Explaining patterns in abundance of juvenile fish using Caribbean mangroves: A multi-scale seascape approach

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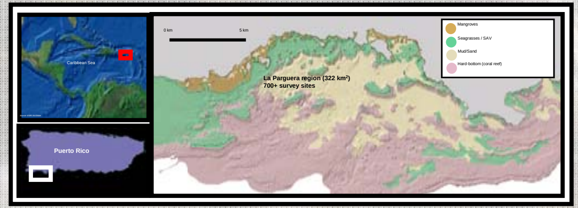
Introduction

Mangroves are generally considered to offer enhanced nursery function for many species of fish and have been linked to highly productive fisheries worldwide. Studies of individual fish movements, however, reveal that many species are using mangroves during only part of the daily home range movements (e.g., day/night shifts) or during distinct phases in their life-cycle. Consequently, it is increasingly acknowledged that: (1) mangroves do not function in isolation to provide nursery function and hence support local fisheries, and (2) mangroves exist as an important component of an interlinked mosaic of habitat types structured along the land-sea interface. Not surprisingly, the complex spatial patterns in fish density observed for many species are rarely explained sufficiently by mangrove characteristics alone. Instead, it is likely that the structure of the surrounding mosaic or "seascape" will also influence the way that fish species use mangroves. Shifting our focus to examine how fish species density and assemblage attributes vary with the structure of the surrounding seascape may allow us to identify the key explanatory variables driving spatial patterns and provide information at spatial scales useful to resource managers.

Objective and Study Area

This study was designed to identify and determine the relative importance of key explanatory variables for fish assemblages and individual species using mangroves in southwestern Puerto Rico (Fig. 1). The study area (La Parguera) is a Natural Reserve designated by the Puerto Rico Department of Natural Resources.

Figure 1. Location of study area



Methods

- Survey sites were selected randomly across hard and soft-bottom strata. Mangroves (n=126) were a component of the soft-bottom
- Fish were identified, counted and lengths estimated using daytime underwater visual surveys along a 25m long by 4m wide belt transect (100m²)
- Within-patch characteristics of mangroves (e.g., water depth, epibiont cover, sediment type, root density, biotic diversity, etc.) were quantified at each site using five random 1m² quadrats
- Structure of the surrounding seascape was quantified within radial extents of 50m, 100m, 300m and 600m using: (1) spatial analyses applied to bathymetry data, and (2) pattern metrics applied to NOAA' s benthic habitat map
- Metrics included bathymetric complexity, habitat diversity (patch richness, taxonomic diversity, Shannon diversity), patch density, number of patches, total edge and contagion for each habitat type and for the seascape unit as a whole

Analyses and Results

Multi-habitat utilization

Underwater visual fish census data (n=771) collected across habitat mosaics in Puerto Rico showed that many species use more than one habitat type (Fig. 2). 20% of all species (46 species) were utilizing all three major habitat types. These multi-habitat species were also the most abundant across the region (Fig. 3).

Figure 2.

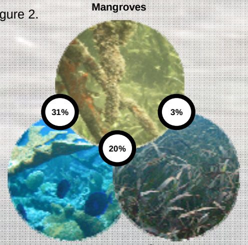
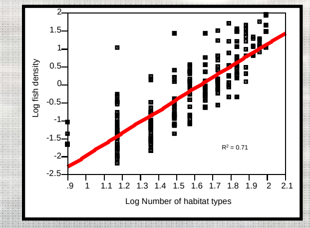


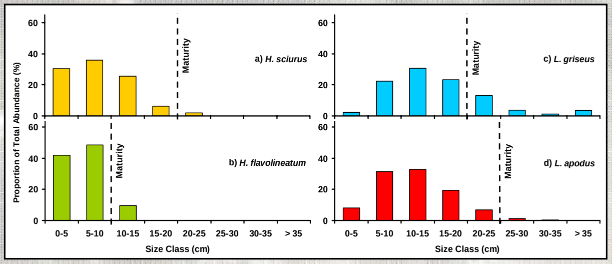
Figure 3.



