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Project Information

# Effects of Eelgrass Density on Filter Feeder Biomass and Condition Index in a Multi-habitat Living Shoreline

## Introduction and Conceptual Background

Estuarine ecosystems have suffered 50% loss in habitat around the world over the last two decades[1]. This loss is detrimental to efforts by humans to increase shoreline protection against climate change. Man-made structures such as seawalls were introduced to combat shoreline erosion, but they decrease plant diversity and estuarine habitat while sometimes actually increasing rates of erosion[2]. Shoreline infrastructure using natural resources may provide shoreline protection while increasing local biodiversity and native habitat[3]. These "living shorelines" provide a way to maintain habitat while stabilizing our coasts.

Traditionally, a single foundational species is targeted and used in living shorelines projects, but recent work has shown that including more than one foundation species may lead to greater restoration benefits[3]. Multi-habitat living shoreline projects combine foundation species in order to increase ecosystem services while simultaneously increasing biodiversity[4]. In Chesapeake Bay, Maryland, the Eastern oyster, *Crassostrea virginica*, and the hooked mussel, *Ischadium recurvum*, were restored together, resulting in a doubling of filtration capacity than when target species were restored alone[4]. In Mosquito Bay, Florida, *C. virginica,* and smooth cordgrass, *Spartina alterniflora*, were restored together resulting in a larger reduction in wave energy than when restored in isolation[5]. Although the majority of living shoreline projects occur on the U.S. East coast, practitioners on the U.S.West coast have recently initiated living shoreline projects as well. A study in San Francisco Bay, California, involving Olympia oysters, *Ostrea lurida,* and eelgrass, *Zostera marina*, resulted in a doubling of sedimentation, which stabilizes shorelines, in plots where both existed together[6]. Although researchers saw benefits in San Francisco Bay, knowledge about co-restoration in the West coast with a living shoreline approach is limited. We need further investigations into how co-restoration of *O. lurida* and *Z. marina* in a multi-habitat living shoreline can improve target species success, ecosystem services, and biodiversity.

Oysters provide myriad ecosystem services such as shoreline stabilization, habitat provision for marine species, water filtration services, nutrient provision for fish, and habitat provision for many migratory birds[7]. In the late 1800s and early 1900s, native oyster reefs dominated estuaries worldwide both ecologically and economically, but due to habitat loss, pollution, and overconsumption, today 85% of oyster reefs have been lost[7]. On the U.S. west coast, *O. lurida* reefs also declined and are now considered functionally extinct. Simultaneously, southern California estuaries have seen the introduction of many non-indigenous species, some of which are invasive, including the Asian date mussel, *Arcuatula senhousia*[8], and the blue mussel, *Mytilus galloprovincialis*[9]. These bivalves, even if non-indigenous, all return filtration services and are broadly classified as filter feeders.

Eelgrass, native to the U.S. West coast, is another species targeted for living shorelines projects. These aquatic plants provide important ecosystem services as food sources and habitat for marine species, shoreline stabilization, and nutrient cycling[10]. Also, like oysters, eelgrass habitat has declined significantly over the last couple of decades, with a 60% decline due to wasting disease[11,12]. Eelgrass beds provide shoreline stabilization via sediment capture because they decrease water velocity, allowing particles to settle out of the water column[13,14,15]. In a multi-habitat restoration setting with oysters restored adjacent to eelgrass, this sedimentation may pose a threat to oysters. Sediment impact on oysters depends on where it is deposited and how quickly oysters grow. If oyster shell accumulation is exceeded by sedimentation rates due to eelgrass, this could be detrimental to oysters because sedimentation can obstruct gills in oysters and other filter feeders[16]. Sedimentation stress in *O. lurida* may be high and is thought to be the only threat to *O. lurida* that has a combined high sensitivity and exposure index[17].

