The Influence of Habitat Complexity on Diversity, Abundance, and Distribution of Fish on a Coral Reef

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INTRODUCTION

Structural complexity of the coral-reef substrata play significant roles in the structuring of coral-reef fish communities. Several studies demonstrated that fish species diversity and abundance of fish are strongly influenced by the type of coral reef substrate and its topographic complexity (Talbot, 1965; Emery, 1973; Risk, 1972; Luckhurst and Luckhurst, 1978; Sale and Dybdahl, 1975, 1978; Bell and Galzin, 1984). Habitat characteristics of coral reefs also exhibit strong influence on the recruitment of coral reef fishes (Sale *et al.*, 1980; Luckhurst and Luckhurst, 1977; Shulman, 1984, 1985a,b).

Turingan and Acosta (1990) report that the diversity and abundance of fish from five transects on a small submerged coral patch reef in Puerto Rico vary. They stress that comparisons of the species composition and abundance of fishes on any pairs of transects yield a low percentage of similarity values, indicating that a distinct fish assemblage occurs on each transect.

In this paper we present preliminary results of our ongoing study designed to examine the relationships between fish community parameters (*e.g.* diversity and abundance) and several substrate characteristics (*e.g.*, non-fish diversity, coral diversity, and substratum rugosity).

MATERIALS AND METHODS

The study was conducted on a redundant submerged patch reef known as Corona de Laurel located about 2 km off La Parguera on the southwest coast of Puerto Rico (see Turingan and Acosta 1990 for description of the study site). Five 50 m line transects were established on the reef (Figure 1).

Fishes on each transect were visually censused 6 times (one every three days) during February and March of 1990 and 1991. Turingan and Acosta (1990) detail the procedure employed to record fishes on each transect. During the summer (June to August) of 1991 about 100 man-hours of SCUBA diving were spent collecting quantitative data on several substrate variables from each transect. Except for substratum rugosity, all measurements were made using the belt quadrat method adapted from Dodge *et al.* (1982). A 1 m^2 quadrat made of iron (further subdivided into 1/4 m^2) was centered on a line marking each

