San Francisco Bay Living Shorelines: Near-shore Linkages Project
8 month Progress and Preliminary Monitoring Results

Covering Activities July 2012- February 2013

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***PLEASE NOTE – this progress report includes preliminary monitoring data that hasn't been fully analyzed or published. Please do not cite any text or figures without permission from the State Coastal Conservancy (mlatta@scc.ca.gov, 510-286-4157)**

I. Introduction to Project

The San Francisco Bay Living Shorelines: Near-shore Linkages (Living Shorelines) Project is a multi-objective habitat restoration pilot project. It is managed by the State Coastal Conservancy in collaboration with biological and physical scientists at San Francisco State University, University of California at Davis, U.S. Geological Survey Western Ecological Research Center, and consultants from ENVIRON Corporation, Isla Arena Consulting, and ESA-PWA. Funding partners include the State Coastal Conservancy, EPA and the San Francisco Estuary Partnership, the Wildlife Conservation Board, and NOAA Fisheries. The project helps to implement several of the research and restoration recommendations in the San Francisco Bay Subtidal Habitat Goals Report (www.sfbaysubtidal.org).

This is a pilot-level, experimental restoration project to learn more about best locations and techniques for native oyster and eelgrass restoration, gather information about fish, invertebrate, and bird use of the reefs, and assess whether the reefs can provide physical benefits such as reducing wave action and protecting adjacent shorelines. The Coastal Conservancy worked with partners to construct oyster and eelgrass reefs at two sites in San Francisco Bay in July/August 2012, including a large and small experiment at a site owned by The Nature Conservancy on the San Rafael Shoreline, and small experiment only at a site owned by the California Department of Fish and Wildlife in Hayward offshore from the Eden Landing Ecological Reserve.

General Concept

In general, Living Shorelines projects utilize a suite of bank stabilization and habitat restoration techniques to reinforce the shoreline, minimize coastal erosion, and maintain coastal processes while protecting, restoring, enhancing, and creating natural habitat for fish and aquatic plants and wildlife. The term “Living Shorelines” was coined because these techniques provide living space for estuarine and coastal organisms, which is accomplished via the strategic placement of native vegetation, natural materials, and reinforcing rock or shell for native shellfish settlement. The approach has been implemented primarily on the East and Gulf Coasts, where such techniques enhance habitat values and increase connectivity of wetlands and deeper intertidal and subtidal lands, while providing a measure of shoreline protection.

Living Shorelines in San Francisco Bay

While not a new concept, Living Shorelines projects are new to SF Bay, where pilot restoration work on eelgrass and oyster reefs has recently led to recommendations for additional experimental testing of techniques and gradual scaling up to larger projects. The ***2010 San Francisco Bay Subtidal Habitat Goals Report*** (see www.sfbaysubtidal.org) recommended that the next generation of projects consider the possibility of integrating multiple habitat types to improve linkages among habitats and promote potential synergistic effects of different habitat features on each other as well as associated fauna. Such habitat features, if scaled up slightly beyond previous projects would have the potential to positively influence physical processes (such as sediment erosion and accretion) that influence shoreline configuration.

The State Coastal Conservancy has assembled an interdisciplinary team to build on previous restoration lessons and move toward integrating multiple habitats in the "San Francisco Bay Living Shorelines: Near-shore Linkages Project". The project will further test subtidal restoration techniques, restore critical eelgrass and oyster habitat, test the individual and interactive effects of restoration techniques on habitat values, begin to evaluate connectivity between submerged areas and adjacent tidal wetlands and creeks, and test alternatives to hard/structural stabilization in a multi-objective project. Due to limited historical information on distribution and abundance of native oysters and eelgrass, we use the term "restoration" in the sense of enhancing valuable functions and services promoted by these types of features in SF Bay and elsewhere, rather than in the strict sense of replacing previously known distributions or extent.

Potential Climate Change Adaptation Approach

In addition, in developing the California (State Resources Agency) Climate Change Adaptation Strategy, state agencies have recommended the use of Living Shorelines as a potential adaptation method to reduce the need for engineered hard shoreline protection devices and to provide habitat functions and values. The State Coastal Conservancy Climate Change Policy also recommends implementation of Living Shorelines due to their ability to reduce erosion and trap sediment, allowing for both buffering of tidal wetlands and migration of habitats ("estuary rollover) – towards a goal of stronger estuarine habitat resiliency in the future due to sea level rise and other climate change related projections.

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.

Objectives

1) Use a pilot-scale, experimental approach to establish native oysters and eelgrass at multiple locations in San Francisco Bay.

2) Compare the effectiveness of different restoration treatments in establishing these habitat-forming species.

3) Determine the extent to which restoration treatments enhance habitat for invertebrates, fish, and birds, relative to areas lacking structure and pre-treatment conditions.

4) Determine if the type of treatment (e.g., oyster reefs, eelgrass plantings, or combinations of oyster reefs and eelgrass) influences habitat values differently.

5) Begin to evaluate potential for subtidal restoration to enhance functioning of nearby intertidal mudflat, creek, and marsh habitats, e.g., by providing food resources to species that move among habitats.

6) Evaluate potential for living subtidal features to reduce water flow velocities, attenuate waves, and increase sedimentation, and assess whether different restoration treatments influence physical processes differently.

7) Determine if position in the Bay, and the specific environmental context at that location, influences foundational species establishment, habitat provision, and physical processes conferred by restoration treatments.

8) Where possible, compare the ability to establish restoration treatments, habitat functions, and physical changes along mudflats/wetlands versus armored shores.

Design features

***The Larger scale experiment at the San Rafael site is meant to test both biological and physical effects*.** This experiment includes four, 32 x 10m treatment plots situated parallel to the shore, approximately 250 m from shore. This design will allow the project team to compare the effects of one type of native oyster substrate alone; eelgrass alone; and both together; in comparison to a control of the same size. We designed this experiment to be at a large enough scale to compare effects on physical factors such as wave attenuation and accretion as well as effects on biological properties that operate at larger scales (e.g., bird and fish utilization, water quality interactions of oysters and eelgrass). In 2012, this experimental design is only constructed at the San Rafael site. We intend to repeat this design at two sites along Eden Landing in the future, pending the outcome of the Phase 1 "substrate element" experiment in 2012 (see below).

The project team is comparing one type of oyster reef treatment (oyster shell bags; see below) on this larger scale. This treatment, described in detail below, has a footprint of 1x1m per element. We lay these out in sets of 4 elements to make larger units of 4 m^2. To minimize scour, our team members with expertise in physical processes recommended we have spaces of the same size (in this case, 4 m^2) between these oyster reef units. We installed 3 rows of eight units, for a total of 24 units per plot (96 elements).

We also planted and seeded eelgrass in its own treatment plot with the same spacing as the oyster reef units. The central 1.5 x 1.5 m (2.25 m^2) space within every other 4-m^2 space was planted with clusters of shoots and also seeded. See details of planting methods below.

Oyster treatment A also occurs in combination with eelgrass in a separate plot. We combined the oyster treatment with eelgrass planting/seeding using an additive design, with eelgrass placed into the central 2.25-m^2 of the 4-m^2 spaces between oyster substrate features. This design permits us to maintain a spacing of oyster substrate that will minimize scour while providing enough space around eelgrass plantings to permit access for sampling.

A control plot of the same size is also included. All four plot types were arranged randomly in the four possible positions, with 30 m between each plot.

Adjacent to the overall treatment area, a control area of equal size is monitored throughout the project time period.

***The small "substrate element" experiment is meant to examine small-scale biological effects at both sites- San Rafael and Hayward*.** This experiment consists of replicate 1x1 m substrate elements of different substrate types, intended to compare native oyster recruitment and growth parameters to inform future restoration projects. At the San Rafael site in 2012, this experiment was set up in the 30-m spaces between and on either side of the line of larger scale plots described above . At San Rafael, four oyster substrate types not tested in the large scale experiment were replicated 5 times, for a total of 20 elements. These elements were placed in groups (blocks) of four, with each of the four substrate types represented in each block.

A substrate element experiment is the only project installed at the Hayward site in 2012 (Phase 1 for that location). This is similar to that described for the San Rafael site in that it includes 1x1 m substrate elements replicated in 5 blocks and aligned parallel with the shoreline at ~250 m from shore. However, at Eden Landing, there are 5 substrate types: the 4 tested in the San Rafael substrate element experiment plus the substrate type used in the larger scale project at San Rafael (oyster shell bags; see below). In addition, there are 5 replicate 1x1m plots of eelgrass planted, one in each block, as well as a treatment that includes one of the oyster substrate types along with eelgrass planted directly adjacent to it. The layout of these replicate blocks of 7 elements allows space for a future installation of the larger scale project pending a positive outcome of this Phase 1 experiment. Thus 32 m-long spaces are left between substrate element blocks to accommodate the 32 m long plots of the larger scale experiment if it goes forward in a future year.

For more information about the full project design, please see the BCDC Standard Permit Application #M2012.005.00, which includes all relevant acreages, substrates used, and construction and monitoring methods. Please also see the May 2012 Project Description compiled by ESA PWA. In the near future, all project information will be posted on a website tiered from www.sfbaysubtidal.org.

For more information about any aspect of the project, please contact:
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II. Brief Summary of Oyster Element Procurement and Construction

*** Eelgrass transplant and seed buoy preparation is discussed in the next section.**

Pacific Oyster (*Crassostrea Gigas*) Bare Half Shell:

Drakes Bay Oyster Company provided bare Pacific oyster half shell (*Crassostrea gigas*) for the shell bag element portion of the project. Drakes Bay followed the protocol developed by Dr. Chela Zabin and Dr. Andrew Cohen to let the half shell cure in the sun over at least a one year period, to prevent any non-native species or other disease pathogens from hitchhiking on the shells and impacting the restoration project site. Drakes Bay provided a total of 6,000 clean half shell. These were bagged into plastic mesh bags, and 30 bags were grouped as an element onto a wood frame. A total of 215 elements were provided for the project- 205 were placed at the large project site at San Rafael, and 10 of these were placed as part of the smaller substrate element experiment at the Hayward site. Drakes Bay staff delivered the shell bag elements via 5 large truckloads to Dixon Marine in Richmond, who then loaded them onto a barge for deployment at the sites.

Native Oyster Artificial Elements:

Reef Innovations provided a technician certified by the Reefball Foundation to construct several of the artificial reef elements for the project, including the large reef balls, mini bay balls, and layer cakes (cross-sections of reef balls). These were constructed from a mixture of ~80% native sand and native oyster shell mined from the bay (provided by Jerico Products) with ~20% Portland cement. All elements were constructed in June 2012, and allowed to cure for up to three weeks before being deployed at the project sites.

Dixon Marine Services provided their yard for the element construction, and also led the construction of the fourth type of artificial element (oyster blocks). This design includes an interlocking system of blocks that can be configured in various shapes to increase surface availability for oyster settlement. The oyster blocks were based on a modified design of the trademarked Castle Blocks that have been used successfully in many east coast projects.

Robert Abbott from ENVIRON conducted water washing of these elements and tested the pH for at least two weeks, with all elements at an acceptable level of pH of 7.3 before deployment into the bay.

Construction:

Construction planning was led by Robert Abbott of ENVIRON, Marilyn Latta of the State Coastal Conservancy, and Amy Larson of the California Wildlife Foundation (CWF). CWF put out a request for qualifications and selected Dixon Marine Services for construction at both sites. Dixon Marine Services has a successful track record of in-bay construction and restoration work, and had the staff and equipment necessary for the construction of the oyster elements. All elements were delivered to Dixon's Richmond yard and loaded onto a barge. Construction occurred during mid-level tides between July 17-August 8, 2013. Dixon's crew included 3-4 people on the boat and barge, and 1 person in the water to direct specific placement of the oyster elements.

III. San Francisco State University: Introduction, Eelgrass Methods, Monitoring, Epibenthic Invertebrate Monitoring, Fish Monitoring (in collaboration with ENVIRON), Water Quality Monitoring

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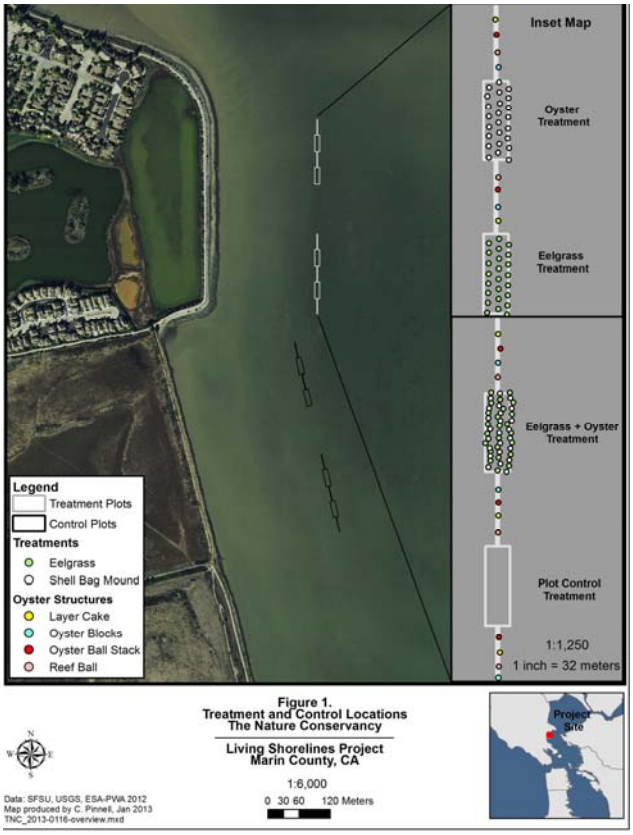
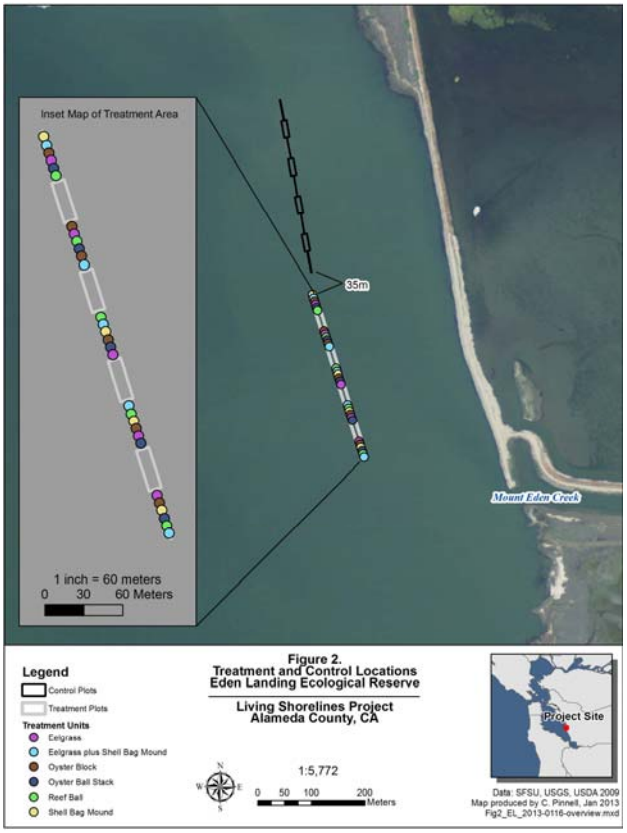
Introduction

This report summarizes the methods and results of the first year of activity for the San Francisco Bay Living Shorelines: Near-Shore Linkages Project at the The Nature Conservancy ('TNC') site in San Rafael Bay and the Eden Landing Ecological Reserve ('ELER') site in south San Francisco Bay, near Hayward (Figures 1 and 2). Following pre-installation site assessments, San Francisco State University scientists transplanted vegetative eelgrass shoots at both TNC and ELER and conducted buoy-deployed seeding at TNC during the summer of 2012. SFSU has begun monitoring the effectiveness of these restoration methods on establishment of eelgrass, alone and in combination with oyster settlement substrate (see experimental design, Figures 1 and 2). SFSU has also been working to monitor fish and invertebrate assemblages both before and after project installation as an indicator of the impacts of eelgrass and oyster substrate elements on local wildlife communities and abundances.





SECTION 1: Methods.

1. 1. Eelgrass planting and seed buoy installation: San Rafael Bay (TNC site)

1.1.1 Vegetative Shoots

In July 2012, we transplanted eelgrass to the San Rafael site ('TNC') in the two large plots indicated in Figure 1. A total of 1152 vegetative plants were collected, 576 from Point Molate ('PM'), and 576 from Point San Pablo ('PSP'). The plants were dipped in freshwater (three times for 1 minute) to remove as many invasive invertebrates as possible, and were then attached to bamboo stakes with twist-ties and burlap (to protect the shoots from abrasion). The plants were then stored in shallow rectangular tanks in running bay water for 1-2 days. The eelgrass shoots were planted at TNC, in a dice formation (5 positions, as in the number five on a die) with 24 plants in each 1.5m x 1.5m unit (four patches of 5 plants in a 0.25-m^2 quadrat, and one center patch of 4; see Figure 3). A total of 48 units of this configuration were planted at the site; 24 were planted in the eelgrass only plot (EG) in three rows of 8 units, and 24 were planted in between units of oyster shell bag plots (the eelgrass + oyster plot = EG+O) again in 3 rows of 8 units. At the time of planting, a PVC stake was also installed in each eelgrass unit for later anchoring of buoy-deployed seeding.

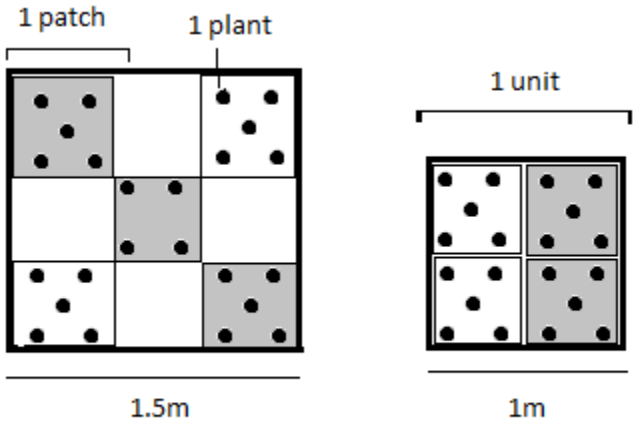


Figure 3. Planting schematic for eelgrass units at TNC (left) and ELER (right). Shaded patches and unshaded patches indicate different donors. The central patch of eelgrass in each eelgrass unit at TNC alternated between PM and PSP donor eelgrass shoots to give 12 PM dominated and 12 PSP dominated units in each plot (24 total in both EG and EG+O treatment plots). Each ELER unit contained 10 plants from BFI and 10 from ELER (20 total).

