Comparative Restoration Attributes in the Cache Slough Complex

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The northern Sacramento-San Joaquin Delta is recognized as home to a notably higher abundance of native fishes than the rest of the Delta region. Little is known, however, as to how different locations throughout the north Delta foster this native fish community. We used otter trawls, minnow traps, beach seines, electrofishing, and zooplankton tows, along with water quality monitoring and habitat assessment, to evaluate the ecological functioning of Cache and Lindsey Sloughs. During the drought conditions of the past three years, sites along Cache Slough displayed sparse submersed aquatic vegetation (SAV), high turbidity, high zooplankton densities, and high concentrations of chlorophyll a. Cache Slough's higher turbidity and zooplankton abundance offered shelter and food resources for planktivorous fishes and the slough displayed a higher abundance and diversity of native fishes than the Lindsey complex. Sites in Lindsey slough contrasted Cache with greater quantities of SAV, low turbidity, and low pelagic productivity. Lindsey's SAV dominated network contributed to more favorable conditions for SAV-associated sunfishes and other non-natives which likely prefer the lower turbidity in the slough for visual predation. In addition to inter-slough differences, we found considerable intra-slough differences in fish assembly and density. Chlorophyll a concentration, zooplankton density and fish density increased toward the terminal ends of the Cache Slough complex. We examine how these differences in slough function can be applied to design and implementation of new restoration projects in the Delta, by considering a few proposed and existing examples.

Keywords: native fishes, drought, restoration, north Delta, ecology

Poster Topic: Habitat & Ecosystem Function Restoration

Beyond the Levee: Strategies for Ecologically Functional High Tide Refugia in San Francisco Bay Tidal Marshes

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In the 1970s, researchers from the U.S. Army Corps of Engineers pioneered revegetation techniques that utilized tidal wetland vegetation to stabilize eroding shorelines in San Francisco Bay and other estuaries throughout the United States. This work emphasized the critical role that vegetation plays in damping wave energy and increasing the shear strength of wetland soils. Since then, the consideration of vegetation in Bay tidal salt marsh restoration has shifted: modern projects tend to prioritize vegetation structure to provide high tide/flood escape cover for listed wildlife species, especially along flood control levees at the landward limit of project sites. Insufficient vegetative stabilization of habitat-priority levees, especially in early tidal restoration stages, may expose levees to episodes of intensive wave erosion from winter storms. This can lead to proposals for rock armoring as pre-emptive or "emergency" levee stabilization. Rock armoring of salt marsh shorelines eliminates high tide refugia, increases high tide predation risk, and conflicts with shoreline transgression upslope as sea level rises. In broad salt marsh plains dissected by tidal channels, listed wildlife are able to find flood refuge within their relatively small home ranges by utilizing high marsh with tall vegetation along the channel banks. In contrast, modern tidal salt marsh restoration projects tend to leave marsh plains with sparse internal high tide cover, instead emphasizing landward-edge high tide cover. This configuration can leave wildlife with no cover within their home ranges, increase wildlife flood movements (and predation risk) during extreme high tides, and set up potential conflicts between wildlife with public trail use of levees. We discuss alternate approaches that balance vegetation and topography for high tide cover and vegetative shoreline stabilization across the entire marsh profile, increase shoreline resilience to accelerated sea level rise, and focus on plant functional traits as well as species composition in vegetation communities.

Keywords: tidal, marsh, restoration, refugia, ecotone, levee, mouse, rail, erosion, vegetation