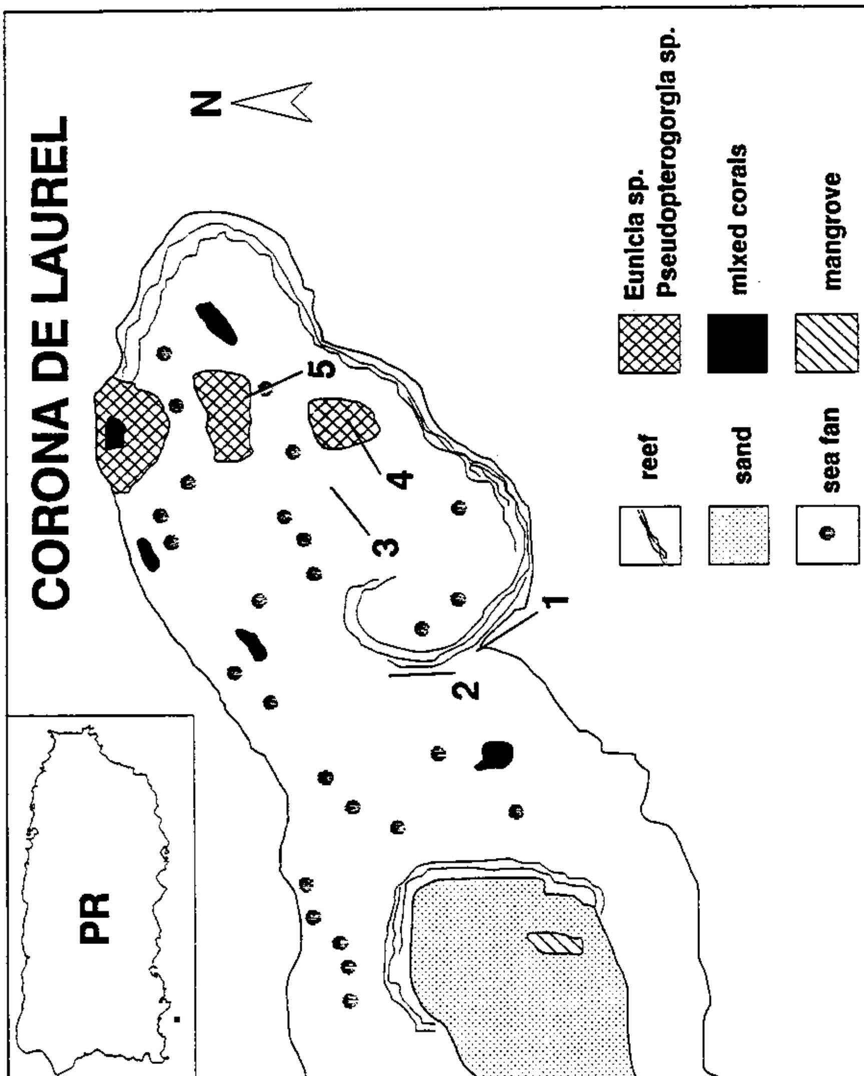

Figure 1. The study site, Corona de Laurel reef, located on the southwest coast of Puerto Rico. The map is not drawn to scale.

transect (Figure1). The quadrat was flipped every other meter starting from the first meter to the end of the transect, making a total of 25 quadrats surveyed on each transect. From each quadrat, the percent cover of the lowest identifiable taxon of soft and hard corals, algae, echinoderms and molluscs was estimated, and the number of taxa was recorded. Total coverage of each taxon and the total number of taxa for each transect was obtained by pooling the data from all 25 quadrats. For each transect, proportionate or relative coverage was obtained by dividing the total area covered by each taxon by the total area covered by all taxa.

Substratum rugosity was measured using a modified version of the "chain-link" procedure developed by Luckhurst and Luckhurst (1978). A 100 m long fiberglass tape was used instead of a "chain-link". Starting from one end of the transect line and through 50 meter mark was the tape pressed on the substrate to follow its contour as accurately as possible. This was repeated at every 0.5 m interval parallel to the main transect line up to the two-meter boundary on either side of the transect line. A total of seven rugosity measurements were made on each transect station.

The Shannon-Wiener Diversity H' index (Pielou, 1966a,b) was calculated: (1) Fish Species Diversity $H' = -(N_i/N)*Ln(N_i/N)$, where N is the total number of fishes for all species, N_i is the number of individuals of the ith species ($i = 1$ to S, the total number of species) and Ln is natural logarithm; (2) Non- fish Diversity $H' = -(N_i/N)*Ln(N_i/N)$, where N is the total substratum coverage for all non-fish taxa, N_i is the proportionate coverage of the ith taxon ($i = 1$ to S, the total number of taxa) and Ln is natural logarithm; and (3) Coral Species Diversity $H' = -(N_i/N)*Ln(N_i/N)$, where N is the total substratum coverage for all coral species, N_i is the proportionate coverage of the ith species ($i = 1$ to S, the total number of species) and Ln is natural logarithm . The evenness J' component for each of the above H' indices was also calculated: $J' = H'/Ln(S)$.

Correlation analyses were made using Systat 5.01 (Wilkinson, 1990) on an IBM personal computer. For these analyses all percentage coverage data were arcsine transformed.

RESULTS

A summary of the fish community parameters is presented in Table 1. Except for the evenness index which varied the least, parameter values tend to decrease from transect I to III, then increased toward transect V. *Thalassoma bifasciatum* topped the list of fish species in terms of number of fish per 200 m^2. Only four of these species occurred in all five transects and majority of these fishes were not observed in transect V.

Table 2 summarizes the community parameters for the non- fish communities on Corona de Laurel reef. Transect I was the most species rich and

Table 1. Quantitative distribution of the ten most abundant fish s (I - V) at Corona de Laurel reef.

SPECIES	TRANSECTS I	II	III	IV	V
Holocentrus rufus	12.03	1.67	0.00	0.00	6.92
Acanthurus bahianus	9.10	5.58	3.20	4.75	5.08
Chromis multilineatus	13.57	0.00	0.00	0.00	12.25
Stegastes planifrons	15.85	0.00	0.00	0.00	6.73
Stegastes partitus	19.75	4.33	0.00	3.33	13.54
Thalassoma bifasciatum	11.21	2.60	4.00	11.00	44.17
Sparisoma aurofrenatum	8.20	6.08	4.75	3.92	6.20
Scarus croicensis	10.75	0.00	1.50	4.33	18.00
Scarus taeniopterus	2.88	1.67	0.00	3.75	11.12
Mulloidicthys martinicus	16.20	0.00	0.00	3.00	1.33

Table 2. Quantitative distribution of non-fish community paramet substratum rugosity on five transects at Corona (See text for description of each parameter).

