The Coral Reef Fishes of Broward County Florida, Species and Abundance: A Work in Progress

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ABSTRACT

The inshore environment of Broward County, FL consists of three coral reef/hard bottom reef tracts, separated by sand substrate, running parallel to the coast in sequentially deeper water. At quarter nautical mile intervals, for a five mile coastline section, fishes were censused at western, eastern and crest sites of each of the three reef tracts. On SCUBA and using the Bohnsack/Bannerot point-count method, we recorded: fish abundance, species richness, size, and general habitat of an imaginary cylinder 15 m in diameter. The position of each site was recorded by DGPS after census. One hundred and eighty-one sites were censused during a 10 month period (August 1998 to May 1999).

A total of 16,746 fish belonging to 139 species of 39 families were recorded. There were significant differences ($p < 0.05$, ANOVA) in the species richness and the total abundance of fishes among the three reef tracts. There were significantly fewer total fish ($p < 0.001$) and fewer fish species ($p < 0.001$) on the inshore reef tract as compared to either the middle or offshore reef tracts. The middle and offshore reefs tracts did not differ ($p > 0.05$, SNK). Differences were also found based on the location (edges or crest) on the reef. With all data from the three reef tracts combined, the eastern edge showed significantly fewer total fish ($p < 0.001$) than either the crest of the reef or the western edge, which did not differ significantly ($p > 0.05$). Species richness also varied with the western edges of the tracts having significantly more species ($p < 0.01$) than the crests or the eastern edges, again there was no significant difference between these two ($p > 0.05$). Statistical analysis of a subjective complexity rating taken at each site mirrored the results of fish abundance and species richness. This supports the hypothesis that topographical complexity is, at least in part, a determinant in the differences in fish assemblages among the three reef tracts.

KEY WORDS: Visual census, coral reef fish, complexity

INTRODUCTION

Monitoring of marine resources is becoming more important as the popularity of fishing, diving, boating and development of coastal areas increases. Baseline surveys are a vital part of this monitoring process. With little to no studies conducted in rapidly growing and changing areas such as Broward County, Florida, USA, it is important to determine a baseline inventory and understanding of the fish assemblages. Such data is required to monitor changes resulting from anthropogenic or natural activities and provide useful information for the management of aquatic resources.

The purpose of our research is to conduct a quantitative study of the inshore marine fishes of Broward County. This preliminary study examined both abundance and distribution of reef fishes on Broward County's three natural reef tracts over a stretch of five nautical miles (approximately 25% of Broward County's coast line).

METHODS AND MATERIALS

Study Area

The near-shore marine environment off the coast of Broward County, FL, USA, is characterized by three reef tracts that run parallel to the coast in a north-south direction, in sequentially deeper water (Goldberg, 1973). The individual reef tracts are plateau-like structures with the largest changes in profile usually at either their western or eastern edges or both. Sandy soft sediment separates each reef tract. Hereafter we refer to these three tracts as the inshore, middle, and offshore reef tracts.

The area of this study was located off the coast of Broward County from Port Everglades inlet (265 05.5° N, 0805 06° W) south for five nautical miles and from the western edge of the inshore reef tract to the eastern edge of the offshore reef tract (approximately 1.5 nautical mile). The area was divided into 20, east-west transects, each transect separated from its neighboring transect by one quarter nautical mile. Along each transect were nine sample sites: one on the western edge, one on the reef crest (or midpoint if no crest was determined) and one on the eastern edge of each of the three reef tracts for a total of 180 planned sites.

Sampling Technique

Sampling was conducted using the non-destructive Stationary Visual Census Technique (Point-Count) which censuses the fish in an imaginary 15 m diameter cylinder from substrate to surface (Bohnsack and Bannerot 1986). Individual transects were followed, with the aid of DGPS, from inshore to offshore and using a depth plotter, the bottom composition was observed and topographical characteristics were determined. The gross topographical characteristics were used to determine specific sites along the tract. Sites, on each transect, were chosen to represent the eastern and western edges and crest of each of the three reef tracts. In certain instances there were no obvious crests and a middle point between the eastern and western edges was used as the crest sample site. A total of 20 transects were sampled.

