Using Scenarios to Support Climate-Smart Adaptation for the South Bay Salt Ponds Restoration Project

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Managers and decision makers in the San Francisco Estuary are struggling to develop effective conservation and restoration plans because of the large uncertainty surrounding the future effects of sea-level rise and other aspects of climate change on inter-tidal ecosystems. The South Bay Salt Pond Restoration project, the largest wetland restoration project on the west coast of North America, exemplifies the challenges in planning for uncertain futures as the project's adaptive management plan attempts to balance the needs of species that utilize tidal marsh habitats and managed pond habitats. We used predicted future distribution and abundance of marsh bird and shorebird species in response to changes in habitat availability and suitability as a result of projected sea-level rise, salinity, sediment availability and management scenarios in the South Bay. The effectiveness of management scenarios was evaluated by comparing the modeled future abundance of birds to current abundance at the south bay and complex levels. Through our analysis we identified combinations of scenarios in which management targets were not met. We then used scenario planning stakeholder meetings to formulate adaptive management actions that could ensure management targets are met under each scenario. Additionally, the results from our analysis will be used to guide and prioritize future monitoring efforts to help inform ongoing adaptive management. Our project demonstrates how scenario planning can be used to incorporate uncertainty into effective climate smart adaptation planning.

Keywords: Uncertainty, Scenario Planning, Tidal Marsh, Shorebirds, Restoration, Sea-level rise, Conservation
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Lessons Learned in Large Scale Environmental Restoration Project Management and Scale Dependent Alternatives Assessment

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This paper highlights findings and outcomes of a nationally prominent wetlands restoration program unusual in physical scale (55,000 acres), hydraulic complexity and frame (years in development, decades in implementation) and examines linkages between regional, local and larger-scale processes, and their implications in terms of ecosystem behavior and management. Ecosystems prevailing in the area of the Picayune Strand Restoration Project (PSRP) in southwest Florida had been markedly affected by the installation of canals and drainage features designed to promote various development interests. This shifted flow regimes, altered hydroperiods, and had a massive effect on native populations characteristic of the region. The intent of the current effort was to recover a more natural mix of natural overland flow and amorphous flowways, coupled with positive drainage features necessary to preserve development in and surrounding the restoration area. Constraints associated with neighboring areas, including agriculture, residential, business, transportation and natural systems areas, which were to be explicitly accounted in assessment and intervention. This led to a need to reconcile scale dependent hydraulic requirements spanning roadway clearances and crossings, small and large scale flood conditions, regional levees and protective works, and long term shifts in groundwater regimes, all of which can have an impact on ecosystems in this sensitive and highly valued coastal system. To accomplish this basic scheme, a range of candidate configurations were considered. This paper explores the technical, political, jurisdictional and scientific issues that were at play as the program progressed. The concerns raised by selected rehabilitation practices are discussed and lessons learned for this type of large scale rehabilitation are provided. Suggestions are made regarding preferred practice, and areas meriting further research are identified. Comparisons are made between Bay-Delta systems and processes, and those in this program, with the intent of exchanging experiences that may lead to mutually beneficial insights.

Keywords: large-scale ecosystem management, political jurisdictional constraints, human impact, Florida
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Evaluation of Restoration Actions in the San Joaquin River using Ecosystem Diagnosis & Treatment

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The San Joaquin River Restoration Program (SJRRP) prescribes flow augmentation and specific restoration projects to restore spring-run Chinook salmon between Friant Dam and the Merced River (150 miles). The Bureau of Reclamation, working with fishery agencies, has used the Ecosystem Diagnosis & Treatment model (EDT) to understand factors controlling success of the restoration actions and to evaluate their potential benefits. To date, actions in reaches 2B and 4B (respectively above and below Mendota Pool) have been analyzed, including expansion of floodplain areas and alternative flow and fish routings. The base condition assumed SJRRP settlement flow and fish passage at existing barriers--substantial modifications from current conditions. Because spring-run Chinook were extirpated from the San Joaquin River, an important task was to evaluate alternative juvenile Chinook life histories and their relative success under restored conditions. Survival rates in the Bay-Delta and ocean were based on recommendations from the fisheries agencies. Under the base condition, habitat supported a small and fragile spring Chinook population that was highly dependent on water year conditions. Scale and location of restoration were key to fish population benefits. The value of actions in reaches 2B and 4B (and likely other actions) was highly dependent on flow and water temperature and the juxtaposition of fish presence. Successful juvenile behavior was to emigrate as fry before water temperatures increased or remain over summer in the cool water below the dam. Benefits of floodplain restoration were limited by the timing of inundation and juvenile emigration. Pre-spawn adults needed to move upstream quickly to cool water below the dam before temperature increased. The analysis showed the close coupling of restoration benefits to the fish life history and the synergy of flow, temperature, and other in-stream conditions. Achieving the SJRRP goals will require a suite of actions across the study area.