Poster Topic: Habitat & Ecosystem Function Restoration

Testing a Novel Adaptation Strategy in a California Salt Marsh

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Coastal wetlands around the world are threatened by sea-level rise (SLR). While current research demonstrates that many, but not all, wetlands in California are keeping pace with SLR via sediment accretion, this resiliency is expected to only resist SLR projections for 2030 and likely 2050. To ensure wetland resilience for 2100 and beyond, wetland management must incorporate a range of tools at various scales. The Seal Beach National Wildlife Refuge (Refuge) encompasses 911 acres of remnant saltwater marsh in the Anaheim Bay estuary and is a perfect location to test a new SLR adaptation strategy, sediment augmentation, where a thin-layer of sediment is placed on a marsh plain to raise elevations. The Refuge is currently experiencing elevated rates of SLR (~3Xs higher than other California wetlands; 6.23 mm/yr) due to subsidence and with Orange County's imminent plans to dredge the adjacent harbor; this is the perfect opportunity to test sediment augmentation. This project placed 8-10 inches of clean, dredge material on approximately 8-acres of low-elevation (*Spartina*-dominated) marsh. Sediment was transported by floating pipe and placed on the marsh plain using a rainbow sprayer. One year of pre-construction monitoring, started in April 2015, and five years of post-construction monitoring will determine the effectiveness of sediment augmentation at the Refuge. The monitoring program will assess augmentation effects on elevation and sediment dynamics, creek morphology, carbon sequestration including greenhouse gas flux, invertebrates, emergent and submerged vegetation, and avian communities. The results of this project will be shared via trainings hosted by the USFWS for potential utilization throughout California's salt marsh systems.

Keywords: salt marsh, sea level rise, spartina, tidal wetland, adaptation, resilience

Poster Topic: Habitat & Ecosystem Function Restoration

Facilitating Salt Marsh Formation through Vegetative and Physical Barriers to Erosion

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The predicted acceleration of sea level rise in the mid-21st century has increased the need for salt marshes to build elevation capital in order to adapt to rising seas. Salt marsh restoration projects face an additional challenge of building large quantities of sediment on often-subsided lands in addition to building capital for resilience. A novel restoration technique has been used at the Sears Point restoration site within San Pablo Bay National Wildlife Refuge. Marsh mounds, which were created to buffer wave action, decrease erosion and serve as nuclei for colonizing marsh vegetation, are eroding. This study seeks to determine whether protecting the mounds through vegetation and physical barriers can decrease erosion and facilitate accretion to accelerate marsh formation. We protected mounds using a vegetative treatment of *Spartina foliosa* and a physical barrier treatment consisting of a coir erosion log oriented to intercept either wind-waves or tidal action. We hypothesize that *S. foliosa* will stabilize sediments, eliminating erosion and potentially leading to sediment accretion on the tops of mounds. We further expect that physical barriers to wind-waves or tidal action will reduce erosion, and in conjunction with *S. foliosa* treatments will enhance erosion protection and sediment accretion. In addition, we expect that changes to soil elicited by *S. foliosa* presence will foster development of soil invertebrates associated with tidal marshes and valuable to marsh functions including food web support. Early results show that the tops of unprotected mounds are eroding, while significant sediment accretion is occurring at low elevations on the mounds. We discuss the implications of our results for salt marsh restoration sites in the San Francisco Bay and other estuaries. These findings can be used to evaluate the efficacy of protecting marsh mounds to develop mature marsh, and to inform management decisions at sites replicating the marsh mound design.

Keywords: salt marsh; restoration; *Spartina foliosa*; sediment; erosion

Poster Topic: Habitat & Ecosystem Function Restoration

Decker Island Restoration Project

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Although Bay-Delta managers are likely interested in the final product of restoration actions, the process by which a restoration project becomes reality is just as important in achieving restoration goals and successful management of the ecosystem. Tidal habitat restoration in the Bay-Delta has a varying degree of difficulty based on size, location, existing conditions, permitting requirements, and expected outcomes. The Fish Restoration Program, a cooperative program between Department of Water Resources and Department of Fish and Wildlife, is tasked with restoring 8,000 acres of intertidal marsh and associated subtidal habitat in the Delta and Suisun Marsh as part of a restoration requirement in the federal biological opinions and state incidental take permit for the long-term operation of the State Water Project and Central Valley Project. The Decker Island Restoration Project, located on the Sacramento River in southern Solano County, partially fulfills that goal by providing 140 acres of tidal freshwater marsh. The Project site was once farmed and grazed, but is now partially underwater due to an abandoned rock weir/culvert structure. Existing habitats include a muted tidal wetland with emergent vegetation, riparian trees and shrubs, and ruderal grassland. The restoration team employed multiple phases of modeling, utilized best available science and adaptive management, and held a professional review panel to develop the most beneficial restoration possible while minimizing impacts to the existing wetland and riparian habitats. Permits and environmental documentation are now being pursued, and a monitoring plan is being developed to demonstrate Project effectiveness. Restoration construction is slated for summer/fall of 2017.