1.1.2. Flowering Shoots

In conjunction with vegetative shoot collection, 740 flowering shoots were collected, only from the PSP donor, as PM flowering shoots were not available. These shoots were placed into mesh bags (15 per bag) and held in tanks of running baywater at the Romberg Tiburon Center. Mesh bags were dipped in freshwater repeatedly to remove epifauna and were attached along with a buoy and rope to the PVC stakes within each eelgrass unit approximately two weeks after the vegetative shoots were planted. An extra 20 flowering shoots were collected from each donor site, to be used as a reference for recording flowering stage and seed drop within the eelgrass units.

1.2 Eelgrass planting: Hayward (ELER site)

In August 2012 we collected 200 vegetative eelgrass shoots, 100 from the shoreline adjacent to Bay Farm Island (BFI) in Alameda and 100 from eelgrass patches at Eden Landing Ecological Reserve (ELER) offshore of our study site. These shoots were dipped in freshwater carried in tubs and attached in the field to their bamboo stakes as described above. The vegetative shoots were planted in sets of 20, with five plants in a 0.25-m^2 quadrat, within 1m x 1m units (see figure 3). Two eelgrass units (n = 40 plants) were planted within each of the five blocks at ELER, one with eelgrass only, and one directly adjacent to an oyster shell bag mound. The flowering shoots at BFI and ELER had already dropped seed at the time of shoot collection so seed buoys were not installed. Seed buoys may be installed at Eden Landing in spring or summer 2013, depending on availability of flowering shoots.

1. 3. Eelgrass Monitoring

The first round of planted eelgrass monitoring was conducted in November, 2012. This monitoring included density counts, shoot heights, epiphyte load, epifauna abundance and diversity, and nutrient analysis. Density and shoot height monitoring were conducted concurrently, and eelgrass collections were made immediately after these measurements.

1.3.1 Densities

All shoots within each eelgrass unit were counted for survivorship. At TNC, an “exclusion zone” has been included within each treatment plot, and the small control area (figure 1) to reduce sediment disturbance during monitoring. The plants in these zones were counted and their locations mapped on schematic maps, but no collections were taken from the EG+O treatment. Due to low densities in the EG only treatment, collections were taken from the exclusion zone, but this was carried out by floating over the area on boogie boards, when water was over the sediment to prevent any disturbance. The number of shoots per genet was also recorded, along with an assessment of rhizome presence in four of the plots within the eelgrass-only treatment. Shoot location in relation to bamboo stakes indicated whether a shoot was a parent of clone. This total number of shoots, including any that have emerged from clonal growth, informs the total shoot survivorship value. Additionally, the number of flowering shoots was recorded, along with their condition, height and the stage of flower or fruit development on spathes, according to de Cock (1980).

1.3.2 Heights

The heights of all recorded vegetative shoots (and of flowering shoots, if present) were measured to the nearest centimeter, with the plant extended fully upright.

1.3.3 Epifauna, Epiphytes and Nutrient/Isotope Analyses

Eelgrass collections were made to assess epifaunal communities, epiphytic loading, and nutrient and stable isotope composition. Collection methods were designed to minimize the impact to each plant. Due to low densities, we were unable to achieve our target collection sizes.

Two portions of selected shoots were collected from both sites, including the top 10 cm of the second and fourth most interior leaves ('leaf 4 and leaf 2'). At Eden Landing, a total of 29 portions of leaves were collected, including 13 'leaf 4' samples (seven from ELER and six from BFI) and 16 (eight from ELER and eight from BFI) 'leaf 2' samples. At TNC, only three 'leaf 4' (all from PM patches) and three 'leaf 2' samples (also all from PM patches) were collected from the eelgrass-only plot due to low shoot densities. A further 20 'leaf 4' (10 from each donor) and 18 (11 from PSP, and seven from PM patches) 'leaf 2' samples were collected from the eelgrass +oyster plots. Both sample types were kept cold and taken back to the laboratory for processing over the following three days.

To assess epifaunal communities, 'leaf 4' samples were processed in the laboratory. Each sample was emptied onto a 500 μm sieve and subjected to three 1-minute freshwater dips to remove clinging epifauna. Invertebrates removed during the freshwater dips were preserved in 70% ethanol and will be identified to the lowest possible taxon according to Carlton (2007), and enumerated (per shoot or sub-sample) in the winter 2013.

To assess epiphytic loading, 'leaf 4' samples were then gently rinsed in bay water in a flat-bottomed tray to remove loose sediment. Using a microscope slide, each sample was scraped three times inside the tilted tray (or until all epiphytes had been visibly removed). The epiphytes were then transferred from the tray (and any from the collection bags) to a pre-weighed microfilter glass fiber filter using a hand-operated vacuum pump, and dried in a 65° C oven for 48 hours to determine dry weights. Leaf 4 samples were then weighed after blotting with paper towels then placed into pre-weighed weigh dishes before being dried for 48 hours at 65°C so that the dry weight of plant material could be taken.

To determine %C, %N, and C:N of eelgrass as well as the stable isotopes $\delta^{13}C$ and $\delta^{15}N$, 'leaf 2' sub-samples were washed with de-ionized water, weighed in clean plastic pre-weighed weigh dishes, dried at 65° C, and ground with a pestle and mortar. Samples were sent for analysis at UC Berkeley's isotope analysis facility. Epiphytes collected from future monitoring efforts will also be analyzed for $\delta^{13}C$ and $\delta^{15}N$ content determination.

1.4. Invertebrate Community Monitoring Methods

1.4.1 Minnow and Collapsible Traps

Six pre-construction monitoring plots (spaced approximately 66 m apart) were established along a 330-m sampling transect located 250 m offshore at each site (San Rafael and Hayward), to span the length of the current or proposed large-scale restoration treatments (n = 6). Plots were sampled once during each of the four quarterly rounds (October 2011, January, April, and July 2012) prior to the treatment implementation in July/August 2012. Plots were also sampled post-treatment in October 2012. All plots were sampled within a two-week period during each sampling round. Each sampling round consisted of three methods: 1) suction sampling (described in Section 1.4.2), 2) minnow traps, and 3) collapsible multi-species traps.

At the San Rafael (TNC) site, three post-construction monitoring plots were established in July 2012 within each of the four treatments (n = 12) distributed evenly within the 330 x 32 m sampling transect (control, eelgrass, oyster and eelgrass plus oyster) ('TNC Treatment Area'). In addition, 12 sampling plots were established in an adjacent 330 x 32 m area ('TNC Control Area') located approximately 20 m directly south of the TNC Treatment Area.

At the Hayward (ELER) site, six post-construction monitoring plots were established in July 2012, one near each set of trial elements and one at the north end of the entire treatment area ('Eden Treatment Area'). An additional six control plots were established approximately 30 m north of the Eden Treatment Area ('Eden Control Area').

These post-construction monitoring plots are now being sampled with the same frequency and methods as in the pre-construction monitoring (October 2012, January, April, and June 2013). All data (including date and time) are recorded on standardized data sheets, and data are entered within one week into an electronic database file. Each plot is marked and accessed using a sub-meter accurate GPS to ensure continuity between sample rounds.

One minnow trap and one collapsible oval trap (without escape pot) are attached by rope to make one 'two-section' trap array per plot. Each trap is baited with a uniform combination of fish-based bait (1 squid plus 3 anchovies) suspended in mesh bags. Trap arrays are weighted with one half brick, attached to a labeled scientific buoy and deployed for 24 hours within each plot. Upon retrieval, all specimens are immediately identified, sexed, and measured (carapace width, or body length and body + tail length) in a wet tray to minimize harm. All trap catch is released live immediately after processing, or preserved in ethanol if additional steps are required for identification.

1.4.2 Epifauna by Suction

Suction sampling methods are adapted from previous invertebrate surveys within eelgrass beds conducted by the Boyer Lab. A hand-held, battery-operated aquarium gravel vacuum with a modified opening of approximately 10 mm is used to sample the epibenthic aquatic invertebrates and post-larval crabs (<10 mm) in one 0.5 x 0.25 m quadrat within each plot during low tides (<1.0 m). Suction samples

are collected as pairs, with one sample collected from the vertical structure (eelgrass or oyster plot) or water column (control plot), and one sample collected from the epibenthic layer (except in the oyster treatments where the epibenthic layer is covered by the oyster structure).

At the San Rafael site, six paired suction samples are collected from each single treatment (eelgrass only and oyster only) and each of the two control plots. An additional 12 suction samples are collected from the eelgrass plus oyster treatment (6 samples for both). Therefore, a total of 30 paired samples (eelgrass and control) and 12 single samples (oyster) are collected quarterly.

Sampling locations are selected using a random number generator, with each unit per plot being assigned a number from one to 24. Quarterly samples are each collected from a different quarter-section within the unit to avoid disproportionately sampling within a unit. If the selected quarter-section is damaged or otherwise unable to be sampled, then a secondary protocol is implemented to select the next appropriate sampling location.

At the Hayward site, paired samples are collected within every eelgrass unit (n = 5) and eelgrass portion of the eelgrass plus oyster units (n = 5). Single samples are collected from every shell bag mound oyster unit (n=5) and oyster portion of the eelgrass plus oyster units (n = 5).

A section of fine mesh pantyhose is connected to the output of the vacuum, allowing all water to pass through while trapping fine sediments and invertebrates. The mesh is then removed from the output and placed in ethanol to preserve the sample in the field. In the lab the sample is washed through a series of fine sieves (500 µm) to remove the sediment and isolate the invertebrates. The invertebrate sample is then split to ½ using a professional grade sample splitter. Invertebrates are then sorted to the most appropriate taxonomic level and counted under a light microscope. Five paired samples are also collected from the control site (n=5). Therefore, a total of 15 paired samples and 10 single samples are collected from the ELER site.

1.5 Fish Monitoring

1.5.1 Minnow and Collapsible Traps

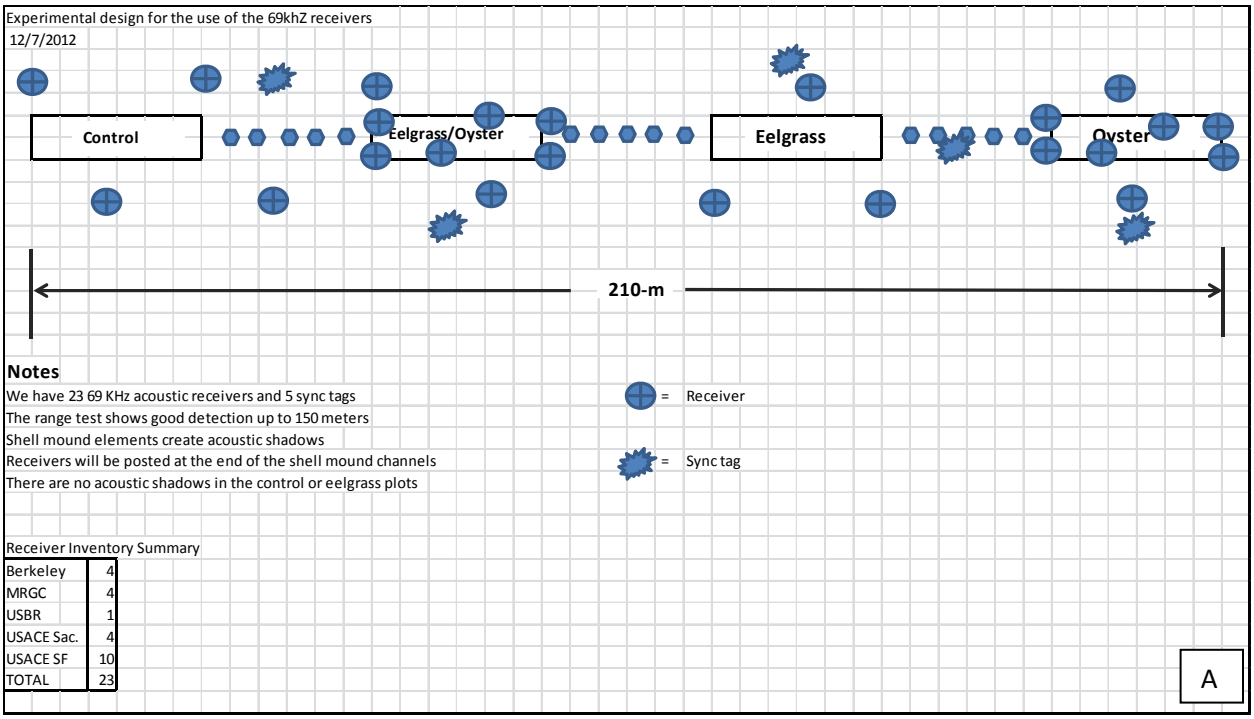
Fish are monitored quarterly using the same sampling array and gear as described for invertebrates in Section 1.4.1. Fish captured are identified, measured, and released.

1.5.2 Acoustic Monitoring Array at TNC

A comprehensive array of 27 acoustic receivers was installed at the TNC site in December 2012 (see figure 4 for a schematic of their positions) and is now continuously detecting the presence and position of any acoustically tagged fish that visit the site. For 2013 and possibly beyond, the Project was able to borrow Vemco VR2W acoustic receivers from the US Army Corps of Engineers (8 from the Sacramento office, 10 from the San Francisco office), Marin Rod and Gun Club (8 receivers), and the US Bureau of Reclamation (1 receiver). Please see appendix 1, photo 4 for an image of a receiver installed at TNC.

Additionally, the California Coastal Conservancy purchased 5 Vemco synchronization transmitter tags to enable precise positioning of visiting tagged fish within each plot at the site (Figure 4B).

The first data download from the acoustic receiver will occur in April or May 2013. Members of the Project are working collaboratively with the California Fish Tracking Consortium.



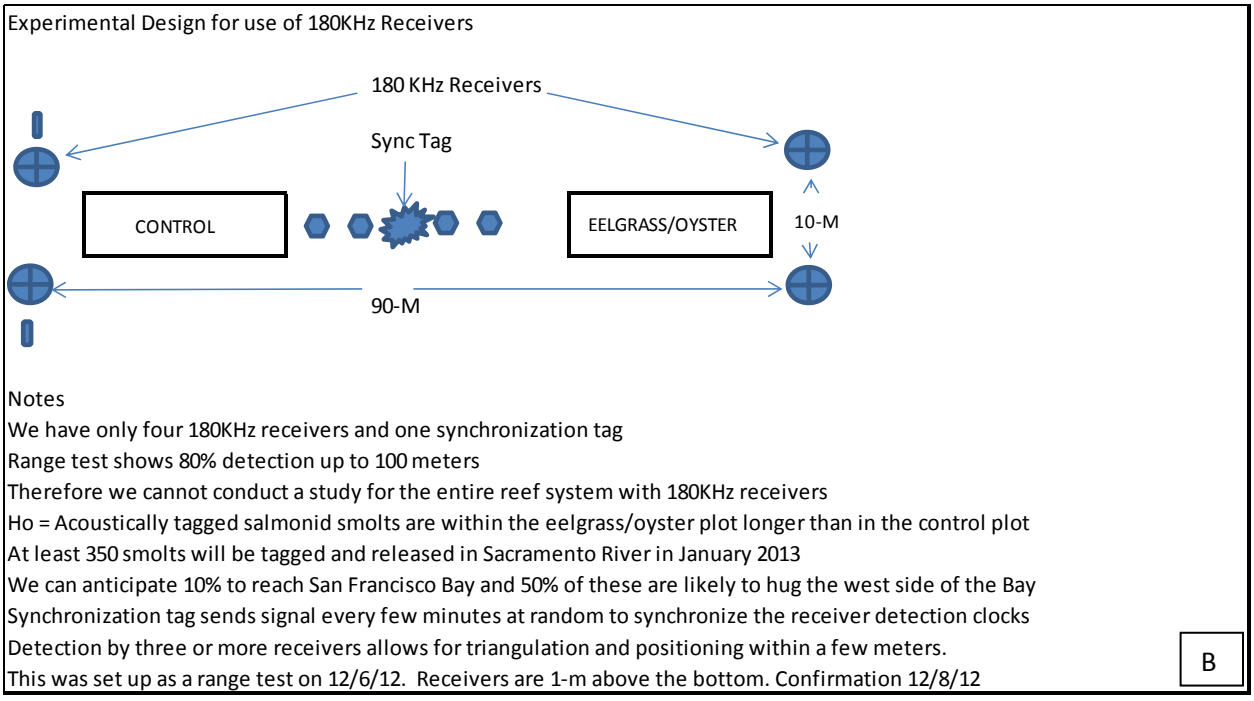


Figure 4 – a schematic of the locations of 27 Vemco acoustic receivers for fish monitoring at the TNC site (A), and a detailed schematic of the design of sync tag and acoustic receiver layouts between the EG+O treatment and control (B). Drawings courtesy of Bud Abbott.

1.6 Water Quality Monitoring

1.6.1 Temperature and Salinity

We deployed Onset HOBO conductivity/temperature (CT) data loggers to collect continuous data on salinity and temperature at both the ELER and TNC sites. In November 2012, a total of five CT sensors were placed at the TNC site, one in each of the large-scale plots and one in the large control area (Figure 1). Two days later, five CT sensors were placed at the ELER site, four spaced along the small-scale substrate elements installed in 2012 and one in the large control area outside the substrate element project area (Figure 2). Each CT logger is attached vertically to a 5ft x 4in fiber reinforced plastic rectangular stake via 316 stainless steel fixings, with the sensor approximately three inches from the top of the stake. Copper mesh is covering the sensor panel to deter biofouling. The loggers are deployed so that the base is approximately six inches from the sediment. This mooring minimizes CT logger contact against the stakes and reduces the potential for sediment loading on the sensors. Each logger is deployed on the shore-side of each oyster structure or eelgrass unit (exact locations will be mapped with GPS), with the sensor facing the shore at both sites. At TNC, the logger in each patch is located just west of the most southern unit in the eastern row.

These sensors are recording conductivity and temperature continuously and are cleaned when the data are downloaded in the field using a waterproof shuttle. Cleaning and data downloads were taken in the beginning of December 2012 and will be taken at least every 6 weeks.

