Patterns and Drivers of Reef Fish Biodiversity in the Florida Keys National Marine Sanctuary from 1999 - 2016

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Abstract

The biodiversity of reef fish in the Florida Keys National Marine Sanctuary was evaluated in terms of abundance, biomass, evenness, species richness, Shannon diversity, Simpson diversity, and functional diversity, using observations collected from 1999 – 2016 by the Reef Visual Census program. To compare the different diversity indices, species richness, Shannon diversity, Simpson diversity, and functional diversity were converted into effective number of species. We examined the seven indices by level of protection and type of no-take marine zones and by three habitat strata. The study detected abundance, biomass, and diversity were significantly greater (except evenness) inside no-take marine zones compared to areas open to fishing. Smaller reserves had higher abundance, biomass, and richness values than larger reserves and areas open to fishing, but had moderately higher diversity values. This may be attributed to a few species with many individuals that are dominant inside and outside no-take marine zones. Surprisingly, none of the indices were significantly different (except for functional diversity) between the larger Ecological Reserve and areas open for consumption. This may be due to spillover effects. Furthermore, the no-take marine zones only explained a small proportion of total percent deviance in the indices. Habitat type had a greater influence on patterns in composition and diversity where high relief reef habitats had the greatest abundance, biomass, and diversity indices. Based on our results managers should prioritize preserving high relief reefs through a network of small reserves to enhance reef fish composition and biodiversity.

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Background

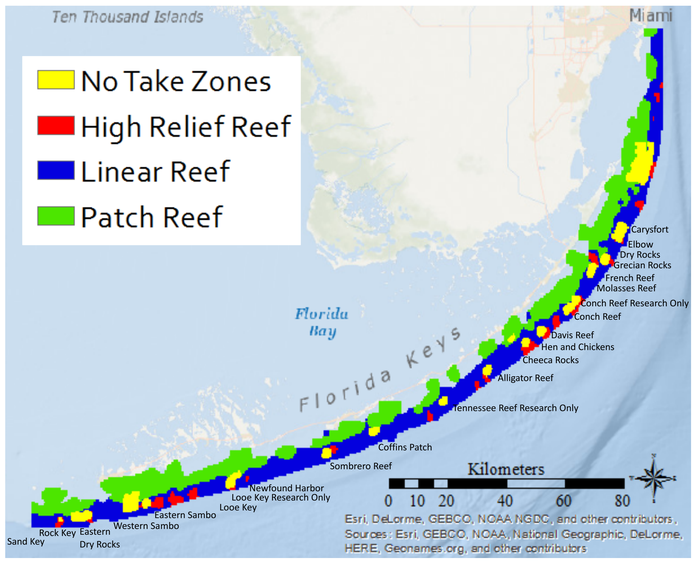

Figure 1. Map of the Florida Keys domain classified by habitat strata (High Relief Reef, Linear Reef, and Patch Reef) and 23 no-take marine reserves.

As part of the Marine Biodiversity Observation Network (MBON) efforts we sought to determine the efficacy of no-take marine zones on reef fish biodiversity in the Florida Keys National Marine Sanctuary (FKNMS). We analyzed and compared. changes in seven indices which were evaluated by level of protection, by multiple temporal and spatial scales, and were segmented across three habitat strata: High Relief Reefs, Linear Reefs, and Patch Reefs.

Functional Dendrogram

Table 1. Functional Traits (Stuart-Smith et al. 2013)

1. Maximum length
2. Trophic breadth
3. Trophic group
4. Water column position
5. Gregariousness
6. Diel activity pattern
7. Preferred substrate
8. Habitat complexity

