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Cover photograph – “Little Ricky” - juvenile dolphin, San Salvador, Bahamas (courtesy of Sandra Voegeli, 2003)

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FISH ASSEMBLAGES ASSOCIATED WITH CORAL PATCH REEFS AT SAN SALVADOR, BAHAMAS

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ABSTRACT

Coral reef ecosystems have the greatest diversity of all aquatic realms in terms of species and habitats. During the past 30 years, ecologists have tried to elucidate processes that account for the great biodiversity of fishes found on coral reefs. Now it is widely accepted that both recruitment and post-settlement processes shape an assemblage of reef fish. We examined reef fish assemblages at three contrasting patch reefs at San Salvador, Bahamas, and the potential role of each reef's coral community in structuring its fish community. The three reefs differed in percent coral cover (total, scleractinian, gorgonian), dominant coral species, rugosity and algal cover, but not in coral species richness or Shannon's diversity. Differences in mean fish counts (total, Acanthuridae, Labridae, Scaridae, Invertivores, Herbivores) and species richness were also found. The patch reefs at Rice Bay consistently had lower fish abundance and lower coral cover. A number of significant correlations linked fish variables with coral variables, especially between fish abundance and stony and total coral cover at Rice Bay, the most impoverished patch reef. However, establishing strong or consistent relationships among fish community and coral community characteristics remains elusive.

INTRODUCTION

Coral reefs are the most diverse aquatic ecosystems, exhibiting high species (alpha) and microhabitat (beta) diversity. Stony or hard corals

(P. Cnidaria, C. Anthozoa, O. Scleractinia) secrete a hard aragonite (CaCO_3) skeleton that certain forms (Suborders Astrocoeniia, Faviia), in association with red algae (D. Rhodophyta: Families Sporolithaceae, Corallinaceae), use to construct reefs over many decades. Extensive vertical topography and networks of "nooks and crannies" provide many potential microhabitats for fish. Soft corals (O. Alcyonaria) do not contribute to the formation of reefs. However, in Caribbean waters soft corals in Suborder Gorgonacea may constitute a significant portion of the coral community (Ruppert and Barnes 1994). Species such as the black sea rod *Plexaura homomalla* provide as much as 10% of live coral on patch reefs at San Salvador (Walter, personal observation). Gorgonians exploit the water column and the limited reef surface area with their slender holdfasts, substantial vertical growth, and dichotomous or lateral branching (Ruppert and Barnes 1994). Colonies will grow closely, forming dense aggregations, potentially providing fish with cover, and increasing reef substratum complexity (Goldberg 1973, Lasker and Coffroth 1983, Jordán 1989, Sánchez *et al.* 1997). Little information exists on whether gorgonians play a role in shaping reef fish assemblages. Therefore, questions about relationships between diversity and abundance of fish and scleractinians may also be asked of gorgonians.

Increased coral cover provides increased reef surface area, structural and topographic complexity, more microhabitats (Bell and Galzin 1984), and potentially greater food sources for invertebrates and fishes. With corals as a principal site for primary production (i.e., zooxanthellate symbioses, *Symbiodinium* sp.; Taylor 1971, Yonge

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1973) in the reef environment, live cover may also influence reef trophic structure. Furthermore, higher coral diversity may be correlated with higher diversity of reef fishes (alpha), through increased microhabitat diversity (beta). However, there are conflicting views regarding the strength of this long-proposed relationship (Chabanet *et al.* 1997).

Fish and Coral Associations

Among the benthic coral community is an assemblage of transient and site-attached reef fishes. Larger transient predators such as jacks, barracudas and sharks are commonly seen as they traverse the reef in search of prey. Fish collected from small regions of a reef are predominantly residents (Sale and Dybdahl 1975), and it appears that a number of species never stray beyond a few meters of the coral head on which they first settle. This often results in a densely packed collection of generalist, specialist and fiercely territorial fishes.

The majority of reef fishes are placed in the Order Perciformes. A rapid evolutionary radiation of perciform fishes occurred during the late Tertiary and coincided with a rapid radiation of modern scleractinian corals (Sale 1991). If both communities have been evolving side-by-side, meaningful interactions between these the communities, or even co-evolution, can be reasonably hypothesized.

Aside from evolutionary intersection between fishes and corals, as the chief agents in the formation of coral reefs the live cover of scleractinian corals provides a rough estimate of reef health and complexity and potential for growth (Lirman 1999). So, one can ask whether reef fish assemblages are structured or influenced by coral cover, species richness or diversity. If reef fishes favor areas of increasing coral cover, scleractinian or alcyonarian attributes (e.g., % cover, species, growth form proportions, etc.) are potentially measurable influences on reef fish abundance, species richness and diversity (Bell and Galzin 1984).

