Upper Newport Bay Living Shorelines Project Final Report

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Executive Summary: Restoration of wetlands and the key species within them has greatly increased over the past few decades as recognition of the ecological and economic value of these ecosystems has improved. Two key focal species for restoration within wetland habitats are oysters and eelgrass. Oysters and eelgrass both increase the abundance of fish, birds, and other marine species by creating complex habitat, nursery, and foraging grounds. Both habitats also stabilize shorelines and oysters improve water quality through filter feeding. Despite the recognized importance of these two habitats, they have declined in southern California due to coastal and watershed development. Simultaneous restoration of Olympia oyster and eelgrass has never been attempted in southern California, but restoration of both species individually in Newport Bay has been successful. The overall goals of our project are to (1) improve the ecological integrity and resilience of southern California embayments through living shorelines habitat restoration, (2) maintain restoration through adaptive management informed by detailed monitoring, and (3) enhance the public's understanding and stewardship of coastal habitats. From a sato-umi perspective, our project is a platform through which we are increasing public awareness about how humans can more productively interact with their bay, as well as directly involving the public in habitat restoration.

The project goals to enhance the native Olympia oyster (*Ostrea lurida*) and eelgrass (*Zostera marina*) populations have been met. In the three years since this project first began, we have increased the available oyster habitat by placing shell in various configurations on the bare mudflat in coconut coir and exceeded our eelgrass acreage goals by nearly three times. Importantly, we have seen no evidence so far that oysters have a negative impact on either the quantity or the habitat provision function of eelgrass. Preliminary results indicate a potential and relatively small negative impact of eelgrass on adult oyster density; this will be explored in detail in future studies and as the oyster bed itself matures. Even in the presence of the highest eelgrass densities, adult oyster density (at its lowest) was higher than prior to restoration and equal to or higher than reference sites throughout Upper Newport Bay.

In addition to understanding oyster recruitment and eelgrass habitat creation, we have evaluated associated ecosystem benefits, specifically invertebrate and fish biodiversity and shoreline protection. Our evidence shows that integrated oyster and eelgrass restoration mitigates the reduction in invertebrates under the oyster beds by increasing the overall abundance and richness of the entire plot (e.g. eelgrass habitat compensates for loss of invertebrates under the oyster beds). Habitat value of the restored habitats for fish appears to have increased marginally as a result of the restoration, but it is not yet possible to tease out differences between oyster/eelgrass and eelgrass treatments.

Our results across multiple metrics are preliminary and are site-specific, therefore one preliminary conclusion we can reach is that site can influence restoration success and associated benefits. As oyster abundances continue to increase on the beds and the habitat matures, we will be better poised to determine the specific habitat value associated with oysters versus paired oyster-eelgrass habitat.

Below, we provide an overview of the main results relative to our project goals and specific data and progress on select metrics.

Restoration Design: Starting in summer 2016, we constructed a series of four, 110 m X 12 m, Living Shoreline Blocks in Upper Newport Bay (UNB) (Figure 1a). Within each block, we added four restoration treatments: 1) a restored oyster bed (20 m by 1.5 m), 2) a transplanted eelgrass bed (20 m by 8 m), 3) a restored oyster bed inshore of a restored eelgrass bed, and 4) a control treatment left un-manipulated, with 10 meters separation between each treatment (Figure 1b). The four blocks were placed parallel to shore at four locations in UNB, including along DeAnza Peninsula, Shellmaker Island, and two locations on Castaways beach (PCH and Westcliff). This design, with four replicates of each treatment, enabled comparisons of species performance, habitat value and shoreline protection to determine the success of combined eelgrass and oyster restoration compared to either eelgrass or oyster restoration alone.

Figure 1a and b. Project sites (red) in Upper Newport Bay, Newport Beach, CA (a). At each site, one plot of each treatment (right schematic) is represented (b).

To address our ecological integrity and resilience objectives we monitored the following parameters:

- Oysters: native and non-native oyster abundance, density, and size; percent shell cover
- Eelgrass monitoring: areal extent, eelgrass turion density
- Community parameters: diversity and abundance of infauna and fish

Oysters: We expected statistically greater density of native oysters in restored plots where shell habitat has been added, relative to densities present pre-construction and control plots where habitat has not been manipulated. We also endeavor to maintain at least 70% shell cover and 80% of original restoration area.

Oyster density: Mean oyster densities (*O. lurida*/m^2) were recorded within each treatment plot using 10 randomly located 20 cm X 20 cm quadrats along a 20 m X 1 m transect laid across each treatment prior to restoration in January and May 2016, January 2017, and again six months (November 2017), one year (May 2018), two years (May 2019) and three years (May 2020) post-oyster bed construction. Densities were converted to per m^2 for comparative purposes. For the purposes of this final report, we have analyzed density data through 24 months post-restoration and will focus on the one-year and two-year post construction data.