Keywords: Decker Island, restoration, tidal wetland

Poster Topic: Habitat & Ecosystem Function Restoration

Giving Land to Water, Placemaking of An Experimental Flooded Polder in the Sacramento-San Joaquin Delta

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Land subsidence, aging levee infrastructure, and predicted sea level rise are creating unique flooded polders in the Sacramento-San Joaquin Delta. Those flooded polders are considered novel ecosystems because it is not economically and ecologically feasible to return them back to historical states. With the continuous climate change and sea level rise, more and more flooded polders are expected to arise. Therefore, this study seeks to discover the design opportunities of flooded polders in order to optimize their future uses and place values in the Sacramento-San Joaquin Delta.

This study is conducted in two phases. The first phase includes case studies on the existing flooded polders in the Delta, interviews towards different groups of stakeholders in the Delta, and fieldwork on the Delta flooded polders. Through this process, the study discovers that that the potential users of the Delta flooded polders are the scientists who study and work at the Delta and the recreationists who enjoy a waterfront lifestyle. During the second phase, this study uses design research to uncover design opportunities of Delta flooded polders by testing out design at an experimental flooded polder: Bacon Island in South Delta. Working with the UC Davis Watershed Center scientists, an ecological planning framework is proposed to intentionally breach the island at three locations, and the design research is built around this ecological framework. Considering the feral nature of the Delta and the fact that minimum investment and maintenance will be allocated to flooded polders, the proposed design is capitalizing around the existing infrastructure with subtle interventions. Through design research, the study discovers that the Delta flooded polders have the chance to become a vivid place where scientists can study ecologies, recreationists can develop friendships, and all users can start a conversation about the Delta future.

Keywords: Flooded Polders, Adaptive Management, Landscape Architecture, Novel Ecosystem Design

Poster Topic: Habitat & Ecosystem Function Restoration

Comprehensive Ecology of *Schoenoplectus californicus*: Recommendations for Restoration of Tule Marsh

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Historically, the Sacramento-San Joaquin Bay Delta has lost more than 95% of its wetlands due to anthropogenic activity. Marsh restoration is a pivotal focus for the state of California. To maximize success of these restoration efforts and enhance decision making tools for effective planning of future restoration projects, it is essential to understand plant colonization and expansion dynamics, as well as constraints on plant species desired in planting efforts. We conducted a seed-bank assay, a field transplant study, a multi-year field sampling effort at Liberty Island, CA, as well as a series of controlled greenhouse experiments to characterize conditions for optimal growth of *Schoenoplectus californicus*. Results from these studies indicate that *S. californicus* expands primarily via vegetative rhizomatous expansion, as seed germination is inhibited by seasonal dormancy and hydrologic regime. *Schoenoplectus californicus* adults can survive extreme flooding conditions (>100% exceedence) as long as a portion of the aboveground biomass remains emergent. However, longer durations of flooding may retard lateral expansion. Lateral expansion may also be impeded by compacted soils; however, results from a soil core collection study indicates that *S. californicus* acts as an ecosystem engineer over time, reducing soil bulk density, adding soil organic matter and ameliorating densely compacted soils at restoration sites. Finally, results from a nutrient study suggest that *S. californicus* stem strength and resistance to lodging can be maximized with silica, particularly in the presence of high concentration of nitrogen. In summary, *S. californicus* is a stress-tolerant species with characteristics ideal for rapid Tule marsh establishment, levee protection and habitat provision. We recommend including *S. californicus* in restoration efforts in fresh to oligohaline tidal marshes, particularly in environments where flooding stress or high energy shorelines may limit the use of other emergent plant species.