As only one month's data has been recorded from these CT loggers, we will include temperature and salinity information in the next report when more data has been gathered.

1.6.2. Water Column Chlorophyll-a Measurements

SFSU is collecting chlorophyll a data to determine if treatments influence phytoplankton abundance, thus potentially affecting competition for light and nutrients with eelgrass. Post-construction chlorophyll monitoring commenced in October 2012 and will occur next in January 2013. Replicate samples were collected at the TNC site (all plots plus control area) on October 5th and from the Eden Landing site (Elements and Control Area) on October 12th. Back at the Romberg Tiburon Center, chlorophyll extractions follow the method of Arar and Collins (1992) followed by fluorometry analyses as described by Smith et al. (1981). The Turner Designs model 10 fluorometer used in this study is calibrated annually with a Turner primary (chlorophyll) standard that is serially diluted to obtain a standard curve and coefficients. This fluorometer is occasionally (approximately every other year) cross-calibrated with other fluorometers at RTC (e.g., RTC joint-use Turner Designs 10AU bench top fluorometer).

1.6.3. Light

Photosynthetically active radiation (PAR) has been measured quarterly just below the surface and at one-meter depth using a YSI spherical PAR sensor. Measuring light at two depths will permit calculations of light attenuation through the water column, which can then be compared among

treatments and with other such measures for San Francisco Bay (Zimmerman et al. 1991, Merkel and Associates 2005). Three replicate measures within each large-scale treatment plot were taken at TNC on each sampling date. One measure in each of three of the blocks of the small-scale substrate element experiment at ELER North were also taken, and an additional three replicate measures in the large control plot with no habitat structure at each sampling date. The data from these light measurements will be included in the next report.

SECTION 2. Results and Discussion

2.1 Eelgrass Monitoring Results

2.1.1. Densities

Densities of surviving eelgrass shoots were found to be very low at both sites. At TNC, only four out of 576 shoots survived in the eelgrass only (EG) plot (0.5%, Figure 5). Of these four shoots, three originated from PM and one from PSP. In addition, one flowering shoot from the PM donor site was observed. In the eelgrass + oyster (EG+O) plot, a total of 55 of 576 shoots survived (9.5%, including shoots emerging from clonal growth), 34 from PM and 21 from PSP, including some emerging from clonal growth.

Overall, in both treatment plots PM plants tended to have better survivorship and plants at the EG+O treatment had a much higher survivorship than the EG treatment.

Additionally, of the four eelgrass units in the EG plot that were assessed for rhizome presence, rhizomes were observed at the base of most stakes (which previously had eelgrass shoots attached), indicating a die off of above-sediment eelgrass biomass. It is unlikely rhizomes will enable a re-growth of eelgrass shoots, as most shoots were missing from a point below where the meristematic tissue would have been.

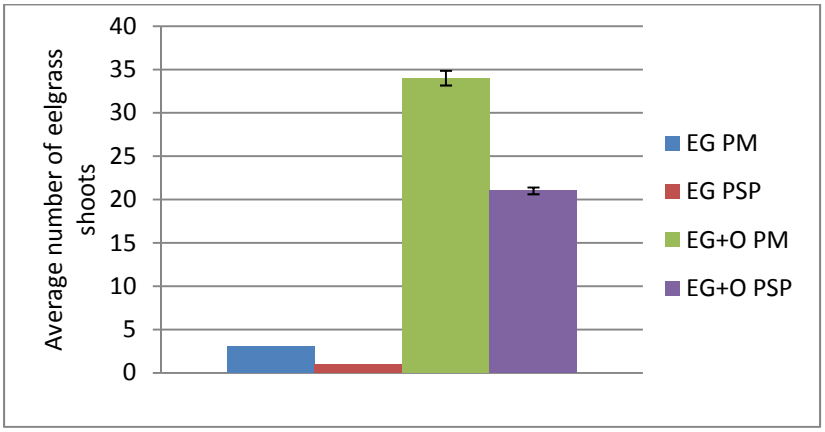


Figure 5 - Number of vegetative eelgrass shoots present, by donor and treatment plot at TNC. Error bars = standard deviation.

At ELER, a total of 58 vegetative shoots of 200 survived (29%, Figure 6), which consisted of 31 from the ELER donor site and 27 from BFI. There seems to be little difference in survivorship between plants from the two donors. Three flowering shoots were also observed from the ELER donor site, and one from BFI. Eelgrass units in blocks 3 and 5 had the highest survival rate, with 15 and 30 surviving shoots, respectively.

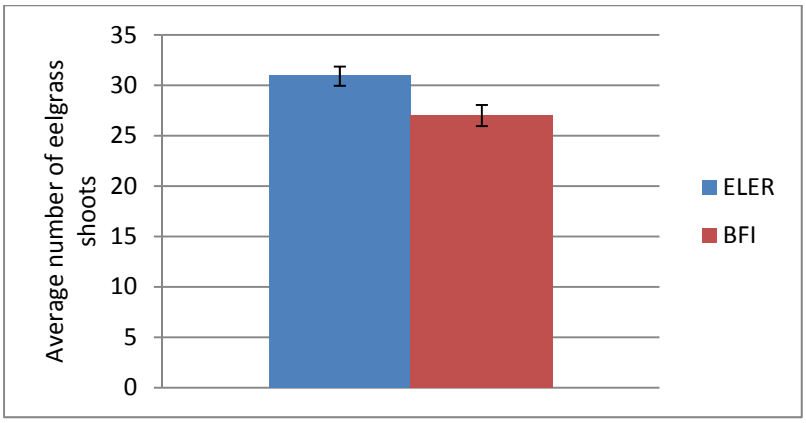


Figure 6 – Average number of vegetative eelgrass shoots present, by donor at ELER. Error bars = standard deviation.

Overall, ELER eelgrass seems to have had better survivorship than TNC (29% vs. 9.5-10%). We will be repeating the transplantation effort in Spring 2013 and hope to see better survivorship with an earlier planting date (compared to the late summer in 2012).

When mapping where each eelgrass shoot was observed within each patch, most surviving shoots seemed to be growing away from any bamboo stakes. This suggests clonal growth had occurred prior to loss of shoots. It is possible but unlikely that new shoots will develop from these plants.

2.1.2. Heights

The mean height of vegetative eelgrass shoots across all plots at TNC was 97.2cm. In the EG plot, average height of PM plants was 110cm (n=3), and of PSP plants was 53.2cm (n=1). In the EG+O plot, the mean height of PM plants was 111.1cm (n=18) and of PSP plants was 114.5 cm (n=15, figure 7). All donors and treatments seem to produce similar plant heights, except the EG treatment PSP plant, but as the sample size was only one plant, we cannot assume a trend from this. Further monitoring efforts will allow a better understanding of the height variance.

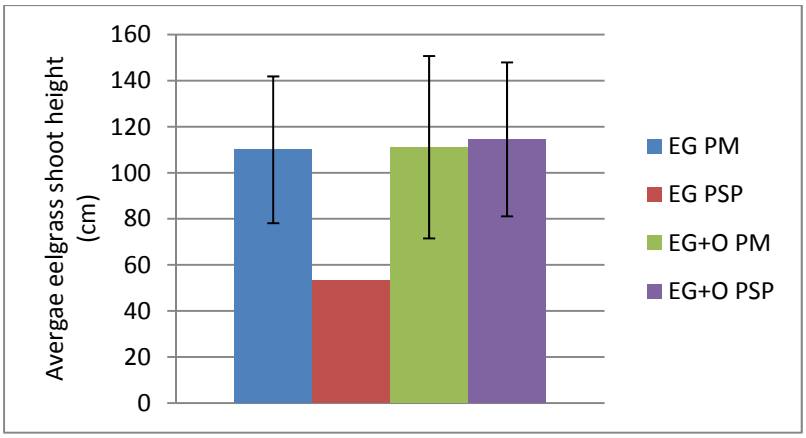


Figure 7 - Average height of the tallest eelgrass shoot in each genet present by donor and treatment at TNC. Error bars = standard deviation.

At ELER, the mean height of eelgrass was 65.3cm (n=34). The average height of shoots from the ELER donor site was 61.2cm (n=20), and the average height of shoots from the BFI donor site was 69.4 cm (n=16, Figure 8). The eelgrass shoot height seems not to vary between the donors at ELER, but on average the plants from this site reached smaller heights than those at TNC.

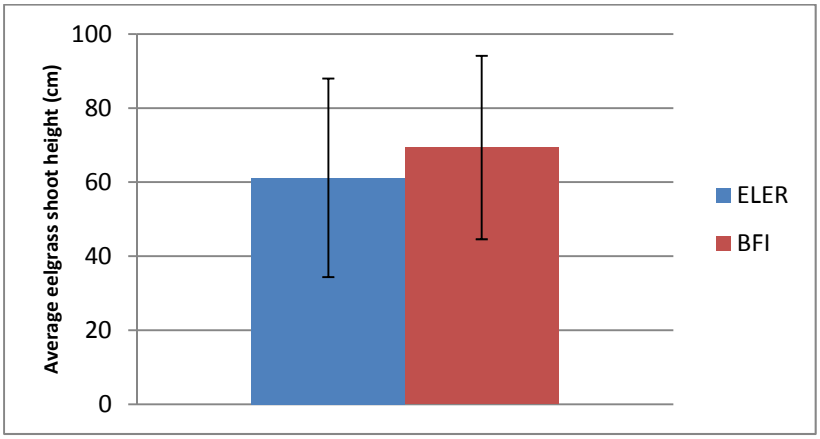


Figure 8 - Average height of the tallest eelgrass shoot in each genet present, by donor at ELER. Error bars = standard deviation

2.1.3 Epiphyte load

The following values for epiphytic loading represent the loads on older leaves (leaf 4 and older), and are not representative of newer leaves (leaves 0-3). Therefore, these values are intended to be used for comparison of donor populations, sites and treatments, and are not intended to represent whole plant loading. Epiphyte load is expressed as a ratio of epiphyte biomass to eelgrass biomass, with higher ratios indicating a higher load.

2.1.3.1. TNC

TNC supported high epiphyte: eelgrass biomass ratios (Table 1). The average ratio of dry biomass was 2.6g epiphyte: 1.1g eelgrass. The average epiphyte load in the EG plot was lower than the EG+O plot. However, due to low eelgrass densities and therefore low sample size we cannot infer a trend from this result. In the EG+O plot, leaves collected from PM donors had a higher epiphyte load than plants from PSP donor site. Further assessments from our quarterly monitoring efforts will help confirm this finding.

Table 1- average biomass (g) of dry eelgrass and epiphyte collections, along with epiphyte: eelgrass biomass ratios by donor and treatment at TNC

	Donor	Average ratio of dry biomass (g) Epiphyte: eelgrass	Average dry eelgrass biomass (g)	Average dry epiphyte biomass (g)
EG	PM	2.2: 1.1	0.342233333	0.790466667
EG+O	PM	2.9: 1.1	0.150544444	0.361577778
Both treatments	PM	2.8: 1.1	0.189061538	0.452269231
	PSP	2.3: 1.2	0.13651	0.19672
	Both	2.6: 1.1	0.166213043	0.34116087

2.1.3.2. ELER

Table 2 shows the average dry biomass of eelgrass and epiphytes, along with the ratio of epiphyte to eelgrass biomass at ELER. The average epiphyte: eelgrass ratio was 1g: 2.9g. Samples collected from BFI donors had lower epiphyte loads than EL donors.

Table 2 - Epiphyte: eelgrass biomass (g) ratios by donor at ELER

Donor	**Average ratio of dry biomass (g)** Epiphyte: Eelgrass	Average dry eelgrass biomass (g)	Average dry epiphyte biomass (g)
BFI	1: 2.5	0.130566667	1.2047
ELER	1: 3.2	0.1487	1.166085714
Both	1: 2.9	0.140330769	1.183907692

Overall, plants at TNC seem to have a higher epiphyte load than ELER. The eelgrass shoots at ELER were found to have very high numbers of eggs laid by *Ilyanassa obsoleta* (an invasive snail species); these eggs were not covering plants at TNC, and this left higher surface area for epiphyte growth on plants at TNC. Monitoring efforts during months when these eggs are not in high abundance will better show if epiphyte levels are indeed higher at the TNC site.

2.1.4. Isotope Analysis

From the leaf 2 samples taken from both ELER and TNC, there does not seem to be observably high variance in 13C : 15N ratios in leaf 2 samples between sites or donors. The 13C: 15N ratios in leaf 2 samples from ELER do seem to be more similar to each other than to those from TNC. Among TNC samples, there seems to be a somewhat different signal developing in the eelgrass only plots relative to the eelgrass + oyster plots, but low sample sizes makes any interpretation of this pattern premature. Future samples of epiphytes and invertebrates will also be analyzed for their 13C : 15N ratio, and this will allow some interpretation of food web relationships of these groups.

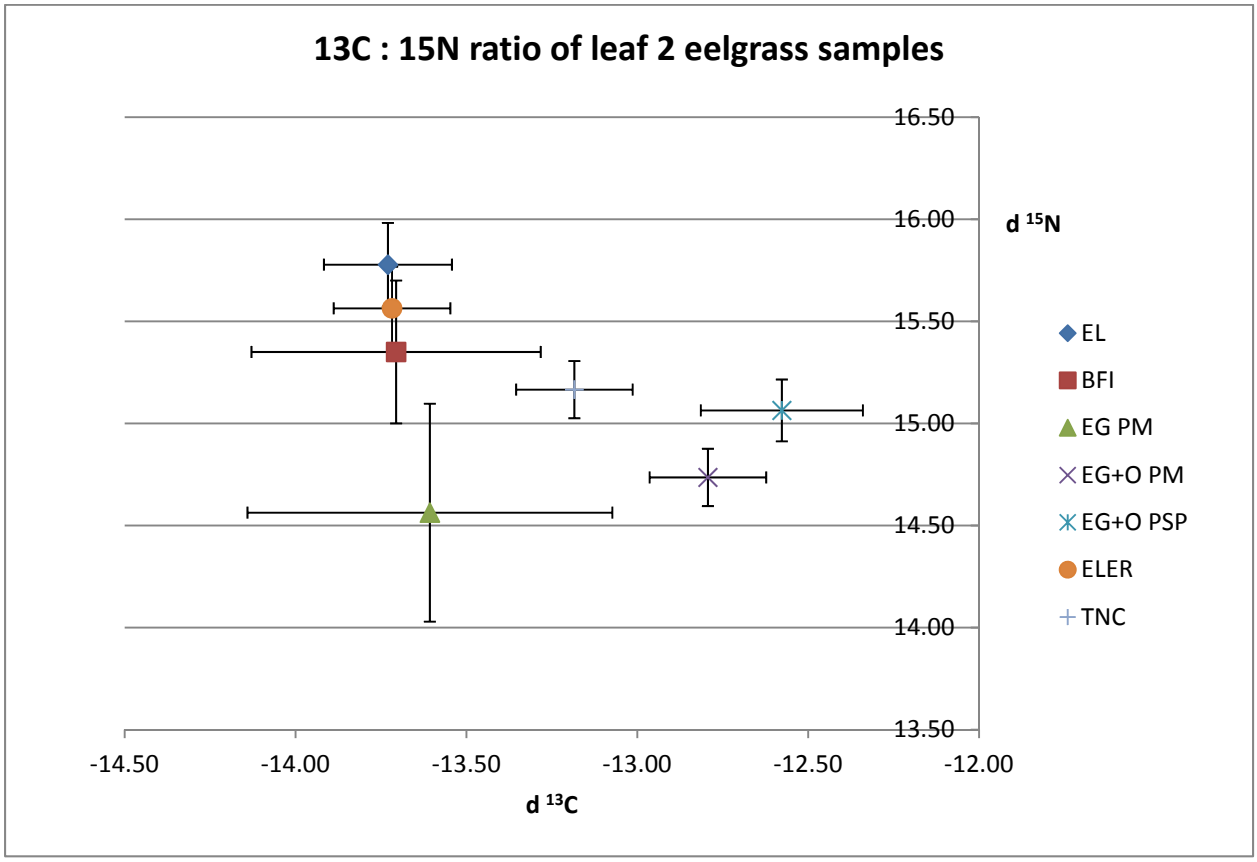


Figure 9 – 13C : 15N ratio of leaf 2 eelgrass samples taken from both ELER and TNC in November 2012. Error bars = standard error.

2.2. Invertebrate Monitoring Results

2.2.1. Minnow and Collapsible Traps

A total of four invertebrate taxa have been observed in the traps, including the native mud crab/yellow shore crab (*Hemigrapsus oregonensis*), the native Dungeness crab (*Metacarcinus magister*), shrimp species (*Crangon* sp.) and the non-native eastern mud snail (*Ilyanasa obsoleta*). Invertebrate community composition varies between the two sites, with TNC dominated by the yellow shore crab and ELER dominated by the eastern mud snail.

Early preliminary results indicate that the addition of structure (oyster or oyster plus eelgrass) may provide habitat for juvenile Dungeness crab and shrimp at the TNC site. The results from the first round of post-construction monitoring (October 2012) show an increased abundance of both these taxa relative to the yellow shore crab in the oyster and oyster plus eelgrass treatments over the control and eelgrass only plots (Figure 10). At ELER, preliminary results showed a small increase in yellow shore crab and shrimp in the treatment areas, compared to the control (Figure 11). Mean abundances for quarterly sampling at both sites are shown in Table 3.