Buoys were deployed to mark each site. Divers were deployed in two man teams consisting of one trained fish counter and a safety diver. Each dive team was equipped with: a 7.5 m line and attached anchor weight; a clipboard with a waterproof data sheet and pencil; an underwater watch; and a one meter fish-stick, used as an aid in measuring fish lengths. At the bottom, the safety diver would attach a 7.5 m line to the buoy line, then swim it out from the center in a straight line before anchoring it on the bottom in an area clear of delicate benthic organisms. This line was used as a reference to define the sample cylinder. The safety diver would then remain outside of that cylinder, within visual contact, while the trained fish counter would complete the sample. Prior to beginning the fish count, the counter recorded the bottom coverage, estimated in percent of 21 different substrates (i.e. coral, sand, sponge etc.),and assigned a complexity rating to the site. The complexity rating was a subjective scale from 1 - 10 which used a local, complex site as a standard. On initiating the census the fish counter would pivot around to scan the entire cylinder and would record all species observed during a five minute period. Following this initial five minute sample, the abundance, mean size, minimum size and maximum size were recorded for each species observed during the initial five minutes. Sample times outside of the five minute initial count were normally kept to no more than 20 minutes. The 20 minute time limit was sufficient to complete abundance and size data collection and allowed divers to complete repetitive dives within a day without decompression.

The data collected was entered into RVC Data Entry System (Weinberger 1998) program, Microsoft Excel and SAS (Statistical Analysis Systems). Microsoft Excel was used to determine general descriptive statistics. The same data entered into SAS was analyzed with non-parametric analysis of variance techniques [PROC GLM of ranked data (≈ Kruskal-Wallis k-sample test), and the Student-Newman-Keuls test between means].

RESULTS

General site description

During data collection, we noted the sample sites included a variety of environments including large reef rock, coral rubble, ledge lines and low profile hard bottom. The inshore reef tract was found in depths ranging from 3.1 m to 9.2 m with the lowest point of the western edge ranging from 4.6 m to 8 m deep. The crest of the inshore reef ranged from 3.1 m to 8 m. The eastern edge of the inshore reef was found between 5.2 m and 9.2 m. Generally, the western edge of the inshore reef tended to be a well defined ledge. The crest of the inshore reef varied from relatively barren hard bottom to diverse coverage with very little to no vertical profile. In most cases, the eastern edge of the inshore reef tapered out from low relief hard bottom to rubble and sand (Figure 1).

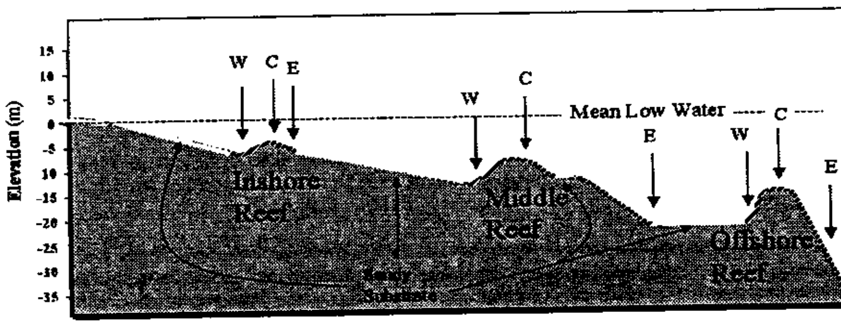

Figure 1. Depth profileof a generalized transect from west to east. Census sites indicated by: W = Western Edge, C = Crests, E = Eastern edges. Diagram not to scale.

The middle reef usually had a well defined western ledge followed by an obvious crest that would taper out to a wide sand flat. The reef extended from 7.4 m to 21.8 m in depth with the western edge 7.7 m to 13.5 m deep; the crest ranged in depth from 7.4 m to 13.2 m; and the eastern edge was between 10.8 m and 21.8 m deep. Unlike the western edge, the eastern edge of the middle reef varied from a ledge to an edge with continual hard bottom which lead onto an initial sandy flat. Following this sand flat there was a narrow downward hard bottom approximately 15.4 m in width, before a well defined edge occurred followed by a sand flat. For this study, the eastern edge of the middle reef was defined as this second edge.

The offshore reef tract ranged in depth from about 14.2 to 31.4 m. The western edge of the offshore reef begins at a depth of about 15.4 m but was found as deep as 20.9 m. The offshore crest was found anywhere between 14.2 and 19.4 m while the eastern edge of the offshore reef ranged from 24.9 m to over 31.4 m deep. The western edge of the offshore reef was generally defined by an obvious edge. The crest of the offshore reef was found to be hard bottom with varying amounts of hard and soft corals. The eastern edge was well defined with, in some cases, the appearance of spur and groove formations. In some instances our definition of the eastern edge was limited by our diving limitations (35 m).