Keywords: restoration; tule marsh; *Schoenoplectus californicus*

Poster Topic: Habitat & Ecosystem Function Restoration

Restoration approaches and planning for the Prospect Island Tidal Habitat Restoration Project

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In order to address long term declines of native fishes in Suisun Bay and Delta, the California DWR and DFW initiated planning of the 1,600-acre Prospect Island Tidal Habitat Restoration Project. The project is intended to restore tidal habitat connectivity and function in partial fulfillment of 8,000-ac tidal habitat restoration obligations of DWR, contained within biological opinions (BiOps) for long-term coordinated operations of the SWP and CVP. Physical, biological, and chemical processes were considered in developing screening metrics to relate ecosystem drivers (e.g., hydrodynamics, sediment supply, water quality, vegetation community composition) to species response for Delta Smelt, salmonids, and other native fishes. Hydrodynamic models were used to compare the potential benefits (e.g., phytoplankton production within the restoration site, tidal mixing of exported productivity, changes in intertidal extent) of various conceptual design alternatives, as well as any potential adverse impacts (e.g., promotion of invasive species, changes in flood conveyance, regional salinity). In order to address project uncertainties in addressing productivity and export, selected alternatives represented a range of intertidal connectivity and habitat mosaics. The proposed project is currently undergoing environmental permitting and when completed will enhance primary and secondary productivity and food availability for Delta Smelt and other native fishes, increase rearing habitat for salmonids and other listed species, and provide other ecosystem benefits associated with increased Delta freshwater tidal marsh habitat.

Keywords: restoration, modeling, tidal, habitat, wetland

Poster Topic: Habitat & Ecosystem Function Restoration

Advancing Transition Zone Restoration: Application of Soil Amendments to Increase Vegetation Establishment

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Transition zones between brackish marsh and upland areas of San Francisco Bay are critical habitat for hundreds of species, some of which are threatened or endangered. This habitat is integral for wildlife seeking high tide refugia as well as flood protection during storms. The Baylands Goals Update prioritizes the need to create, restore, and protect this habitat, particularly in anticipation of sea level rise. However, the restoration and creation of large transition zones (10-30 acres) is a relatively new endeavor and restoration practitioners are just beginning to consider how to implement these projects. There is an urgent need for pilot projects to develop methods to cost-effectively revegetate and restore these areas at a large scale.

This study focuses on the challenges of restoring transition zone vegetation on a levee adjacent to marshes in the Palo Alto Baylands. The site is comprised of heavily disturbed, low-nutrient soils from a variety of sources. Standard restoration practices of removing invasive species and planting native plants demonstrated low survivorship after planting in 2011. Subsequently, in 2012 a soil amendment experiment was conducted to explore alternative methods. This ongoing experiment assesses the efficacy of (1) soil tilling, (2) compost addition, and (3) a combination of both to in improve vegetation establishment at a site with low quality soils.

Our results show the highest native plant cover in the compost treatment plot (57.1%), followed by the till and compost treatment plot (34.1%). Both the tilled-only treatment and control showed lower percent cover (3.8% and 23.9%, respectively). While the experiment is ongoing, these results influence our work in adjacent transition zone restoration projects. Looking forward to the future of transition zone restoration in the San Francisco Bay, continued monitoring at this site and these results can inform similar projects to maximize restoration efforts.

