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SHORT COMMUNICATION

ASSESSMENT OF LIVING SHORELINES FOR RESTORING FISH HABITATS: A CASE STUDY FROM COASTAL ALABAMA§

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KEY WORDS: Restoration, nekton abundance, species richness, diet, condition

INTRODUCTION

Shallow coastal ecosystems such as salt marshes are vital habitats for a diversity of species and are especially important nurseries for juvenile fish and crustaceans that support fisheries (Baker et al. 2020). Coastal shorelines are also highly prized areas (Gedan et al. 2009), with significant areas of shorelines being occupied by human infrastructure such as houses (Waltham and Connolly 2011). To combat issues such as storms, erosion from wave action and increasing rates of sea level rise, as well as maintaining navigation channels, hard armoring methods such as seawalls or rip–rap have been widely implemented. However, armored shorelines tend to degrade the natural ecosystem (Munsch et al. 2017). Living shorelines are becoming a popular alternative to hard armoring as they are designed to counteract erosion while maintaining the ecosystem services provided by natural coastal seascapes (Bilkovic et al. 2016, Smith et al. 2020).

Although the enhancement of fish habitat is one of the most widely stated benefits of employing living shoreline approaches, evaluating the effectiveness of achieving this goal is a challenging task (Sheaves et al. 2015). A number of studies have examined nekton responses to shoreline restoration (Smith et al. 2020), however, larger studies comparing multiple treatment types across multiple locations remain relatively rare and show mixed results (Guthrie et al. 2022). Understanding if and how restoration projects enhance shoreline habitat is critical for guiding future restoration projects to maximize beneficial outcomes (Bilkovic et al. 2016). The aim of this project was to evaluate multiple metrics for quantifying the values of restored shorelines as fish habitat. To achieve this aim, we compared (1) nekton community composition, (2) diets, and (3) caloric content of common fish species between living shorelines, adjacent controls, and a nearby rip–rap hardened shoreline in Mississippi Sound, AL.

MATERIALS AND METHODS

Mississippi Sound, AL contains large areas of salt marsh ecosystems, multiple large–scale living shoreline restoration projects, and rip–rap hardened shorelines, making it an ideal location to evaluate fish habitat values of restored shorelines. Samples were collected from several living shorelines, adjacent marsh control sites, and a rip–rap hardened shoreline (Figure 1). Northeast Point aux Pins (PaP), Little Bay Peninsula (LB),

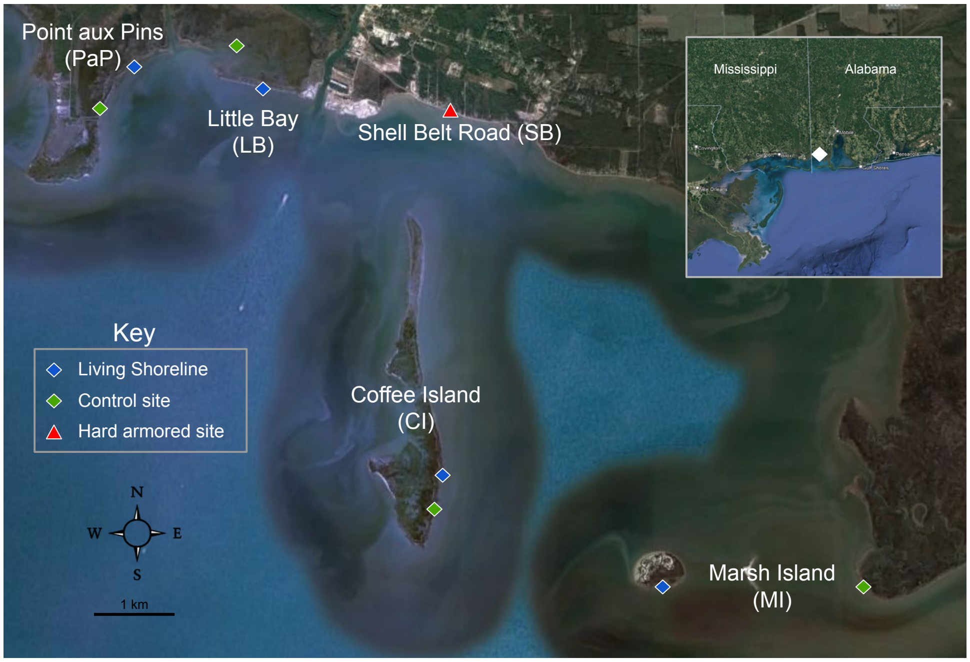

***FIGURE 1.** Map of the study sites in Mississippi Sound, AL. Base images from Google Earth.*

§*The first author conducted this research as part of the Dauphin Island Sea Lab's Research Experience for Undergraduates in the coastal and nearshore marine science program.*

