SEAGRASS RESTORATION AND THE ENHANCEMENT OF ECOSYSTEM FUNCTION

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PROJECT HIGHLIGHTS

- **147m^2** of eelgrass restored, triggered by the initial transplanting effort in 2015.
- **Species richness has increased** in restored plots when compared to adjacent mudflat plots
- **Species evenness has increased** in restored plots when compared to adjacent mudflat plots
- **pH minimum values in restored plots were 7.83**, compared to mudflat pH minimum values at 7.77 (10th percentile)
- **Dissolved oxygen (DO) minimum values averaged 6.15 mg/l in restored plots**, compared to mudflat plots which were 5.86 mg/l (10th percentile)
- Funding allowed us to train a team of **17 Undergraduate and 2 Graduate student volunteers** from a range of local, national and international universities and academic institutions and spurred new collaborations with Dr. Kathy Boyer and her lab at San Francisco State University

INTRODUCTION

Seagrasses are considered a “foundation species” because they provide habitat upon which other species rely on. Therefore, disturbances that trigger widespread loss of seagrasses would cascade through the entire ecosystem. Seagrasses are in decline globally. This is due in part to anthropogenic stressors ranging from poor water quality, coastal development and dredging. Seagrasses provide an estimated value of US $22,832 per hectare per year in ecosystem services[1]. Such ecosystem services include, but are not limited to, serving as nursery grounds for commercially and recreationally harvested species of invertebrates and fishes, improving water quality, providing a storm buffer to developed coastlines through wave attenuation and carbon sequestration[2,3]. Thus, restoration attempts of seagrass meadows have been motivated in part by the interest in preserving the wealth of ecosystem services provided by these systems.

Globally the majority of seagrass restoration attempts have been unsuccessful[4]. Restoration is rarely approached from an experimental ecology perspective. Grounded in ecological theory, we carried out an experimental restoration designed to answer the following questions:

1. In a highly eutrophic estuary where algal blooms regularly form, is seagrass restoration possible? Where do we find higher restoration success? Can we learn from restoration success and failure?
2. If so, what are the ecosystem benefits of seagrass restoration?

We hypothesized that 1) the self-facilitating ability of seagrass would increase the likelihood of restoration success and rapid plot expansion given strategic consideration of temporal patterns (i.e. ephemeral macroalgal blooms) and 2) seagrass restoration would enhance ecosystem services in two primary ways; through the modulation of water quality via increased concentrations of dissolved oxygen and increased pH values (lower acidity) in the water overlaying restored plots and through increases in biodiversity and community complexity.

[1] Costanza et al. Nature 1997
[2] Beck et al. Bioscience 2001
[3] Orth et al. Bioscience 2006
[4] van Katwijk et al. Journal of Applied Ecology 2016

METHODS

To test if transplanted seagrass could trigger its own persistence and expansion in a restoration context in the Elkhorn Slough, an estuary located in Monterey Bay, CA that suffers from nutrient over-enrichment, we carried out an experimental restoration project in spring of 2016 (Figure 1). Building on previous efforts from a similar restoration experiment in 2015 that revealed a positive correlation between high algal cover and seagrass mortality, we decided to transplant earlier in the year before the ephemeral macroalgal blooms. We saw a jump in restoration success (persistence of restoration beds) when comparing the two restoration efforts—from less than 50% in 2015 to 69% plots survival in 2016.

