were scaled to the amount of habitat available for each primary producer group, the relative importance of each group varied by location. Given that each primary producer group supports a different subset of estuarine consumers, the type of food subsidy desired should influence the amount open water channel, mudflat and low marsh area restored. Large-scale wetland restoration activities should consider the types of primary producers likely to occupy restored habitats when estimating future food web impacts.

Keywords: Salt Marsh, Primary Production, Microphytobenthos, Phytoplankton, Restoration

Poster Topic: Habitat Restoration: Wetlands

Restoration of Bair Island Complex Nears Completion

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Substantial progress has been made towards implementing the Bair Island Restoration and Management Plan. The tides were recently restored to Middle Bair Island. This was the second completed component of a larger restoration project aimed at restoring 1,400 acres of the entire 2,600-acre Bair Island complex. Historically, the island complex (Inner, Middle, and Outer Bair Islands) was part of a large expanse of tidal wetlands that extended along the southeastern edge of San Francisco Bay. The island complex was diked for agriculture in the late 1800s. In 1946 the area was converted to salt production, which continued until 1965, though the legacy of wetland conversion remains.

The goal of this 848-acre project was to restore a more natural tidal hydrologic regime and salt marsh habitat on Middle Bair Island. To complete the restoration, several specific construction activities were required: flow constrictors were constructed in Smith and Corkscrew Sloughs to limit sedimentation in Redwood Creek; internal and perimeter levee breaches were excavated to restore tidal exchange to remnant tidal sloughs within the island; and internal borrow ditches were blocked with earthen ditch blocks in select locations to direct tidal flow into historic slough channels. A newly constructed pedestrian bridge now provides access to Inner Bair Island, and a future phase will provide trail access to observation platforms offering birds eye views of the island complex.

Keywords: Tidal, Estuarine, Wetland Restoration, Endangered Species, Public Access

Poster Topic: Habitat Restoration: Wetlands

The Contribution of Vegetated Ponds to Phytoplankton Carbon and Material Flux in the Freshwater Tidal Wetland Liberty Island

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Liberty Island is a freshwater tidal wetland thought to provide habitat and food resources for the endangered delta smelt and other fish species of interest in San Francisco Estuary. However, little is known about the mechanisms that control environmental conditions and material production within the wetland. This study addressed the question: Do small vegetated ponds contribute habitat and are they a source of carbon and material to this freshwater tidal wetland? To address this question, continuous measurements of water temperature, specific conductance, turbidity, pH, dissolved oxygen and nutrients were used to characterize the water quality and material flux in three wetland ponds between 2010 and 2011. Daily average carbon production rate was computed from continuous measurements of chlorophyll fluorescence, phytoplankton yield and underwater light. Concentrations were combined with continuous flow measurements to quantify material flux among the wetland ponds. Over the year-long study, daily average chlorophyll *a* concentration, primary productivity, water temperature, specific conductance, turbidity, soluble reactive phosphorus and dissolved organic nitrogen were greater in the vegetated ponds. Vegetated ponds also exported suspended solids, salt and chlorophyll and carbon to ponds within the wetland and adjacent river channels. Vegetated ponds contrasted with the large open water pond which stored material. Chlorophyll, suspended solids and salt flux were dominated by advective flow in the vegetative pond and tidal flow in the open water pond. Chlorophyll flux was further influenced by carbon production rates which increased on flood tide. Although their percent contribution to the total material flux of the wetland was small, the elevated primary productivity and chlorophyll concentration plus their export to ponds within the wetland contributed significantly to the wetland production. This study provided information needed to assess the amount of material and carbon wetland restoration projects can contribute to the estuarine food web.

Keywords: Liberty Island, Freshwater Tidal Wetland, Material Flux, Carbon Production

Poster Topic: Habitat Restoration: Wetlands

Spatial Heterogeneity in Flow Paths in a Dense Delta Marsh

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We use a novel 3D submersible camera to measure the velocity of surface water flow in a Typha-Schoenoplectus marsh. Our goal is to understand spatial heterogeneity in the surface water velocities caused specifically by the geometry within a dense stand of emergent vegetation. For this reason, we work in a marsh that has relatively simple boundary conditions: one inlet, one outlet, near-constant depth (non-tidal), and an apparently homogeneous distribution of plants. Notably, there are no known "channels" in this marsh, i.e. neither contiguous paths that are free of vegetation nor contiguous paths in which the peat surface is lower than average. This site is located on Twitchell Island, in the "West pond" of the experimental carbon capture wetland project run by the Department of Water Resources and USGS. We perform a series of velocity measurements along a transect that bisects the marsh. From these we assess the spatial variability of flow velocity. We compare this to the temporal variability in velocity caused by wind gusts, which force the water via both surface shear and through a "honami" coupling.

Keywords: Freshwater Wetland, Flow Velocity, Particle Tracking, Honami

Poster Topic: Habitat Restoration: Wetlands