One year after oyster bed construction (May 2018), *O. lurida* density ranged from 41.60 ± 12.67 oysters/m^2 to 238.4 ± 49.49 oysters/m^2 on the constructed beds. Each bed had densities significantly higher than any measured just prior to restoration in Jan 2017, and higher than the nearest two reference locations in UNB (Coney Island and Hwy1) (Tronske et al. 2018). At 238 oysters/m^2, density on the DeAnza oyster treatment increased 14 times relative to Jan. 2017. After 2 years, oyster density ranged from 59.20 ± 26.67 oysters/m^2 to 420.8 ± 129.96 oysters/m^2 on the constructed beds (Figure 2). At two sites, we had consolidated beds fused by living oysters (DeAnza, Shellmaker), with the most consolidated beds at Shellmaker, which had up to 10 times higher density than reference sites (see photos included). Importantly, of all oysters detected two years after bed construction, we have recorded only 6 *C. gigas*, representing less than 0.5% of total oysters.

% Shell Cover: In two pre-restoration surveys (January and May 2016), average percent cover of hard substrata was below 6% on all treatment plots at all study locations except at DeAnza peninsula, where the percent cover of hard substrata on the future "Oyster" treatment plot was 15.3 ± 4.7% in May 2016; the majority of the hard substratum was composed of dead clam and oyster shell. After construction of the oyster plots, shell cover was 100%. By May 2018, one year after oyster bed construction, shell cover remained high (>80%) and slightly outperformed a previous restoration effort in the bay using shell bagged in jute (Zacherl et al. 2015) on all constructed beds except the oyster treatment at PCH, which averaged 57.8 ± 4.7%. By two years after construction, shell cover remained above our target of 70% except on both oyster beds at PCH and one bed (Oyster treatment) at Westcliff. Importantly, there was a strong relationship between shell cover and oyster density ($R^2 = 0.97$, Figure 3), underscoring the importance of maintaining high shell cover.

Oyster Restoration Rebuild June 2019: Part of our impetus for applying for this funding opportunity was to rebuild our PCH site, which experienced a significant disturbance due to public traffic and shell collection, and where shell cover dipped below the target 70%. After careful consideration, we decided rather than rebuild one site we would rebuild additional oyster beds at each of our four sites increasing the overall total area of our oyster restoration (48 square meters). We constructed two new mini-beds (each measuring 4 x 1.5 m) at each site, varying tidal elevation so that one bed per site was situated at 0.0 and the other at -0.5 ft MLLW. This was to address the disparity between Shellmaker and the other sites, with Shellmaker originally being constructed at 0 ft MLLW versus all other sites at -0.5 ft MLLW. Shellmaker was the site with the best reef consolidation, so our new mini-beds could help tease out whether the site location or the differing elevation contributed more to consolidation success. We also established new mini-control plots at all sites.

Eelgrass: Our experimental design called for two 8 X 20 meter eelgrass beds at each site. Divers surveyed and mapped eelgrass and control beds 6 months after restoration and annually each year post restoration. In June 2018, the total areal extent of eelgrass by site was 1,108 m^2 for PCH, 854 for Westcliff m^2 and 1,667.1 m^2 at DeAnza, far exceeding the goal of 40% of original planted area! Shellmaker was the only site that had a lower areal extent than originally planned at 146.7 m^2. The combined total eelgrass area was 3,775.8 m^2 in summer 2018 which is nearly 3 times our original eelgrass area target restoration goal of 1,280 m^2 (Figure 4). From a restoration perspective, the persistence and spread of eelgrass at three out of four of our sites are successes.

Community/Ecosystem Level Impacts:
Fish: Fish were monitored quarterly beginning in April 2017 (pre-oyster restoration), using baited video traps. We calculated mean abundance of fish with $MaxN_{species}$: the maximum number of each species present simultaneously in the field of view (e.g. Wakefield et al. 2013). One-year after oyster restoration, fish abundance and diversity values were similar across sites and treatments, but fish community composition showed different fish species were differentially using the restored habitats. For example, shiner perch was more abundant in oyster-eelgrass habitats than in other habitats, indicating that these complex habitats may support different species but not have higher means overall.

Infaunal invertebrates: In 2018, intertidal infaunal abundance and species richness were significantly lower beneath restored oyster beds (O, O/E) relative to other intertidal plots and pre-oyster restoration, likely due to the placement of shell at the sediment-water interface (Figure 5). Infaunal invertebrate communities under oyster beds were similar to each other regardless of neighboring eelgrass, as driven by lack of organisms and dominance by organisms tolerant of low oxygen and disturbance. Within subtidal eelgrass beds, there was no evidence of any construction impact until two years post-restoration when we saw that increased abundance and species richness in eelgrass beds with the highest shoot density. This increase may begin to counteract losses of the under-bed invertebrates for the overall community and food web.

