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FISH COMMUNITY MODELING AGENTS ON AN ARTIFICIAL REEF ON THE NORTHERN COAST OF RIO DE JANEIRO – BRAZIL

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ABSTRACT

Stationary visual census surveys were performed on an experimental artificial reef (21°29'S, 41°00'W) to clarify the role of structural complexity and benthic community as fish community modeling agents. Concrete modules of four types were grouped according to the combination of structural complexity through the presence/absence of holes and favourable/unfavourable surface for benthic colonization by anti–fouling painting. The survey (December 2002 to March 2003) showed higher abundance, richness and diversity in the complex modules. The same habitat usage pattern was observed according to vertical position and bottom type categories: demersal, hard-bottom and habitat generalist fishes preferred the complex ones. A higher number of juveniles occurred at those modules. It is assumed that trophic relationships and different habitat selection related to ontogenetic stages are also important modeling agents to the fish community structure since juvenile fish seem to actively seek the experimental complex modules.

RESUMO

Censos visuais estacionários foram realizados em um recife artificial (21°29'S, 41°00'W) para determinar o papel da complexidade estrutural e da comunidade bêntica como agentes modeladores da comunidade íctica. Módulos de concreto foram agrupados de acordo com a combinação do fator complexidade estrutural através da presença/ausência de cavidades internas nos módulos e de superfícies favoráveis/desfavoráveis à colonização da comunidade bêntica através de tinta anti-incrustante. De dezembro de 2002 a março de 2003, foram registrados maiores valores de abundância, riqueza e diversidade nos módulos complexos. Padrões de uso de habitat similares foram observados de acordo com a posição vertical na coluna de água e tipo de fundo: peixes demersais, de fundo consolidado e habitat generalista preferiram módulos complexos. Os resultados indicam que relações tróficas e seleção de habitat relacionada ao estágio ontogenético são também importantes agentes modeladores da comunidade íctica, uma vez que peixes juvenis buscam ativamente os módulos experimentais estruturalmente mais complexos.

Descriptors: Artificial reef, Fish community, Modeling agents, Structural complexity, Rio de Janeiro.
Descritores: Recife artificial, Comunidade íctica, Agentes modeladores, Complexidade estrutural, Rio de Janeiro.

INTRODUCTION

The ecological implications of artificial reefs must be achieved in ecological researches, as they are essential to generate the knowledge for its establishment and management. The considerable efforts allocated to artificial reefs construction surpass the efforts to comprehend their ecology (Bohnsack & Sutherland, 1985). According to Carslile *et al.* (1964), Sale & Dybdahl (1975) and Ogden & Ebersole (1981), the presence of a sessile diversified community on experimental modules increases the diversity of microhabitats, an important and necessary resource to invertebrate and fish colonization. Physical space increases the available habitat, providing food and shelter in minimum levels, which guarantees the capacity of maintaining recruitment and survival rates through the perpetuation of their populations. Sherman *et al.* (2002) found a positive correlation between habitat complexity, fish abundance and diversity. Ferreira *et al.* (2001) characterized benthic organisms as one of the reef fish community modeling factors on rocky shores. Hard bottoms of heterogeneous relief are naturally rare in the north coast of Rio de Janeiro increasing the concern for artificial reefs (Zalmon *et al*., 2002). It is fundamental to understand the events after artificial structures implantation to identify the ecological patterns inherent to the associated communities in order to achieve a better understanding of the usage patterns of these habitats by the fish community. The hypothesis to be tested is: if the structural complexity of the substrate and benthic community recovery are determinant factors of the reef fish community, it would be expected that an artificial reef with different availability of these variables would result in a distinct ichthyofauna related to composition, species abundance, richness and diversity.

Material and Methods

In January 2002 an experimental reef complex was settled at 21°29'S, 41°00'W, 3.0 miles north Rio de Janeiro state on a flat and homogeneous bottom, 9 m deep (Fig. 1).

