Differential Habitat Use and Reef-Fish Community Organization among the Reef-Top and Slope Morphology Within a Single Shelf-Edge Ecotone in La Parguera, Puerto Rico

El Uso del Hábitat Diferencial y la Organización Comunitaria de Peces del Arrecife Entre la Cima del Arrecife y el Pared dentro de un Ecotono en La Parguera, Puerto Rico

Utilisation Différentielle de L'habitat et Structuration de la Communauté Ichtyologique Récifale entre Pente Externe et Crête Récifale au Sein D'un Écotone de la Marge Continentale de La Parguera, Puerto Rico

JOSHUA P. KILBORN[1], ORIAN E. TZADIK[1], and RICHARD S. APPELDOORN[2]
[1]*University of South Florida - College of Marine Science, 140 7th Ave South, St. Petersburg, Florida 33713 USA.*
jpk@mail.usf.edu. otzadik@mail.usf.edu.
[2]*University of Puerto Rico at Mayagüez - Department of Marine Science, PO Box 9000, Mayagüez. Puerto Rico 00681.*
richard.appeldoorn@upr.edu.

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EXTENDED ABSTRACT

Introduction

The shelf-edge coral reef habitats parallel to the coast off La Parguera, Puerto Rico support high abundance and biomass of local flora and fauna (Christensen et al. 2003), even though the entire region's fisheries resources have historically been overfished. Ecotones tend to support higher biodiversity than their neighboring habitats (Risser 1995), can manifest in many ways on many spatial scales (Risser 1993), and can be difficult to describe. We define an ecotone as the transition zone between two differing, but homogenous, habitat types (Risser 1993), and we extend this definition to a shelf-edge coral reef system. The purpose of this study is to determine if the La Parguera shelf-edge reef system approaching the slope drop-off acts as an ecotone between the continuous and fringing barrier reefs and the adjacent deep mesophotic reefs as evidenced by differential habitat use by the resident animals.

Methods

We examined beta-diversity in both benthic habitat characteristics and associated fishes at 11 randomly selected sites within the same depth zone between Guanica and La Parguera. Observations were limited to a single depth zone because water depth is known to organize fish communities in shelf-edge habitats (Bejarano et al. 2014). Observations were made within each site at a "reef top" location leading up to the shelf-edge drop off point as well as at a "slope" location on the actual drop off feature. The location stratifications within each site did not differ by more than 5 m. From 24-Feb-2008 to 09-Dec-2008, four 25 x 4 x 2 m belt transect visual census surveys were conducted at each site stratification to enumerate non-cryptic diurnal fish species; any species observed > 2 m above the belt transect were not assessed. From 28-Feb-2009 through 28-Apr-2009, two 10 m benthic point-intercept (every 25 cm) surveys were employed at each site strata to assess the habitat composition. Fish data were converted to catch per unit effort (CPUE) values and habitat composition was estimated as percent cover for algae, hard and soft corals, sand, and sponges.

Statistical analyses consisted primarily of distribution free, distance-based multivariate techniques, implemented in the Fathom Toolbox (Jones 2014) and executed in Matlab R2014. Fish CPUE data were transformed via a square-root transformation and benthic composition data were standardized to z-scores. Beta-diversity was assessed among all sites for fishes using the Morisita-Horn dissimilarity metric (Horn 1966, Chao et al. 2005, Chao et al. 2006, Clarke et al. 2006) and with the Euclidean distance metric (Faith et al. 1987, Batagelj and Bren 1995, Clarke et al. 2006) for habitat composition. For hypothesis testing employing p-value distributions, the significance level (α) was set to 0.05 with a tolerance of 0.005. We examined differences in beta-diversity of fishes and habitat composition among site types (i.e., reef top vs. slope) using a non-parametric multivariate analysis of variance (np-MANOVA) (Anderson 2001). We verified the np-MANOVA results, and produced visualization plots, using a canonical analysis of principle coordinates (CAP) (Anderson and Willis 2003; Legendre and Legendre 2012). Fish species indicative of each site stratification were determined using the indicator value method (IndVal) (Dufrene and Legendre 1997) and habitat and diet preference information for each IndVal species was obtained via the FishBase© database (Froese et al. 2015).