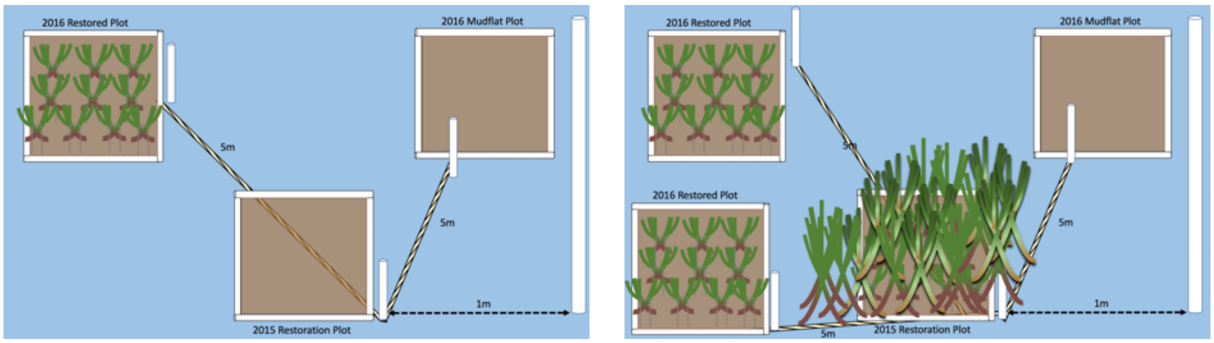


Figure 1. Experimental design of eelgrass restoration 2016. If at the time of transplanting for our 2016 restoration there were no remaining shoots from our 2015 restoration project **(A)** we transplanted a single plot adjacent (~5m away) to the 2015 plot location. We also placed a PVC post at an adjacent mudflat spot for monitoring. If the 2015 restoration plots were present **(B)** we transplanted two plots adjacent to the 2015 plot location, in addition to the demarcated mudflat plot.

Figure 2. Water quality instruments that measure pH, DO and other parameters were deployed and secured to milk crates using PVC, surgical tubing, galvanized chain and anchors. Pictured above A) deployment of instrument at low tide near a mudflat site, B) deployment in a growing restoration plot, C) deployment in expanded restoration plot where we observed both increases in shoot count, canopy length and plot area and D) Graduate student, Kat Beheshti deploying instrument at high tide by freediving in full-snorkel gear.

To test the ecosystem level effects of restoration we deployed water quality instruments in restored plots, adjacent mudflat and large existing seagrass beds and compared the pH and dissolved oxygen (DO) values among habitat types (Figure 2). In order to quantify differences in biodiversity of mobile species across habitat types and test whether species diversity is greater in seagrass (restored and naturally occurring beds) than mudflats we collected data on faunal (fishes and invertebrates) diversity and abundance before and after transplanting. To do this we deployed sets of traps place at the bottom and in the water column (Figure 3). Water quality instruments and trap arrays were deployed from June-September 2016 and 2017.

Figure 3. Trap array deployment June-September 2016 & 2017. Baited shrimp pots and minnow traps were deployed in 2015 restoration plots, 2016 restoration plots, mudflat plots and existing beds. All species caught were measured, sexed and identified to the lowest taxonomic classification. Photos are of undergraduate and graduate team members carrying out trapping effort.

RESULTS

Our results supported the hypothesis that it is possible, using an experimental restoration approach, to successfully carry out a seagrass restoration in a highly eutrophic system. We initially planted a total of 63 plots, 26 of which have persisted and grown both vertically and laterally. The total area initially planted was 15.75m^2. As of September 2017, the total area that our 2016 restored plots had reached was 147m^2. Initial plot size at the time of transplanting