Shoreline Stabilization Impacts: Sedimentation immediately upshore of each treatment plot (0.85 m) was calculated using sedimentation pins (US Geological Survey, 2012). A year after the oyster beds were constructed, in May 2018, sedimentation did not differ by site or up-shore of treatment. There was, however, a trend towards net sedimentation upshore of the Oyster, Oyster/Eelgrass, and Eelgrass treatments compared to the erosional Control treatments.

Broader Impacts: A goal of this project is to enhance public scientific understanding of the wetland environment and the threats facing these habitats along with an understanding of the intrinsic connection between a healthy wetland ecosystem and the associated benefits.

Sato-umi: Recreational fishermen regularly visit three out of four of our restoration sites with the primary beach presence being at our PCH and Westcliff sites. OCCK found bags full of oyster shell upshore of our restoration plots on the beach in spring and fall 2017, likely removed via snagging on fishing hooks. In general, the PCH and Westcliff plots maintained lower % shell cover, likely due to this increased recreational activity. Through the creation of pamphlets and direct conversations, we are striving to build awareness about our restoration efforts, Olympia oysters themselves, and the benefits of conserving wetland habitats for recreational fisheries. From August 2018 to November 2019 we conducted a total of 26 beach outreach visits to distribute pamphlets and interact with the public. These interactions varied in length, scope and duration. We also worked with the city of Newport Beach to install an additional marine protected area sign advising the public about the no take from shore area at our PCH site in March 2018. The new signage anecdotally seems to have reduced trash and damage to the site.

We have interacted with volunteers and the public for a total of over 1,500 hours during this award period and have given over 25 presentations on the project since it first began. These included over 10 scientific presentations and posters at various conferences (Restore America's Estuaries, National Shellfisheries Association) as well as four talks in the community including with students at Concordia University, Orange Coast College, Saddleback College, to the Newport Bay Fecal Coliform TMDL stakeholder group at the Southern California Coastal Water Research Project, to the Southern California Wetlands Recovery Project, and at a Honda Marine Science Foundation Board meeting.

The project also provided support for two graduate students (Victoria Wood from CSUF and Marjorie Howard from CSULB) and approximately 4 undergraduates from both schools. Additionally, several OCCK interns gained valuable experience over the course of the project and two students from Troy High School contributed 300 volunteer hours to the project.

Budget: The project expenditures were consistent with the project budget. The budget requested for the project was $74,998. By far, our greatest expense was dedicated to monitoring and field work, because of the exceptional manpower required. Funding went to partially support PI Katie Nichols as well as to provide partial salary support for 2 M.S. graduate students, and 4 undergraduates, who, with extensive volunteer support, completed field surveys, oyster bed modifications, sample processing, data entry and analysis. Other costs associated with the project were allocated to outreach, expendable supplies and field gear; including SCUBA and boat use, and travel to field sites and conferences.

Timeline to completion: The project timeline was consistent with our proposal. The grant agreement began on March 1, 2018 and was extended to June 1, 2020. We are grateful for the extension to allow more time for biological monitoring and data analysis. The oyster restoration implementation occurred in 2017 and we are hoping to continue biological and physical monitoring to provide ecologically realistic, scientifically defensible, long term data (on the order of 5-10 years). We have obtained and are pursuing funding to continue the project and have expanded the sampling to include shoreline profiling to examine elevational changes upshore of restored areas as well as marker horizon monitoring to gain more accurate estimates of upshore sedimentation. We are grateful for the continued support of the Honda Marine Science Foundation in helping to answer questions around the benefits of living shorelines, expand community outreach, and calculate the functions of this restoration at multiple scales.

Attachment

Figures 2-5:

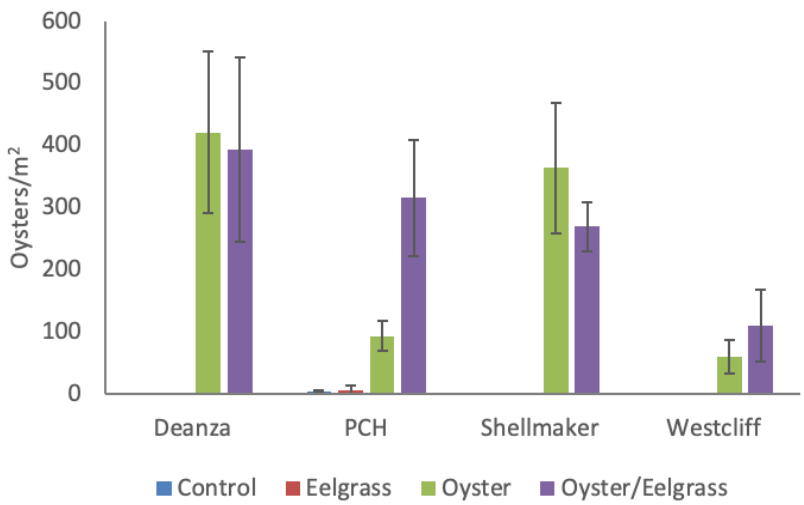

Figure 2. Mean oyster density per meter squared by treatment two years after oyster bed construction. Error bars represent 1 standard error.