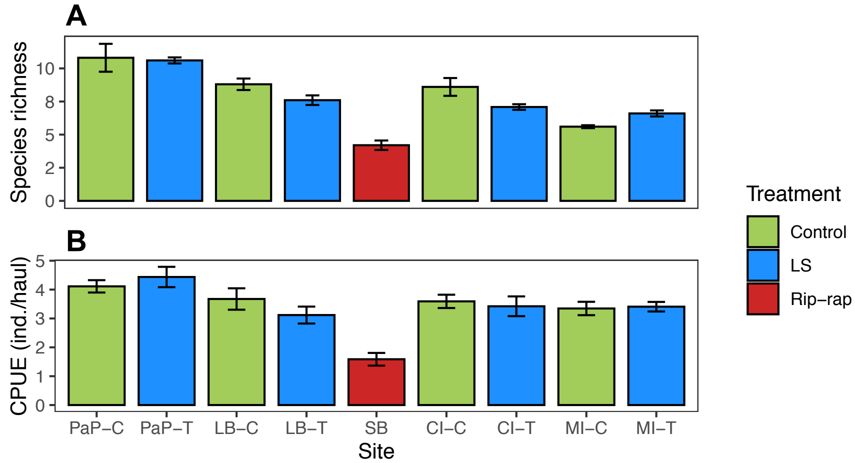

Figure 2. *Means (± se) of nekton from replicate seine net sampling at restored (LS), control, and rip-rap hardened shorelines in Mississippi Sound, AL. A. Species richness. B. Abundance (catch per unit effort, CPUE). Site codes: CI—Coffee Island; LB—Little Bay; MI—Marsh Island; PaP—Point aux Pins; SB—Shell Belt Road; C—control sites; T—restored sites.*

and Marsh Island (MI) living shoreline sites are protected by breakwaters made from concrete wave attenuation devices (WADs), while the Coffee Island (CI) living shoreline is protected by an alternating series of loose shell, Reef Blocks, and Reef Balls. Control sites for each of these living shoreline projects consisted of adjacent unprotected marsh shorelines. A rip–rap protected shoreline along Shell Belt Road (SB) was also sampled to represent a typical alternative shoreline protection approach to living shoreline methods. These sites span a gradient of exposure from the prevailing southeasterly winds, with PaP, LB, and SB along the northern mainland shore of Mississippi Sound being partially protected by Coffee Island, Marsh Island, and the marsh complex at Barron Point (Figure 1). Further details about each of the restoration sites are available in Moody et al. 2013 and Sharma et al. 2016a.

To represent nekton communities at each site, and to collect nekton for diet and condition analyses, between 4 and 12 (mean = 6) replicate seine hauls were collected at each site during the summer of 2022, using a 17 x 1.8 m seine net with 6 mm mesh. Replicate locations were positioned at the marsh edges behind each living shoreline structure. The number of replicates performed at each site was based on the length of the shoreline and variety of structures present. Replicate seine hauls were located at least 100 m apart to ensure independence. Each replicate involved a 10 m haul with each end of the seine maintained at 10 m apart using a headrope to provide standardized 100 m^2 replicate samples. All samples were submerged in an ice slurry immediately after capture according to IACUC protocols, and returned to the laboratory for further processing. All individuals were identified to species with the exception of *Palaemonetes* shrimp, which were identified to genus only. All individuals were measured (mm); total length was recorded for all fish species, carapace width was recorded for crab species, and mantle length was taken for squid species. Both carapace length and total length were taken for all shrimp species.

Pinfish (*Lagodon rhomboides*) and Silver Perch (*Bairdiella chrysoura*) were the most abundant and widespread generalist fish species sampled and were therefore selected for diet analysis to give a sense of resource availability in the areas (Warburton et al. 1998, Barbosa and Taylor 2020). The stomach contents were examined underneath a dissecting microscope to identify prey items to the lowest taxonomic level possible. The presence of each prey type in each stomach was recorded to provide the frequency of occurrence of each prey type since this metric provides the least biased measure of general dietary composition (Baker et al. 2014).

We measured the caloric content of Pinfish as a measure of fish condition (e.g., Wedge et al. 2015). The empty stomach and other organs were added to the rest of the individual fish and dried to a constant weight. The stomach contents and intestines were not included because food contents could bias the calorimetry data. Each dried fish was then ground to a homogenous powder, sieved to remove scales which do not homogenize well, and further ground to fine powder for analysis (LaBon 2021). The resulting homogeneous powder was pelletized into 0.1 g units for analysis in a Parr 6772 semi—micro bomb calorimeter. The bomb calorimeter was standardized with a 0.1 g pellet of benzoic acid, which has a known calories/gram value. Results from each sample were returned as calories/gram of the dry weight, and reported here as mean ± 1 se.