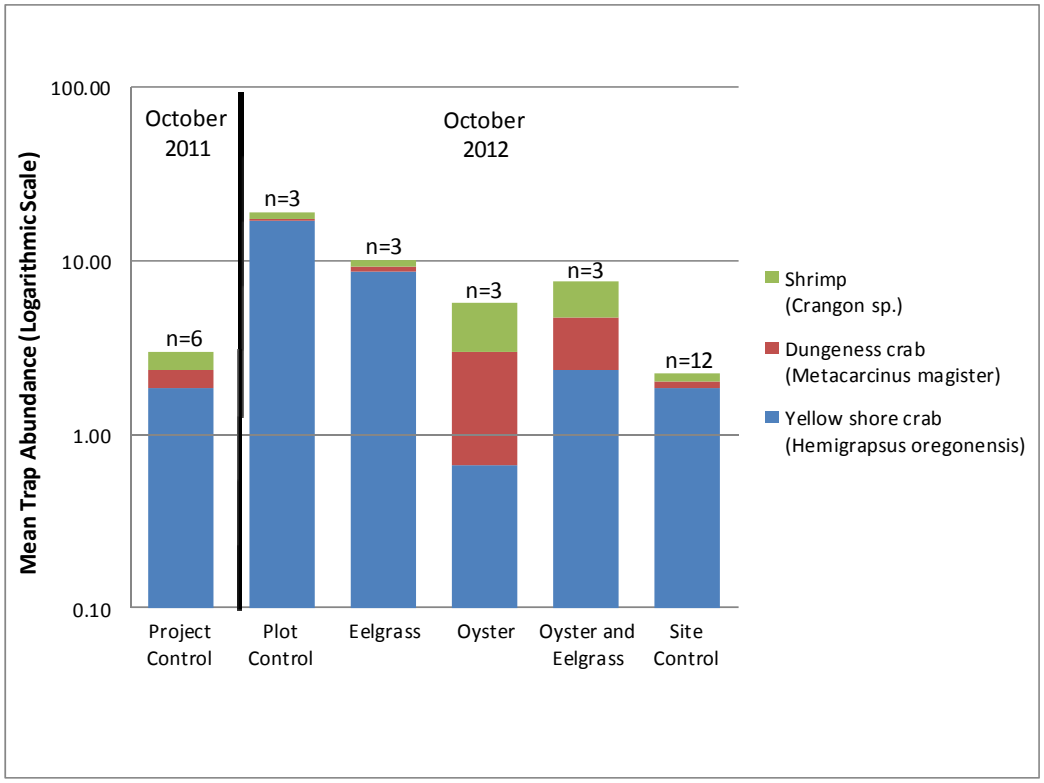


Figure 10. TNC mean abundance of aquatic invertebrates in minnow and opera traps (combined) during October 2011 and 2012 sampling rounds. Data collected and compiled by SFSU 2011-2012. *Data is shown on a logarithmic scale.*

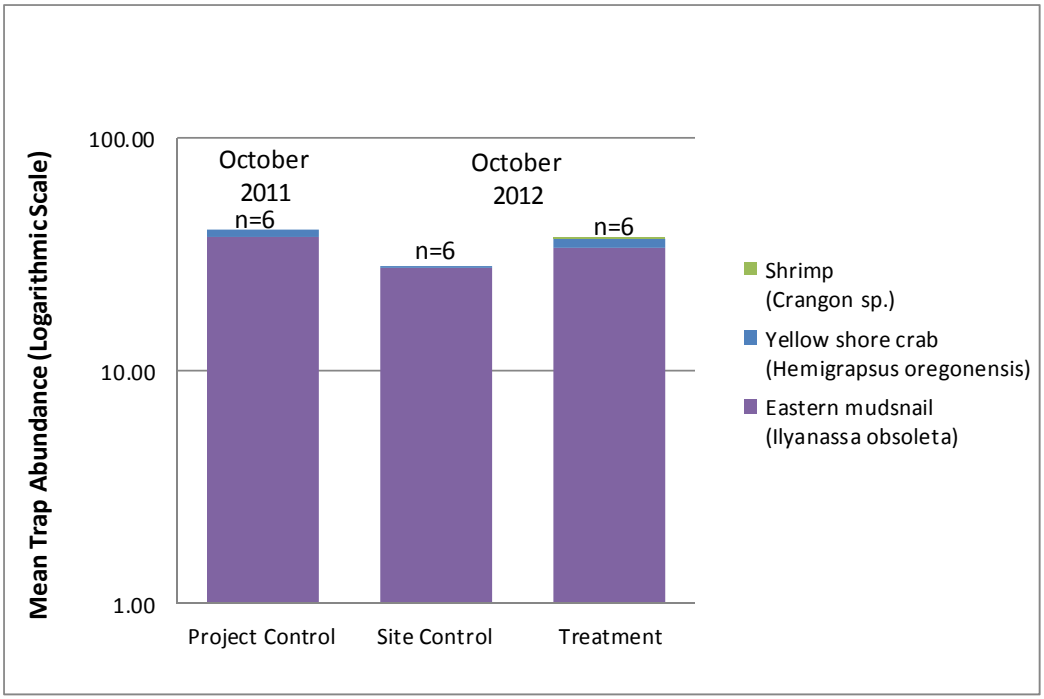


Figure 11. ELER mean abundance of aquatic invertebrates in minnow and opera traps (combined) during October 2011 and 2012 sampling rounds. Data collected and compiled by SFSU 2011-2012. *Data is shown on a logarithmic scale.*

Table 3. Mean trap abundance and SD of aquatic invertebrates at TNC and Eden Landing North sites, Living Shorelines Project. Data collected and compiled by SFSU, 2012-2013. *Grey rows are shown in Figures 8 and 9.*

					mean abundance ± SD[1]			
Site	**Date**	**n**	**Plot**	**Soak Hours**	**HEMORE**	**METMAG**	**CRsp**	**ILYOBS**
TNC	Oct 2011	6	Proj Control	24	1.83 ± 1.47	0.50 ± 0.84	0.67 ± 0.52	0
	Jan 2012	6	Proj Control	6	0.33 ± 0.52	3.20 ± 2.17	0	0
	May 2012	6	Proj Control	6	1.00 ± 0.63	0	0.17 ± 0.41	0
	Jul 2012	6	Proj Control	24	70.33 ±20.69	0	1.67 ±1.86	0
	Oct 2012	3	Plot Control	24	17.00 ± 15.87	0.33 ± 0.58	1.67 ± 1.53	0
		3	Eelgrass	24	8.67 ± 3.79	0.67 ± 0.58	0.67 ± 1.15	0
		3	Oys+Eelgrass	24	2.33 ± 3.21	2.33 ± 2.08	3.00 ± 2.00	0
		3	Oyster	24	0.67 ± 0.58	2.33 ± 4.04	2.67 ± 0.58	0
		12	Site Control	24	1.83 ± 1.37	0.17 ± 0.19	0.25 ± 0.17	0
Eden	Oct 2011	6	Proj Control	24	2.83 ± 1.72	0	0	37.50 ± 29.45
	Jan 2012	6	Proj Control	3	0.17 ±0.41	0	0	0
	Apr 2012	6	Proj Control	6	0	0	0	0
	Oct 2012	6	Site Control	24	0.17 ± 0.41	0	0	27.67 ± 32.55
		6	Treatment	24	2.83 ± 1.17	0	0.33 ± 0.52	33.83 ± 40.53

1. HEMORE- *Hemigrapsus oregonensis*
METMAG- *Metacarcinus magister*
CRsp- *Crangon* sp.
ILYOBS- *Ilyanassa obsoleta*

2.2.2. Epifauna by Suction Sampling

Invertebrate sampling was conducted at ELER and TNC in October 2011, February 2012 and April 2012, July 2012 and October 2012. Samples have been sieved and preserved in ethanol. Samples are in the process of being sorted and counted.

Figure 12 presents the preliminary results of two rounds of epibenthic suction samples, October 2011 and February 2012, from both TNC and ELER. The most common taxon observed at ELER was the amethyst gem clam (*Gemma gemma*). The most common taxon observed at the TNC site was the Asian cumacean (*Nippoleucon hinumensis*).

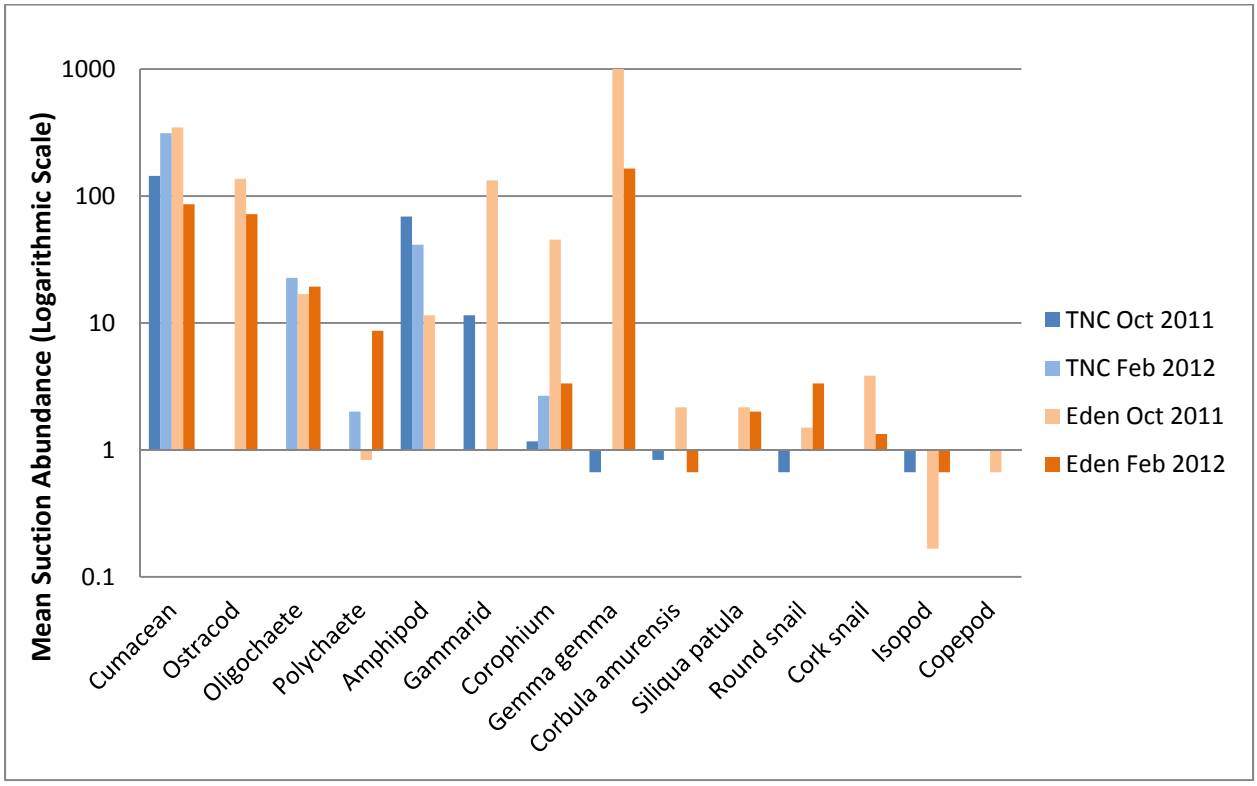


Figure 12. Preliminary mean aquatic invertebrate abundance data collected by suction sampling in 0.25m x 0.25m quadrat during October 2011 and February 2012 at TNC and ELER sites. Data collected and compiled by SFSU.

Data shown on logarithmic scale
n=6 from each series, SD not shown due to logarithmic scale.

2.3. Fish Monitoring Results

2.3.1. Minnow and Collapsible Traps.

Table 4 shows the fish species caught in Minnow and Collapsible traps at TNC and ELER. Note, only one sampling effort has been conducted post-construction, so the lower abundance of fish can be explained by the lower trap numbers. More fish were caught at ELER both before and after construction (13 and 7 pre and post-construction respectively at ELER vs. 11 and 0 at TNC).

Table 4 – Fish species and numbers caught in Minnow and Collapsible traps at TNC prior to construction (data taken between October 2011 and July 2012) and post-construction (data taken in October 2012).

	TNC			ELER	
	Pre-construction	Post-construction		Pre-construction	Post-construction
Bay Pipefish	0	1	**Barred Surfperch**	1	1
Jacksmelt	6	0	**Leopard Shark**	9	7
Leopard Shark	1	0	**Pacific Staghorn Sculpin**	1	0
Pacific Staghorn Sculpin	1	0	**Sevengill Shark**	2	0
Shimofuri Goby	2	0	**Topsmelt**	1	0
Shiner Surfperch	1	0			
Total	11	0	**Total**	13	7

Figure 13 shows the number of fish caught in both trap types, by month. The number of fish caught seems to vary with seasons, but with low numbers caught in total, it is difficult to extrapolate trends. At ELER, the most fish were caught in October in both 2011 and 2012 (13 and 10 fish respectively). At TNC however, the second lowest catch was in October 2011 and 2012 (1 fish for both sampling efforts).

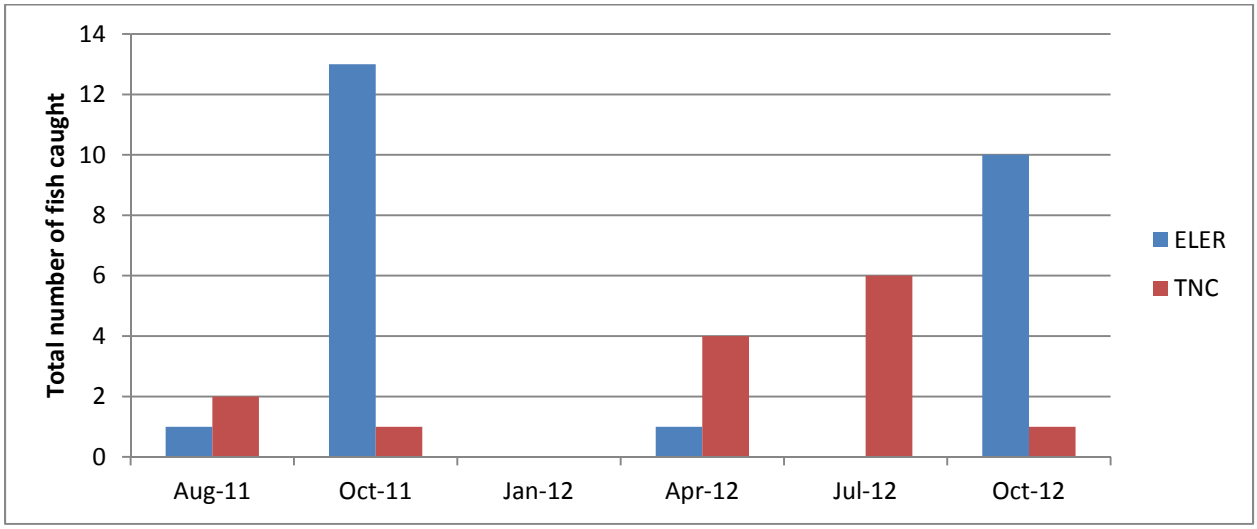


Figure 13 – the number of fish caught in minnow and oval traps at ELER and TNC, during 6 sampling efforts carried out quarterly.

2.4. Water Quality Monitoring Results

2.4.1. Water Column Chlorophyll-a

Samples from the October 2012 post-construction collections at ELER showed higher Chlorophyll-a concentrations than those from TNC (an average of 15.1 ug/L and 7.5 ug/L respectively; Table 5), indicating somewhat higher phytoplankton abundance at ELER. At both sites, the treatment areas had higher Chlorophyll-a concentrations than the control plots. Further samples will be taken quarterly which will establish whether there continue to be any trends between treatments and sites.

Table 5 – Chlorophyll-a measurements of water column samples from treatment and control areas at both ELER and TNC.

Date	Location	Chlorophyll-a (ug/L)	Standard Deviation
12-Oct	ELER Elements	13.4	3.6
12-Oct	ELER Large Control	16.8	1.1
5-Oct	TNC Large Control	5.8	1.1
5-Oct	TNP04 Control	9.5	2.1
5-Oct	TNP03 Oysters / Eelgrass	6.8	0.4
5-Oct	TNP02 Eelgrass	7.8	2.1
5-Oct	TNP01 Oysters	8.0	1.2

References

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Appendix 1: Photographs SFSU field work

Photo 1 – Vegetative eelgrass shoots rigged to bamboo stakes, being transplanted at the TNC site.

Photo 2. Collapsible trap used for invertebrate monitoring

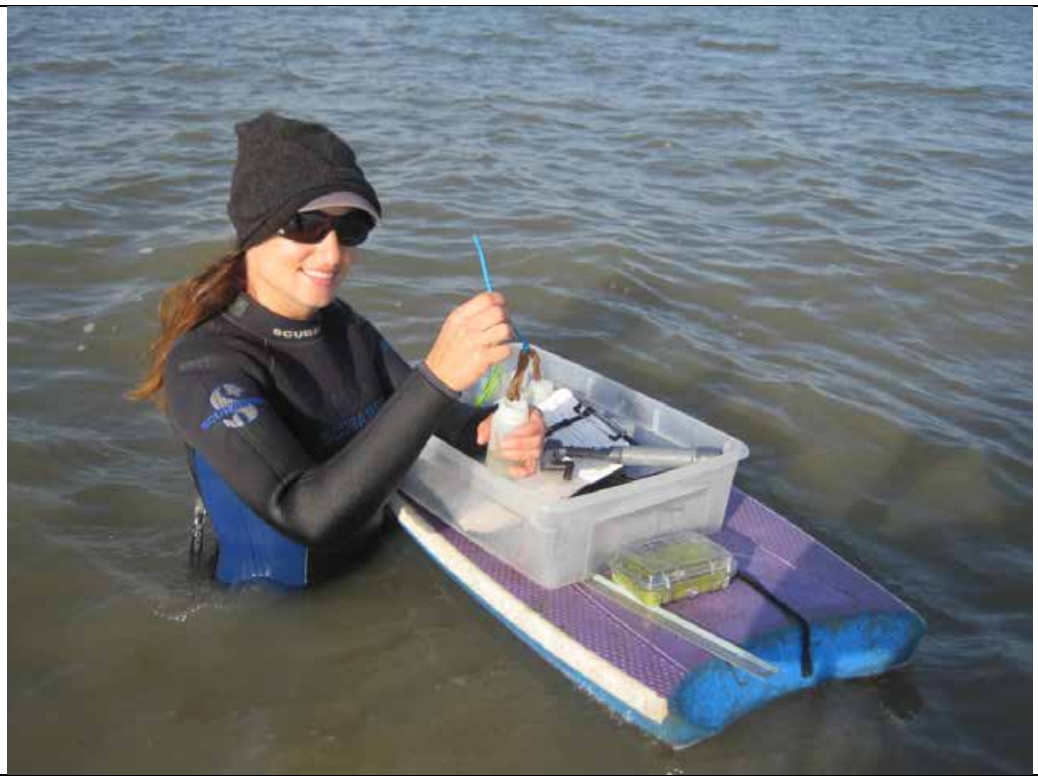


Photo 3. Epifauna by suction sampling at ELER

Photo 4 – Installation of a Vemco acoustic receiver at the TNC site.