Reef attributes such as rugosity, substrate diversity and live coral cover have been correlated with reef fish abundance, diversity and distribution (Lirman 1999). Differences in live coral cover of less than 2 - 5% percent have been linked to differences in total species richness and abundance of fishes (Bell and Galzin 1984). Galzin (1987), Carpenter (1990), Gladfelter *et al.* (1991a, 1991b) and Lirman (1999) reported that decreases in live coral cover resulted in an increase of herbivorous fishes (presumably due to increased algal cover). Similarly, biological diversity of the substratum has been highly correlated with fish species richness (Roberts and Ormond 1987). Gladfelter and Gladfelter (1978) and Lirman (1999) showed that complexity of the reef substratum and the distribution of shelter holes influenced reef fish abundance and diversity.

The literature also includes papers failing to support such relationships (Luckhurst and Luckhurst 1978, Molles 1978, McManus *et al.* 1981, Lewis and Wainwright 1985, Roberts and Ormond 1987, Bohnsack *et al.* 1992). A number of the problems with these studies are methodological (Sale *et al.* 1984); however, there is also significant spatial and temporal variability in reef fish populations (Sale and Douglas 1984), suggesting that some coral-fish relationships may be due to chance alone. Several studies (Sale and Dybdahl 1975, 1978; Sale 1980, Eckert 1985, Jones 1988, Jones 1991) have examined determinism in reef fish assemblages, and revealed that community structure is largely unpredictable.

Many fish-habitat associations appear to be established at the time of settlement (Sale *et al.* 1984, Eckert 1985, Jones 1991). For example, a number of juvenile reef fishes set up cleaning stations, usually at individual small coral heads, over which they solicit larger fishes for removal of necrotic skin and ectoparasites. Thus, within a small spatial scale (meters to tens of meters), reef fish assemblages may be non-equilibrial associations of species varying both temporally and spatially due to the spatial and temporal variation in deterministic and stochastic processes (Sale 1991).

As noted above, relationships of varying significance have been established between aspects of coral assemblages and fish assemblages within coral reef communities. We examined reef fish communities on contrasting shallow patch reefs at San Salvador, Bahamas. Our objective was to determine whether or not the abundance and diversity of reef fishes are influenced by live coral cover, differing coral forms (e.g., gorgonians and scleractinians; branching/pillar, encrusting/massive/boulder, etc.), or coral diversity and species richness within differing patch reef communities.

METHODS

The study sites selected were Lindsay Reef, Rocky Point, and Rice Bay (Figure 1). Data from McGrath and Smith (2001) provided some information about these reefs. In December 2000 and January 2001, we conducted initial surveys that also suggested the reefs differed, not only terms of geographic location (i.e., wave exposure), but also in dominant coral species, % hard coral, and topographic complexity. Ultimately, 16 randomly placed plots were sampled for corals and fish on each of the three reefs.

One HOBOTEMP[®] digital temperature monitor was installed at each reef in late May 2001 to monitor temperature. Salinity was measured with a refractometer on sampling days. Underwater data collected in June and July 2001 and January 2002 were recorded with a wax pencil on transparency film (with copied spreadsheet cells) attached to a white clipboard.

To sample corals, 16 - 50 m² belt transects were placed randomly on each reef (Walter 2002). Live coral cover was estimated visually within the belt transect using 10 - 1 m² quadrat frames (PVC) placed haphazardly within the 50 m² sampling area. Within each frame, we visually estimated the percent cover of individual coral species employed by Ormond *et al.* (1996). Algal cover also was visually estimated but taxa were not identified; belt transects appeared to have no differences in algal cover. Data from the 10 quadrats

was used to estimate mean cover values for each 50 m² belt transect. Proportional cover values for each coral species were computed by dividing the sum of each species' cover values by the sum of total coral cover for the 10-1 m² plots.

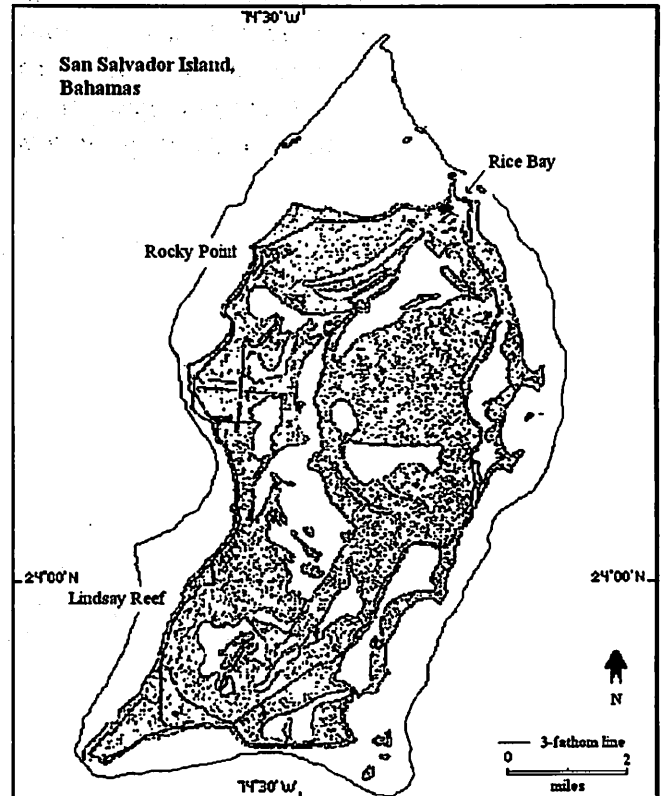


Figure 1. San Salvador, Bahamas.