Keywords: transition zone, soil amendment, levee, habitat restoration

Poster Topic: Habitat & Ecosystem Function Restoration

Climate Change Adaptations in a North Bay Centennial Marsh

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The Sonoma Creek Enhancement Project was completed in November of 2015, bringing tidal action to a 265 acre North Bay Centennial Marsh, and incorporating several experimental climate change adaptation elements. Audubon, CA, Marin/Sonoma Vector & Mosquito Control District and the San Pablo Bay National Wildlife Refuge partnered on this project and worked with ESA and Hanford, Arc to improve the ecological function of the Sonoma Creek Tidal Marsh Ecocsystem, and to prepare the system for Climate Change. The central component of the project was a 5,460 ft. long, 7 ft deep, 5 acre drainage channel, which was excavated from Sonoma Creek, through the 100 acre depressed central marsh basin of Sonoma Creek Marsh. The channel allows daily tidal waters to innundate and flush the previously stagnant water which accumulated in the central basin, killing and degrading marsh vegetation and wildlife habitat, and providing mosquito breeding grounds. Along with the myriad benefits that daily tidal flushing and draining bring, the tidal waters deposit sediment and increase bio-accumulation through increasing plant health and biomass. These processes will allow the central basin and eventually the 265 acre Sonoma Creek Marsh to build vertically in to the future. Twenty 20 foot wide by 50 foot long, and approximately 2 foot above mid marsh plain, marsh mounds were constructed on either side of the central channel. These will provide high tide refugia for endangered species and other marsh dwelling wildlife as storms become more frequent and intense. A seven acre 40:1 gently sloping transition ramp, built against the marsh side of the Tubbs Island levee also provides high tide refugia, and will allow geomorphological space for active and passive re-colonization of native transition zone plant communities, which are now in decline and which are anticipated to be adversely affected by Climate Change without active management.

Keywords: Climate Change, Enhancement, Transition Zone, Adaptation, High Tide Refugia

Poster Topic: Habitat & Ecosystem Function Restoration

A Storm Water Basin with Growing Diversity

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Upper Sand Creek Basin (USCB) is located in East Contra Costa County. The site was designed to fill multiple needs of the community. Of primary importance, the retention basin serves to manage storm water runoff from the streets of Antioch and from Sand Creek. The retention basin was designed to protect the cites of Brentwood and Oakely during periods of high rain fall. Other goals of USCB were environment enhancement, habitat restoration and open space. To help achieve those goals, within USCB 10 acres of constructed wetland was established with a natural creek design. In the Spring of 2014 under the coordinated effort of a local community organization (Friends of the Marsh Creek Watershed), and Contra Costa Flood Control, over 150 volunteers came together to plant California native trees and bushes.

The result is that today, just two years later, USCB is host to hundreds of red wing black birds, swallows, and the occasional red tail hawk. A few Blue Oak have grown almost 2 meters tall, with cottonwood, buckeye growing nicely as well. Tule was not planned but now lines 100% of the bank. Upper Sand Creek Basin will only become more diverse with species as the oaks, cottonwood and willows mature. Since the initial planting the local community has been out to help weed around the young saplings and mulch, and clean up trash that flows in during high rain events. More ideas to involve the community with the site are; a quarterly bird census, insect community evaluation, a benthic macroinvertebrate survey and we plan on testing alternative methods of hebivory protection to maximize oak sapling survival. Thanks to the insight of the Contra Costa Flood Control to construct Upper Sand Creek Basin we will have the opportunity to learn how our management practices effect developed wetlands.

Keywords: Storm water retention basin, constructed wetland, community involvement

Poster Topic: Habitat & Ecosystem Function Restoration

The Oro Loma Horizontal Levee Demonstration Project - Scaling Up Native Species Propagation Methods to Accommodate Large Transition Zone/Ecotone Projects of the Future

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The Baylands Ecosystem Habitat Goals Report Update emphasizes the need to protect and restore 100,000 acres of tidal marsh habitat. Around the bay, project sites totaling approximately 35,000 acres of tidal marsh are currently awaiting restoration. Many of these projects include large transition zone/ecotone habitats, a habitat type fundamental in protecting against sea level rise, providing wildlife refugia, and increasing biodiversity. Pilot projects to test methods for restoring baylands processes are a high priority, particularly to identify the most effective techniques to restore significant acreage in the face of sea level rise.