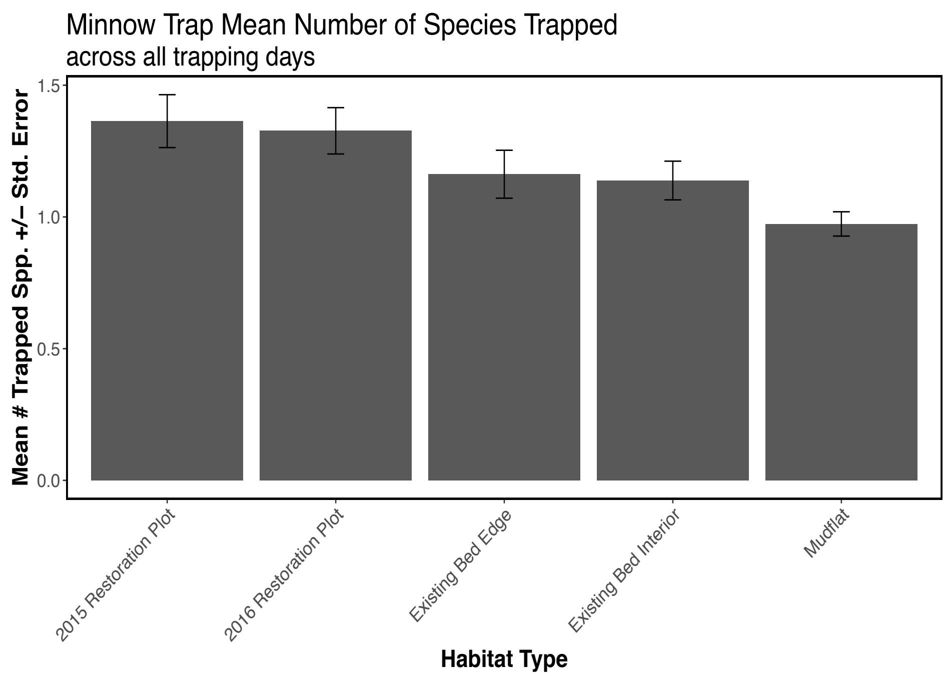


Figure 4. Mean number of species trapped in baited minnow traps by habitat type. This figure demonstrates that the average number of species trapped was greater in both 2015 and 2016 restored plots than in existing beds (edge and interior) or mudflat.

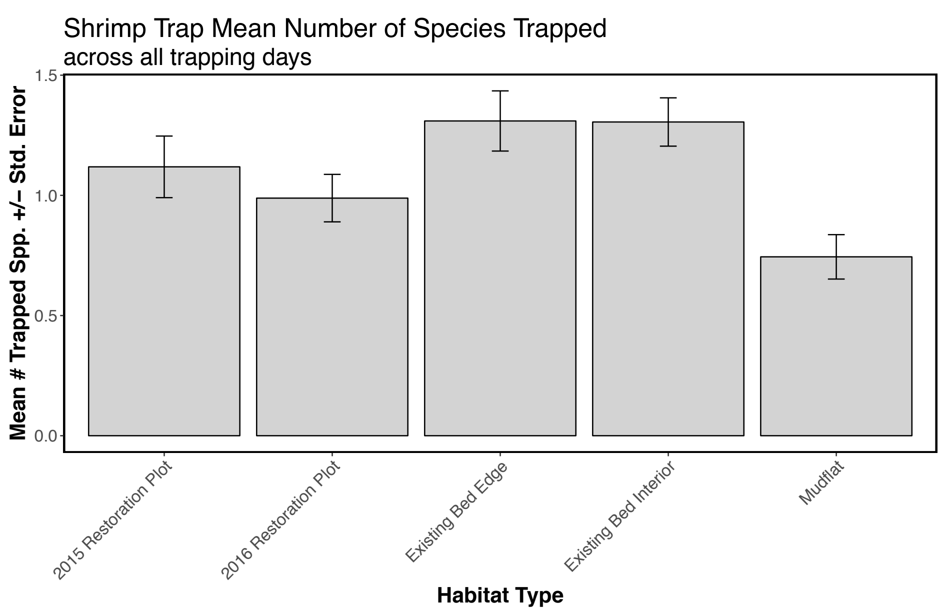


Figure 5. Mean number of species trapped in baited shrimp pots by habitat type. This figure demonstrates that the average number of species trapped in restored plots (2015 & 2016) was greater than the number of species trapped in mudflat.

(March 2016) was 0.25 m^2. Eighteen months post-transplanting, a number of plots have expanded to greater than 4 m^2.