Results

The slope morphology at Point 378 was beyond safe working-depths (i.e., depth > 35 m) and, therefore, the data obtained for this slope location was not retained for further analysis (as it was not representative of the slope drop off). Of the 83 fishes observed, 70 spp. were seen in the reef top strata and 66 were observed in the slope locations. Habitat composition was shown to be significantly different among location strata (np-MANOVA: $F = 5.18$, $p = 0.022$, $df = 20$), and the

CAP results indicate that our classification model, built using location type, could explain 96.87% of the observed variability among sample habitat compositions. Among the reef top locations, the benthic habitats were characterized by relatively higher concentrations of sand and algae, which the slope locations were comprised of coral (hard and soft) and sponge habitats (Figure 1). Beta-diversity of fishes was also significantly different among the locations sampled ($F = 7.85$, $p = 0.001$, $df = 20$) and our CAP model was able to explain 63.43% of the variability in beta-diversity among sites based solely on the location type of the sample. A total of 15 different fishes were identified with significant IndVals; eight species were indicative of the reef top morphology and seven for the slopes (see Table 1).

Discussion

Here, we present evidence for the existence of, and differential habitat use by reef fishes within, a spatially narrow shelf-edge ecotone residing at single depth zone. The observed organization of fishes along the reef top and slope suggests a link to trophic structure within the greater ecotone. The community indicator species identified highlight the trophic relationships based on known feeding and habitat preferences for each species. Reef top habitats had 17% more algae and 94% sand cover than the slopes. The functional groups represented by reef top indicator species primarily include herbivores and invertivores specializing on hard-bodied animals that are typically found in high sand environments. At the slope sampling locations the benthic habitat was characterized by 29%