It is important to note that the characteristics for the three reef tracts, outlined above, represent an average impression; even within an edge of a single reef tract there were substantial differences in depth and habitat characteristics.

Study sites were initially sampled between August 1998 and May 1999. A total of 181 sites were surveyed during this period. Although we planned to census 180 unique sites, four planned sites were inadvertently missed and one transect received five additional sites. A total of 16, 746 individual fish made up of 139 species representing 39 families were recorded.

Statistical analysis indicated significantly lower abundance ($p < 0.001$) and lower species richness ($p < 0.001$) on the inshore reef tract as compared to either the middle or offshore reef tracts. The middle and offshore reefs tracts did not appear to differ between each other ($p > 0.05$) (Figures 2 and 3). Interestingly, an analysis of the complexity ratings indicated similar differences among reef tracts. The middle and offshore reefs did not differ from each other ($p > 0.05$) but both were significantly greater than the inshore tract.

Differences were also found based on the site location on the reef. With all data from the three reef tracts combined, the eastern edge showed significantly fewer total fish ($p < 0.001$) than either the crest of the reef or the western edge, which did not differ significantly ($p > 0.05$) (Figure 4). Species richness also varied with the western edge of the tracts having significantly more species ($p < 0.01$) than the crest or the eastern edges, again no significant difference was apparent between these two ($p > 0.05$) (Figure 5). Site complexity also mirrored this pattern with the eastern edge having the lowest complexity ($p<0.05$).

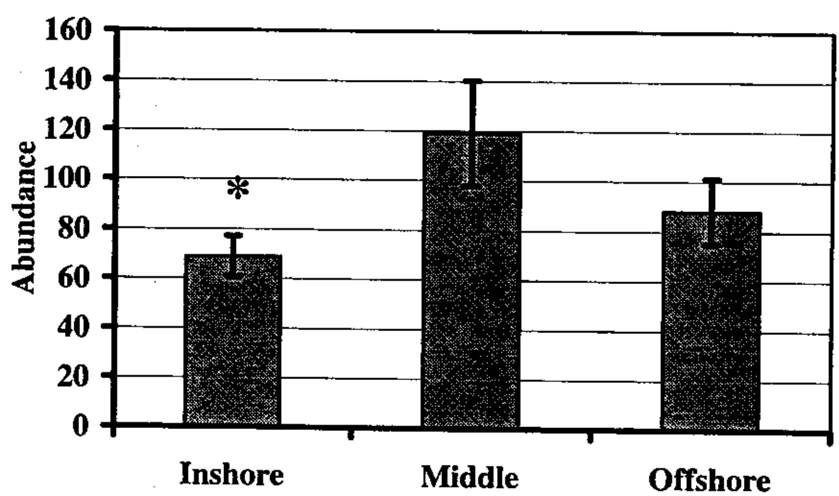

Figure 2. Mean (± 1 SEM) Fish abundance on each of the three reef tracts. *Indicates significantly different from non-asterisked tracts ($p < 0.05$, SNK)

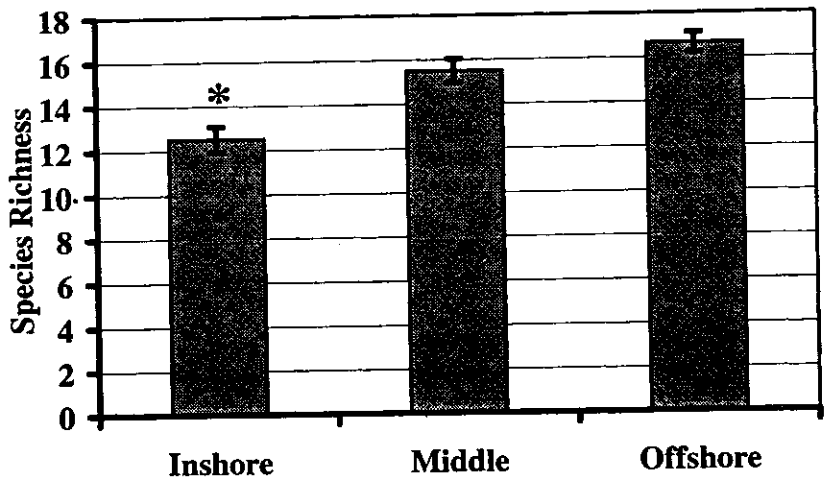

Figure 3. Mean (± 1 SEM) Species richness on each of the three reef tracts. *Indicates significantly different from non-asterisked tracts ($p < 0.05$, SNK)