We assessed topographic complexity using a rugosity index, following a modification of the method employed by McGrath and Smith (2001). We adjusted the numbers by subtracting rugosity values from 1 to create an index where larger numbers indicated higher rugosity. Ten random measurements of rugosity were made at each reef location.

We conducted fish surveys in the same 50 m² belt transects established for coral surveys. We sampled fish using non-destructive visual estimation techniques, which are preferred over destructive methods that alter the environment and fish community (Mapstone and Ayling 1998). From two stationary observation points along the periphery of each belt transect we identified and counted all individual fish observed in the 50-m²

plot. The criterion for deciding when the census was complete was observing the reef for 5 min without recording a new species (Sale 1991). Following the stationary surveys, we performed swimming surveys within each plot to search for demersal and hiding individuals (e.g., Labrisomidae, Gobiidae). The stationary and swimming surveys were done twice for each plot, which provided an average abundance rounded up to the nearest whole fish.

We assigned coral species to the growth forms indicated in Table 2, and % cover values were computed for scleractinians, gorgonians, hydrocorals (C. Hydrozoa), and total corals. For fish communities, data were categorized by total abundance, abundance of each family, and abundance of feeding guilds: herbivores, invertivores, piscivores, planktivores and detritivores (Hiatt and Strasberg 1960, Randall 1967).

We computed biodiversity measures for the coral and fish communities. Species richness (S) was the number of species per 50-m² belt transect. The Shannon Index ($H' = -\sum p_i \ln p_i$, where p_i is the proportion of individuals of the i th species) estimated species diversity (richness and evenness components). Species evenness ($E = H' / \ln S$) was used as an indicator of equitability in the abundances of species (Magurran 1988).

Statistical Analyses

Where applicable, we used $\ln(x+1)$ transformations to achieve normality. Coral and fish data were tested for normality and equal variance by Anderson-Darling normality and F -tests, respectively.

To test for relationships between coral and fish communities, we analyzed each reef separately by calculating Pearson correlation coefficients (r) between individual fish and coral variables. Computation of a correlation coefficient does not involve statistical assumptions; however, there are assumptions underlying the testing of hypotheses about correlation coefficients (Zar 1999). Therefore, we only tested the significance of relationships with correlation coefficients greater than 0.5. Again, Bonferroni corrections

(dividing the α - value = 0.05 by the number of correlations performed for each variable) were used to determine the significance of relationships.

Canonical correspondence analysis (CCA) was used to analyze fish and coral data for each reef studied. Only fish species with greater than 1% abundance were used in the analyses. Coral cover was partitioned according to growth form (Walter 2002). To test the robustness of the CCA analyses, Monte Carlo procedures ($\alpha = 0.05$) were also performed to test the null hypotheses that no structure existed in the fish communities and, therefore, there were no relationships among fish and coral variables. Only fish species showing "final scores" within the top quarter of absolute values for a significant ordination axis were considered to be associated with that axis. Only coral variables with r^2 -values ≥ 0.3 were considered correlated with the fish species ordination axes (see Walter 2002 for full CCA data and analyses).

RESULTS

Mean daily water temperatures during this study for Rice Bay, Rocky Point, and Lindsay Reef (Figure 1) were 29.7, 29.0, and 29.1° C, respectively. Salinities at all three reefs were 36 parts per thousand (‰), as indicated by refraction. Depths ranged from 0.5 to 4 m at each reef (Walter 2002).

Fish-Coral Associations

For correlations between fish and coral variables where $r > 0.5$ (Table 2), we tested hypotheses for relationships between fish community characteristics and coral community characteristics. After Bonferroni corrections, fish abundance was not significantly correlated ($P < 0.05$) with any coral variable at Lindsay Reef; however, it was correlated ($0.05 < P < 0.1$) with total coral cover ($r = 0.561$), scleractinian cover ($r = 0.579$) and coral species richness ($r = 0.606$) at Rice Bay (Table 2). Fish counts at Rocky Point were significantly correlated with total coral cover ($r = 0.629$) and coral species richness ($r = 0.596$) and correlated (r

= 0.599, 0.05 < P < 0.1) with gorgonian cover (Table 2).