To compare nekton abundances and species richness between sites and treatment types, 2—way analyses of variance (2—way ANOVAs) with interaction terms were conducted. Weighted means and Type I sum of squares were used to account for the unbalanced design. Each seine pull was treated as an independent replicate in the analysis. Test assumptions of homogeneity of variances between factor levels (Levene's test), and residual normality (Shapiro—Wilks' test) were verified before accepting test results. Statistical analyses were conducted in the R software for statistical programming version 4.0.5 (R Core Team, 2022).

Results and Discussion

Nekton community composition

A total of 2,346 individuals from 40 taxa were collected during replicate seine net sampling (Supplemental Table S1). The nekton assemblage was dominated by white shrimp (*Litopenaeus setiferus*), brown shrimp (*Farfantepenaeus aztecus*), Pinfish, grass shrimp (Palaemonidae), Silver Perch, and Hardhead Catfish (*Ariopsis felis*), which are typical of shallow water nekton communities of the region (e.g., Scyphers et al. 2015, Sharma et al. 2016b). Across the restored and adjacent control sites, species richness followed the gradient of exposure, being highest at the most protected site, PaP in the northwest, and lowest at the least protected site, MI in the southeast (Figure 2A). Although also located along the partially sheltered mainland coastline, the riprap shoreline of SB had the lowest species richness and abundance of any site (Figure 2A, B; $F_{2,5}$ = 5.067, $p < 0.05$). Like species richness, nekton abundance varied according to treatment type ($F_{2,5}$ = 22.026, p = 0.0108) and was highest at PaP (Tukey pairwise test, $p < 0.05$), and intermediate at the other restored and control sites (Figure 2B).

Although based on limited sampling, our community results were largely as expected. Each of the restoration sites studied was designed to protect the eroding shorelines of natural salt marsh areas, and the nekton assemblage sampled is typical of shallow nekton communities in the region (Scyphers et al. 2015). The gradient of species richness from the northwest to southeastern sites (Figure 2A) probably reflects the gradient of wave exposure. While shallow coastal waters in general provide nursery habitat for a diversity of species (Beck et al. 2001), the most physically sheltered waters seem to be particularly important (Blaber and Blaber 1980). The PaP restored site also has the greatest diversity of habitat types, with the concrete WADs, constructed loose—shell oyster reefs, seagrass, unvegetated sediment, marsh edge, and tidal marsh creeks, so it is unsurprising to see the highest abundance and diversity of nekton at this site.

Our findings clearly suggest that the natural shorelines and those restored using living shoreline approaches are more valuable fish habitat than the rip—rap hardened shoreline sampled. This is consistent with previous findings that hardened shores have lower habitat values (Munsch et al. 2017). Among the various shoreline hardening techniques, rip—rap appears to provide the highest quality habitat, with the meta—analysis of Gittman et al. (2018) finding no difference in biodiversity and abundance of nekton between rip—rap and natural shorelines. However, high heterogeneity in their results show effects can be site—dependent and vary considerably, probably due to seascape—level effects and influences of factors other than habitat type (Bradley et al. 2020; Nagelkerken et al. 2015). Therefore, while rip—rap may provide the highest habitat quality among hardening types, our findings suggested the rip—rap shoreline we sampled was poorer in habitat quality than our natural and restored sites.

Patterns between the restored and control sites were more subtle, with similar species richness and abundance between restored and controls. Similarly, Scyphers et al. (2011) used seine nets at nearby restored sites and found no difference in demersal fish abundances between restored and adjacent controls, although they did find decapod crustaceans were more abundant near the breakwater structures at their sites. This general lack of differences between treatment types could be interpreted in various ways. The similarity to adjacent controls could indicate success in maintaining the habitat values of the shoreline (e.g., Guthrie et al. 2022). Alternatively, if the goal of the restoration was to improve the habitat values of actively eroding shorelines, then a lack of difference could indicate limited success in achieving this goal. The control sites were mostly directly adjacent to, and contiguous with, the shorelines protected by breakwater structures, and a lack of difference in community metrics could simply indicate that the same nekton populations occupy the restored and adjacent control sites. The preliminary findings from the limited sampling in the current study cannot distinguish between these possibilities. However, high spatial and temporal variability is characteristic of coastal nekton communities (Sheaves et al. 2012), and even substantially higher replication may still be insufficient to detect subtle effects of shoreline restoration efforts on fish habitat values (Guthrie et al. 2022).