Keywords: San Joaquin Habitat Restoration Life Cycle Modeling Salmon habitat
Session Title: Restoration Lessons Learned I
Session Time: Thursday 8:20AM – 10:00AM Room 311-313

Immediate Fish Response to Salmonid Rearing Habitat Enhancement in the Spawning Reach of a Highly Altered Central Valley Stream

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Gravel and gold mining, in conjunction with altered flows and decreased coarse sediment transport, has resulted in deterioration of the lower Stanislaus River into a homogenous, incised channel with few functional floodplains or other off-channel rearing areas. Consequently, long-term monitoring of Chinook salmon escapement and subsequent juvenile production indicates an apparent limitation of suitable spawning and juvenile rearing habitat on the Stanislaus River. To alleviate these population constraints, the Oakdale Irrigation District and the Anadromous Fish Restoration Program jointly funded the Honolulu Bar Restoration Project, which was designed with the primary objective of increasing and enhancing juvenile salmonid rearing habitat along a mile-long stretch of the primary spawning and rearing reach. Rearing habitat was enhanced through re-contouring 2.4 acres adjacent to an existing side-channel to function as a small floodplain, and by using harvested material to construct shallow gravel benches along the main channel margin.

Over the past two years, frequent post-construction assessment of habitat use during winter and spring suggests that localized benefits were realized almost immediately in the restored area which was consistently utilized for rearing by juvenile salmonids across a broad range of sizes. These findings illustrate that such restoration projects can provide nearly immediate amelioration of habitat scarcity in Central Valley rivers. In the larger picture, continued long-term monitoring provides the data necessary to evaluate the combined success of multiple restoration efforts in the Stanislaus River. Encouraging and facilitating natural production is crucial to the long-term sustainability of native fish populations, and restoration and management plans for Central Valley salmonids would benefit from the inclusion of rearing habitat enhancement in natal spawning areas where habitat limitations have been identified.

Keywords: floodplain, side channel, salmon, rearing, Stanislaus, habitat, enhancement, production, juvenile
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Session Time: Thursday 8:20AM – 10:00AM Room 311-313

Managing for Changing Tides: Restoring a Tidal Marsh in an Urbanized Area

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Restoring wetland habitats is complex in any environment, but tidal restoration is particularly challenging in urban areas. Ecological needs must be balanced with the concerns of neighboring property owners, and the restoration opportunities are often limited by infrastructure constraints. In 2003, Solvay USA, Inc. launched the Peyton Slough Remediation and Restoration Project in Martinez, California to remedy legacy contamination and restore diked historic tidelands on their property and that belonging to the California State Lands Commission. Construction of a new slough channel was completed in 2007, and a portion of the property, which had been diked and drained over 100 years, was reintroduced to tidal action in 2009. Reintroduction of tidal action required vigilance and adaptation as Solvay and other stakeholders worked to restore wetland without compromising existing infrastructure. Pipelines, subsided roadways, and culvert constrictions adjacent to the restoration presented challenges; the elevation difference between the marsh and the roadways was less than one foot. With daily and seasonal tidal variation greater than the freeboard, water management was a critical and labor intensive element of the plan. Despite these challenges, the site has successfully been restored to a pickleweed marsh now used by numerous fish and wildlife species. This success has been attributed to careful water management, close collaboration with the neighboring stakeholders who now collect upstream data and make recommendations for tide gate operations, and implementation of adaptive management (e.g, re-grading the marsh plain, altering the tide gate structure, changing the tide gate operations). Future tidal restoration projects in urban areas of the Bay-Delta will benefit by incorporating an effective stakeholder working group, tidal data modeling, and regular habitat monitoring to inform adaptive management decisions and lead to better water management.

Keywords: tidal marsh, restoration, stakeholder, adaptive management, infrastructure, pickleweed, wetland
Session Title: Restoration Lessons Learned I
Session Time: Thursday 8:20AM – 10:00AM Room 311-313

How Do Restoration Site Characteristics, Plant Caging, and Parental Source Affect Native Pacific Cordgrass (*Spartina foliosa*) Establishment?