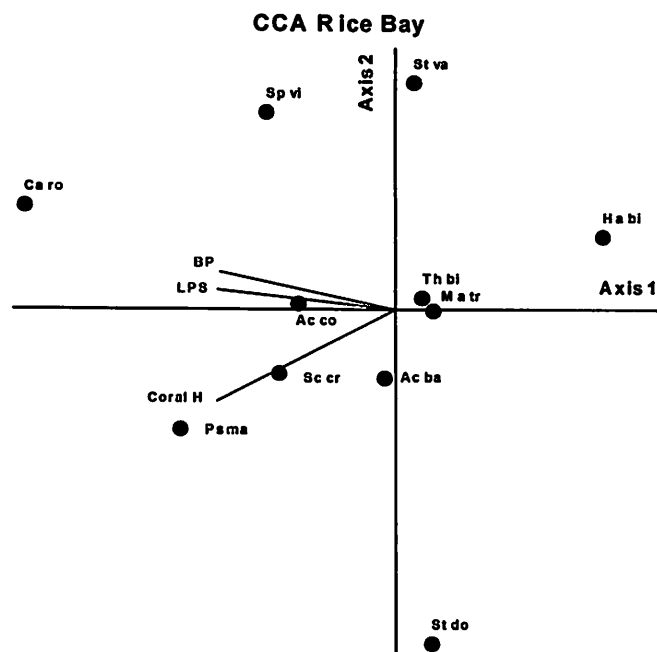


Figure 2. CCA of fish and coral variables from Rice Bay, San Salvador, Bahamas, 2003. See text for fish species and coral abbreviations.

Fish Species Richness/Diversity and Coral Community Characteristics

At Rice Bay fish species richness (*S*) was correlated (0.05 < P < 0.1) with total coral cover ($r = 0.607$) and scleractinian cover ($r = 0.581$) and significantly correlated with coral species diversity (H') ($r = 0.738$, $P < 0.01$) (Table 2). Fish species diversity (H') was correlated (0.05 < P < 0.1) with total coral cover and significantly correlated ($r = 0.861$, $P < 0.001$) with coral species diversity (Table 2).

At Lindsay Reef, fish species richness and diversity were negatively correlated ($r = -0.605$, -0.539 , respectively) with gorgonian cover (Table 2). For Rocky Point, there were no relationships among fish species richness and diversity and coral variables (Table 2).

Canonical Correspondence Analysis

At Rice Bay, 11 fish species were found at 1% or greater relative abundance, and 63.5% of the variance in fish species data was extracted by CCA (Figure 2). The Monte Carlo test showed a significant fish-coral correlation for CCA-axis 1 ($r = 0.998$, $P = 0.02$), but not for axes 2 and 3 (Walter 2002). Axis 1 accounted for 31.6% of the variance in the fish data. Among fishes, the slippery dick (*Ha bi*) was positively associated with axis 1, while the sharpnose puffer *Canthigaster rostrata* (*Ca ro*), the spotted goatfish *Pseudupeneus maculates* (*Ps ma*), and the striped parrotfish (*Sc cr*) were negatively associated with axis 1 (Figure 2). Coral diversity (Coral *H*), LPS (leaf, plate, saucer coral; Table 2), and BP (branching, pillar coral; Table 2) were also negatively correlated with axis 1 (Figure 2).

At Rocky Point, 14 fish species were found at 1% or greater relative abundance, and 68.7% of the variance in the fish species data was extracted by CCA (Walter 2002). However, the Monte Carlo test revealed no structure within the fish community at Rocky Point, and therefore no significant relationships between fish species and coral variables.

For Lindsay Reef, 17 fish species were found at 1% or greater relative abundance, and CCA explained 55.1% of the variance in fish species data (Walter 2002). Again, the Monte Carlo revealed no structure in the fish community and therefore no significant relationships between fish species and coral variables were found at Lindsay Reef.

DISCUSSION

Fish Abundance and Coral Community Characteristics

Mean fish abundance may have a positive relationship with coral cover, but the relationships are not clear in our data especially at Lindsay Reef. At Rice Bay, total coral cover, scleractinian cover and coral species richness were correlated (0.05 < P < 0.1) with fish counts after

Bonferroni corrections (Table 2). At Rocky Point, fish counts were significantly correlated with total coral cover and coral species richness and correlated ($0.05 < P < 0.1$) with gorgonian cover, but at Lindsay Reef there were no relationships between fish counts and coral community variables. The fact that at least three coral variables at each of two reefs are correlated with fish abundance suggests that a relationship, albeit an inconsistent one, exists.

Our results suggest that gorgonian cover may weakly influence fish abundance at Rocky Point, where gorgonians are most abundant (Table 1). However, the significant positive correlation between fish abundance and gorgonian cover at Rocky Point may be explained more simply by the fact that gorgonian cover was 3X and 1.5X higher at Rocky Point than at Rice Bay and Lindsay Reef, respectively, and not by any positive relationship between fish and gorgonians (see below).