TRANSECTS	I	II	III	IV
Non-fish Sprecies Richness	34.00	30.00	19.00	25.00
Non-fish Evenness J'	0.68	0.74	0.54	0.65
Non-fish Diversity H'	2.39	2.51	1.58	2.09
Coral Species Richness	19.00	14.00	7.00	11.00
Coral Evenness J'	0.54	0.69	0.84	0.75
Coral Diversity H'	1.59	1.82	1.63	1.81
Substratum Rugosity	1.90	1.44	1.04	1.14

structurally complex as indicated by non-fish richness, coral species richness, and substratum rugosity.

Correlation coefficients between the fish and non-fish community parameters are presented in Table 3. Only two fish community parameters (Fish Diversity H' and distribution of *Acanthurus bahianus*) was significantly correlated with non-fish richness. The only parameter that was positively correlated with Coral Diversity was Fish Species Evenness J'. Among the negative correlations obtained with this variable, only the distribution of *Scarus croicensis* was significant. Coral Species Evenness J' had the most number of significant negative correlations with the fish community parameters. All fish parameters except Fish Species Evenness J' were positively correlated with substratum rugosity.

Table 3. Coefficients of correlation between fish and non-fish (including substratum rugosity) community characteristics from five transects at Corona de Laurel reef. NOFISHH' = Non-fish Species Diversity H', NOFISHJ' = Non-fish Species Evenness J', NOFISHSP = Non-fish Species Richness, CORALH' = Coral Species Diversity H', CORAL J' = Coral Species Evenness J', CORALSP = Coral Species Richness and RUGOSI TY = Substratum Rugosity (See text for description of each parameter).

	NOFIHH'	NOFISHJ'	NOFISHSP	CORALH'	CORALJ'	CORALSP	RUGOSITY
Fish Species Diversity H'	0.896	0.803	0.872*	-0.220	-0.947*	0.883*	0.962**
Fish Species Evenness J'	0.069	-0.560	0.268	0.966**	0.485	0.165	-0.287
Fish Density	0.458	0.452	0.387	-0.789	-0.914*	0.480	0.820*
Fish Species Richness	0.705	0.652	0.658	-0.564	-0.990**	0.716	0.954*
Holocentrus rufus	0.509	0.940	0.631	-0.575	-0.919*	0.728	0.942*
Acanthurus bahianus	0.701	0.507	0.919*	-0.093	-0.843	0.969**	0.940*
Chromis multilineatus	0.395	0.358	0.399	-0.778	-0.893*	0.507	0.829*
Stegastes planifrons	0.410	0.262	0.621	-0.517	-0.852	0.733	0.901*
Stegastes partitus	0.577	0.485	0.639	-0.569	-0.959*	0.727	0.939*
Thalassoma bifasciatum	0.154	0.336	-0.215	-0.841	-0.519	-0.163	0.253
Sparisoma aurofrenatum	0.603	0.467	0.737	-0.399	-0.850	0.797	0.958*
Scarus croicensis	0.248	0.329	0.058	-0.878*	-0.738	0.151	0.543
Scarus taeniopterus	0.213	0.405	-0.192	-0.771	-0.511	-0.156	0.230
Mulloidicthys martinicus	0.360	0.131	0.732	-0.138	-0.669	0.829	0.787

* = $P < 0.05$; ** = $P < 0.01$

DISCUSSION

Variations in species composition and abundance of fishes on Corona de Laurel reef were evident over the small spatial scale examined. Several studies demonstrate that the community structure of coral reef fishes in the Caribbean is highly correlated with several characteristics of coral reef substrata. Smith and Tyler 1972, 1975, Luckhurst and Luckhurst 1978, Gladfelter and Gladfelter 1978, Gladfelter *et al.* 1980, Anderson *et al.* 1981, and Kaufman and Ebersole 1984 revealed that habitat microtopography, substrate complexity or rugosity and food availability play very important roles in organizing and structuring coral-reef fishes. Among the substratum variables examined in this study, substratum rugosity seemed to have the strongest influence on fishes of Corona de Laurel reef. Fish species diversity was strongly positively correlated with rugosity. Risk (1972) and Luckhurst and Luckhurst (1978) have demonstrated positive correlations between diversity and abundance of fish and substrate topographical complexity in the Virgin Islands and Netherlands Antilles respectively. However, the substrate rugosity values that they obtained (about 4.5 maximum) were greater than the values we obtained in our study. This was because most of our transects were set on flat sandy back reef areas.

In our study, fish species diversity was significantly correlated with non-fish diversity but not with coral species diversity. Although there were few species of hard coral observed in our study site, most of the species present had growth forms that provided more shelter sites for fishes and surface area for possible colonization by prey organisms and algae. Luckhurst and Luckhurst (1978) also found that coral species richness is not correlated with fish species density.

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