Researchers from CSU Fullerton, CSU Long Beach, and OC Coastkeeper in southern California initiated an ongoing multi-habitat living shoreline in June of 2016 in Newport Bay, CA, including restoration of eelgrass and oyster habitat combined and in isolation from one another. Within the bay, at each of four locations, four treatments were established with randomized restored eelgrass beds, restored oyster beds, oyster beds restored adjacent and upshore from eelgrass beds, and control plots. The project goal is to explore if co-restoration returns more ecosystem services and target species success compared to restoring each habitat in isolation. Since project initiation, restored eelgrass and oyster beds have experienced differential success, causing a shift away from the original experimental treatment design. Instead of a clear difference among treatment plots, the differential success created a mosaic of restored habitats with varying densities of the two target species.

To observe and compare short-term versus long-term restoration effects, total biomass and per capita, or per individual, condition index of native and non-native filter feeders will be measured one year (2018) and three years (2020) post-restoration. Total biomass provides an estimate of how much ecosystem service, in the form of filtration, will be returned[18]. For instance, the higher the total biomass, the more filtration services can be provided by the filter feeders[19]. Condition index provides biological information on how a species is doing at the individual level. The condition index is a summary on the health of the organism and a proxy for its potential success in having viable offspring[20]. High condition index is a proxy for healthy and fertile individuals, which are the building blocks for successful restoration. Together, a holistic picture of the ecosystem services being returned and health of the target organisms will inform management of future living shorelines.

## Purpose and Hypotheses

The purpose of my project is to determine how the total biomass and per capita condition index of filter feeders on restored oyster beds respond to (1) increased sedimentation caused by adjacent eelgrass (2) variation in density of eelgrass in adjacent restoration plots, and (3) filter feeder density. I will test the following six hypotheses. H1: Sedimentation onto oyster beds will be positively correlated with eelgrass density. H2: Filter feeder total biomass and per capita condition index will be negatively correlated with eelgrass density. H3: Filter feeder total biomass and per capita condition index will be negatively correlated with increased sedimentation. H4: Filter feeder total biomass will be positively correlated with density of filter feeders. H5: Filter feeder per capita condition index will be negatively correlated with the density of filter feeders. H6: There will be no interannual variation in the effect eelgrass density has on response factors.

## Research Design and Methods

### Study Site and Experimental Set-up

In June 2016, researchers from CSU Fullerton (Dr. Danielle Zacherl, Professor), CSU Long Beach (Christine Whitcraft, Associate Professor), and Orange County Coastkeeper (Katie Nichols, Restoration Coordinator) in southern California collaborated to create the Upper Newport Bay Multi-habitat Living Shoreline. The living shoreline study design consists of four living shoreline blocks in Upper Newport Bay, California. These blocks are located at Deanza

Peninsula (Deanza), Pacific Coast Highway (PCH), Shellmaker Beach (Shellmaker), and Westcliff Beach (Westcliff) (Figure 1). The four sites were chosen because they all have similar erosive wave impacts and environmental conditions such as water quality, and sedimentation seemed to be consistent among sites.

**Figure 1.** Study locations Deanza (DA), Pacific Coast Highway (PCH), Shellmaker (SM), and Westcliff (WC) in Upper Newport Bay, California. Each of the sites has four treatments, including oysters restored alone, eelgrass restored alone, oysters restored adjacent and upshore from restored eelgrass, and a control plot where no restoration took place.

Within each of the shoreline blocks, there are four treatments: 1) Oyster, a constructed oyster shell bed (20 X 1.5 m) restored alone; 2) Eelgrass, a transplanted eelgrass bed (20 X 8 m), restored alone; 3) Oyster/Eelgrass, a constructed oyster shell bed directly upshore from a transplanted eelgrass bed, and 4) Control, an un-manipulated control treatment (Figure 2). These treatments were constructed parallel to shore and 10 m apart from one another to reduce the influences of treatments on one another. Eelgrass restoration was finished in June 2016, and oyster bed construction was finished in April 2017.