The Oro Loma Horizontal Levee Demonstration Project constructed an ecotone slope, designed to provide transition zone functions, at the Oro Loma Sanitary District facilities in San Lorenzo, CA. The native species assemblage for the project was chosen to mimic historic moist grassland/bayland ecotone habitat that has been largely eradicated from San Francisco Bay.

The plant propagation methods for the project were designed to “scale-up” and to reduce the cost and time of growing large numbers of plants propagated in a nursery setting. Over 70,000 plants were grown to vegetate the ecotone slope. Propagules were sourced locally from remnant plant communities of the East Bay. The majority of plants were grown in a large scale and low-maintenance method at a division bed nursery constructed on the Sanitary District property adjacent to the project site. This approach reduced the amount of vegetative material initially collected by utilizing the species ability to propagate rhizomatously.

Within the compressed timeline of one year, the species chosen for the project thrived in the division bed nursery environment, producing healthy rooted stock and greatly surpassing the 70,000 plants requested. The demonstration project established a low-cost and low-intensity labor method for large-scale plant propagation and can inform propagation methods for future large-scale ecotone/transition zone restoration projects.

Keywords: Native plant propagation, Transition zone, Demonstration project, Sea level rise

Poster Topic: Habitat & Ecosystem Function Restoration

Restoration Design in the Sacramento-San Joaquin Delta: Lessons from Case Studies

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While the goals for tidal, floodplain, and riparian restoration projects in Delta may range from meeting habitat mitigation needs to providing other benefits such as flood attenuation or water quality improvements, the common goal of restoring self-sustaining native habitats and ecosystems means that most, if not all, restoration projects should be based upon a common set of principles and tools to ensure success. This requires awareness of tidal and riverine processes and disturbance regimes, vegetation, fisheries, and wildlife response to these processes as well as ecological interactions. The ultimate measure of our success will be the degree to which native species are able to use and thrive in the habitats we provide. We build upon experiences throughout the Delta using specific examples to illustrate a variety of methods for restoring ecosystems for a sustainable future. Case studies include projects aimed at enhancing the physical template to restore ecological processes such as restoring tidal action in the Cache Slough region to enhance primary and secondary productivity and food availability for Delta Smelt and other native fishes; increasing tidal access and tidal wetland habitat in the central Delta to support spawning and rearing of salmonids; and combining changes to the physical template with revegetation in the eastern Delta to benefit giant garter snake and native fishes. Another project in the central Delta involves no changes to physical site conditions but is focused on improving vegetation composition and structure to support wildlife diversity, including benefits to Swainson's hawk. For all these projects, the explicit integration of ecosystem processes operating at appropriate scales is a fundamental part of planning, implementation, and adaptive management. Practical but often critical matters of site selection, sequencing, funding, stakeholder interactions, and permitting are also recognized as equally important aspects of restoring or enhancing the Delta for native species.

Keywords: tidal, floodplain, restoration, self-sustaining, ecosystems, revegetation, productivity, Delta Smelt, salmonids

Poster Topic: Habitat & Ecosystem Function Restoration

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

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This research was conducted to monitor the response of aquatic macroinvertebrate populations to the restoration of intertidal habitat, including eelgrass (*Zostera marina*) and native oyster reefs (*Ostrea lurida*) in the San Francisco Estuary. Plots of each habitat-forming species, alone and interspersed, were established in 2012 and 2013 by the State Coastal Conservancy's Living Shorelines: Nearshore Linkages project (LSP). Living shorelines have been used throughout the world to reduce physical impacts on shorelines (e.g., increased wave action from storm surges and sea level rise), while simultaneously providing habitat to intertidal invertebrate and fish species. The LSP was the first project in the Estuary to implement restoration of eelgrass and oyster reef at a scale large enough (30m x 10m plots) to quantify both biological and physical results. Quarterly invertebrate monitoring was conducted in the restoration plots for one year prior to restoration (2011-12), and for two years post restoration (2012-15), using a series of traps, shoot collection, and vacuum sampling. The results from the trapping and suction sampling were intended to inform the degree to which restored eelgrass and oyster reef habitat, alone and together, promote colonization and use by invertebrates. The results from the shoot sampling were intended to determine if epiphytic invertebrate assemblages vary significantly between natural and restored eelgrass beds in the Estuary. Within two years, correspondence analysis revealed that eelgrass and oyster reef supported a unique invertebrate assemblage composition as compared to baseline and control plots, and that the composition was intermediate in combined eelgrass/oyster plots. Restored eelgrass has not established an assemblage equivalent to natural beds; several invertebrates beneficial to eelgrass growth are absent. We conclude that habitat structure provided through restoration will quickly support many invertebrate species, but some may require manual addition to provide the full range of natural functions.