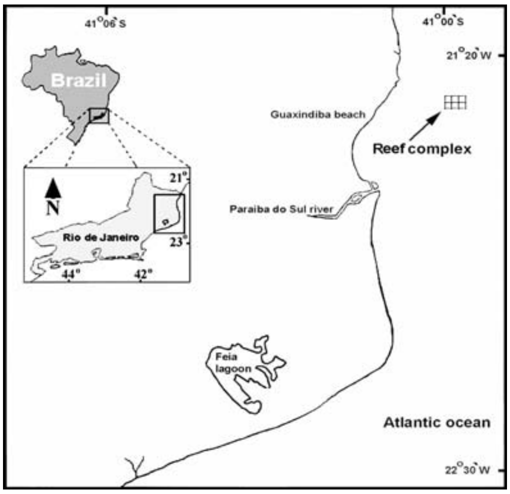

Fig. 1. Study site of the artificial reef (AR) implantation on the north coast of Rio de Janeiro.

The artificial complex comprising 36 prefabricated reef balls of four types were grouped into 12 sets according to the combination of structural complexity by the presence (WC) or absence (NC) of holes and favorable (WB) or unfavorable (NB) surface for benthic colonization with anti–fouling paint (Fig. 2).

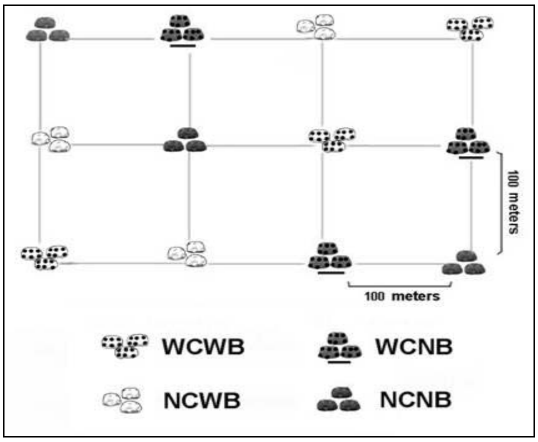

Fig. 2. Schematic drawing of the reef complex (WCWB: with complexity/with benthos, WCNB: with complexity/no benthos, NCWB: no complexity/with benthos and NCNB: no complexity/no benthos).

From December 2002 to March 2003 (N = 6) scuba divers used a non-destructive, stationary visual census method adapted from Bohnsack & Bannerot (1986) to determine fish species richness and abundance at the concrete modules. The technique is a point count of fishes in a 6 m diameter cylinder, which extends from the bottom up to 6 m high (Fig. 3). Divers recorded all the demersal, pelagic and cryptic fishes associated to the modules and adjacent bottom. After a 5-min period of species recording, the number of fish per species and the estimated total lengths were recorded by comparing the fish size to the dimensions of a known object (ropes, diving gear or reef modules).

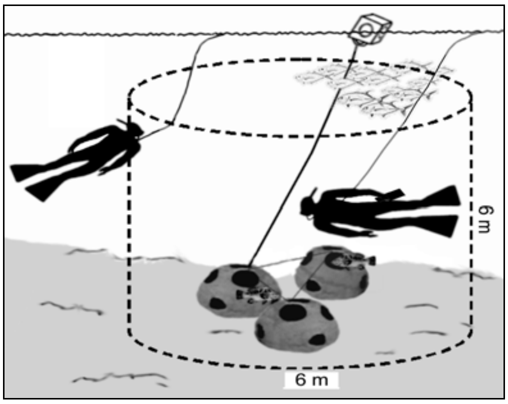

Fig. 3. Schematic representation of the sampling method.

Density, species richness and Shannon diversity were used to determine differences between fish assemblages according to each module type. Richness and density values were prior log-transformed to minimize heterocedasticity. A statistical analysis consisting of one-way ANOVA followed by a posteriori Tukey test (HSD) were used to determine the independence among sampling units and the differences among the four types of modules ($p < 0.05$). A cluster analysis (UPGMA, Euclidean distance) was performed to determine the similarity between fish assemblages on the different modules.

Results

A total of 3481 fishes and 21 species were recorded during the sampling program. Fish assemblages associated to modules with structural complexity (WCWB and WCNB) presented higher densities and species richness values and two exclusive species (*Cyclichthys spinosus* and *Acantostracium quadricornis*). The fish assemblages associated to modules with no structural complexity (NCWB and NCNB) presented half the density of the most abundant species (*Haemulon aurolineatum*, *Chaetodipterus faber* and *Chloroscombrus chrysurus*) than in the complex ones (Table 1).

Table 1. Species density on the different modules of the reef complex (WCWB – with complexity/with benthos, WCNB – with complexity/no benthos, NCWB – no complexity/with benthos and NCNB – no complexity/no benthos).