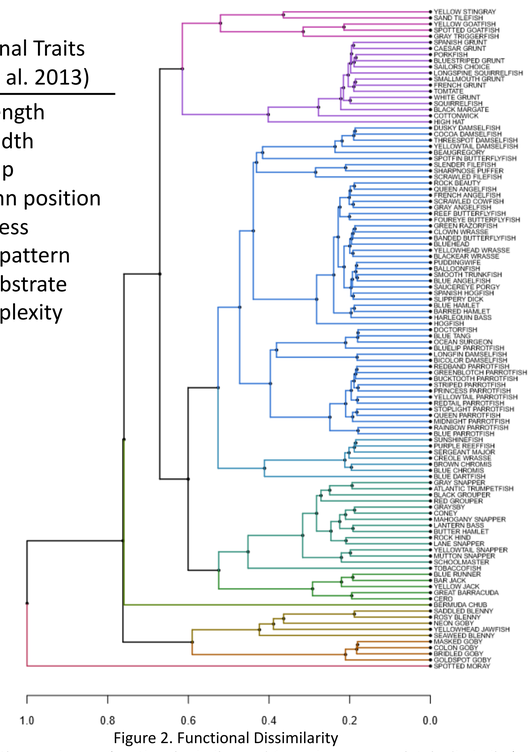

Figure 2. Functional Dissimilarity
(where 0 the species are functionaly similar, and 1 species are completely dissimilar)

Functional diversity was calculated based on eight traits known to influence fish assemblages (Table 1) and weighted by species relative abundances. Ecosystems with low functional diversity (i.e., the Florida Keys reef fish community; Fig. 7) are characterized as having high functional redundancy and implies low vulnerability to functional loss.

Drivers

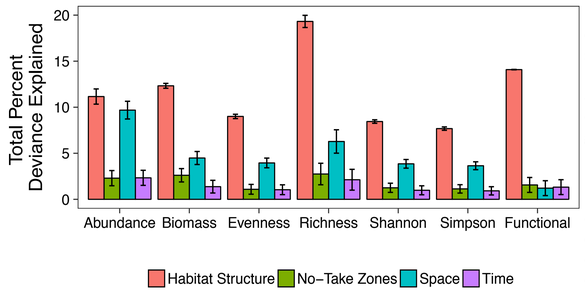

Figure 3. The partial contributions of habitat structure, no-take marine zones, space, and time to the total explained deviance from generalized additive models fit to the seven indices. Units are in percentage of total explained deviance, and error bars denote ± SE on partial deviance estimates.

Using generalized additive models, habitat structure (strata and depth) accounted for the largest proportion of total explained deviance for all the response variables. Our results further support the importance of habitat characteristics in controlling reef fish composition and diversity.

Summary

1. Biodiversity was significantly greater in more complex High Relief Reef habitats than in Linear or Patch reefs, and habitat strata explained the largest portion of total percent deviance over no-take zones, time, and space.

2. Biodiversity was significantly greater in no-take marine zones compared to areas open to fishing.

3. The low Shannon and Simpson diversity is a result of a few dominant species (i.e., species with large populations) and many rare species (i.e. species with small populations).

4. The low functional diversity and high functional redundancy (i.e., high number of species performing similar traits) may provide a level of resiliency against functional loss.

Habitat Strata

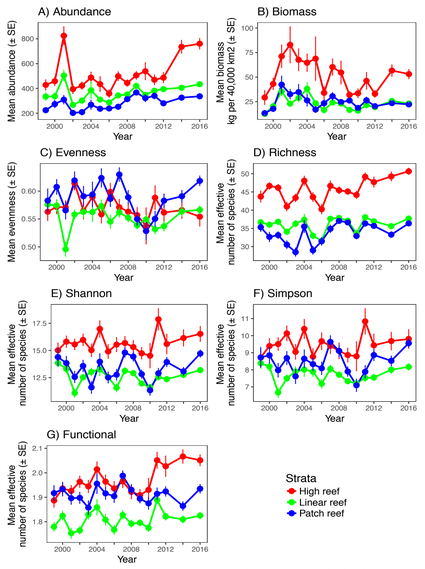

Figure 4. Reef fish biodiversity by habitat strata.

Reef fish composition and biodiversity was significantly greater in more complex High Relief Reef (>2m vertical relief) habitats than in Linear or Patch reefs. Reef fish often prefer more complex habitats because they provide refuge sites as well as foraging grounds.