Further research is needed to establish whether or not relationships exist between fish abundance and gorgonians. Thus far, Syms and Jones (2001) are the only researchers to experimentally address this question; they showed that fish abundance on alcyonacean soft corals at Pacific Ocean patch reefs was indistinguishable from equivalent-sized habitat formed by bare rock. They suggested that chemical deterrence by or overgrowth of crevices by soft corals may negatively affect fish assemblages, a hypothesis consistent with our finding of negative correlations between gorgonians and fish community attributes at Lindsay Reef (see below). Both alcyonaceans and gorgonians (the majority of Caribbean soft corals) contain compounds rendering colonies unpalatable to many fish species. In the Caribbean it appears that butterflyfishes (F. Chaetodontidae) and angelfishes (F. Pomacanthidae) are the only reef fish that feed on gorgonians (Randall 1967). Because gorgonians constitute a significant portion of some of San Salvador's reefs (Table 1), fish populations may be adversely affected if gorgonians expand or scleractinians decline.

Fish Species Richness/Diversity and Coral Community Characteristics

Although widely studied, causes for the great diversity of coral reef fishes remain unclear. Coral cover and diversity of reef substrata have been correlated with fish species richness (Bell and Galzin 1984, Chabanet *et al.* 1997). However, other authors found no correlation between coral cover and fish species richness (Luckhurst and Luckhurst 1978, Roberts and Ormond 1987, McManus *et al.* 1991).

Quite confusing were the strong negative correlations between fish species richness and diversity (H') and gorgonian cover at Lindsay Reef, especially since there were no similar relationships at Rocky Point or Rice Bay. At Rice Bay, there were significant correlations between coral diversity (H') and fish species richness (S) and fish diversity (H'). There were also correlations ($0.05 < P < 0.1$) between fish species richness and total coral cover and scleractinian cover and between fish diversity and total coral cover (Table 2).

The majority of relationships (8 of 13) we found between fish assemblages and coral communities were at Rice Bay (Table 2), which is considered the most compromised of the reefs we studied in terms of coral cover and fish abundance (T. McGrath, Corning Community College, pers. comm.). Chabanet *et al.* (1997) reported significant correlations between fish abundance and coral diversity only in disturbed environments. Furthermore, Syms and Jones (2000) experimentally demonstrated that change in habitat structure as a result of different regimes of disturbance resulted in changed fish communities. Our results are consistent with these earlier studies.

Bell and Galzin (1984) showed that the presence and amount of live coral cover was related to significant differences in fish species richness and density of individuals on topographically similar reefs. They found highly significant positive relationships between live coral cover and number of fish species, number of species 250 m⁻², and number of individuals 250 m⁻²

at Mataiva Atoll, Pacific Ocean. They also reported that 91% of the variance in fish species richness was explained by scleractinian cover—much more conclusive results than those presented here (Table 2).

Multivariate CCA of Fish Species-Coral Community Relationships

Species-environment correlations were significant only at Rice Bay (Figure 2). The blue tang *Acanthus coeruleus* (Ac co) was associated with branching/pillar (BP) and leaf/plate/saucer (LPS) corals (Table 2, Figure 2). The striped parrotfish (Sc cr), one of the more abundant parrotfishes at San Salvador's patch reefs, and the spotted goatfish (Ps ma) were associated with coral diversity (Coral H), suggesting that these fish may seek areas where a variety of coral species are found. The slippery dick (Ha bi) had a high positive loading with axis 1, suggesting that it may avoid areas of high coral diversity (Figure 2). In direct contrast, the sharpnose puffer (Ca ro) had a high negative loading with axis 1 indicating probable association with areas of higher LPS and BP cover. At Rice Bay, most sharpnose puffers were observed at the reef edge, where higher cover of LPS (e.g., lettuce coral *Agaricia agarcites*) was observed.

Other Factors Potentially Influencing Fish-Coral Associations

Chabanet *et al.* (1997) suggested that the relationship between the abundance of fish and the coverage by coral might be stronger in shallow water because fish must be in closer proximity to the substratum. All of the reefs we sampled were less than 3-4 m deep, so differences in depth do not explain our results.

Another consideration is that lower coral cover likely results in lower numbers of non-fish species inhabiting a reef; this is the basis for using coral cover as an indication of reef organism abundance and diversity. Fishes may be dependent on, or influenced by, the presence or

abundance of other reef residents that in turn are dependent on or influenced by the coral cover. Such indirect relationships would be difficult to detect with our experimental design.

SUMMARY AND CONCLUSION

Coral cover has been proposed as a major factor influencing the abundance of reef fish and their diversity. The occurrence of higher fish abundance and higher coral cover at Rocky Point and Lindsay Reef and lower fish abundance and lower coral cover at Rice Bay suggests that coral cover does influence the number of fish at patch reefs near San Salvador. However, our results do not clearly define this relationship, and the relationship between fish abundance and the coverage of corals is not without contention in the literature. An equal number of studies show positive correlations between the number of reef fishes and the coverage of corals (Bell and Galzin 1984, Galzin 1987, Carpenter 1990, Gladfelter *et al.* 1991a, 1991b, and Lirman 1999), and no relationship between the two variables (Luckhurst and Luckhurst 1978, Molles 1978, McManus *et al.* 1981, Lewis and Wainwright 1985, Roberts and Ormond 1987, Bohnsack *et al.* 1992).