IV. UC Davis in collaboration with Isla Arena Consulting, ENVIRON: Native Oyster Methods, Monitoring, Community-Level Parameters, Physical Measurements

The oyster team monitoring plan collects three categories of data: 1) oyster performance, such as live oyster density, recruitment of juveniles, growth, fecundity and survivorship; 2) key community-level parameters that may affect restoration success, including competition with other sessile organisms, predation, and facilitation (both of oysters and by oysters); 3) two physical parameters, temperature and sedimentation, which are likely to impact oysters. To the best of our ability, these components are being measured in a BACI (before-after-impact-control) design to scientifically assess the impacts of the restoration project.

Oyster performance

Aspects of oyster performance are being measured both in the existing, pre-construction population and in the population settling on the oyster structures as well as at control sites adjacent to project sites at The Nature Conservancy (hereafter TNC) in San Rafael and at both the Eden Landing Ecological Reserve north and south sites (hereafter ELN and ELS). Existing populations are being measured quarterly (since May 2012) and populations on the restoration structures will be monitored each year in spring, summer and fall (beginning Nov 2012).

Data analyses are not completed, but qualitatively, the existing oyster populations differ enormously between the TNC and EL sites. At TNC, high numbers of oysters are present along 50 m transects along the intertidal rip-rap (Fig. 1); oysters began brooding larvae in July; and recruits had settled on tiles placed out quarterly (Fig. 2) and collected in July and October. By October, many of the recruits (which would have settled between July and October) were in the 20 mm range, indicating high levels of growth. In contrast, at Eden Landing, few oysters are found on existing hard substrate, recruits to tiles were found in October surveys only and at very low numbers, and these were generally small, with typical size 10 mm or less. We were unable to assess oyster fecundity at EL due to low numbers of adult oysters.

Figure 1. Intertidal oysters along the shoreline at the TNC site. Oyster density and size are measured quarterly along a 50 m transect. Percent cover of other sessile organisms is also measured. Oyster drills are counted in transects as well; to date, no drills have been found at the TNC site.

Figure 2. To assess recruitment to the sites, we used sets of tiles attached to frames at each of the study sites. The tiles were placed at the same tidal height and distance from shore as the restoration project at TNC, ELN and ELS. Tiles were first deployed in May 2012, and are removed and replaced quarterly. The standardized surface area of the tiles provides an ability to compare recruitment rates among the sites and between quarters.

The first monitoring of the restoration structures (Fig. 3) took place Nov. 10-14 2012. The baycrete restoration structures (reef ball, oyster ball stack, oyster block and layer cake) were subsampled *in situ.* At each site, we used 10-cm square quadrats placed at three elevations on each of five replicate structures to count and measure oyster settlers (Fig. 4). More detailed measurements, including the marking of individual oysters to track growth and survivorship, will be made in the spring when minus tides occur during daylight hours.

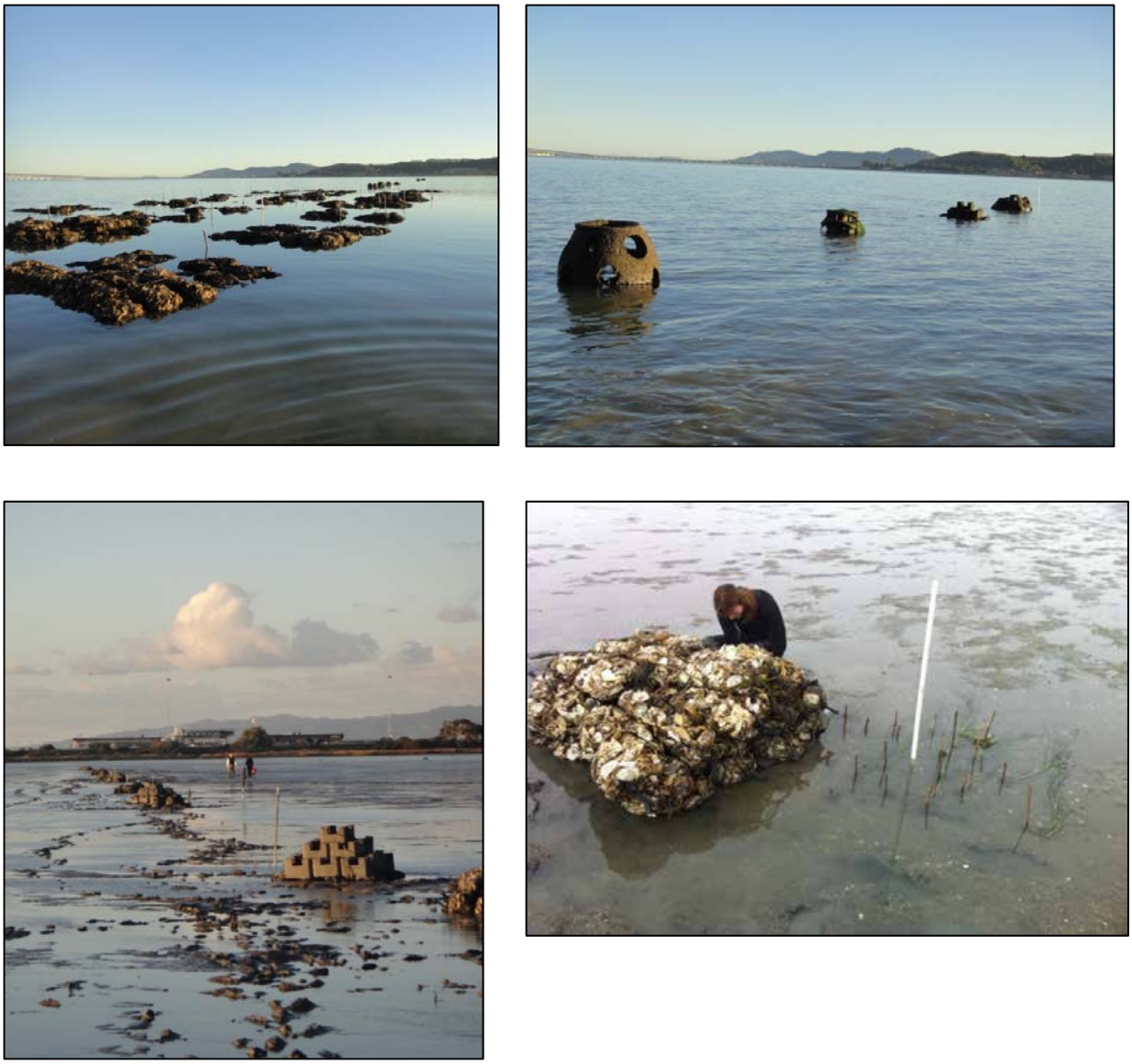
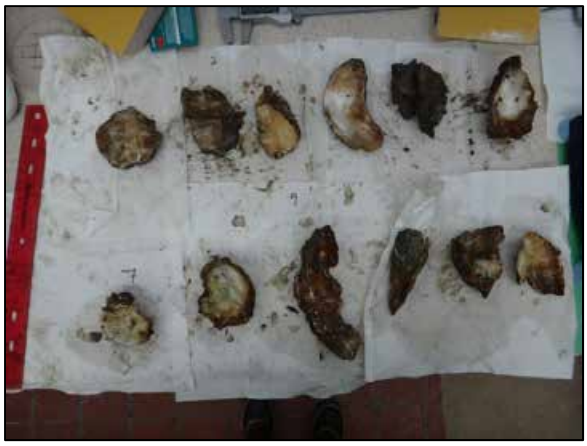


Figure 3: Shell bag mounds and Baycrete elements located at TNC (top), at EL (below).



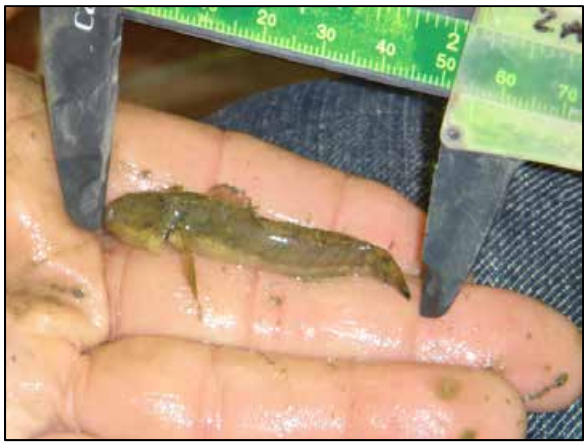


Figure 4. Oyster density, oyster size, and cover of other sessile species were measured in small quadrats placed at various tidal heights across the various oyster substrates (top image). Recruits to oyster shells were assessed and measured from the monitoring shell bags, along with other resident organisms (bottom images).

To assess oyster performance on the elements composed of bags of oyster shell (oyster-bag mounds with eelgrass and without eelgrass), we used small monitoring bags that were placed on the structures within one week after construction. The monitoring bags are ~1/4 the size of the bags used in shell-bag

mounds, and can be easily removed, processed, and replaced without destroying the integrity of the constructed element. In November, these bags were removed, placed on ice, processed in the laboratory at the Romberg Tiburon Center, and returned to the sites within 48 hours. Oysters were counted on 12 shells removed randomly from the monitoring bags, and oysters on six shells were measured and marked for later comparisons (Fig. 5). The 12 shells were measured in three dimensions for later computation of surface area so that recruitment/unit area could be standardized across the treatment types.

Data analyses are not complete, but recruitment to the oyster structures at TNC was far greater than at EL; oysters were also larger, indicating either earlier recruitment or faster growth at TNC. Data from the oyster bags are shown in Figs. 6 and 7, data from elements in Fig. 8. Oysters were plentiful enough at TNC and large enough that they could be easily distinguished from the bagged oyster shell in the field (Fig 9).

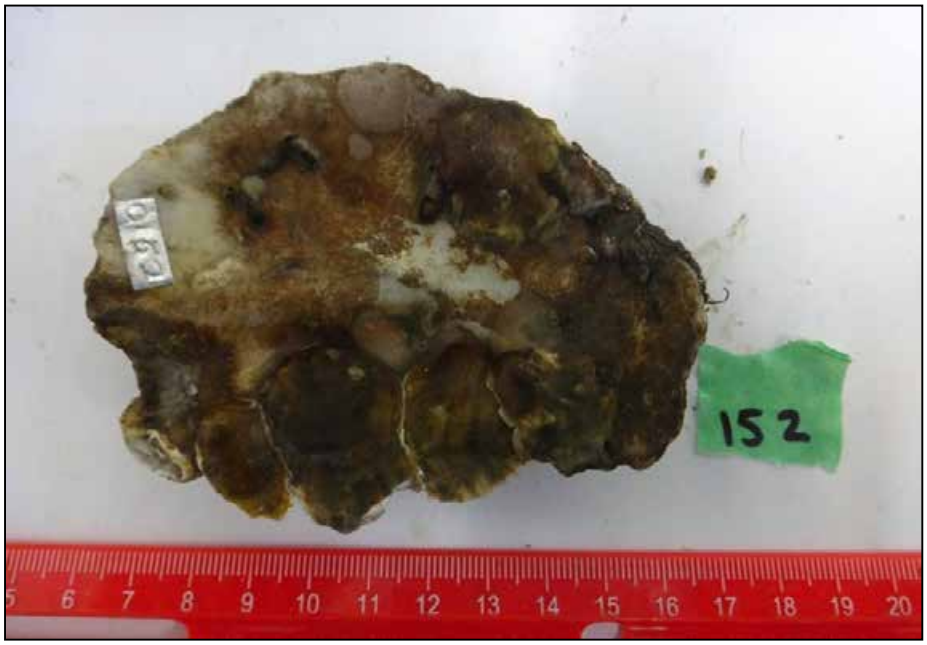


Figure 5. A Pacific oyster shell removed from a monitoring bag, with several smaller native oyster settlers on the edge at the bottom of the photograph. Six shells per bag were tagged with a numbered aluminum tag. All live oysters were measured and photographed so that they can be tracked over time for growth and survivorship measurements.

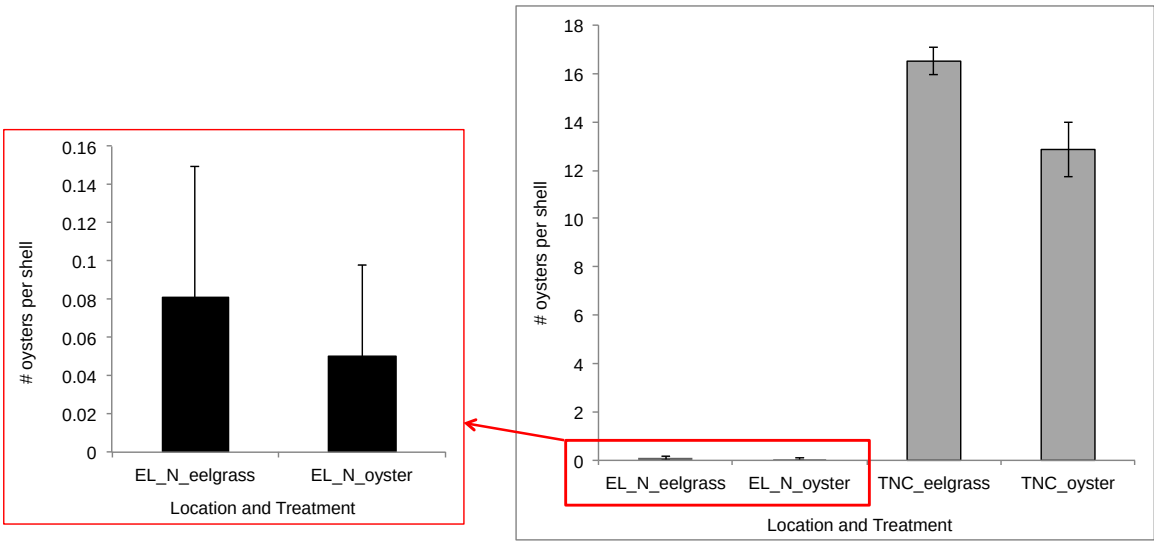


Figure 6. Mean number of oysters per shell from the monitoring bags at the TNC and EL sites, from 1) oyster-bag only (denoted as site_oyster) and 2) oyster-bag and eelgrass combination (site_eelgrass) plots or elements. Recruitment was low at Eden Landing relative to TNC. Error bars are standard error. There was a trend toward higher settlement in the mixed oyster/eelgrass treatments.

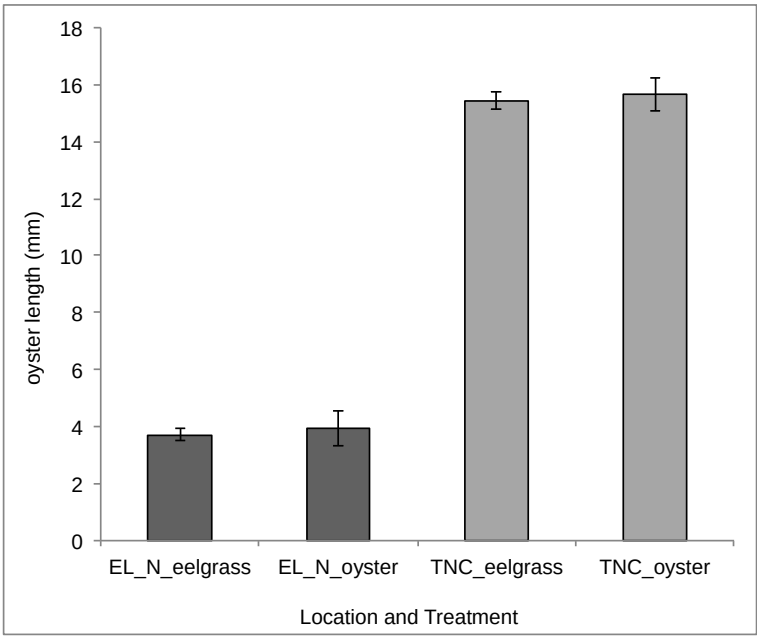


Figure 7. Mean size of oysters per shell from the monitoring bags at the TNC and EL sites, from 1) oyster-bag only (denoted as site_oyster) and 2) oyster-bag and eelgrass combination (site_eelgrass) plots or elements. Oysters were smaller on average at Eden Landing relative to TNC. Error bars are standard error.

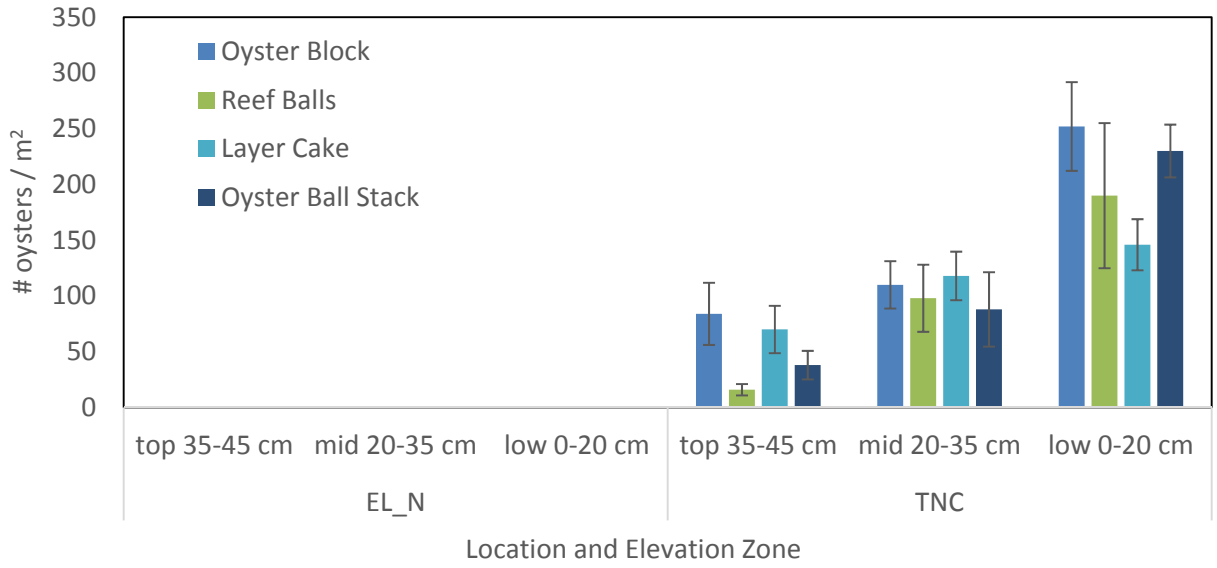


Figure 8. Mean number of oysters recruiting to baycrete elements located at the TNC and EL sites, as of November 2012. No recruitment was seen at Eden Landing. Recruitment at TNC was favored at lower elevations and overall greatest for Oyster Blocks Error bars are standard error.