Mangroves support high densities of juveniles

For many species that use multiple habitat types, higher densities of juveniles than adults were observed along the mangrove edge (Fig. 4a-d).

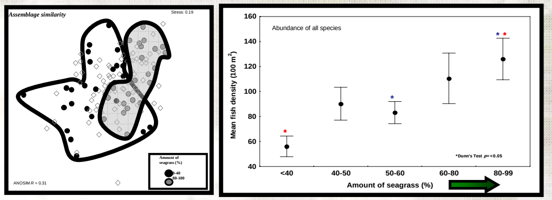
Figure 4.



Fish abundance in mangroves is determined by seascape composition

Preliminary results indicate that the amount and proximity of seagrass in the surrounding seascape influenced the density of juveniles and the composition of the fish assemblage in mangroves more than any other single variable type. Of secondary importance for many of the abundant species was the diversity of habitat types in the seascape and the total edge of mangroves. Within-patch characteristics were not strong predictors. Ordination plots of assemblage similarity (Bray-Curtis) and analysis of similarities (ANOSIM) indicated that fish assemblages using mangroves in seascapes with a large proportion of seagrass cover were significantly different from fish assemblages using mangroves in seascapes with little or no seagrass cover (Fig. 5).

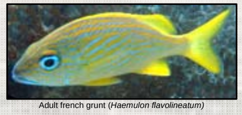
Figure 5.



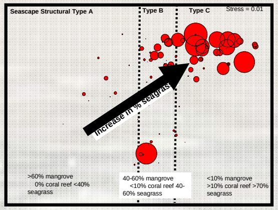
Juvenile grunts (*Haemulon flavolineatum* & *H. sciurus*) and a damselfish (*Stegastes leucostictus*) contributed most to assemblage dissimilarity.

Juvenile french grunts prefer mangroves with high seagrass cover in close proximity (Fig. 6a)

Fig. 6a



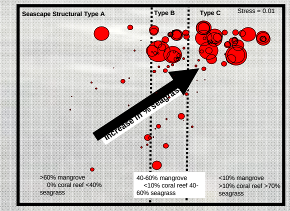
Adult french grunt (*Haemulon flavolineatum*)



Unexpectedly, a damselfish (*S. leucostictus*) and a butterflyfish, *Chaetodon capistratus,* (not shown) also showed a high preference for mangroves with adjacent seagrasses (Fig. 6b)

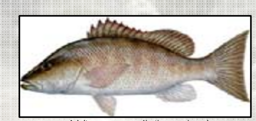
Fig. 6b

Juvenile beaugregory (*Stegastes leucostictus*)

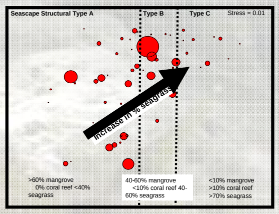


Juvenile gray snapper (*L. griseus*) and at least two species of Gerridae (not shown) have a preference for seascape with high mangrove area but with low seagrass cover/high unvegetated sediment cover (Fig. 6c)

Fig. 6c



Adult gray snapper (*Lutjanus griseus*)



Initial Findings

- Many fish species use multiple habitat types across coral reef ecosystems
- Juveniles are found in higher abundance in mangroves with large areas of continuous seagrasses in close proximity
- Indicative of the process of landscape complementation / supplementation

Management Implications

- These results have implications for design of habitat restoration schemes and prioritization of monitoring and protection
- Recent reports indicate that both seagrasses and mangroves have experienced substantial declines worldwide

Relevant Publications

Christensen JD, Jeffrey CFG, Caldow C, Monaco ME, Kendall MS, Appeldoorn RS (2003) Cross-shelf habitat utilization patterns of reef fishes in southwestern Puerto Rico. Gulf and Caribbean Research 14(2), 9-27.

Kendall MS, Kruer CR, Buja KR, Christensen JD, Finkbeiner M, Warner RA, Monaco ME (2002) Methods used to map the benthic habitats of Puerto Rico and the U.S. Virgin Islands. NOAA Technical Memorandum NOS NCCOS CCMA 152

Pittman SJ, McAlpine CA, Pittman KM (2004) Linking fish and prawns to their environment: A hierarchical landscape approach. Marine Ecology Progress Series 283: 233-254.