The water quality data was analyzed by looking at the 10th percentile of the data, or the lower thresholds of the dataset. The analyses support our hypothesis that restoration of seagrass has the capacity to improve water quality. We observed higher pH values in restored plots than in mudflat, meaning that comparably, restoration plots were less acidic than adjacent mudflat (Figure 6A). We also observed higher DO values in restored plots than in mudflat plots when

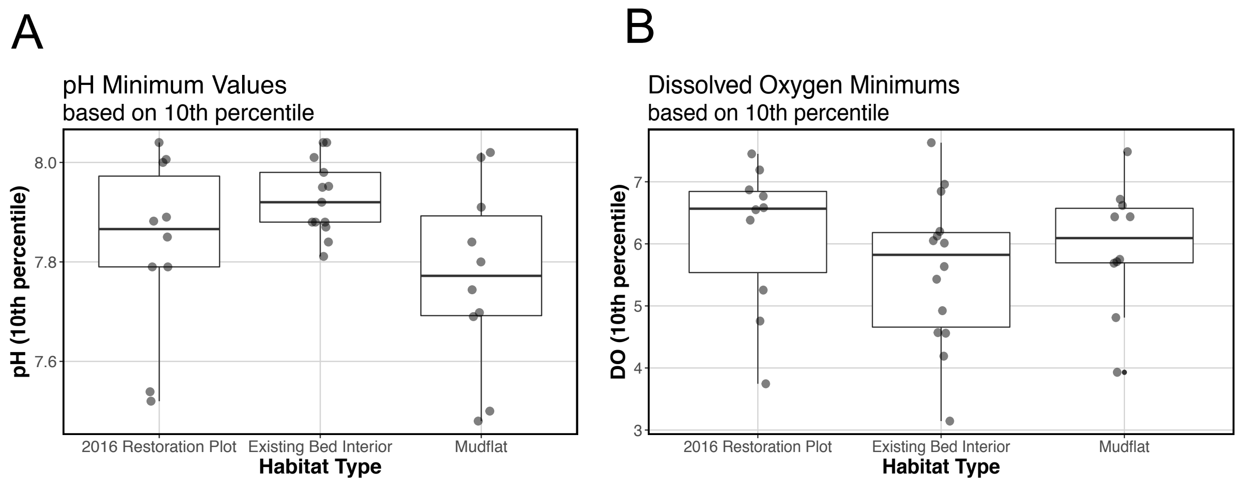
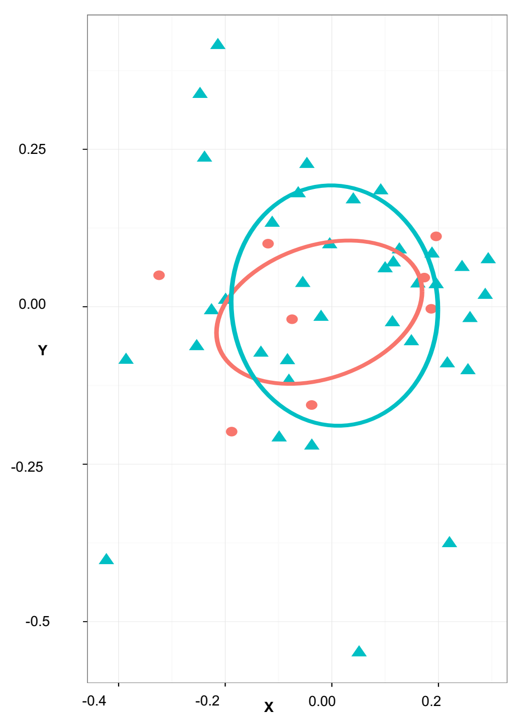


Figure 6. Water quality data (10th percentile, minimums) A) pH values are comparably more acidic in mudflat than in restored plots or existing beds. This means that restoration may have the capacity to provide a pH buffer to calcareous or sensitive estuarine species with ocean acidification. B) The minimum (10th percentile) values of DO observed in restored plots was higher than that of mudflat.

focusing on the 10th percentile. This means that the lowest dissolved oxygen values we observed across all deployments in restored plots were higher than that of mudflat. The DO values for restored plots more closely resembled the profile of existing beds (Figure 6B).



