Resilient Design for New Coastal Shoreline Park

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Breuner Marsh is an innovative coastal shoreline park on San Francisco Bay. It is one of the first restoration projects in the San Francisco Bay Area that anticipates and accommodates rising sea levels due to climate change. Simultaneously, it creates habitat for endangered and threatened tidal marsh species endemic to the region, including the salt marsh harvest mouse, Ridgway's rail, and California black rail. Restoration, already underway, will benefit endangered species and provide public access to the Bay now and into the future. Following a century of coastal marsh loss from human development, the park restores and enhances 40 acres of tidal and seasonal wetlands. Using rigorous data and spatial modeling, the project plans habitat for endangered and threatened species and access to parkland for adjacent underserved communities.

Anticipating three feet of sea level rise, the team planned site grading to allow the tidal marsh to migrate incrementally to higher elevations over the next 50 to 100 years. The analysis also helped to identify the location of the trail to avoid disruptions to public access in the future. Surface models and vibrant three-dimensional graphics, were created for the community meetings. These provided the stakeholders with a clear idea of the design and played a significant role in consensus-building.

Preservation of Breuner Marsh is the culmination of planning by the East Bay Regional Park District following decades of community-led activism. Situated on a 150-acre shoreline site in the City of Richmond, the project fills a 1.5-mile gap in the San Francisco Bay Trail, a regionally significant trail system. A raised boardwalk integrates public access with protection of sensitive wetland habitat. These enhancements benefit the local community, including the adjacent neighborhood, with access to expanded open space.

Keywords: resilient design, habitat restoration, endangered species, shoreline, wetlands, public access

Poster Topic: Climate Change: Habitat Restoration

Movin' On Up: How Uplands Can Save Wetlands and Restore San Francisco Bay Tidal Marshes

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Over a billion dollars have been spent in San Francisco Bay restoring lands to tidal action, with millions more needed in order to reach the 60,000 additional acres recommended in the Baylands Ecosystem Habitat Goals Report. However, with limited dollars, decision-makers need to be strategic in selecting where, within the Estuary, those marsh acres should be restored. Upland areas that provide space for tidal marshes to move to as sea levels rise are not often considered in marsh conservation efforts. These areas will be essential in sustaining tidal marshes, especially under higher rates of sea-level rise. Acquiring these lands now will increase the diversity of marsh habitats along the elevational gradient, and provide a buffer to storm surge and flooding in the future. However, natural topography, development, and levees can block wetland migration. The Future San Francisco Bay Tidal Marshes Climate-Smart Planning Tool provides spatially explicit projections of marsh and marsh bird response to sea-level rise at multiple scales bay-wide. We demonstrate how Point Blue's Future Marshes Tool can be used to map upland areas around the Bay that can accommodate marsh migration and reveal areas that may require action such as removing barriers to current or future tidal flows. We will demonstrate areas where marshes are projected to exist through 2110, under a range of sea-level rise (0.5 m and 1.65 m) and accretion assumption scenarios. Including marsh migration space in permitting, acquisition, and restoration decisions can lead to a more resilient tidal marsh ecosystem. The goal is to guide decision-making in order to create a thriving Bay that provides habitat for diverse avian species and benefits Bay communities, both now and in the future.

Keywords: restoration, tidal marsh, upland transition zone, sea-level rise, planning tool

Poster Topic: Climate Change: Habitat Restoration

Bringing Climate-Smart Conservation to the San Francisco Bay Estuary: California Landscape Conservation Cooperative

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The California Landscape Conservation Cooperative (CA LCC) is a science-management partnership designed to promote understanding of and integrate climate science into natural resource management. Through the process of Climate-Smart Conservation, the CA LCC informs the implementation of conservation actions that increase the adaptive capacity of species and ecosystems in the face of climate change.

In the San Francisco Bay Estuary, the CA LCC has supported projects that develop management-relevant science on the topics of Pacific coastal fog and sea-level rise modeling. Collaborating with San Francisco Bay scientists and managers, the CA LCC is supporting the development of adaptation strategies in the Gulf of the Farallones National Marine Sanctuary that will be piloted in Green Resilient Shoreline projects. The CA LCC is also building collaborative partnerships through structured decision making to conserve tidal marsh ecosystems and scenario planning in support of the South Bay Salt Pond Restoration Project.

The CA LCC will continue to support Climate-Smart Conservation through collaborative partnerships and projects. Complete information about CA LCC efforts can be found on the CA LCC's website at californialcc.org and all data and products are made available on the Climate Commons (www.climate.calcommons.org). The Climate Commons also offers a starting point for discovery of climate change data and related resources, information about the science that produced it, and guidance for applying climate change science to conservation in California.

