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 and fish 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, intertidal, restoration, invertebrates, *Zostera marina*

Poster Topic: Living Shorelines Project

Avian Predator and Invertebrate Prey Response to Subtidal Restoration Efforts: Living Shorelines Near-shore Linkages Project 2011-2015

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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. Using an experimental approach we established native oyster, eelgrass, eelgrass and oyster, and control treatments at a site in San Rafael. The USGS Western Ecological Research Center, San Francisco Bay Estuary Field Station conducted one year of avian and benthic invertebrate pre-installation (Nov 2011 – April 2012) and three years of post-installation (September – April 2012 – 2015) monitoring. Our primary objective was to determine species and guild specific responses to restored habitat relative to control areas and pre-installation conditions using a Before-After Control-Impact (BACI) design. Oyster reefs appeared to influence avian diversity and species richness, as densities of some avian species increased at treatment plots in comparison to pre-installation and control densities. Black Oystercatchers, Forster's Terns, dabbling ducks and wading birds used oyster reefs at low tide; some species, including oystercatchers, used them primarily for foraging. Preliminary analyses suggest that Living Shoreline treatments have influenced density, richness and biomass of benthic invertebrates. The oyster treatments appeared to have a positive effect on amphipod density, while eelgrass treatments benefited polychaete density. Our results suggest that some avian and invertebrate species are responding positively to established oyster and eelgrass habitat restoration. Repeating this experiment at additional sites and continued long-term monitoring of these habitats will be important for understanding species responses to living shoreline restoration methodologies.

Keywords: Living Shoreline, oystercatcher, invertebrates, shorebirds, restoration, waterfowl, wading birds

Poster Topic: Living Shorelines Project

Invertebrates Isotopic Niche Widths and Trophic Relationships in a San Francisco Bay Living Shorelines Project

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Disentangling trophic interactions can provide an understanding of restored ecosystems beyond structural monitoring, contributing critical information for assessing functionality of restoration projects. The San Francisco Bay Living Shorelines Project is a pilot ecological restoration study aimed at answering key questions about the individual and interactive effects of eelgrass plantings (*Zostera marina*) and native Olympia oyster beds (*Ostrea lurida*), and their potential to act as an adaptation method to climate change. We used natural abundance stable isotopes (SI), including ^{13}C, ^{15}N and ^{34}S, as a way to 1) identify the main organic matter sources fueling food webs in different restoration treatments (either eelgrass, oyster reefs or together), 2) characterize the diet of consumers for which they provide habitat, and 3) compare the isotopic niche widths of those recently established invertebrate communities. Roughly 1.5 years after project construction, the potential autochthonous and allochthonous sources of organic matter were collected in May, June and July 2014 to account for any short-term variability in their signatures and for potentially different tissue turnover rates in the consumers, which were collected in July. Primary food sources supporting invertebrates in the eelgrass habitat included eelgrass tissue itself and epiphytes (*Ampithoe valida*), particulate matter (Bryozoa) and macroalgae (*Corophiidae*). Community-wide isotopic niche metrics suggested a greater degree of trophic diversity, more trophic levels and increased trophic redundancy in the oyster and combination plots. At this stage of the restoration process, while little or no differences were observed in individual species SI composition between the eelgrass or oysters only and "combination" treatments, the oyster reefs appear to add some variety and complexity in trophic linkages, associated with higher species richness. With this baseline study for comparison, future "isotopic" monitoring events should allow us to capture potential changes in trophic structure as the restored habitats mature and new species eventually establish.

Keywords: food web, stable isotopes, eelgrass, oyster, restoration

Poster Topic: Living Shorelines Project

Effects of Living Shorelines on Substrate, Sedimentation, and Waves: the San Francisco Bay 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 managed by the State Coastal Conservancy, in collaboration with scientists with San Francisco State University, University of California, Davis, USGS Western Ecological Research Center, and consultants at ESA. The goal of the project is 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. While not a new concept, Living Shorelines projects are new to San Francisco Bay. The San Francisco Bay Living Shorelines project was constructed in July-August 2012. This poster presents three years of physical processes monitoring data for the project, as part of a five-year monitoring program.

Waves, currents, sedimentation/erosion, and substrate composition are monitored at four experimental 32 m x 10 m plots in San Rafael Bay. Turbidity of the water column is also 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 to provide data for a 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: Living Shorelines, Oyster, Wave Attenuation, Mudflat, San Francisco Bay, Sedimentation

Poster Topic: Living Shorelines Project