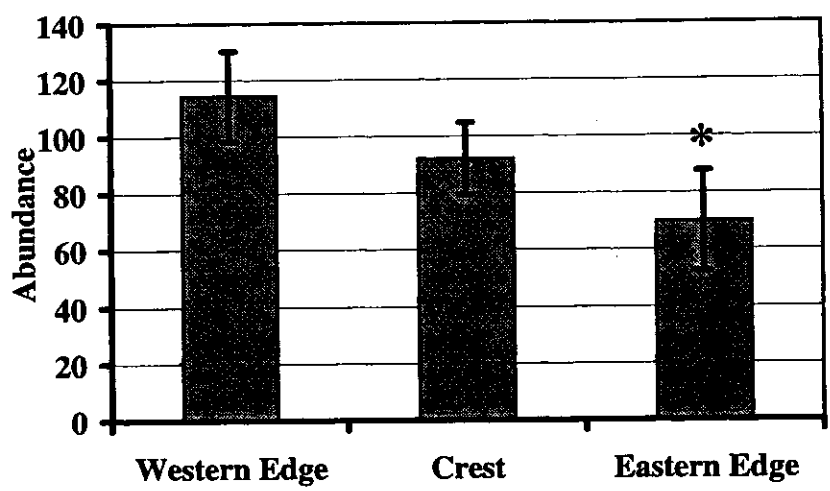

Figure 4. Mean (± 1 SEM) Fish abundance by reef site. *Indicates significantly different from non-asterisked edges ($p < 0.05$, SNK)

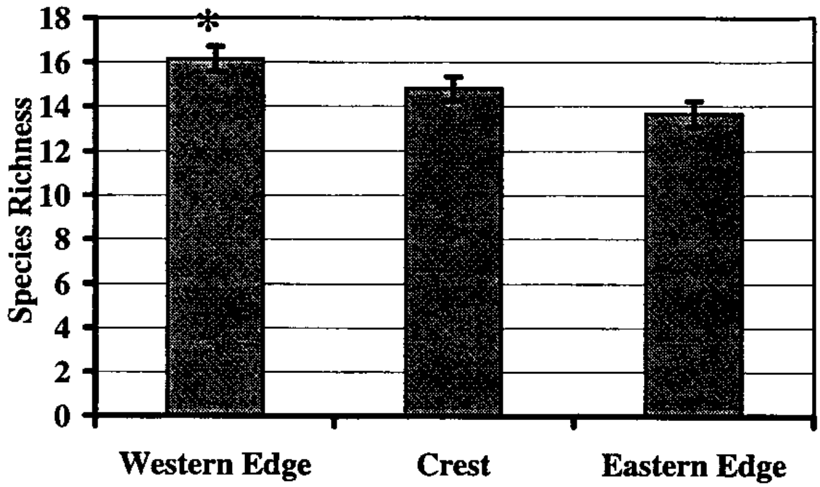

Figure 5. Mean (± 1 SEM) Species richness by reef site. *Indicates significantly different from non-asterisked edges ($p < 0.05$, SNK)

DISCUSSION

Results of this study indicate an overall difference in abundance and species richness among the three reef tracts with both fewer species and total fish on the inshore reef as compared to both the middle and offshore reef tracts. The study was intended mainly to inventory a portion of the Broward County reef tracts. Nonetheless, the differences in fish assemblages among the three tracts warrants some discussion. It is not surprising that we find differing species associated with three reef tracts at differing depths. Most marine fishes appear to have a depth preference, or at least a range in which they are routinely found (Robins et al. 1986, Humann 1994, Froese 1997). Of interest, both from ecological as well as management standpoints, are the biotic and abiotic factors which are involved in forming and maintaining the associations of fish with specific areas of a reef.