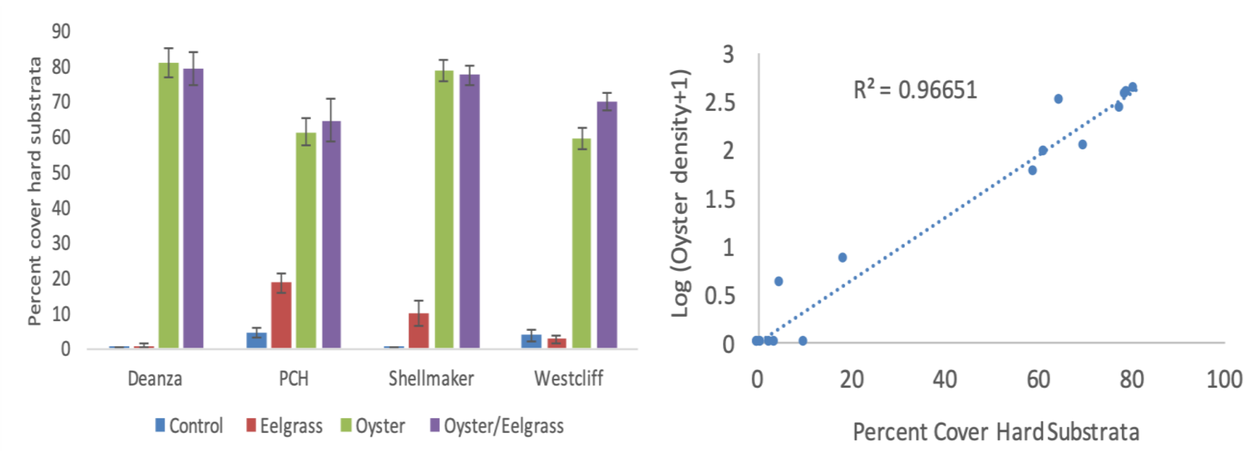

Figure 3. Left: Mean cover of hard substrata per meter squared by treatment two years after oyster bed construction. Error bars represent 1 standard error. Right: Oyster density as a function of percent cover hard substrata, with best-fit regression line.

Figure 4. Results of Areal Eelgrass Mapping Conducted in summer 2018. Bright green shows areal extent of eelgrass. Hunter green indicates the footprint of the original 20 m X 8 m transplanted eelgrass, the intermediate shade of green at DeAnza indicates where eelgrass was present prior to restoration, brown boxes indicate “control” areas where eelgrass or oysters were not transplanted/restored.

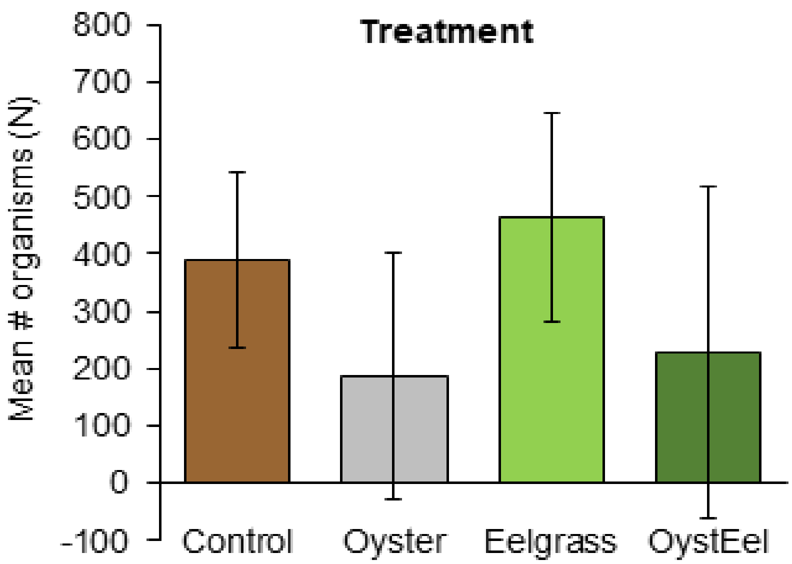

Figure 5. Mean total abundance of infaunal invertebrates by treatment, combining both intertidal and subtidal cores collected in 2018 (one-year post oyster restoration).