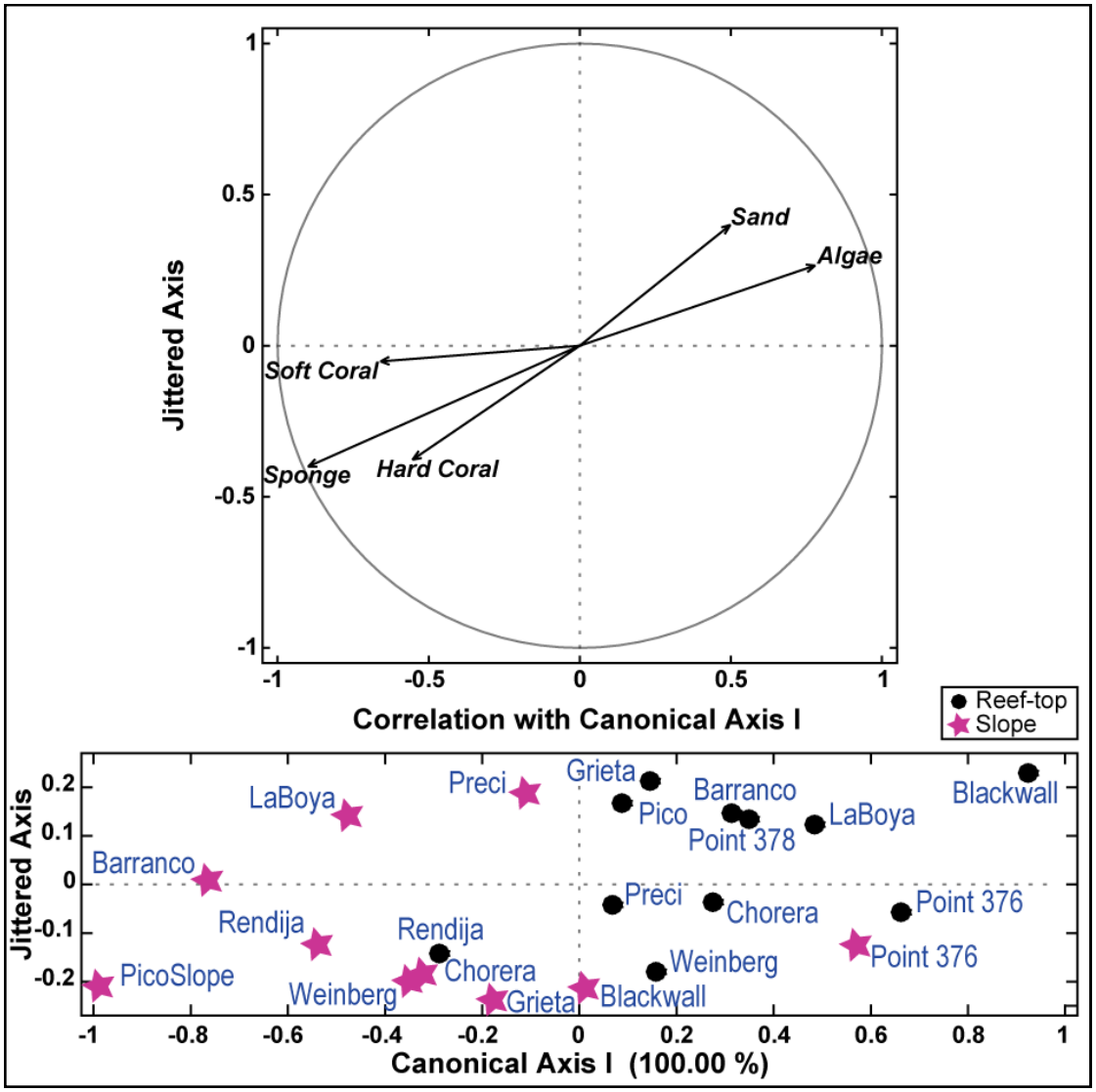

Figure 1. CAP ordination for habitat composition across all sites among the reef top and slope location stratifications. The ordination represents the relative dissimilarity between sampling sites and illustrates the division in substrate composition between sampling locations. The substrate biplot vectors above the ordination represent each variable's correlation with Canonical Axis I. Canonical Axis I explains 100% of the observed variability in substrate composition between the two location strata.

Table 1. Fish species (α = 0.05) and associated significant indicator values for the reef top vs. slope division. P-values are based on 1000 permutations.

Scientific Name	Common Name	Location	Functional Group	IndVal	P-value
Thalassoma bifasciatum	Bluehead	Reef Top	Invertivore (small crustaceans)	61.45	0.001
Halichoeres garnoti	Yellowhead wrasse	Reef Top	Invertivore (brittle stars, polychaetes)	56.96	0.001
Acanthurus bahianus	Ocean surgeonfish	Reef Top	Herbivore	55.1	0.002
Stegastes partitus	Bicolor damselfish	Reef Top	Planktivore	54.99	0.001
Haemulon flavolineatum	French grunt	Reef Top	Invertivore (small crustaceans)	54.97	0.03
Sparisoma aurofrenatum	Redband parrotfish	Reef Top	Herbivore	54.77	0.006
Scarus taeniopterus	Princess parrotfish	Reef Top	Herbivore	52.91	0.01
Chaetodon capistratus	Four eye butterflyfish	Reef Top	Invertivore (Gorgonian & coral polyps)	52.67	0.03
Gramma loreto	Fairy basslet	Slope	Planktivore	88.46	0.001
Neoniphon marianus	Longjaw squirrelfish	Slope	Zooplanktivore	69.54	0.003
Canthigaster rostrata	Sharpnose pufferfish	Slope	Invertivore	63.31	0.007
Mulloidichthys martinicus	Yellow goatfish	Slope	Invertivore (brittle stars, polychaetes)	58.35	0.006
Myripristis jacobus	Blackbar soldierfish	Slope	Planktivore	56.87	0.007
Abudefduf saxatilis	Sergeant major	Slope	Omnivore / Invertivore	53.11	0.027
Pomacanthus arcuatus	Gray angelfish	Slope	Sponge / Gorgonian	24.44	0.05

more hard coral, 56% more soft coral, and 41% more sponge cover. The presence of slope indicator species from the planktivore/Zooplanktivore, invertivore (soft bodied)/ omnivore, and sponge feeding functional groups, with a marked absence of any herbivorous fishes, was observed. These results suggest that when taking management action, within a shelf-edge ecotone, it is best to consider the unique combination of species and habitats present in the local environment. Individual species' trade-offs between food availability and shelter are likely to be impacting the organization of resources and, in order to account for the potential impacts of management, these trade-offs should be identified and considered. This work represents a framework for identifying community organization and ecological preference within a high-diversity ecotone, and it can be applied at varying levels of spatial and temporal resolution.

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