Pittman SJ, Christensen JD, Caldow C, Menza C, Monaco, ME (submitted) Predictive mapping of fish species richness across shallow-water seascapes in the U.S. Caribbean. Ecological Applications.

NOAA Center for Coastal Monitoring and Assessment's Biogeography Team

The Biogeography Team is in NOAA's National Centers for Coastal Ocean Science's Center for Coastal Monitoring and Assessment (CCMA). CCMA is currently involved in mapping, monitoring, and characterizing the marine environment.

The goal of the Biogeography Team is to develop knowledge and products on living marine resource distributions and ecology throughout the Nation's estuarine, coastal and marine environments, and to provide managers and scientists with an improved ecosystem basis for making decisions.

The Biogeography Team activities focus on developing products, applications and processes for defining and interpreting the relationships of species distributions and their environments. Most of our projects are done in cooperation with other groups. For information on all CCMA and Biogeography Team projects please visit the following website: http://ccma.nos.noaa.gov/about/biogeography/welcome.html

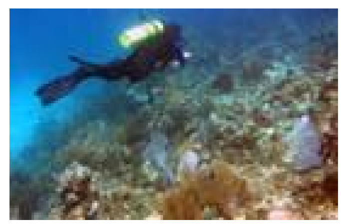
Work presented at this symposium is associated with Biogeography Team's Caribbean Coral Reef Ecosystem Monitoring Project.

Caribbean Coral Reef Ecosystem Monitoring Project

Objectives

The goals and objectives of this project are:

1. To spatially characterize and monitor the distribution, abundance, and size of both reef fishes and macro-invertebrate (conch, lobster, Diadema);
2. To relate this information to in-situ data collected on water quality and associated habitat parameters;
3. To use this information to establish the knowledge base necessary for enacting management decisions in a spatial setting;
4. To establish the efficacy of those management decisions; and
5. To work with the National Coral Reef Monitoring Program to develop data collection standards and easily implemented methodologies for transference to other agencies and to work toward standardizing data collection throughout the US states and territories. Toward this end, the Center for Coastal Monitoring and Assessment's



Project Summary

To achieve the above objectives, the CCMA's Biogeography Team (BT) has been working since 2000 in the US Virgin Islands and Puerto Rico. It is critical, with recent changes in management at both locations (e.g. implementation of MPAs) as well as proposed changes (e.g. zoning to manage multiple human uses) that action is taken now to accurately describe and characterize the fish/macro-invertebrate populations in these areas. It is also important that BT work closely with the individuals responsible for recommending and implementing these management strategies. Recognizing this, BT has been collaborating with partners at the University of Puerto Rico, National Park Service, US Geological Survey and the Virgin Islands Department of Planning and Natural Resources.

To quantify patterns of spatial distribution and make meaningful interpretations, we must first have knowledge of the underlying variables determining species distribution. The basis for this work therefore, is the nearshore benthic habitats maps (less than 100 ft depth) created by NOAA's Biogeography Program in 2001 and NOS' bathymetry models. Using ArcView GIS software, the digitized habitat maps are stratified to select sampling stations. Sites are randomly selected within these strata to ensure coverage of the entire study region and not just a particular reef or seagrass area. At each site, fish, macro-invertebrates, and associated water quality and habitat information is then quantified following standardized protocols see methodology link below). By relating the data collected in the field back to the habitat maps and bathymetric models, BT is able to model and map species level and community level information. These protocols are standardized throughout the US Caribbean to enable quantification and comparison of reef fish abundance and distribution trends between locations. Armed with the knowledge of where "hot spots" of species richness and diversity are likely to occur in the seascape, the BT is in a unique position to answer questions about the efficacy of marine zoning strategies (e.g. placement of no fishing, anchoring, or snorkeling locations), and what locations are most suitable for establishing MPAs. Knowledge of the current status of fish/macro-invertebrate communities coupled with longer term monitoring will enable evaluation of management efficacy, thus it is essential to future management actions.