Keywords: Living shorelines, eelgrass, oyster, restoration, San Francisco Estuary, invertebrate

Poster Topic: Habitat & Ecosystem Function Restoration

Coon Creek Watershed Assessment: An Interdisciplinary Approach for Evaluating Impacts and Developing a Restoration Strategy for a Foothill Watershed

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Many Sierra foothill watersheds suffer from a complex history of land use and flow management impacts that have caused impairment of physical processes and declines in anadromous salmonid populations. However, accurate assessment of the causal factors driving these problems and the subsequent development of watershed-appropriate rehabilitation and management strategies remains challenging. This presentation describes an interdisciplinary watershed assessment of Coon Creek, a foothill stream draining a 112-square mile catchment with its headwaters near Auburn. The watershed's numerous impacts include channel modification, flow manipulation, unscreened diversions, fish passage barriers, agricultural encroachment and urbanization. Nonetheless, the catchment remains one of the least developed foothill watersheds in the area and is prioritized by Placer County for protection and restoration actions. We adopt a 'spatially-nested' approach to generate a process-based understanding of the basin across multiple spatial scales and to identify causal mechanisms of watershed impairment. A fluvial audit assessment characterizes sediment supply and storage, vegetation influences and river engineering at the sub-reach scale to establish an understanding of the system's geomorphic processes and controls. Investigation of flow management, particularly base flows, at both the reach and basin scale characterizes impacts of water supply operations on various aspects of salmonid life cycle history. Combining this work with anadromous fish habitat assessments, targeted juvenile fish surveys, riparian habitat assessments, and water quality monitoring facilitates an integrated understanding of physical and ecological functions. This interdisciplinary methodology enables us to assess impacts of flow management and to identify controlling factors for anadromous fish decline. This approach also facilitates the development of cost-effective and appropriate process-based restoration and management strategies that include collaborative projects with water management agencies.

Keywords: Process-based restoration, flow management, salmonid, foothill

Poster Topic: Habitat & Ecosystem Function Restoration

What do Skaggs Island and Sagrada Familia have in Common?

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What could the 4,400-acre Skaggs Island in San Francisco Bay have in common with a famed Roman Catholic minor basilica in Barcelona, Spain? Skaggs Island was converted from tidal marsh into agricultural land in the 19-teens. In 1940, the U.S. Navy purchased 3,300 acres, leaving the remainder in farming. The primary goal of the restoration project is to restore the complex mosaic of estuarine tidal marsh habitats to support native plant and animal species. An overarching challenge is building sea level rise resiliency into the project design to ensure these habitats persist as sea level rises. Both parcels have subsided 6 feet below surrounding high marsh on average.

Beneficial reuse was considered, but sediment supply is limited. Roughly 1 million cubic yards is available annually, with far greater demand at this and other sites. With 40-70 million cubic yards of capacity, this would be a multi-decadal project with a completion horizon at least 50 years in the future. Similarly, the Sagrada Familia was conceived of and designed by Antonin Gaudi with his expectation that it would be completed by others decades after his death.