Keywords: Climate-Smart Conservation, Collaborative, Adaptation Strategies, Landscape-scale

Poster Topic: Climate Change: Habitat Restoration

Toward an Integrated Vision for a Resilient Urban Estuary: SFEI's Shore Resilience Initiative

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Climate change and associated stressors – sea level rise, water availability, temperatures, and extreme floods - as well as reduced sediment supply, add complexity and new challenges to managing the San Francisco Bay ecosystem. With an uncertain future, it is imperative that we promote landscapes that support Bay ecosystems which benefit both people and wildlife, that are likely to adapt, thrive, and be self-sustaining over time – that is, landscapes that are ecologically resilient. We need to integrate ecological, social and economic dimensions to create a holistic vision for an urbanized estuary.

SFEI (Resilient Landscapes Program) has undertaken interdisciplinary projects to begin informing and visioning this future landscape. Numerous historical ecology studies provide an understanding of San Francisco Bay's unique ecological and geophysical context. Comprehensive mapping of present day flood infrastructure and the adjacent Bay shore; the mapping of marsh edge change in San Pablo Bay; the tracking of the 'head of the tide' and quantifying sediment budgets in creeks around the Bay are providing much-needed information on the 'present condition' along with opportunities and constraints. Looking ahead, we are developing some of the first integrated resilient landscape visions for the Bay at Walnut Creek and Novato Creek with a focus on flood risk management and along the East Bay shore with the focus on wastewater. Tying these elements together, SFEI has been instrumental at the regional level for defining landscape resiliency, recognizing natural landscape units and promoting collaborative science.

Our poster demonstrates how these studies contribute to the development of broader visions for the Bay; it also shows where other initiatives undertaken by state and regional partners dovetail into the complex puzzle. Above all, it illustrates the need for further collaboration and integration in the Bay community if we are to develop and realize the vision.

Keywords: sea level rise, resiliency, ecology, flood, wastewater, Baylands, landscape planning

Poster Topic: Climate Change: Habitat Restoration

Tidal Marsh Vulnerability to Climate Change in the San Francisco Bay Estuary

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Multiple climate change drivers, including sea-level rise (SLR), extreme weather events and changes to atmospheric and oceanic conditions are expected to impact the structure and functioning of wetlands in the San Francisco Bay estuary and Delta. To assess tidal marsh vulnerability to climate change in the region, our team integrates observational, experimental and modeling approaches. Since 2008 at sites throughout San Francisco Bay, we have collected baseline data on marsh topography and vegetation composition, tidal datums, salinity, and historic accretion rates and integrated these data into a mechanistic model of SLR to project potential future habitat composition. Starting in 2015, we will expand our research program into Suisun Bay and the Delta. To better understand SLR impacts to marsh function and refine model accuracy, we are also conducting experiments to assess how plant productivity and decomposition vary along inundation gradients. In a "marsh organ" experiment at Petaluma marsh during summer 2014, we found differences in inundation-productivity relationships among three common species: *Spartina foliosa*, *Sarcocornia pacifica* and *Bolboschoenus maritimus*. *S. pacifica*, a dominant species in many of California's tidal wetlands, was least tolerant of greater inundation. Our initial results also suggest that organic matter decomposition rates varied by species, but were not highly affected by changes in inundation. On-going and future experiments will assess how productivity changes along the region's salinity gradient and how productivity varies in the presence of other species. Our data indicate that vegetation composition may be an important factor affecting how individual wetlands in the San Francisco Bay-Delta region respond to future climate change.

Keywords: primary production; salt marsh; sea-level rise

Poster Topic: Climate Change: Habitat Restoration

Greenhouse Gas Emissions and Carbon Sequestration Potential in Restored Wetlands in the Sacramento – San-Joaquin Delta, California

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Wetlands have the ability to accumulate large amounts of carbon (C), and therefore wetland restoration has been proposed as a means of sequestering atmospheric C to help mitigate climate change. However, wetlands are also the largest natural source of methane (CH_4), a potent greenhouse gas (GHG) that can offset wetland C sequestration. Few studies have quantified the balance between C uptake by wetland vegetation and ecosystem CH_4 dynamics during wetland development. In this study, we examined to what degree CH_4 emissions offset C sequestration during wetland restoration, and how this varies during ecosystem development. To address these objectives, fluxes of CO_2 and CH_4 were measured for multiple years using the eddy covariance method at two restored freshwater marshes of differing ages in the Sacramento – San-Joaquin Delta.