In our study Lindsay Reef supported the highest mean fish abundance, fish species richness, and fish diversity, as well as supporting the highest total coral cover, richness, and species diversity. Also, Lindsay Reef had the highest rugosity. The northern portion of Lindsay Reef has remnants of once thriving staghorn coral colonies. The die-off of *A. cervicornis*, a highly branching scleractinian, in the mid-1980s (R.M. Liebe, Dept. of the Earth Sciences, SUNY at Brockport, pers. comm.) produced coral rubble that now provides considerable shelter for reef fishes. We observed many labrids and pomacentrids within the rubble; however, we did not quantify their abundance in relation to the amount of rubble. The coupling of high rugosity, high coral cover, and high coral species diversity

is probably responsible for the high number of fish and fish species Lindsay Reef supports.

The role of habitat complexity in reef fish communities is heavily studied, but results are inconclusive. However, complexity does provide both transient and permanent shelter (Caley and St. John 1996). Habitat complexity can provide refuge from predation, influence the abundance and range of consumer resources, and influence interactions between predators and competitors (Hixon and Menge 1991, Abrams 1992; both in Caley and St. John 1996). If increased topographic complexity provides a valuable resource by increasing shelter space for reef fishes, it likely provides the potential to support a higher abundance and diversity of reef fishes, as we found at Lindsay Reef (Table 1).

Inconsistency between substrata and fish relationships on coral reefs reported in the literature may be due, in part, to diverse methodologies and spatial sampling scales (Chabanet *et al.* 1997). A more quantitative method of assessing the coral cover or abundance of corals than the method we employed may be required. The method we used was a visual assessment of cover; while inexpensive, it is subject to observer bias. Costly, but reliable underwater video-transects helped to alleviate observer bias in other studies (Syms and Jones 2001).

Interactions among a number of benthic attributes such as coral cover, coral species richness and rugosity; density-dependent factors such as competition and predation within the fish community itself; or density-independent factors such as recruitment processes and weather all potentially affect fish assemblages on a coral reef. Experimental procedures must be used if definitive independent effects of such variables are to be established. The current threatened status of coral reefs worldwide provides sufficient incentive for such research, but obtaining permission to experimentally manipulate reefs is problematic given their ecological sensitivity.

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REFERENCES

- Adams, R. W., 1980, General guide to the geological features of San Salvador. *in* Field Guide to the Geology of San Salvador, Bahamian Field Station, San Salvador.
- Bell, J.D., and Galzin, R., 1984, Influence of live coral cover on coral-reef fish communities: *Mar. Ecol. Prog. Ser.*, v. 15, p. 265-274.
- Bohnsack, J.A., Harper, D.E., McClellan, D.B., Hulsbeck, M.W., Rutledge, T.N., Pickett, M.H., and Ecklund, A., 1992, Quantitative visual assessment of fish community structure in Biscayne National Park. Draft report. U.S. Dept. Comm.
- Caley, M.J., and St. John, J., 1996, Refuge availability structures assemblages of tropical reef fishes: *J. Anim. Ecol.*, v. 65, n. 4, p. 414-449.
- Carpenter, R.C., 1990, Mass mortality of *Dia-
dema antillarum*. II. Effects on population densities and grazing intensity of parrotfishes and surgeonfishes: *Mar. Biol.*, v. 104 p. 79-86.
- Chabanet, P., Ralambondrainy, H., Amanieu, M., Faure, G., and Galzin R., 1997, Relationships between coral reef substrata and fish: *Coral Reefs*, v.16, p. 93-102.
- Eckert, 1985, Settlement of two coral reef fishes to different natural substrata and at dif-