Figure 9. Live oysters (brown) growing on the bags of Pacific oyster shell at the TNC site.

Community-level parameters

Percent cover of other sessile organisms that may compete with oysters for space, and the presence of oyster drills have been assessed quarterly in 50-m transects in the oyster zone along the shoreline at each site. Data analysis is not complete, but bare space is higher at EL than at TNC, and oyster drills, along with drill eggs and dead oysters with drill holes, have been found only at EL.

Cover of sessile organisms and presence of small mobile organisms were assessed during the November monitoring of the restoration structures, using the same quadrats used to count and measure oysters. Generally, structures at TNC had greater amounts of cover than those at EL, and had a more pronounced vertical zonation in terms of species assemblages in initial assessments; barnacles were most abundant in the top 1/3 of each structure, diatoms in the middle third, and macroalgae in the lowest). Percent cover of other sessile organisms was estimated for each of the shells examined from the monitoring bags.

Mobile organisms were also removed from the monitoring bags, identified and enumerated; we noted the presence of mobile organisms on the oyster structures in the field. Three goby species, the chameleon goby, black-eyed goby and bay goby, were found in the bags at EL, which also contained many individuals of *Hemigrapsus* crabs, including numerous gravid females. There were many fewer mobile species in the TNC bags, and no fish. (Table 1)

Physical measurements

Sediment accumulation at each site is being measured using three PVC poles pounded into the substrate along the shore at each location. The poles are measured monthly and the average change in pole height above the substrate used to estimate sediment accumulation or erosion.

Accumulation of sediment on the restoration structures is measured three times a year, during monitoring of oysters. Accumulation of sediment on the concrete structures is measured visually by placing a measuring tool marked in 2 mm increments in a corner of the quadrat used for counting oysters and determining community composition. Sediment accumulation in the monitoring bags was measured by opening the bags, rinsing the shells with a known volume of water, and measuring the volumetric difference between the sediment-water slurry and the initial amount of rinse water.

Temperature at the level of the oyster recruitment tiles and structures is being measured using Hobo temperature loggers, set to record temperature every hour. These are downloaded quarterly.

These data have not yet been analyzed.

Taxa	Phylum	Shell Bags		Elements	
barnacles	Arthropoda	EL	TNC	EL	TNC
isopod	Arthropoda	EL			
bryozoan (encrusting)	Bryozoa	EL	TNC	EL	TNC
bryozoan (upright)	Bryozoa	EL	TNC	EL	TNC
Ciona sp.	Chordata		TNC		TNC
Mogula sp.	Chordata	EL	TNC		TNC
solitary tunicate	Chordata		TNC		TNC
tunicate	Chordata		TNC		TNC
anemone (brown)	Cnidaria	EL		EL	
anemone (pink)	Cnidaria	EL			
hydroids	Cnidaria	EL	TNC	EL	TNC
Atlantic oyster drill eggs	Gastropod	EL			
Mytilus	Mollusca		TNC		
native oyster	Mollusca	EL	TNC	EL	TNC
slipper snail	Mollusca		TNC		
pink polychaete	Polychaeta	EL			
scale worm	Polychaeta	EL			
tube worm	Polychaeta		TNC		TNC
sponge	Porifera		TNC		TNC
algae (red macro)	Rhodophyta	EL			TNC
algae (green macro)	Chlorophyta	EL		EL	TNC
mud crab (*Hemigrapsus oregonensis*)	Arthropoda	EL	TNC	Not Assessed	
bay shrimp (*Crangon franciscorum*)	Arthropoda	EL			
chameleon goby (*Tridentiger trigonocephalus*)	Chordata	EL			
blackeyed goby (*Rhinogobiops nicholsii*)	Chordata	EL			
bay goby (*Lepidogobius lepidus*)	Chordata	EL			

Table 1: Species present in shell bags or on baycrete elements during November 2012 monitoring event. Presence is denoted by site when EL (Eden Landing) or TNC (The Nature Conservancy) is filled in the table.

For more information, please contact: Dr. Chela Zabin zabinc@si.edu

V. USGS Western Ecological Research Center, San Francisco Bay Estuary Field Station: Avian and Benthic Monitoring Report

Background and Methods - The USGS Western Ecological Research Center, San Francisco Estuary Field Station has been conducting pre and post-project monitoring of waterbird and benthic invertebrate densities at eelgrass and oyster restoration sites for the Living Shorelines: Near-shore Linkages project. At each of the 3 intertidal study sites, Eden Landing North (EN), Eden Landing South (ES), and the Nature Conservancy (TNC), we record avian density and behavior in paired treatment and control survey areas. Survey areas are subdivided into zones encompassing eelgrass and oyster treatment plots (zone B) as well as 150-m zones immediately inshore (zone A) and offshore (zone C) of the plots (Fig.1). Our benthic sampling is designed to measure prey availability for foraging shorebirds and waterfowl across these survey areas, including in the eelgrass and oyster treatment plots themselves.

Avian Monitoring - At each site, we conduct low tide (shorebird use) and high tide (waterfowl and piscivore use) surveys twice a month to monitor waterbird density and behavior. During November through April 2011 we measured pre-project bird use. In August 2012, we began post-project monitoring that will continue through April 2013, and resume in August 2013 until project completion in December 2013. During each survey, we use spotting scopes to count all birds in each treatment zone (see Fig. 1). After recording total numbers, we use scan sampling to randomly choose 20% of all individuals of each species and record instantaneous behaviors. In addition, we conduct focal observations on foraging individuals within each of 3 foraging guilds: benthivores, piscivores, herbivores. Foraging birds are chosen at random and observed for 3 minutes (open water birds) or 1 minute (shorebirds) to determine dive:pause durations or peck rates, measures of foraging intensity.

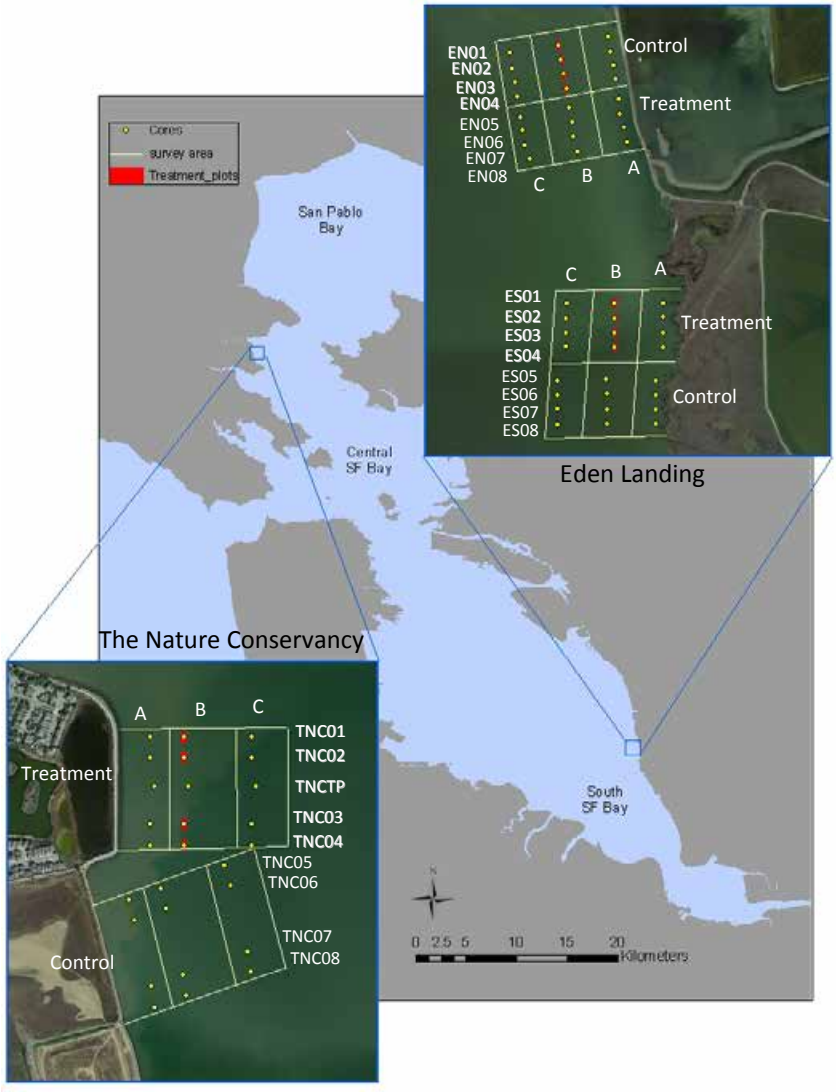


Figure 1. Living Shorelines study sites including avian survey areas, planned eelgrass and oyster treatment plots, and sampling locations for benthic cores. Benthic sampling transects are labeled.

Benthic Invertebrate Monitoring – We sampled benthic invertebrates during the pre-project period in December 2011-January 2012 and in May 2012. In September 2012 we took the first set of post-project samples. At treatment and control areas within each study site we took benthic cores (10-cm deep, 10-cm diameter) along four 500-m transects that ran perpendicular to shore. In the TNC treatment area we took cores from an additional transect (TNCTP) through a previously established eelgrass test site (Fig. 1). Along each transect, 3 replicate samples were taken in each zone. In treatment areas, transects bisected planned treatment plots, and we collected cores in each of these plots. Cores were labeled to indicate sampling transect, zone and replicate (e.g. TNC01-B-1). We refrigerated samples and processed each within 72 hrs of collection by rinsing them through 0.5-mm sieves and preserving all retained invertebrates in 70% ethanol with rose bengal. Invertebrates were sorted, identified to lowest possible taxonomic class, enumerated, and measured. Ash-free dry biomass for bivalves was calculated based on length to biomass transformations taken from the literature or previously determined at USGS. Invertebrate numbers and dry biomass were summarized, and spatial distribution maps were created in ArcGIS by interpolating invertebrate biomass via inverse distance weighting. Preliminary results from December-January 2012 samples have been summarized in an earlier update report (April 2012). We are currently processing samples from May and September 2012.

Highlights of Preliminary Results –

Avian-Pre-project monitoring revealed the following patterns in bird densities:

- High shorebird densities with a similar pattern of use between treatments and controls at EN and ES (Hayward North and South) sites
- Low shorebird densities at TNC (San Rafael) with uneven use of treatment and control sites
- Equal use of in-shore (A), mid (B) and off-shore (C) zones at EN and ES, but only in-shore zone A was accessible to shorebirds at San Rafael due to pronounced sloping of the mudflat
- Diving duck densities were highest in mid and off-shore (B and C) zones at all sites
- Dabbling ducks used in-shore and mid (A and B) zones at all sites and densities were highest at EN and ES

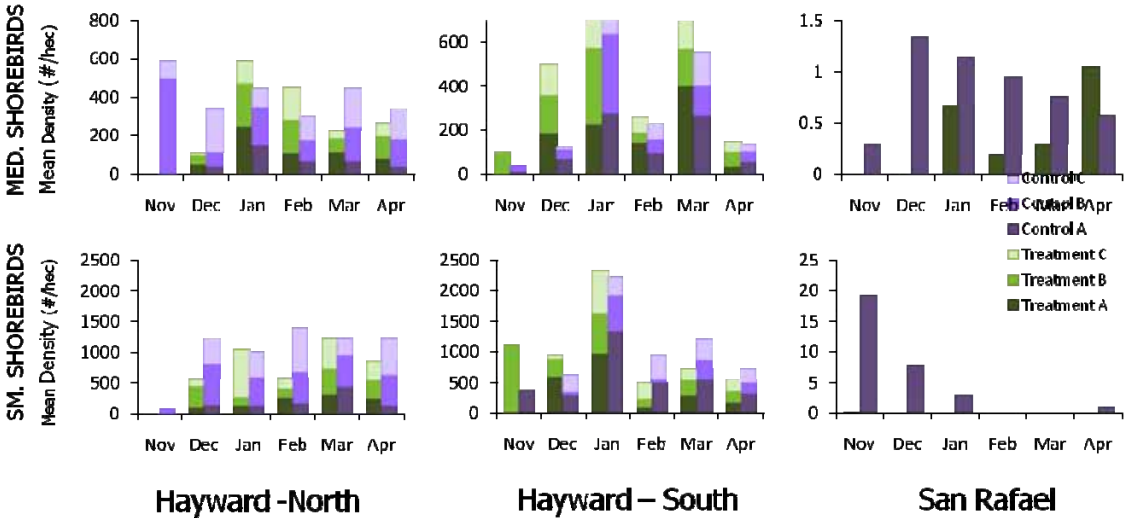


Figure 2. Mean densities of medium and small shorebird species at Living Shoreline treatment and control sites in EN and ES (Hayward North and South) and TNC (San Rafael).

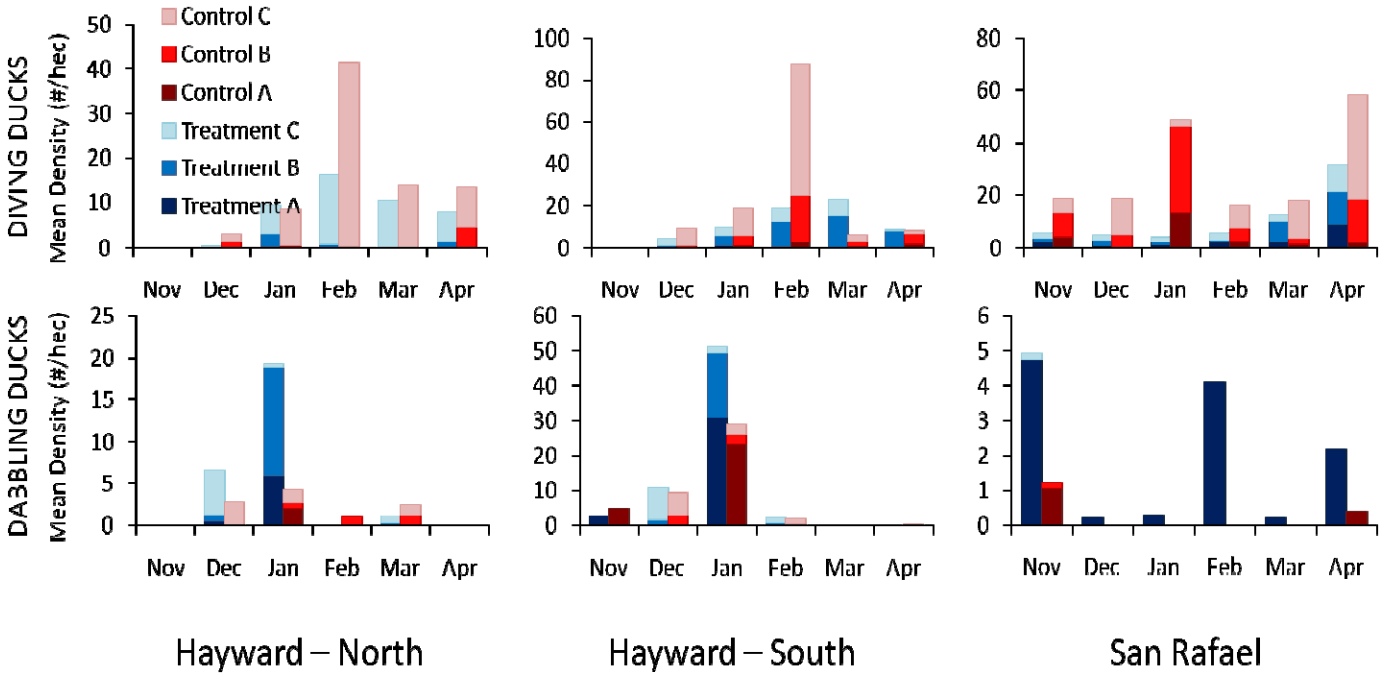


Figure 3. Mean densities of diving and dabbling duck species at Living Shoreline treatment and control sites in EN and ES (Hayward) and TNC (San Rafael)

Benthic Invertebrates –

- Invertebrate biomass at EN (Hayward North) treatment and control sites (Fig. 4) is driven by bivalves
- Interpolated maps show highest bivalve biomass at EN is concentrated in-shore in zone A (Fig. 4)
- Invertebrate biomass at TNC(San Rafael) treatment and control sites is driven by polychaetes (Fig. 5)
- Interpolated maps show highest invertebrate biomass is concentrated in zones B and C (Fig. 5)

- At EN, mean invertebrate densities were lower in control compared to treatment areas in pre- and post- restoration samples, and post-restoration treatment cores had the highest invertebrate densities (Fig. 6).

- The amethyst gem clam, *Gemma gemma* was the most abundant species at EN during all sampling periods (Fig. 6).

- At TNC, mean invertebrate densities were similar between control and treatment areas. Pre-restoration mean invertebrate densities in May 2012 were similar to post-restoration mean densities in September 2012 (Fig. 7).

- The amphipod *Ampelisca abidita* was the most abundant species at TNC (Fig. 7) during all sampling periods.