Diet and Condition

Given the inherently variable nature of coastal nekton communities, we collected preliminary data on other potential metrics of habitat quality, specifically, diet and condition. The stomach contents of 105 Pinfish and 84 Silver Perch sampled from CI and PaP restored and control sites were examined. A greater diversity of prey types was found in the stomachs of both species at PaP than at CI, and in both sites, more prey types occurred in the stomachs of fish from the restored shorelines than the adjacent controls (Figure 3). Stomach content

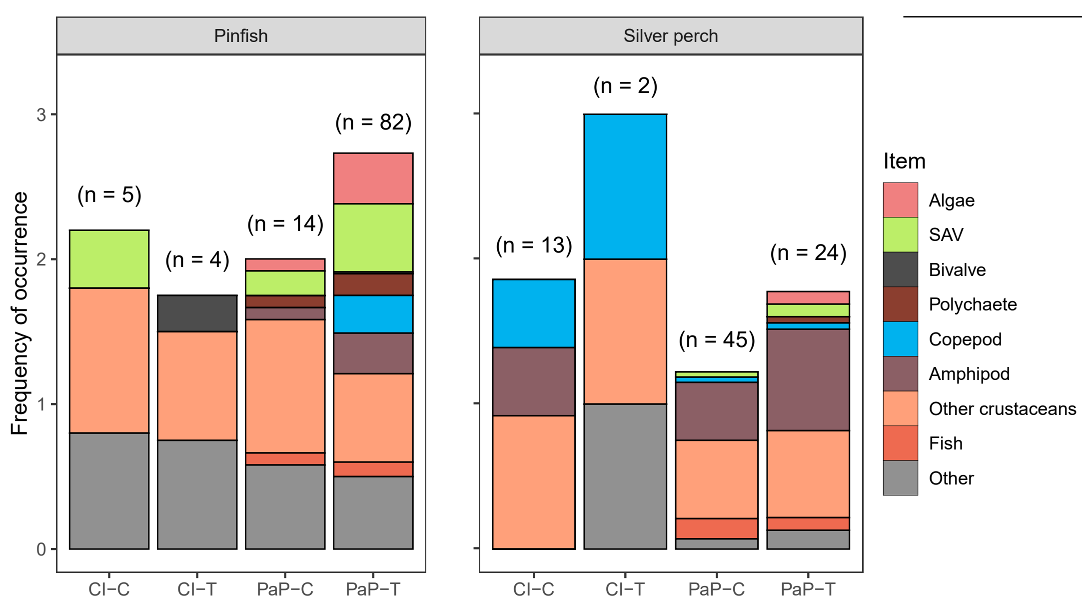

Figure 3. *Diets of Pinfish (Lagodon rhomboides) and Silver Perch (Bairdiella chrysoura) from Coffee Island (CI) and Point aux Pins (PaP) Control (C) and Restored (T) sites in Mississippi Sound, AL. Diets expressed as frequency of occurrence of each prey type, defined as the proportion of stomachs containing each prey type, where 1 indicates all stomachs. Values above 1 arise from individual stomachs containing multiple prey types. Sample size (number of stomachs with food) are shown in parenthesis above each bar.*

sample sizes were very limited, and caution is needed interpreting these findings, particularly since higher prey diversity corresponds to higher sample sizes from those sites. However, the preliminary findings may reflect the greater diversity of habitats and substrates at PaP than CI, and at the restored sites with breakwaters compared to the control sites. The breakwater structures themselves provide hard substrate that is generally lacking from natural shorelines, which may provide additional prey resources. For example, both Pinfish and Silver Perch at PaP living shoreline had algae in their stomachs, which was absent in the stomachs from PaP control. Algae has been observed growing on the WADs at this site, and this may represent an additional prey resource not readily available at control sites. As with the other metrics examined, preliminary calorimetry data suggest that Pinfish from the PaP living shoreline are in better condition (mean ± 1 se; 4,709 ± 99.8 c/g dw, n = 24) than those from the PaP control (4,249 ± 138 c/g dw, n = 3), CI control (4,429 ± 80.8, n = 3), and CI living shoreline (4,222 ± 94.7, n = 2). Caloric content has proven to be a useful metric of habitat quality for Gulf Killifish (*Fundulus grandis*) in tributaries of the nearby Perdido Bay system, with fish from creeks with more natural catchments having significantly higher caloric content than those from catchments with more urban development (Wedge et al. 2015).

Ongoing research at these and other Alabama living shoreline sites will more comprehensively address the utility of diet and condition, along with growth, as alternate metrics of habitat quality and restoration success. Although the enhancement of fish habitat quality is a major goal of many living shoreline projects, it is challenging and expensive to identify the specific benefits gained due to the highly variable nature of these communities. Alternate metrics such as growth and condition, founded on differences in access to prey resources, may provide a more cost—effective and sensitive evaluation of the success of living shoreline projects. Better understanding of the relative success of individual projects can help to refine future project designs and maximize the benefits of restoration investments.

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