- ferent depths: Proc. 5th. Int. Coral Reef Congr., v. 5, p. 385-390.
- Galzin, R., 1987, Structure of fish communities of French Polynesian coral reef. II. Temporal scales: Mar. Ecol. Prog. Ser., v. 41, p. 137-145.
- Gerace, D.T., Ostrander, G.K., and Smith, G.W., 2002, Environment and development in coastal regions and in small islands. San Salvador, Bahamas. Coastal region and small island papers 3 .<http://www.unesco.org/csi/pub/papers/gerace.htm>.
- Gladfelter, W.B., and Gladfelter, E.H., 1978, Fish community structure as a function of habitat structure on West Indian patch reefs: Rev. Biol. Trop., v. 26, p. 65-84.
- Gladfelter, E.H., Bythell, J.C., and Hillis, Z.M., 1991a, Changes in fish assemblage structure at Buck Island, St. Croix, U.S. Virgin Islands from 1980-1990: An indication of predictability in coral reef assemblages based on known habitat changes? in Ecological Studies of Buck Island Reef National Monument, St. Croix, U.S. Virgin Islands. U.S. Dept. Interior, National Park Service, U.S. Virgin Islands, Chp. 2.
- Gladfelter, E.H., Hillis, Z.M., and Bythell, J.C., 1991b, Buck Island Reef Monument: Seasonal and catastrophic changes and recovery: in Ecological Studies of Buck Island Reef National Monument, St. Croix, U.S. Virgin Islands. U.S. Dept. Interior, National Park Service, U.S. Virgin Islands, Chp. 6.
- Goldberg, W., 1973, The ecology of coral-octocoral communities of the southeast Florida coast: Geomorphology, species composition: Bull. Mar. Sci., v. 23, p. 465-488.
- Hiatt, R.W., and Strasburg, D.W., 1960, Ecological relationships of the fish fauna on coral reefs of the Marshall Islands: Ecol. Monogr., v. 30, p. 65-127.
- Jones, G.P., 1991, Postrecruitment processes in the ecology of coral reef fish populations: A multifactorial perspective: in P.F. Sale (ed.), The Ecology of Fishes on Coral Reefs, Academic Press, NY., p. 294-328.
- Jones, G.P., 1988, Experimental evaluation of the effects of habitat structure and competitive interactions on the juveniles of two coral reef fishes: J. Exp. Mar. Biol. Ecol., v. 123, p. 115-126.
- Jordán, E., 1989, Gorgonian community structure and reef zonation patterns of Yucatán coral reefs: Bull. Mar. Sci., v. 45, p. 670-696.
- Lasker, H.R., and Coffroth, M.A., 1983, Octocoral distributions at Carrie Bow Cay, Belize: Mar. Ecol. Prog. Ser., v. 13, p. 21-28.
- Lewis, S.M., and Wainwright, P.C., 1985, Herbivore abundance and grazing intensity on a Caribbean reef community: Ecol. Monogr., v. 56, p. 183-200.
- Lirman, D., 1999, Reef fish communities associated with *Acropora palmata*: Relationships to benthic attributes: Bull. Mar. Sci., v. 65, n. 1, p. 235-252.
- Luckhurst, B.E., and Luckhurst, K., 1978, Analysis of the influence of substrate variables on coral reef fish communities: Mar. Biol., v. 49, p. 317-323.
- Magurran, A.E., 1988, Ecological Diversity and its Measurement., Princeton University Press., Princeton, NJ.

- Mapstone, B.P., and Ayling, A.M., 1998, An investigation of optimum methods and unit sizes for the visual estimation of abundances of some coral reef organisms. Great Barrier Reef Marine Park Authority Research Publication No. 47, p. 70.
- McGrath, T.A., and Smith, G.W., 2003, Monitoring the coral patch reefs of San Salvador Island, Bahamas: Proc. 9th Symp. Nat. His. Bahamas, San Salvador, Bahamas.
- McManus, J.W., Miclat, R.I., and Palaganas, V.P., 1981, Coral and fish community structure of Sombrero Island, Batangas, Philippines: Proc. 4th Int'l. Coral Reef Symp., Manila, v. 2, p. 271-280.
- Molles, M.C., Jr., 1978, Fish species diversity on model and natural reef patches: Experimental insular biogeography: Ecol. Monogr., v. 48, p. 289-305.
- Montgomery, J.C., Tolimieri, N., and Haine, .S., 2001, Active habitat selection by pre-settlement reef fishes: Fish and Fisheries, v. 2, p. 261-277.
- Ormond, R.F.G., and Roberts, J.M., and Jan, R.Q., 1996, Behavioral differences in microhabitat use by damselfishes (Pomacentridae): Implications for reef fish biodiversity: J. Exp. Mar. Biol. Ecol., v. 202, p. 85-95.
- Randall, J.E., 1967, Food habits of reef fishes of the West Indies: Stud. Trop. Oceanogr., v. 5, p. 665-847.
- Roberts, C.M., and Ormond, R.F.G., 1987, Habitat complexity and coral reef fish diversity and abundance on Red Sea fringing reefs: Mar. Ecol. Prog. Ser., v. 41, p. 1-8.
- Ruppert, E.E., and Barnes, R.D., 1994, Invertebrate Zoology, 6th ed., Saunders College Publishing, Fort Worth, TX.
- Sale, P.F., 1980, The ecology of fishes on coral reefs: Oceanogr. Mar. Biol., v. 18, p. 367-421.
- Sale, P.F., 1991, The Ecology of Fishes on Coral Reefs, Academic Press, New York, NY.
- Sale, P.F., and Dybdahl, R., 1975, Determinants of community structure for coral reef fishes in an experimental habitat: Ecol., v. 56, p. 1343-1355.
- Sale, P.F., and Dybdahl, R., 1978, Determinants of community structure for coral reef fishes in isolated coral heads at lagoonal and reef slope sites: Oecol., v. 34, p. 57-74.
- Sale, P.F., Douglas, W.A., and Doherty, P.J., 1984, Choice of microhabitats by coral reef fishes at settlement: Coral Reefs, v. 3, p. 91-99.
- Sánchez, J.A., Díaz, J.M., and Zea, S., 1997, Gorgonian communities in two contrasting environments on oceanic atolls of the southwestern Caribbean: Bull. Mar. Sci., v. 61, n. 2, p. 453-465.
- Syms, C., and Jones, G.P., 2000, Disturbance, habitat structure, and the dynamics of a coral-reef fish community: Ecol., v. 81, n. 10, p. 2714-2729.
- Syms, C., and Jones, G.P., 2001, Soft coral exert no direct effects on coral reef fish assemblages, Oecol., v. 127, p. 560-571.
- Taylor, D.L., 1971, Ultrastructure of the "zooxanthella" *Endodinium chattonii* in situ: J. Mar. Biol. Assoc. U.K., v. 51, p. 227-235.