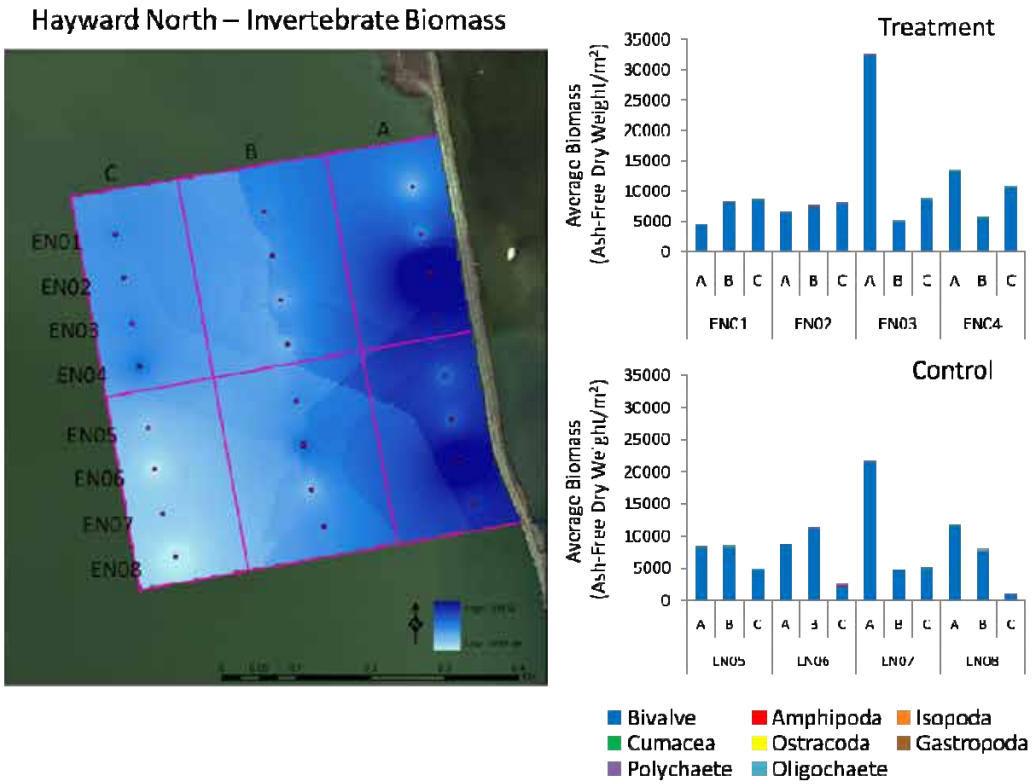


Figure 4. Pre-project (Jan 2012) invertebrate biomass distribution map and average ash-free dry mass in EN (Hayward North) treatment and control sites

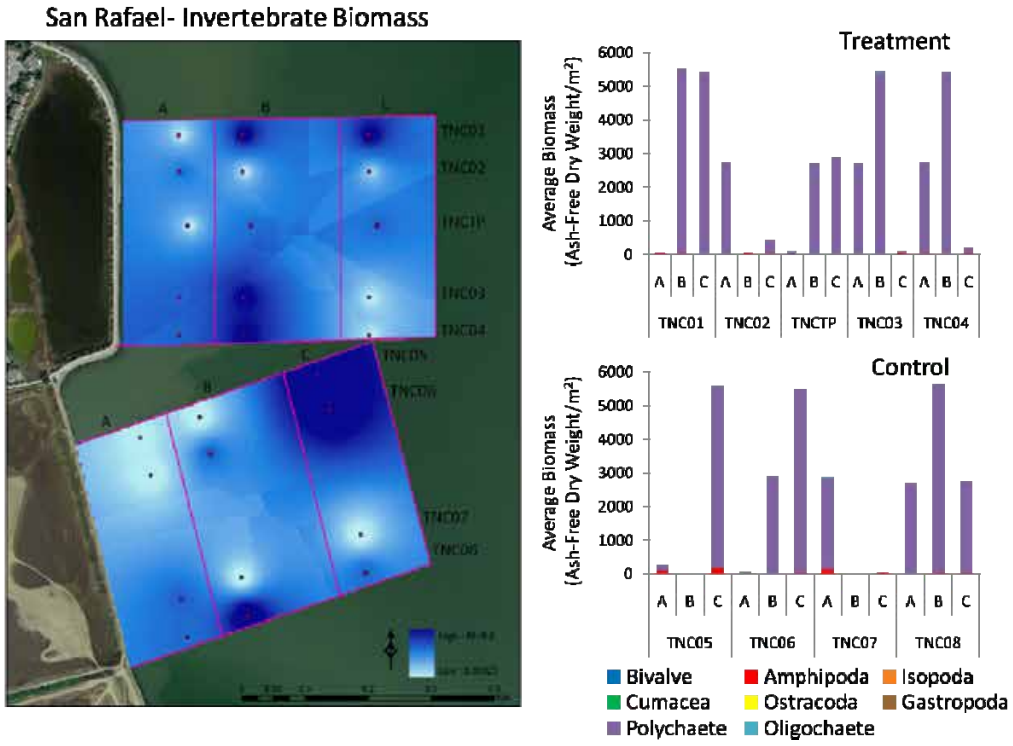


Figure 5. Pre-project (Jan 2012) invertebrate biomass distribution map and average ash-free dry mass in TNC(San Rafael) treatment and control sites

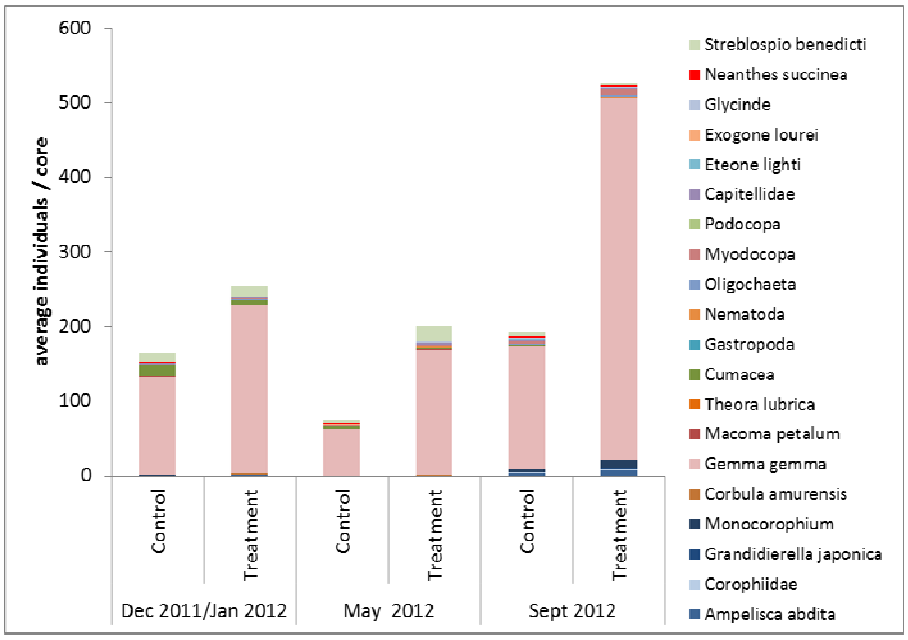


Figure 6. Mean densities of invertebrates inpre- (Dec 2011/Jan 2012 and May 2012) and post-restoration (Sept 2012) cores from control and treatment areas (Zone B only) at Hayward (Eden Landing North) .

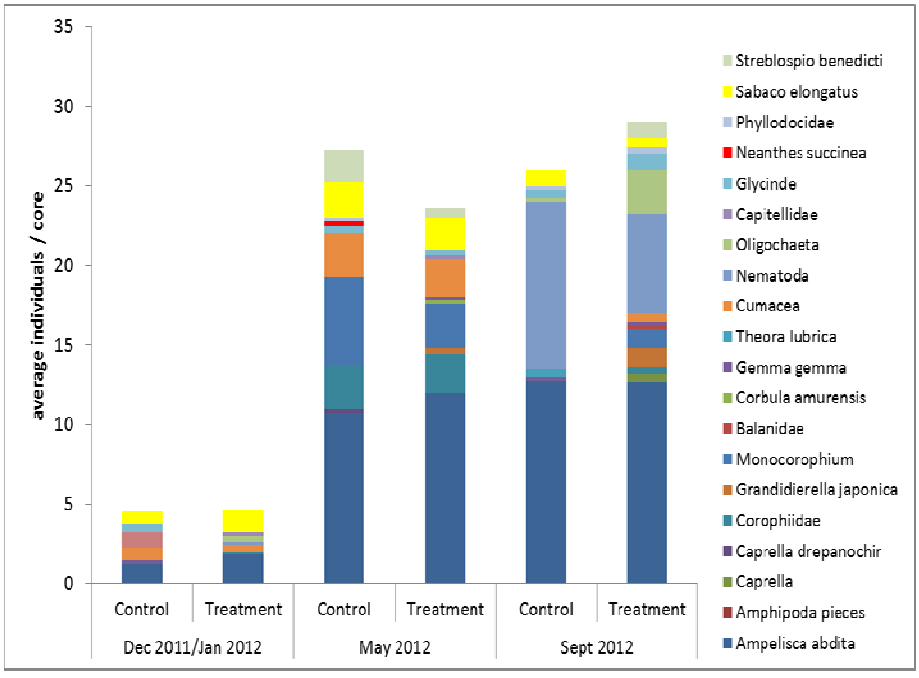


Figure 7. Mean densities of invertebrates in pre- (Dec 2011/Jan 2012 and May 2012) and post-restoration (Sept 2012) benthic cores from control and treatment areas (Zone B only) at San Rafael (TNC) .

Upcoming Activities (January-June 2013) –

- Continue high tide and low tide avian monitoring through April 2013
- Complete data processing and summaries for benthic invertebrate samples taken in May and September 2012
- Conduct spring benthic invertebrate sampling in May 2013

For more information, please contact: Dr. Susan De La Cruz sdelacruz@usgs.gov

VI. ESA PWA: Physical Processes Monitoring Report

Introduction

Prior to the installation of the test plots at TNC and ELER and the treatment plots at TNC in summer 2012, ESA PWA conducted pre-project data collection as follows:

1. Bathymetric survey
2. Sediment composition

After the plots were installed, ESA PWA commenced monitoring on:

1. Elevation of individual elements
2. Sediment accretion

In addition, ESA PWA is preparing to begin additional monitoring of:

1. Physical processes (waves and currents)
2. Ambient water properties

More details about these six topics are provided below.

Pre-project data collection

Bathymetric survey

ESA PWA subcontracted Environmental Data Solutions to conduct a multi-beam bathymetric survey prior to the installation of the Living Shorelines elements (Figure 1). The survey, completed in May 2012 at the two site locations, utilized Class 1 methods and accuracies as outlined in the Army Corps of Engineers' January 2002 Hydrographic Surveying Manual (EM 1110-2-1003). Bathymetric data were collected using an *Odom CVM* survey grade fathometer with a 3-degree, 200-kHz transducer. The transducer was mounted in a fathometer well (housing a mineral oil bath) that is located mid-ship through the hull in the keel. The survey accuracy was high enough resolution to resolve changes to the bed over time, although at this time there are no plans for a post-experiment survey. Bed changes will be measured during the experiment with other methods but will use the results of the bathymetric survey to establish absolute rather than relative bed elevation changes.

Sediment composition

The bed sediment composition may change from the presence of the reefs and eelgrass meadows. To establish a baseline of bed sediment grain size, sediment cores were collected on July 6, 2012 at the TNC site (Figure 2). Five cores were collected using a split spoon sampler pushed into the bed from a boat (Figure 3). On average, the cores were 30 cm long. Because the most grain size change is expected in the upper layers of the bed, the cores were split into the top 10 cm and the remaining bottom portion for grain size analysis at a later date (Figure 4). The cores are stored in a freezer at the ESA PWA office in San Francisco until analysis can be completed. The locations will be re-occupied and new cores collected toward the scheduled end of the project to compare the evolution of the bed sediment grain size distribution.

Established Monitoring

Sediment plate measurement

As part of the monitoring plan for sediment accretion, ESA PWA is using 14 sediment plates placed immediately after the placement of the treatment plots at the TNC site (Figure 2). Sediment plates are flat disks placed on the substrate and held in place laterally by a threaded pole through the center of the plate (Figure 5). The plate is held vertically by galvanized brackets above and below the disk. Half of the plate surface was sanded to enhance sediment trapping of finer particles on a rougher surface. The sediment accretion is measured monthly by taking 3 – 4 measurements of the observable sediment thickness on the plate surface and averaging. Biofouling and bed scouring are challenges for using sediment plates and ESA PWA will document if these occur.

Date of installation: August 31, 2012

Dates of monitoring (to date): quantified measurement - October 15; visual observations (no measurements) – November 12, December 10

Initial findings: Most of the sediment plates are showing negligible deposition on the surfaces throughout the site. The location of the sediment plate (bayward, landward or inside the treatment plot) does not seem to be affecting the sediment deposition rates (Table 1). The bed around some of the 14 plates exhibits scouring.

Table 1 – TNC sediment plate observations, October 2012

Name	Description of location	10/15/2012	
		Sediment thickness	notes
TN North	northern	negligible	biofouling, scour
TNP01 East	oyster inside	negligible	biofouling, scour
TNP01 West	oyster center	negligible	biofouling
TNP01 Mid	oyster outside	negligible	biofouling
TNP02 West	eelgrass inside	negligible	biofouling
TNP02 Mid	eelgrass center	negligible	biofouling
TNP02 East	eelgrass outside	negligible	

TNP03 West	combo inside	negligible	biofouling
TNP03 Mid	combo center	0.5 cm	animal (unknown)
TNP03 East	combo outside	negligible	
TNP04 West	control inside	negligible	
TNP04 Mid	control center	negligible	biofouling
TNP04 East	control outside	negligible	
TN South	southern	negligible	biofouling

Unit subsidence

Prior projects that installed reef elements observed significant subsidence into the bed near the TNC site due to the muddy substrate; some settling of the individual Living Shoreline Project units is expected as a result. To quantify this, ESA PWA is measuring the top elevation of the elements at monthly intervals and developing a trend model based on the rates of change (Figure 6). An initial elevation of every element in the test plots and at least one element per shell bag unit in the larger plots was collected in September and October 2012 at the TNC and the ELER sites using GPS and total station surveying methods. The same element within a shell bag unit will be surveyed each time and was tagged to maintain consistency. We anticipate continuing monthly surveys until the subsidence appears to be leveling off and then will switch to bi-monthly or quarterly frequency.

Dates of monitoring (to date):

TNC – 2012: October 15, November 12, December 10. 2013: January 23

ELER – 2012: September 29, November 13, December 11. 2013: January 22

Initial findings:

The average rate of subsidence at the TNC site from October 2012 to January 2013 is -6.46 ± 1.61 cm for the test plot elements and -5.02 ± 1.25 cm for the treatment plot elements. Table 2 shows the rates per month for the element categories and Figure 7 shows the average elevation of the five elements in each category. The shell bag mounds are shorter than the other four types of elements by approximately 25 cm. To date, the element categories are subsiding at fairly consistent rates with only the shell bag mounds showing a decreasing rate of subsidence.

Table 2 – TNC site element subsidence per month				
	Mean	Standard Dev	Min. Settling	Max. Settling
	(cm/month)	(cm/month)	(cm)	(cm)
layer cake	-1.97	0.28	-5.52	-7.96
oyster ball	-1.73	0.62	-4.36	-10.49
reef ball	-0.90	0.46	-2.65	-6.89
oyster block stack	-1.86	1.12	-0.03	-11.37
shell bags	-1.25	0.69	0.98	-11.34

The average rate of subsidence at the ELER site for the test elements from September 2012 to January 2013 is -5.15 ± 1.29 cm MLLW. The shell bags that were placed with the eelgrass plantings were combined with the shell bag only treatments for analysis under the assumption that the bags would settle at similar rates. Table 3 shows the rates per month for the element categories and Figure 8 shows the average elevation of the five elements in each category. The elements appear to have subsided more rapidly from September to December than between December and January. However, additional surveys are necessary to confirm the decrease in subsidence rate.

Table 3 – ELER site element subsidence per month				
	Mean	Standard Dev	Min. Settling	Max. Settling
	(cm/month)	(cm/month)	(cm)	(cm)
oyster ball stack	-1.40	1.14	-0.82	-10.27
oyster block	-1.63	0.77	-1.49	-8.99
reef ball	-0.64	0.60	0.06	-5.94
shell bags	-1.48	0.80	0.67	-10.03

Planned Monitoring

Wave monitoring

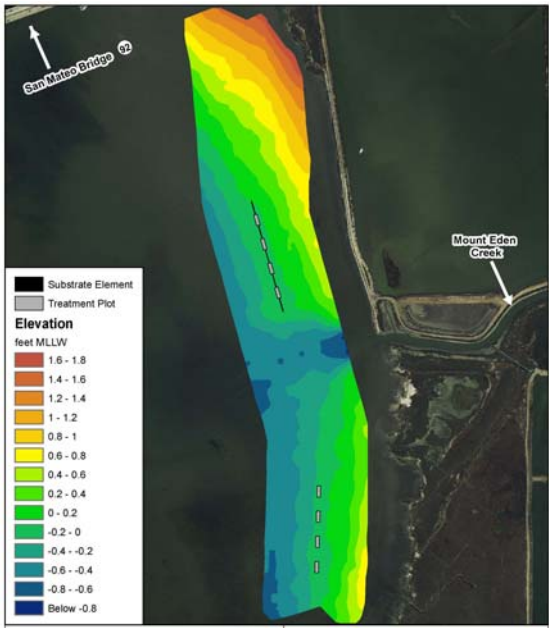
Several parameters are necessary for determining if the reefs are affecting the physical processes. These include wave heights, wave period, wave direction, current speeds, and current directions on both sides of the reef structures. In early 2013, ESA PWA will deploy three bottom-mounted Acoustic Doppler Current Profilers (ADCPs) at the TNC site (Figure 9). One ADCP will be on the bayside of the reefs and be 'stationary' for the duration of its deployment to measure incident waves to the site. The other two ADCPs will be 'semi-mobile' instruments to be moved around the study site as needed to measure transmitted waves. The semi-mobile instruments will be deployed inshore of the reefs over at least 2-week long intervals to measure hydrodynamics through the spring-neap tidal cycle. The first placements will be between the shoreline and 1) the shell bag mound treatment and 2) the control site. Subsequent placements may occur between treatments to determine alongshore currents and acceleration between the treatment blocks. Once all first-year deployments have been completed, the ADCPs will be removed from the site. Additional deployments can occur as the eelgrass plantings mature and begin to impact the hydrodynamics in the second year of the project. ESA PWA will consult with experts at the US Geological Survey (Jessica Lacy) with extensive field experience of deploying instruments around seagrasses in Puget Sound and San Francisco Bay prior to deployment at eelgrass sites.