Epifauna Community Assemblage
Invertebrate community established quickly in restored plots

Habitat Type
Existing Bed
2016 Restored Plot

Figure 7. NMDS plot depicting the overlap in epifauna community assemblage in restored plots and natural existing beds. This data was analyzed by Kathy Boyer and her team. Natural existing beds are plotted as red circles and restored plots as teal triangles. The points that correspond to each habitat type are showing great overlap. This means that the epifaunal assemblages are similar between natural and restored plots, thus it did not take long at all to establish the invertebrate community.

OUTCOMES
This funding allowed us to carry out a successful seagrass restoration project that added 147m^2 of seagrass to Elkhorn Slough using a novel experimental approach to restoration ecology. We were able to demonstrate that restoration can enhance biodiversity and modulate water quality. The results from this research have been presented on at multiple forums, conferences and invited lectures and will culminate with a peer-

reviewed publication that is currently being drafted and will be sent for review in early 2018. The funding for this project allowed us to train seventeen undergraduate and two graduate students in seagrass restoration techniques, standardized monitoring protocols, calibration, deployment and retrieval of sensitive water quality instruments, standardized methods for processing seagrass shoots in the lab and identification of estuarine species. As a result of this funding we were able to establish a collaboration with Dr. Kathy Boyer and her team at San Francisco State University and continue our collaboration with Dr. Kristy Kroeker from UC Santa Cruz who will be utilizing our restoration plots to look closely at restoration as a conservation tool to buffer sensitive species against ocean acidification. This work has given us the opportunity to act as consultants to other California restoration projects led by Morro Bay National Estuary Program, California Department of Fish and Wildlife and the National Oceanic and Atmospheric Administration. This funding has reached far beyond Elkhorn Slough and will continue to influence local and state-wide trajectory of seagrass restoration.

PUBLIC ENGAGEMENT

*media feature

Devitt, Elizabeth. “Restoring seagrass under siege”. MONGABAY, January 2, 2017*

Hughes, B.B. May 2017. Food webs, resilience, and functioning of coastal ecosystems. *Invited Webinar*. Canadian Society of Environmental Biologists.

Hughes, B.B. April 2016. Food webs, resilience, and functioning of coastal ecosystems under threat from multiple anthropogenic stressors. *Invited Seminar*. University of California Santa Cruz, Ocean Science Department.

Hughes, B.B. March 2016. Food webs, resilience, and functioning of coastal ecosystems. *Invited Seminar*. University of Florida.

Beheshti, K., Hughes, B. et al. “From Sarcocornia to Zostera: Just add water.” 7th Annual Ecology and Evolutionary Biology Symposium. Long Marine Laboratory, Santa Cruz. April 29, 2016. 15-minute Talk.

Beheshti, K.M., Hughes, B.B., Boyer, K, Greene, H.G., Endris, C. “Seagrass Restoration and the Trajectory of Enhanced Ecosystem Functioning.” Western Society for Naturalists. Monterey, CA. November 12, 2016. 15-Minute Talk.

Beheshti, Kathryn. “Estuarine Ecology.” Bio 108 Marine Ecology Guest Lecture Series. UC Santa Cruz, February 8, 2017. 50-Minute *Invited Lecture*.

Beheshti, Kathryn. “Estuarine Transition Zones: an experimental approach to understanding the biotic and abiotic drivers of phase shifts.” Ecology and Evolutionary Biology Thesis Proposal Seminar. Long Marine Laboratory, Santa Cruz. May 19th, 2017. 30-Minute Public Talk.

Beheshti, Kathryn. “Just Slough It: what you will see and do when you visit the slough, a field guide.” BIO 82 Introduction to Field Research and Conservation. Natural Sciences II, UC Santa Cruz. October 19, 2017. 30-Minute *Invited Lecture*.