No-Take Marine Reserves

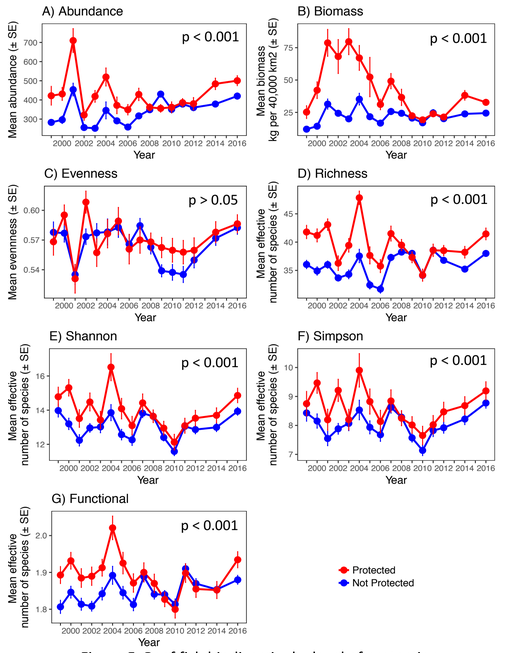

Figure 5. Reef fish biodiversity by level of protection.

The 23 no-take marine zones make up <1% of the FKNMS surface area. However, all indices (except evenness) were significantly greater inside no-take marine reserves than unprotected areas.

Species Abundance Data

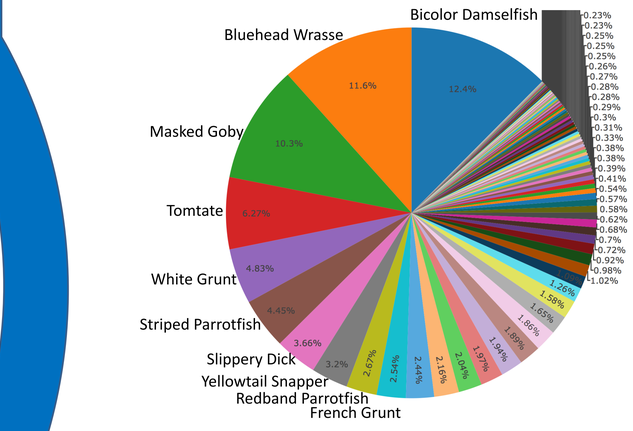

Figure 6. Species percent of total abundance data.

Of the 108 species detected, ten accounted for 62% of the total abundance data and 86 species accounted for <1% of the abundance data. This may be a result of intense competition.

Species Diversity

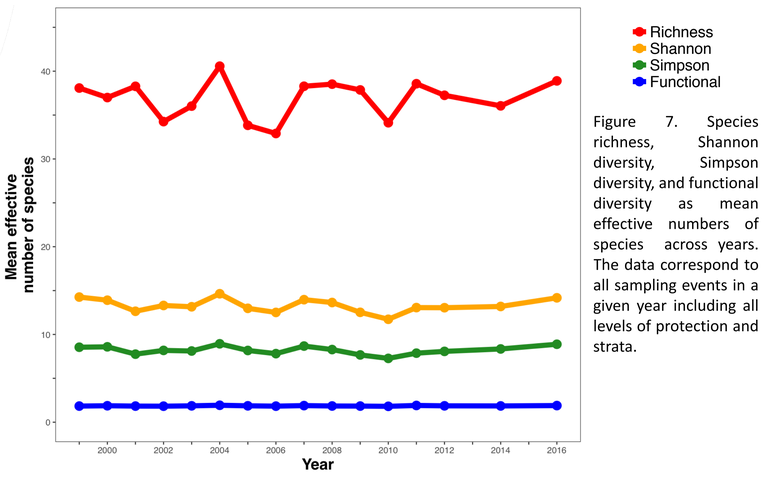

Figure 7. Species richness, Shannon diversity, Simpson diversity, and functional diversity as mean effective numbers of species across years. The data correspond to all sampling events in a given year including all levels of protection and strata.

Richness was on average 3 X greater than Shannon diversity and 5 X greater than Simpson diversity due to the ecosystem being dominated by a few species with large populations and many rare species (Fig 6).

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Reference: Stuart-Smith RD, Bates AE, Lefcheck JS, Duffy JE, Baker SC, Thomson RJ, … Edgar GJ (2013) Integrating abundance and functional traits reveals new global hotspots of fish diversity. Nature, 501(7468), 539–542;