Ambient water properties

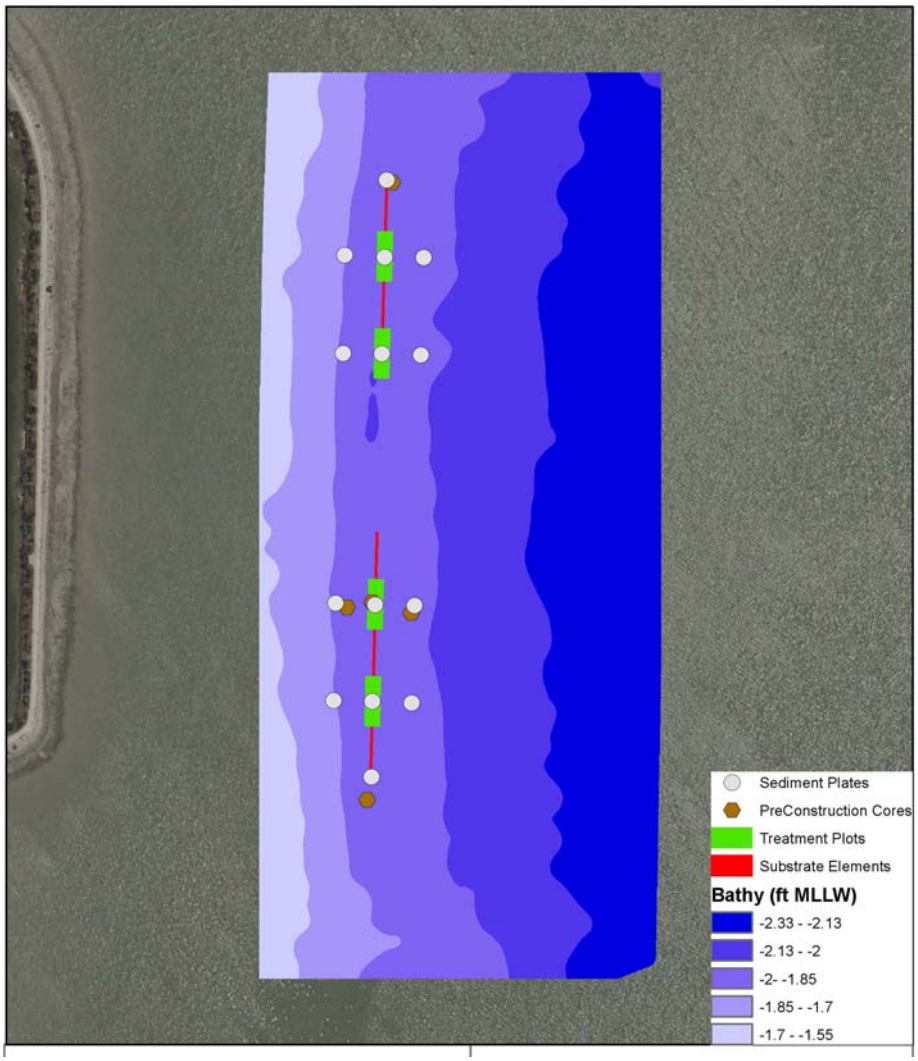
To collect ambient water properties (temperature, salinity, dissolved oxygen (DO), pH, and turbidity), ESA PWA will deploy a single instrument on the bayside of the reef structures at the TNC site in spring 2013 (Figure 10). This instrument will be regularly serviced to maintain low levels of bio-fouling by all LSP team members to maximize cost efficiency. ESA PWA will be responsible for data downloading and transmission of data to the full LSP team. ESA PWA anticipates working with other LSP team members to correlate ambient water properties and water properties inside the three types of treatment plots.

Figures

1. Bathymetric survey maps of San Rafael site and Eden Landing Ecological Reserve site
2. Coring and sediment plate locations map at San Rafael site
3. Collecting core at San Rafael site using a push-corer
4. Example core at San Rafael site prior to splitting into top 10 cm and bottom remainder
5. Sediment plate at San Rafael site
6. Collecting element elevations using total station
7. San Rafael: Average element elevations
8. Hayward Shoreline: Average element elevations
9. Planned ADCP deployment locations at San Rafael site
10. Planned ambient water properties instrument deployment location at San Rafael site



1. Bathymetric survey maps of San Rafael site and Eden Landing Ecological Reserve site. Data was collected by EDS for ESA PWA in May 2012.



1. Coring and sediment plate locations map at San Rafael site

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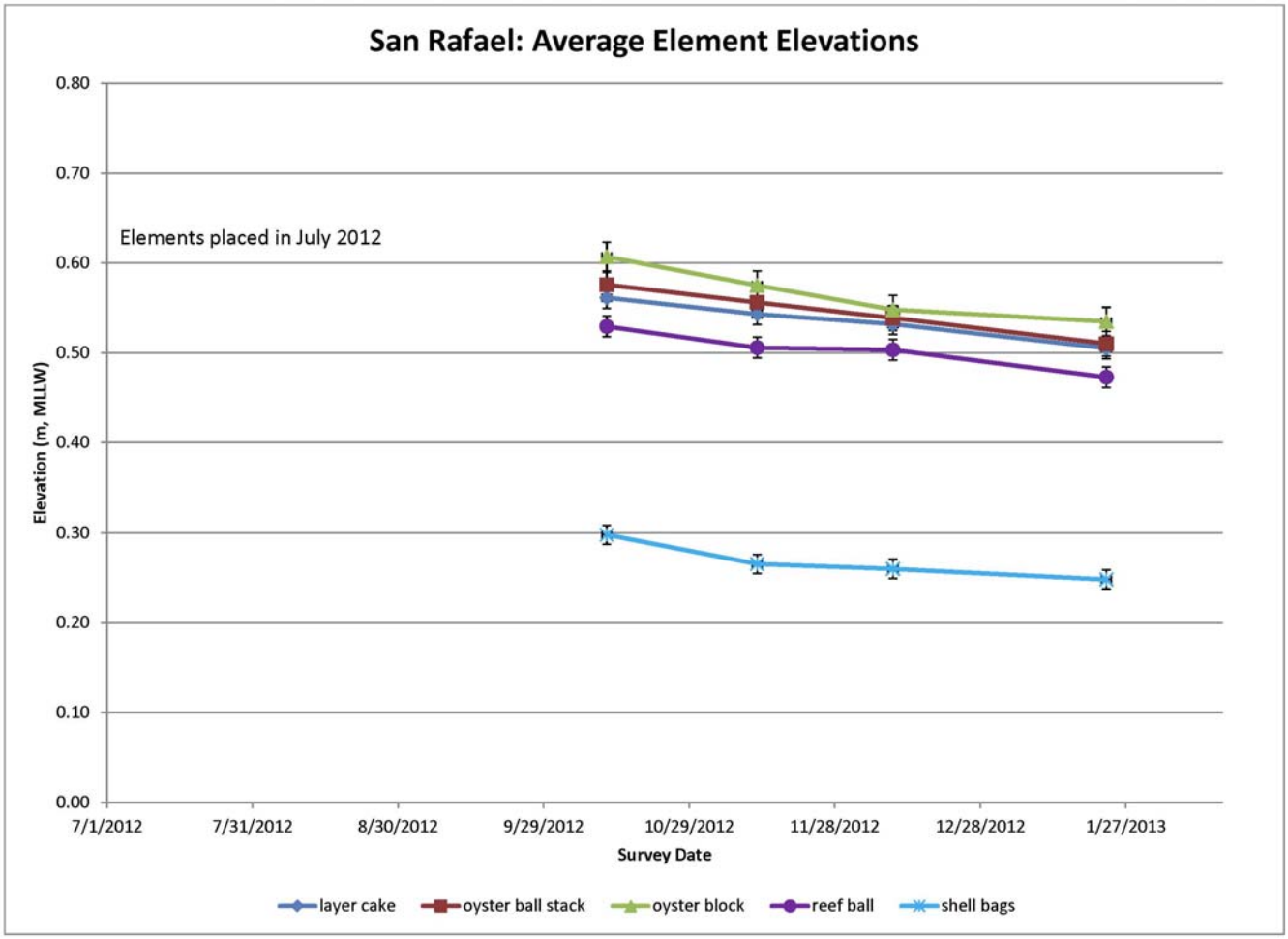
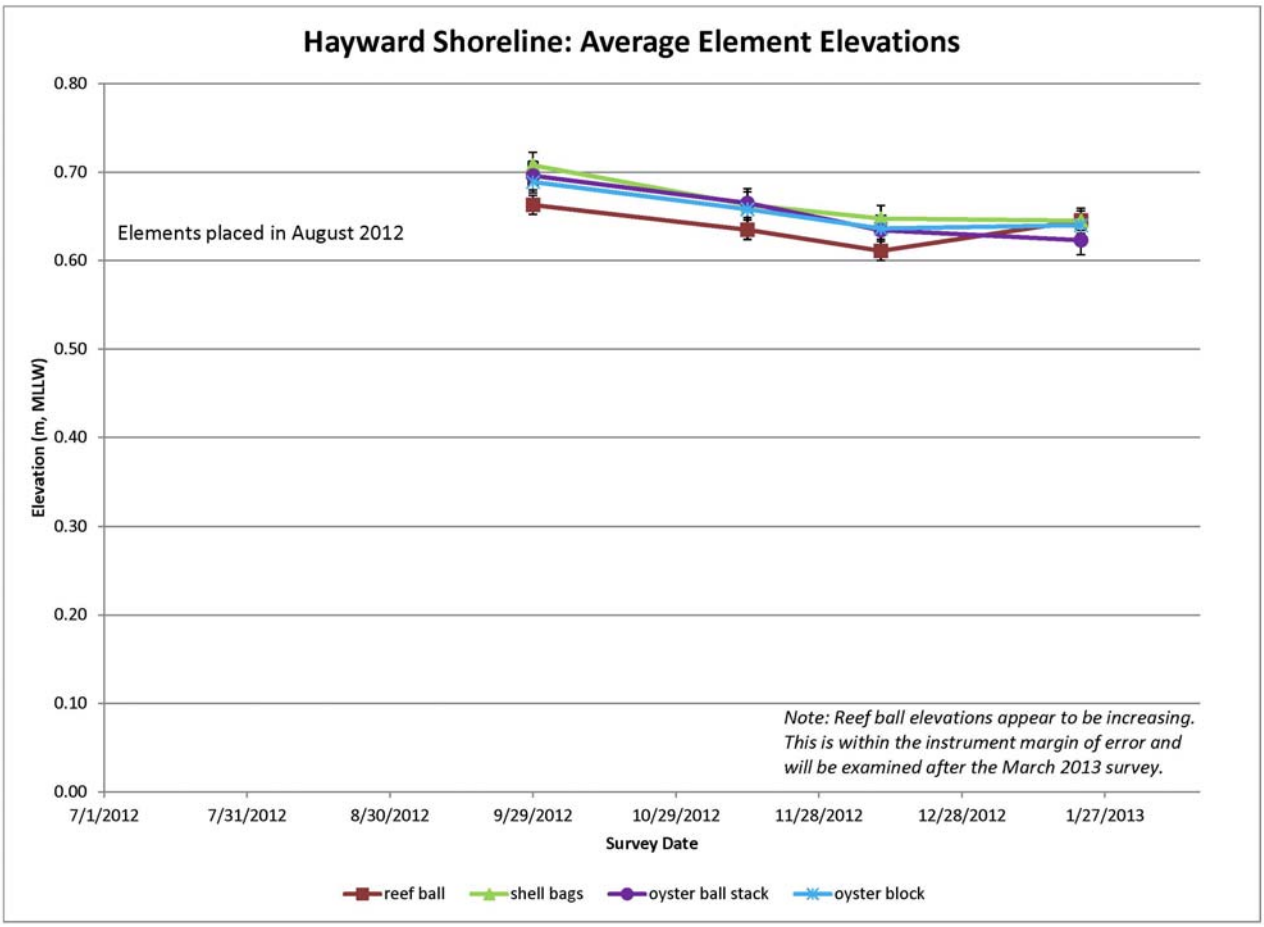
3. Example core at San Rafael site prior to splitting into top 10 cm and bottom remainder

4. Sediment plate at San Rafael site

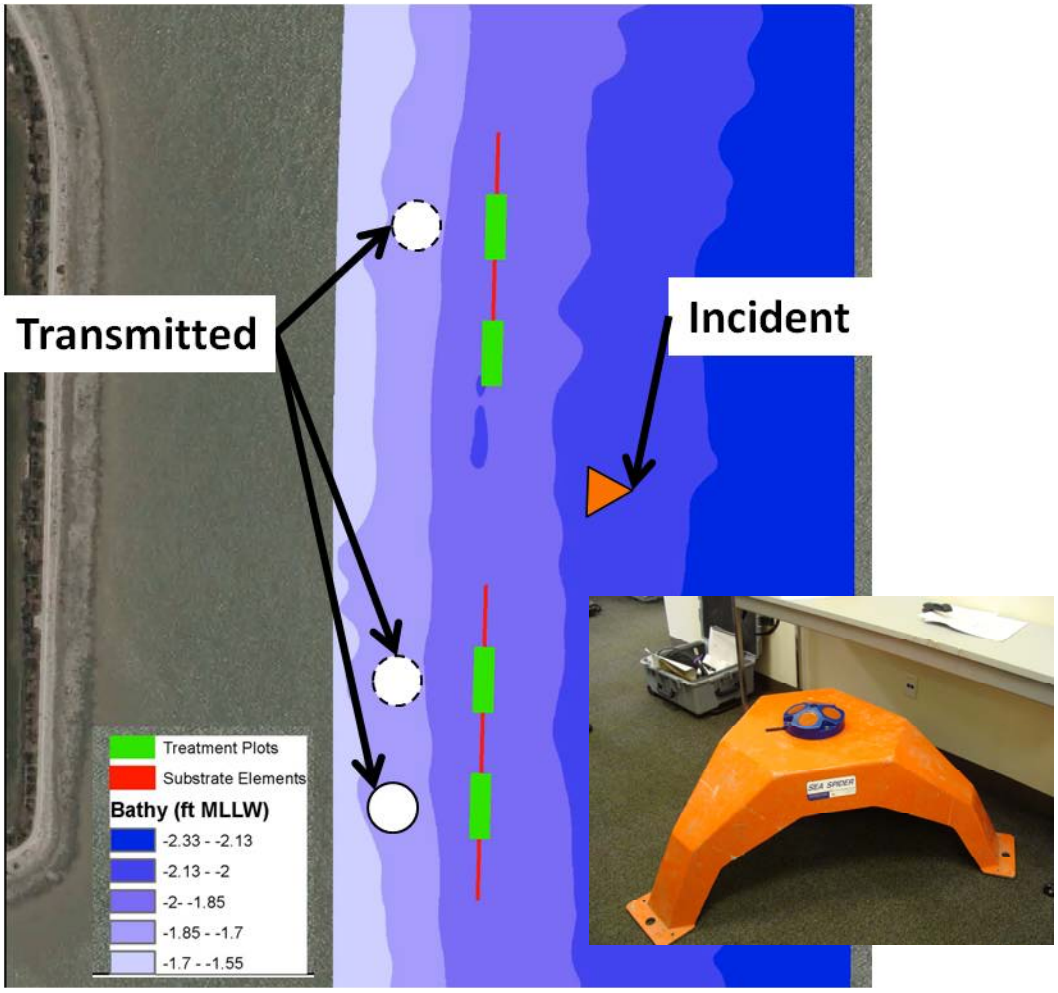
5. Collecting element elevations at Eden Landing Ecological Reserve site



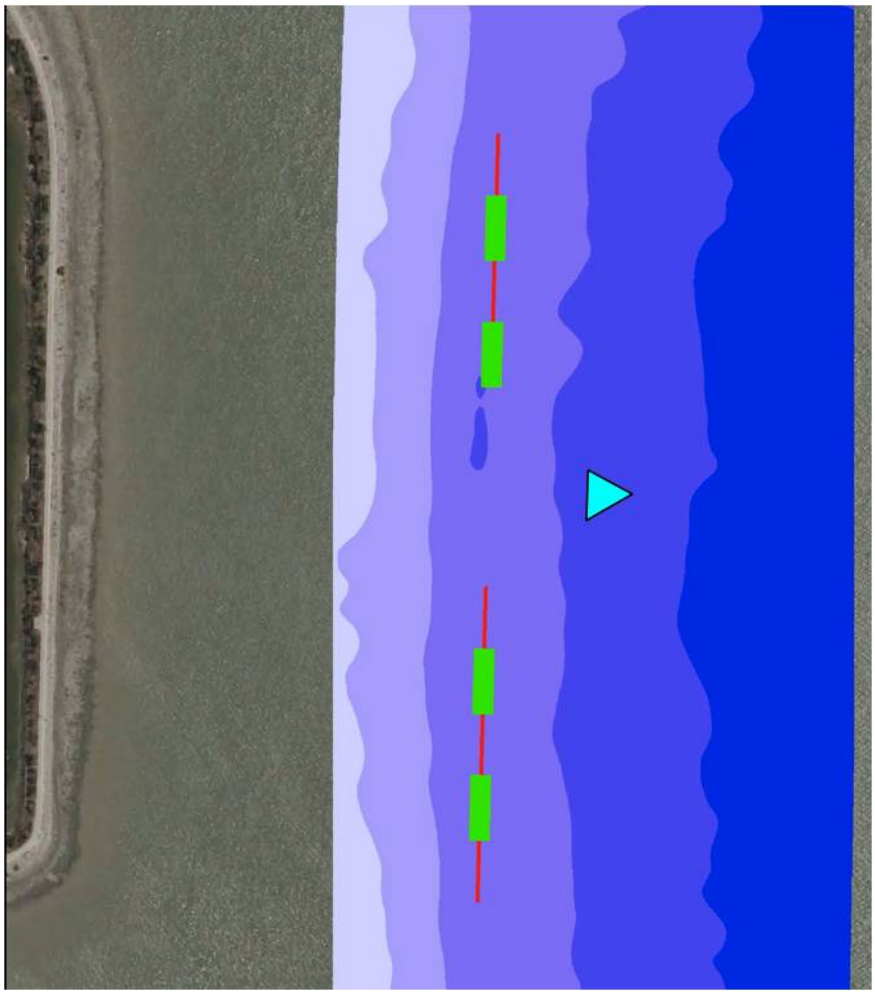
6. San Rafael: Average element elevations



7. Hayward Shoreline: Average element elevations



8. Planned ADCP deployment locations at San Rafael site. The Incident ADCP (orange triangle) will remain at the same location for the duration of the deployment while the two Transmitted ADCPs (gray circles) will be moved as deemed necessary to measure transmitted waves through the different treatment plots, including the control plot. (Inset) The ADCP (raised blue cylinder) prepared for deployment inside a bottom-mounted frame (orange tripod).



9. Planned ambient water properties instrument deployment location (cyan triangle) at San Rafael site