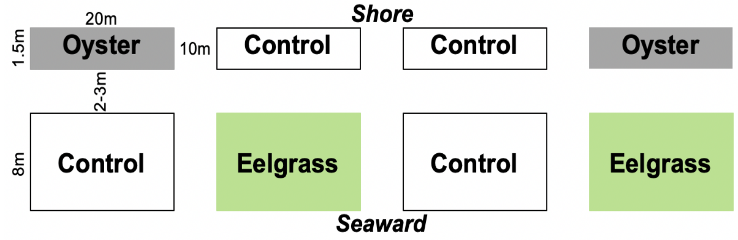

**Figure 2.** Experimental design at each site with a randomized arrangement of each treatment; oyster, eelgrass, oyster/eelgrass, and control.

Excavation of Filter Feeders and Filter Feeder Density

To collect and identify the invertebrate filter feeders that recruit to restored oyster beds, I will examine previously excavated and frozen replicate (n=10) 0.0625-m$^2$ quadrats of restored oyster beds one year and three years after restoration. I will process each individual filter feeder from the excavations in the lab by thawing, cleaning, identifying, and sorting and counting by species. From these data, I will determine filter feeder density for each previously excavated quadrat.

Biomass and Condition Index

Once sorted, I will give each filter feeding bivalve a label and tag them by date, site, treatment, quadrat number, and batch number. I will identify each individual to the species level and then measure their maximum length and width to determine their size, weigh it to determine the wet weight, and then remove the shell and weigh the tissue alone. Samples will be completely dried in a vacuum oven at 100°C for 22 hours, and then re-weighed to determine dry weights. There are many ways to calculate condition index for filter feeders, but I will use an equation determined to be the most accurate, using easily measured parameters, and which is unaffected by freezing[20]. Additionally, it is applicable to multiple species and been cited in studies involving oysters, mussels, and other filter feeders and is calculated as follows [21,22,23]:

$$Condition\ index = \frac{dry\ tissue\ weight}{dry\ tissue\ weight + dry\ shell\ weight}$$

Sedimentation

Upshore sedimentation rate have been monitored using sedimentation pins located at each treatment at each site using methods described in Wood[24]. In addition, to quantify mud deposition directly onto the oyster beds, a point contact technique has been used with 10 quadrats per bed each containing 49 points. At each point a graduated probe assessed the depth of mud deposition in millimeters. Previously collected data using these methods will be used.

## Completed Work

Preliminary data on sedimentation from 2018-2020 indicated that sedimentation was significantly greater on oyster beds restored upshore of eelgrass beds, but also revealed a trend toward more sedimentation on both restored habitat treatments relative to controls[24]. Now, four years post-restoration, studies on sedimentation may reveal whether restored treatments have increased shoreline resiliency via increased sedimentation and improved success for each native target species. One year after restoration, preliminary data indicated *O. lurida* had a higher body condition index, or better overall health, when restored alone instead of adjacent to eelgrass[25]. These preliminary studies set a baseline for this study.

## Benefits to Coastal Wetlands

My proposed research will assess the total biomass and per capita condition index of filter feeders in a multi-habitat living shoreline and inform ongoing restoration efforts on the U.S. west coast. If my hypothesis that eelgrass density and sedimentation are positively correlated is supported, then it will establish and solidify the framework for my third hypothesis. If my hypotheses that filter feeder biomass and condition index are negatively correlated with eelgrass density are supported, it will increase our understanding of how oysters and eelgrass interact in a living shoreline setting. Additionally, if my hypothesis on sedimentation rates being negatively correlated with filter feeder biomass and condition index is supported, our understanding of their relationship will deepen and suggest we may not want to co-locate these two species but rather restore them in isolation, unless other services returned make the trade-off worthwhile. Increasing our understanding of the relationship filter feeders share with eelgrass will inform future management decisions about whether to restore multi-habitat living shorelines together or in isolation. The Upper Newport Bay Multi-habitat Living Shoreline has been recognized by the Wetlands Recovery Project's Work Plan. Their goal is to identify projects that restore wetlands, preserve healthy watersheds, support education, and inform management in southern California. This recognition is significant because it underscores that the efforts in Newport Bay will inform coastal wetland restoration projects throughout southern California.