Walter, R.P., 2002, Fish assemblages associated with coral patch reef communities at San Salvador, Bahamas. M.S. thesis. SUNY at Brockport, NY. 94 p.

Yonge, C.M., 1973, The nature of reef-building (hermatypic) corals: *Bull. Mar. Sci.*, v. 23, n. 1, p. 1-15.

Zar, J.H., 1999, *Biostatistical Analysis*, 4th ed., Prentice-Hall, Upper Saddle River, NJ.

Table 1. Data collected from coral and fish assemblages from 48 belt-transects on three patch reefs at San Salvador, Bahamas.

	Rice Bay		Rocky Point		Lindsay Reef	
	Mean	SE	Mean	SE	Mean	SE
Coral Species Richness	11.9	1.17	14.3	0.67	14.6	0.51
Scleractinia	7	0.56	7.6	0.4	8.1	0.53
Gorgonia	4.4	0.64	5.9	0.49	5.8	0.28
Shannon H'	1.61	0.17	1.92	0.06	1.93	0.07
Equitability E	0.69	0.06	0.73	0.02	0.98	0.09
Rugosity	0.16	0.03	0.28	0.03	0.41	0.05
Algae Cover	60.3	0.78	46.7	0.58	48.9	0.27
Total Coral Cover	2.8	0.66	8.7	1.07	8.1	0.59
Scleractinia	1.2	0.27	3.7	0.54	4.7	0.4
Gorgonacea	1.5	0.47	4.7	0.79	3.2	0.52
Milleporina	0.1	0.04	0.3	0.13	0.3	0.1
	Rice Bay		Rocky Point		Lindsay Reef	
	Mean	SE	Mean	SE	Mean	SE
Fish Species Richness	8.7	1.1	10.3	0.5	13.3	0.81
Shannon H'	1.72	0.1	1.71	0.1	2.1	0.07
Equitability E	0.57	0	0.74	0	0.55	0.02
Fish Counts (50 m ²)	23	3.2	45.6	1.7	47.1	4.4
Labridae	10.3	1.5	22.2	1.7	18.9	1.8
Acanthuridae	4.7	0.7	8.5	0.8	5.5	0.8
Scaridae	2.8	0.7	4.9	1	10.6	0.9
Pomacentridae	1.4	0.3	3	0.4	2.2	0.6
Invertivores	15.4	2.6	26.5	1.7	29.7	3.6
Herbivores	9.1	1.3	17.8	1.3	19.3	2
Piscivores	3.1	0.7	1.4	0.4	2.5	0.7
Planktivores	0.3	0.1	0.4	0.2	0.4	0.2
Detritivores	0.2	0.1	1.3	0.3	1.3	0.4

Table 2. Results of tests of significance for correlations performed between fish and coral variables where $r > 0.5$. Letter designations in a column indicate the corrected α -value after adjusting for the number of tests against each coral variable: $a = 0.001$, $b = 0.01$, $c = 0.05$, $d = 0.1$. S = species richness, H' = Shannon diversity index.

Rice Bay									
	Fish N			Fish S			Fish H'		
	r	P	α	R	P	α	r	P	α
Total Coral Cover	0.561	0.024	d	0.607	0.013	d	0.519	0.039	d
Scleractinian Cover	0.579	0.019	d	0.581	0.018	d			
Gorgonian Cover				0.552	0.027				
Coral S	0.606	0.013	d	0.553	0.026				
Coral H'	0.536	0.032		0.738	0.001	b	0.861	0.000	a

Rocky Point									
	Fish N			Fish S			Fish H'		
	r	P	α	R	P	α	r	P	α
Total Coral Cover	0.629	0.009	c						
Scleractinian Cover									
Gorgonian Cover	0.599	0.014	c						
Coral S	0.596	0.015	c						
Coral H'									

Lindsay Reef									
	Fish N			Fish S			Fish H'		
	r	P	α	R	P	α	r	P	α
Total Coral Cover									
Scleractinian Cover									
Gorgonian Cover				-0.605	0.013	c	-0.539	0.031	c
Coral S									
Coral H'									