To accelerate this timeline, our current conceptual approach is a 3-pronged strategy that includes (1) subsidence reversal, (2) passive restoration of a portion of the site nearest the Bay, and (3) active restoration with dredged sediment import. Rainwater captured across the island would be pumped onto roughly 550 acres reduce salinity to favor growth of bulrush and other large rhizomatous plants to build root biomass and reverse subsidence. A portion of the site nearest the mouth of Sonoma Creek would be breached to passively capture available sediment. Beneficial reuse of dredged sediments would be used to raise the elevation of the majority of the site to some combination of marsh and upland elevations.

Keywords: resilience, marsh restoration planning & design, sediment reuse, subsidence reversal

Poster Topic: Habitat & Ecosystem Function Restoration

Long-Term Changes in Spatial Structure of Restored Wetlands within the Sacramento-San Joaquin Delta of California

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The Sacramento-San Joaquin Delta of California is a prime setting to study interactions between restored ecosystems, pristine habitats, and human-modified landscapes. Major land transformations have deteriorated ecological services historically provided by the Delta and hampered its resilience against global changes. In response, substantial work has been applied toward restoring degraded wetlands of the region. Yet post-restoration monitoring efforts have been lacking and few studies have analyzed the progress made to date at the regional scale. A thorough landscape perspective on wetland restoration is critical for understanding historical shortcomings and better equipping future restoration projects for increased ecological gains. We used 10 years of high resolution imagery from the National Agriculture Imagery Program to characterize changes in spatial structure of thirty wetlands restored between 1995 and 2015, then compared this set to co-occurring protected wetlands. An object-based image analysis was conducted to identify and classify patches of vegetation within each wetland and an overlay analysis was used to identify changes in the shape, size, connectivity, and rate of horizontal expansion of vegetated patches. We assessed how these structural characteristics varied with site design and landscape context. Preliminary results suggest that protected wetlands of the region are characterized by larger and more complex patches than co-occurring restored wetlands. Meanwhile, more recent projects show a greater level of habitat complexity and connectivity than older wetlands. This research highlights the influence of landscape dynamics on restored wetlands and enhances the current understanding of patch dynamics following restoration treatments. This knowledge is crucial for a better design and planning of future restoration projects.

Keywords: wetlands, restoration, landscape metrics, object-based image analysis, ecological trajectory

Poster Topic: Habitat & Ecosystem Function Restoration

Field-Based Monitoring of Restoration Progress in Wetlands of the Sacramento-San Joaquin Delta

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Ecological restoration is increasingly used to compensate for habitat loss and rehabilitate depleted ecosystem services, but has a highly variable level of success. Meeting restoration goals can be challenging in heterogeneous and dynamic landscapes. As such, a consistent monitoring effort is needed to identify factors constraining the recovery of ecosystems and to highlight site designs promoting restoration success. In the Sacramento-San Joaquin Delta, decades of agricultural and urban expansion have altered wetlands and the ecological functions they provided historically. In response, local organizations and governmental agencies are allocating considerable effort to restoring wetland ecosystems through the reestablishment of hydrological processes, improvement of tidal connectivity, and removal of invasive species. Yet post-restoration monitoring has been limited in both temporal and spatial scope. This restrains our understanding of factors modulating the ecological trajectories of projects and our capacity to measure their potential for long-term success. To address this knowledge gap, we monitored during the 2016 growing season plant canopy traits and litter accumulation patterns within a set of freshwater wetlands restored between 1997 and 2016. Using a space-for-time substitution, we assessed how the structural properties of wetland canopies- characterized by their leaf area index, specific leaf area, and leaf water content- varied spatially and temporally. We evaluated feedbacks between plant litter accumulation and the structural properties of wetland canopies. These key indicators of plant above-ground productivity can unravel wetlands' capacity to fulfill key services including soil accumulation and carbon sequestration. An advanced understanding of feedbacks between plant above-ground productivity and litter accumulation patterns is critical to a better prediction of a wetland's response to restoration treatments and long-term capacity to maintain ecosystem services.

Keywords: wetland, restoration, monitoring, litter, leaf area index, specific leaf area

Poster Topic: Habitat & Ecosystem Function Restoration