## Use of Funds

The materials necessary to complete this project are readily available for use at CSU Fullerton's Zacherl laboratory. The funds provided through this scholarship will support undergraduate ($2000) and graduate ($3000) stipends to collect filter feeder samples in the field and extensive time processing them in the laboratory. Too often, undergraduates are expected to put in countless unpaid hours in the lab, but this is excluding low-income and underrepresented students who cannot support themselves through unpaid experience. By providing an undergraduate stipend, the excluded students will be able to support themselves financially and explore research opportunities. The graduate stipend will fund time spent processing thousands of filter feeders in the laboratory alongside the undergraduate student.

## Plans for Sharing Results

This research has been and will be presented at scientific conferences which range from estuarine and shellfish specific conferences to general ecology conferences and diversity conferences by the undergraduate and I funded by travel grants. An abstract has been submitted for an oral presentation at the National Shellfish Association 2021 Conference which focuses on the ecology and management of shellfish resources. An abstract will be submitted to the Coastal and Estuarine Research Federation 2021 Conference, which highlights studies researching the function and management of estuaries. Abstracts will also be submitted to more general scientific societies such as the Western Society of Naturalists and the Ecology Society of America conferences. Preliminary results of the research have been presented by the current undergraduate student Society for Advancement of Chicanos and Native Americans in Science – The National Diversity in STEM 2020 Conference. I also plan to submit an abstract to the Out in STEM 2021 Conference that support research conducted by the LGBTQ+ community. Going to these different conferences is essential because it facilitates communication and collaboration between scientists at all levels of expertise.

Apart from presentation at scientific conferences, I use social media to make science accessible. Through social media accounts such as Twitter and Instagram, I bring the audience to the field and explain my methods in a digestible way. Here, I am trying to close the gap between academia and the public. Academics cannot save the planet alone, but with the help of the public we can successfully preserve our ecosystems. In a couple of months, I have gained over a thousand followers.

At the Back Bay Science Center, an educational center in Newport Bay, I will lead educational seminars on living shorelines and oyster restoration within the context of this project and in general to raise public awareness about the importance of native habitat and filter feeders. In collaboration with Orange County Coastkeeper, a non-profit, Dr. Zacherl and I will train multiple undergraduate students and invite the local community to participate in the upkeep of the restored habitats and active protection of our coast. My concurrent efforts in scientific research and public outreach are a tribute to my dedication to science and society.

## Literature Cited

[1] Barbier et. al, 2011 *Ecological Monographs*. [2] Bozek and Burdick, 2005 *Wetlands Ecology and Management*. [3] Bilkovic et al, 2016 *Coastal Management*. [4] Gedan et al, 2014 *Restoration Ecology*. [5] Manis et al, 2015 *Journal of Coastal Conservation*. [6] Latta and Boyer, 2015 *San Francisco State, University*. [7] Beck et al, 2011 *Bioscience*. [8] Crooks, 2001 *Biological Invasions*. [9] Rawson, 1999 *Marine Biology*. [10] Namba et. al, 2018 *Estuaries and Coasts*. [11] Waycott et al., 2009 *National Academy of Sciences*. [12] Short et. al, 1987 *Biological Bulletin*. [13] Thomsen and McGlathery, 2006 *Experimental Marine Biology and Ecology.* [14] Hansen and Reidenbach, 2012 *Marine Ecology Progress Series.* [15] Koch et al, 2007 *Springer.* [16] Valdez, 2017 *Freshwater Ecosystems*. [17] Wasson et al, 2015 *Elkhorn Slough National Estuarine Research Reserve*. [18] Stevenson and Woods, 2006 *Integrative and Comparative Biology*. [19] Gray et al, 2019 *Estuaries and Coasts*. [20] Davenport and Chen, 2017 *Molluscan Studies*. [21] Steffani and Branch, 2003 *Marine Ecology Progress Series.* [22] Diederich, 2006 *Experimental Marine Biology and Ecology.* [23] Carefoot et al, 1993 *Aquaculture.* [24] Wood, 2018 *California State University, Fullerton*. [25] Sanchez et. al, 2019 *Unpublished Data*.