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A key programmatic goal of the San Francisco Estuary Invasive Spartina Project's restoration program is to reestablish native Pacific cordgrass (*Spartina foliosa*). This foundation species provides critical habitat for native fauna, including the endangered California clapper rail (*Rallus longirostris obsoletus)*. Five large-scale experiments conducted from 2010-2013 have tested how restoration site characteristics, plant caging, and parental source of *S. foliosa* transplants have influenced establishment rates of native cordgrass. Throughout all experiments, outplanting location (e.g., geographic location, substrate, elevation) and caging were strong predictors of planting success. Establishment rate of native cordgrass was highest on uniform mudflats and wide channel banks (62%) with lower establishment rates occurring in 2nd order channels and bayfront habitat (15%). Cage effects varied by marsh, with the strongest cage effects occurring at sites with nesting Canada goose (7% survivorship in uncaged plots, 78% survivorship in caged plots). In a separate experiment, parental source was a strong predictor of planting establishment. Plants were collected from eight widespread marshes, genetically tested using microsatellites, and grown in identical nursery conditions. After 10 months, source populations differed in terms of culm height and density. Following nursery growth, 300 plants from each donor source were outplanted into two marshes and monitored quarterly. Sources varied significantly in terms of survivorship, flower production, and culm density. Field performance was not predictable from nursery bed performance. Successful restoration of native cordgrass requires understanding site specific conditions including marsh hydrology, elevation, substrate, donor source material, and herbivores.

Keywords: restoration, *spartina foliosa*, cordgrass, clapper rail, caging, adaptive management
Session Title: Restoration Lessons Learned II
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Blacklock Restoration Project in Suisun Marsh - 5 Years of Post-Breach Monitoring

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The Blacklock Restoration Project in Suisun Marsh is a 70 acre site in which tidal flow was restored to managed wetlands by the Department of Water Resources. The objectives of this project are to increase the amount of tidal brackish wetlands to aid in the recovery of listed species and to improve the understanding of tidal marsh restoration through collaborative science. There is a 10 year monitoring period following breaching of the levee in 2006. Data on 15 parameters was collected and analyzed to evaluate progress towards meeting these objectives. Monitoring results for years 1 – 5 include: an average elevation increase of 0.3 ft; total channel length increased by 26%; methyl mercury concentrations in water, sediment, and fish tissue were, overall, higher immediately post-breach and decreased to lower concentrations within 2 years; there were similar concentrations of dissolved oxygen within the restored area and adjacent slough; vegetation cover decreased by less than one acre and the growth rate of *Phragmites australis* is double the rate of native species; there is a diverse range of avian species using the site. Lessons learned from this project will aid future tidal restoration projects by potentially lowering costs while still gaining valuable scientific information. For example, surface elevation tables and cryogenic core sampling were found to be ineffective ways to measure accretion in highly subsided unvegetated areas due to scour. Thousands of acres are planned for tidal restoration in the Delta and Suisun Marsh over the next 10 years. Future tidal restoration projects will benefit from the sharing of these monitoring results.

Keywords: Suisun Marsh, Blacklock, tidal restoration, sedimentation, channel formation, methylmercury, DO
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Session Time: Thursday 10:20AM – 12:00PM Room 311-313

Lessons Learned from Community-Based Restoration of Transition Zone Habitat

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Transition zones between tidal marsh and upland habitats provide important functions and ecosystem services for marsh-dependent species, such as providing habitat feeding, nesting, and high tide refuge. In addition, these areas provide important functions, such as predator-prey dynamics, habitat connectivity between the tidal marsh and uplands, and genetic diversity, to name just a few. These areas also provide critical wetland migration space as sea level rises and can also provide accommodation space during flood events. Land management has resulted in fragmented t-zones throughout the Bay-Delta system, thereby reducing functionality of these important habitats. For the last 13 years, Save The Bay has focused our work on community-based restoration using over 6,000 volunteers annually to create and restore T-zone habitat on narrow levee slopes in highly urbanized areas. However, while providing important habitat in urbanized areas where similar habitat didn't exist, our initial projects only focused on one type of t-zone. Over time, we have adjusted our methods to focus on broader, wider t-zones and are starting to scale our work up to larger sites and to design our work so that our results can inform other similar projects. We have also adjusted our plant palette to better reflect species that can adapt to rising seas and predicted changes in weather patterns with climate change. Our work suggests that the creation of wider, low-gradient slopes combined with a thoughtfully designed plant palette will result in successful establishment of an initial t-zone plant community that will develop over time to provide important habitat value. This talk will focus Save The Bay's work in narrow transition zones and provide lessons learned that can be applied to the protection, creation and restoration of t-zone habitat throughout the Bay-Delta system.