Both restored wetlands were net sinks of atmospheric CO_2, with the younger wetland sequestering between 141 and 1409 g CO_2 m^{-2} yr^{-1} and the older restored wetland sequestering between 2394 and 1466 g CO_2 m^{-2} yr^{-1}. However, both wetlands were large sources of CH_4, with higher CH_4 emissions from the younger wetland (up to 68 g CH_4 m^{-2} yr^{-1}) than the older wetland (up to 51 g CH_4 m^{-2} yr^{-1}). Both the wetlands were always C sinks with the younger wetland sequestering less C than the older wetland (up to 334 and 622 g C m^{-2} yr^{-1}, respectively). In terms of the GHG budgets, the younger wetland was a net GHG source, emitting on average 954 g CO_2 eq m^{-2} yr^{-1}, while the older wetland was consistently a GHG sink, sequestering on average 755 g CO_2 eq m^{-2} yr^{-1}. This study suggests that restored wetlands have the potential to act as net C and GHG sinks but this may depend on the time since restoration.

Keywords: Wetlands, restoration, greenhouse gases, methane, carbon dioxide, eddy covariance

Poster Topic: Climate Change: Habitat Restoration

Grindelia stricta Seed Germination Responses to Salinity

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Understanding seed dynamics in relation to the salinity regime that tidal marsh species experience is crucial for understanding the development of tidal marsh plant communities. Projected sea-level rise rates associated with climate change are expected to exceed tidal marsh accretion rates, leading these ecosystems to experience more saline conditions which may inhibit seed germination and growth by complicating physiological mechanisms.

Our research looks at regional variation in germination response to salinity of a widely distributed tidal marsh sub-dominant found throughout the west coast of North America*, Grindelia stricta.* We measured germination success, weekly, across eight populations of *G. stricta*, ranging from the San Francisco Bay to Oregon under varying salinity treatments (0-25ppt) in the lab. We modeled germination response to increasing salinity levels, running generalized linear models to then create logistic models for both the Northern region (Humboldt-Oregon) and Southern region (SF Bay) populations to better understand the establishment behavior of this species. We found support for our first hypothesis, which predicted that Northern region populations have an increased ability to allocate resource energy into individual seeds because of the increased freshwater input and overall lower salinity regimes they experience. We did not find support for our second hypothesis that predicted increased germination success in the Northern region sites under freshwater treatment. Finally, we did not find support for our third hypothesis, which predicted a steeper decline in germination success in higher salinity treatments between the two regions.

Our analysis shows that *G. stricta* germination declines with increasing salinity. Sea-level rise, inter-annual variation in precipitation, reduced freshwater inputs, and increases in temperature associated with climate change can cause increased salinity conditions affecting germination of *G. stricta* seeds. The application of germination success models in the context of increasing salinity may help to inform future tidal marsh restoration establishment efforts.

Keywords: *Grindelia stricta*, salinity, germination, sea-level rise, climate change, restoration

Poster Topic: Climate Change: Habitat Restoration

A Tale of Two Marshes: 15 Years of Vegetation Change at China Camp and Muzzi Marsh

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Understanding temporal trends in plant community composition is an important aspect of interpreting restoration outcomes. Here, we explore plant community trends from 1990 to 2005 along transects at a restoration site (Muzzi Marsh) and a reference site (China Camp) in Marin County, CA. Emerging from the drought of the late 1980's and early 1990's, average diversity per plot at China Camp was low and began to increase following above average rainfall during the 1994-1995 rain year. These trends were largely driven by the increase in sub-dominant, high marsh species. Diversity at China Camp peaked in 1998, following extreme rainfall during the major 1997-1998 El Niño event. Diversity slightly decreased between 1998 and 2005, but by 2005 was still about 3 times greater than during the drought period. Conversely, average diversity at Muzzi Marsh began to decline following above average rainfall during the 1994-1995 rain year, largely driven by the replacement of *Salicornia virginica* by *Salicornia pacifica* and *Spartina foliosa*. Diversity at Muzzi Marsh reached its lowest point following the 1997-1998 El Niño event due to increased dominance per plot, but rebounded by 2005. Percent bare ground decreased over time, declining to nearly zero by 2005. The development of sub-dominant species diversity at Muzzi Marsh lags far behind that of China Camp, even 30 years after initial restoration actions. However, total average diversity per plot is higher at Muzzi Marsh due to the intermixing of *Salicornia pacifica* and *Spartina foliosa.* These results highlight the need to consider the temporal trends at both reference and restoration sites to understand the dynamic nature of vegetation development.

Keywords: Restoration, Plant Community, Long-term data, El Nino, Drought

Poster Topic: Climate Change: Habitat Restoration