Several previous studi es have examined the coral reef fish assemblages on inshore and offshore reefs. None of these studies are readily comparable to this study as they differ substantially in water depth (Thompson et al. 1990, McGehee 1994, Chabanet et al. 1997), distances between reefs (Williams 1982), or sampled a variety of habitats (Galzin and Legendre 1987). However, in each case the authors also found differences amongst sites inshore to offshore. These authors ascribed the difference between sites to a host of potential abiotic and biotic variables. Physical factors deemed to be important included: current, wave exposure, shelter, sediment loads, water depth, substrate, topographical complexity; biological factors included predation, larval recruitment, coral and other benthic communities. Certainly, many of these variables may have played a role in establishing the differences noted in our study. Water depths differed among the three tracts, and although we did not take objective data, it is clear from our diving experience there is substantial differences in sediment load and current between the sites (Sherman et al. 1999). Likewise, there were differences in larval recruitment and resident predators between sites (Gilliam 1999, Sherman et al. unpublished data). Although we recorded data on the bottom substrate, both living (i.e. corals, sponges, algae) as well as non-living (i.e. sand, hard bottom, coral rubble), we have not statistically examined any correlations between substrate or benthic communities and fish assemblages. There has been considerable research on the linkage between topographical complexity or refuge and fish assemblages. There are exceptions, but in general, increased complexity has been correlated with increased species richness as well as increased fish abundance (for references see: Spieler et al. in press). The similarities in our results between the areas of greatest complexity and the areas of greatest species richness and fish abundance support a role for topographical complexity in determining the difference noted between the inshore reef tract and the middle and offshore tracts. A more complete determination of the causal agents involved awaits further research.

In conclusion, this study is part of an ongoing survey of the fishes of Broward County. Upon completion, it will provide baseline data for determining changes in local populations of fishes and appropriate management strategies. In addition, because the census data includes substantial habitat information, we anticipate the survey will generate a host of hypotheses regarding the interaction of coral reef fishes with their physical and biotic environment. This information may ultimately prove essential to understanding and managing critical fish habitat.

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LITERATURE CITED

Bohnsack, J.A. and S.P. Bannerot. 1986. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes. U.S. Dept. of Commerce, NOAA Technical Report NMFS **41**:1-15.

Chabanet, P., H. Ralambondrainy, M. Amanieu, G. Faure and R. Galzin. 1997. *Coral Reefs*. **16**:93-102.

Froese, R. 1997. Fishbase, a database with key information on coral reef fish. *Proc. 8th Int. Coral Reef Sym.* **2**:1545-1548.

Galzin, R. and P. Legendre. 1987. The fish communities of a coral reef transect. *Pacific Science* **41**:158-165.

Gilliam, D.S. 1999. *Juvenile fish recruitment processes in south Florida: a multifactorial field experiment.* Ph.D. Dissertation. Nova Southeastern University, Dania, FL. 111 pp.

Goldberg, W. M. 1973. The ecology of the coral-octocoral communities off the southeast Florida coast: geomorphology, species composition, and zonation. *Bull. Mar. Sci.* **23**:467-488.

Humann, P. 1994. *Reef Fish Identification*. New World Pub. Inc. Jacksonville, FL. 406 pp.

McGehee, M.A. 1994. Correspondence between assemblages of coral reef fishes and gradients of water motion, depth, and substrate size off Puerto Rico. *Mar. Ecol. Prog. Ser.* **105**:243-255.

Robins, R.C. and G.C. Ray. 1986. *A Field Guide To Atlantic Coast Fishes Of North America.* Houghton Mufflin Co. Boston. 354 pp.

Sherman, R.L., D.S. Gilliam and R.E. Spieler. 1999. A preliminary examination of depth associated spatial variation in fish assemblages on small artificial reefs. *Jour. Of Appl. Ichth.* **15**:116-121.

Spieler, R.E., D.S. Gilliam and R.L. Sherman. Artificial substrate and coral reef restoration: what do we need to know to know what we need. *Bull. Mar. Sci.* In Press.

Thompson, T.E., D.G. Lindquist, I.E. Clavijo, S.K. Bolden, S.W. Burk and N.C. Drayton. 1990. Assessment of reef fishes at Sombrero Key, Florida. *Proc. AAUS 10th Ann. Sci. Diving Sym.* 375-381.

Weinberger, L. 1998. *RVC User's Guide, Reef Fish Visual Census Version 1.* National Marine Fisheries Service, Miami, FL. 414 pp.

Williams, D. McB. 1982 Patterns in the distribution of fish communities across the central Great Barrier Reef. *Coral Reefs*.**1**:35-43.