Keywords: Transition, T-zone, Vegetating, Community, Restoration, Management, Ecosystem, Function(s), Wetland, Migration
Session Title: Restoration Lessons Learned II
Session Time: Thursday 10:20AM – 12:00PM Room 311-313

Optimizing Island Nesting Habitat for Waterbirds Breeding in Wetlands of San Francisco Bay

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San Francisco Bay supports approximately 30% of the Pacific Flyway population of breeding Forster's Terns and is among the largest breeding sites for American Avocets in the west. Islands within former salt ponds of South San Francisco Bay provide critical nesting habitat for many waterbirds, especially Forster's Terns and American Avocets. Preserving and enhancing salt pond island nesting habitat is necessary to achieve the South Bay Salt Pond Restoration Project goal of maintaining current populations of breeding waterbirds. In an effort to provide data-driven recommendations for island habitat management, the USGS is evaluating how island density, distribution, morphometry and vegetation cover influences waterbird nesting in South San Francisco Bay. Historic nest monitoring data from over 15,000 nests as well as recent island and nest-site morphometry data were used to examine waterbird nesting patterns. Islands were the main nesting habitat, with more than 90% of Forster's Terns and 70% of American Avocets nesting on salt pond islands. The number of nests increased with island size up to a point and, thereafter, larger islands supported few additional nests. Although Avocets and Forster's Terns often nest on multiple islands within a single pond, a greater number of islands within a pond did not correlate well with more nests per pond, suggesting that a few islands in each of several ponds may be more advantageous than many islands within a single pond. Within islands, Forster's Terns and Avocets were more likely to nest in areas of higher elevation, at an intermediate distance from the water's edge, and in patches containing some vegetation. The results of this study will provide scientific support for adaptive management actions to maintain waterbird populations as restoration projects, which include island construction, are implemented.

Keywords: Forster's Tern, American Avocet, islands, nesting, San Francisco Bay
Session Title: Restoration Lessons Learned II
Session Time: Thursday 10:20AM – 12:00PM Room 311-313

Quantifying Greenhouse Gas (CO_2, CH_4, N_2O) Release via Ebullition in Restored Delta Wetlands

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Restoration of wetlands on agricultural land in the Sacramento-San Joaquin Delta has been proposed to slow land subsidence. However, flooding also affects greenhouse gas emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Measuring greenhouse gas fluxes in wetlands is difficult due to high spatial and temporal variability, and multiple transport pathways of emission. Transport of biogenic soil gas via highly sporadic ebullition (bubbling) events is often ignored or quantified poorly, but can rapidly release large volumes of gas to the atmosphere. To quantify a robust annual bubble flux we measured ebullition rates continuously for a year (2013-2014) using custom-built chambers deployed in Mayberry Wetland, Sherman Island, CA. We combined bubble flux rates with observations of bubble gas concentrations to estimate ebullition emissions of CO_2, CH_4, and N_2O.

Mean bubble flux rates were 18.3 ± 5.6 L m^{-2} yr^{-1}. Bubble CH_4 concentrations were very high and ranged from 23-76 % with a mean of 47 ± 2.9 %; CO_2 concentrations were lower and ranged from 0.7-6.6 % with a mean of 2.8 ± 0.3 %; N_2O concentrations were below atmospheric concentrations and ranged from 130-389 ppb(v) with a mean of 257 ± 13 ppb(v). We calculated well-constrained annual ebullition fluxes of: 6.2 ± 1.9 g CH_4 m^{-2} yr^{-1}, 1.0 ± 0.3 g CO_2 m^{-2} yr^{-1} and 9.3 ± 2.8 mg N_2O m^{-2} yr^{-1}. Methane emissions via ebullition were very large, representing 15-25 % of total wetland CH_4 emissions measured at this site, whereas ebullition released only small quantities of CO_2 and N_2O. Our results demonstrate that large releases of CH_4 via ebullition can be a significant component of restored wetland greenhouse gas budgets and that the balance of open water and vegetation is important to consider during design and management of restored wetlands.

Keywords: wetlands; greenhouse gas; methane; nitrous oxide; carbon; sequestration; subsidence; restoration
Session Title: Restoration Lessons Learned II
Session Time: Thursday 10:20AM – 12:00PM Room 311-313