Species		Density (number of individuals)			
		WCWB	WCNB	NCWB	NCNB
Acanthurus bahianus	Castelnau, 1855	17	5	8	0
Acantostracium quadricornis	Linnaeus, 1758	2	1	0	0
Archosargus rhomboidalis	Linnaeus, 1758	2	1	1	0
Caranx latus	Agassiz, 1831	22	25	11	55
Chaetodipterus faber	Broussonet, 1782	308	421	147	165
Chaetodon striatus	Linnaeus, 1758	11	5	2	0
Chloroscombrus chrysurus	Linnaeus, 1766	285	358	113	190
Cyclichthys spinosus	Cuvier, 1818	4	1	0	0
Gymnothorax funebris	Ranzani, 1840	3	2	2	1
Haemulon aurolineatum	Cuvier, 1829	678	446	214	258
Haemulon steindachneri	Jordan & Gilbert,1882	84	30	1	0
Halichoeres poeyi	Steindachner, 1867	71	27	21	16
Holocentrus adscencionis	Osbeck , 1765	8	4	4	1
Lutjanus annalis	Cuvier, 1828	21	17	2	4
Mycteroperca acutirostris	Bloch, 1793	23	15	1	3
Mycteroperca microlepis	Goode & Bean, 1880	6	9	1	1
Orthopristis ruber	Cuvier, 1830	20	89	36	4
Pareques acuminatus	Bloch & Schneider, 1801	19	8	5	4
Scorpaena isthmensis	Meek & Hildebrand, 1928	7	2	1	3
Dules auriga	Cuvier, 1829	4	2	1	0
Serranus flaviventris	Cuvier, 1829	82	65	45	11
Total		1533	616	616	716

No significant differences ($p > 0.05$) were observed among sampling units of each module type placed at least 100 m apart, suggesting independent samples (Table 2).

Table 2. Analysis of variance (ANOVA, non significant $p < 0.05$) of community descriptors among sample units of each module type (WCWB – with complexity/with benthos; WCNB – with complexity/no benthos; NCWB – without complexity/with benthos; NCNB – no complexity/no benthos).

Types of modules	Density		Richness		Diversity	
	F	p	F	p	F	p
WCWB	0.14	0.87	2.66	0.10	2.38	0.13
WCNB	3.98	0.06	2.26	0.14	1.47	0.26
NCWB	0.24	0.79	0.19	0.83	0.36	0.70
NCNB	0.23	0.80	0.07	0.93	0.20	0.82

Abundance, species richness and diversity values were significantly higher ($p < 0.05$) on complex modules. Although differences were not statistically significant for trophic functional category, herbivorous fish occurred in higher densities at modules provided with benthic community (WCWB and NCWB). Invertivorous, omnivorous and predatory fishes showed a higher association to the complex modules (Fig. 4).

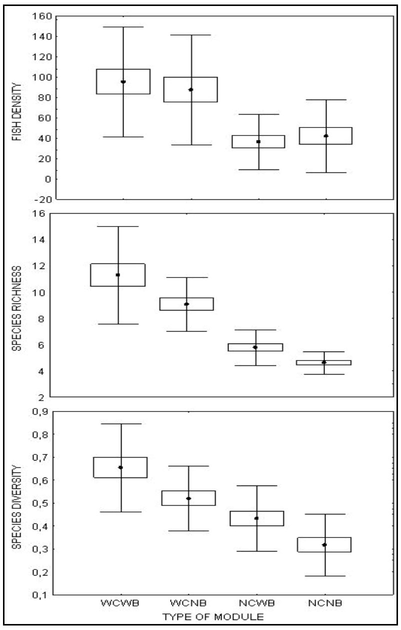

Fig. 4. Community descriptors mean values on different modules. Vertical bars and lines represent standard error and standard deviation (WCWB – with complexity/with benthos,WCNB – with complexity/no benthos,NCWB – no complexity/with benthos and NCNB – no complexity/no benthos).

The same habitat usage pattern was observed according to vertical position on the water column and bottom type categories: demersal and hard bottom fishes plus generalists preferred the complex ones, while pelagic fish showed a homogeneous distribution (Fig. 5).

Adult and juvenile fishes presented a similar pattern of densities among module types, both presenting significant higher densities at the complex ones Fig. 6). The feeding guilds also presented higher densities at the complex modules (Fig. 7).

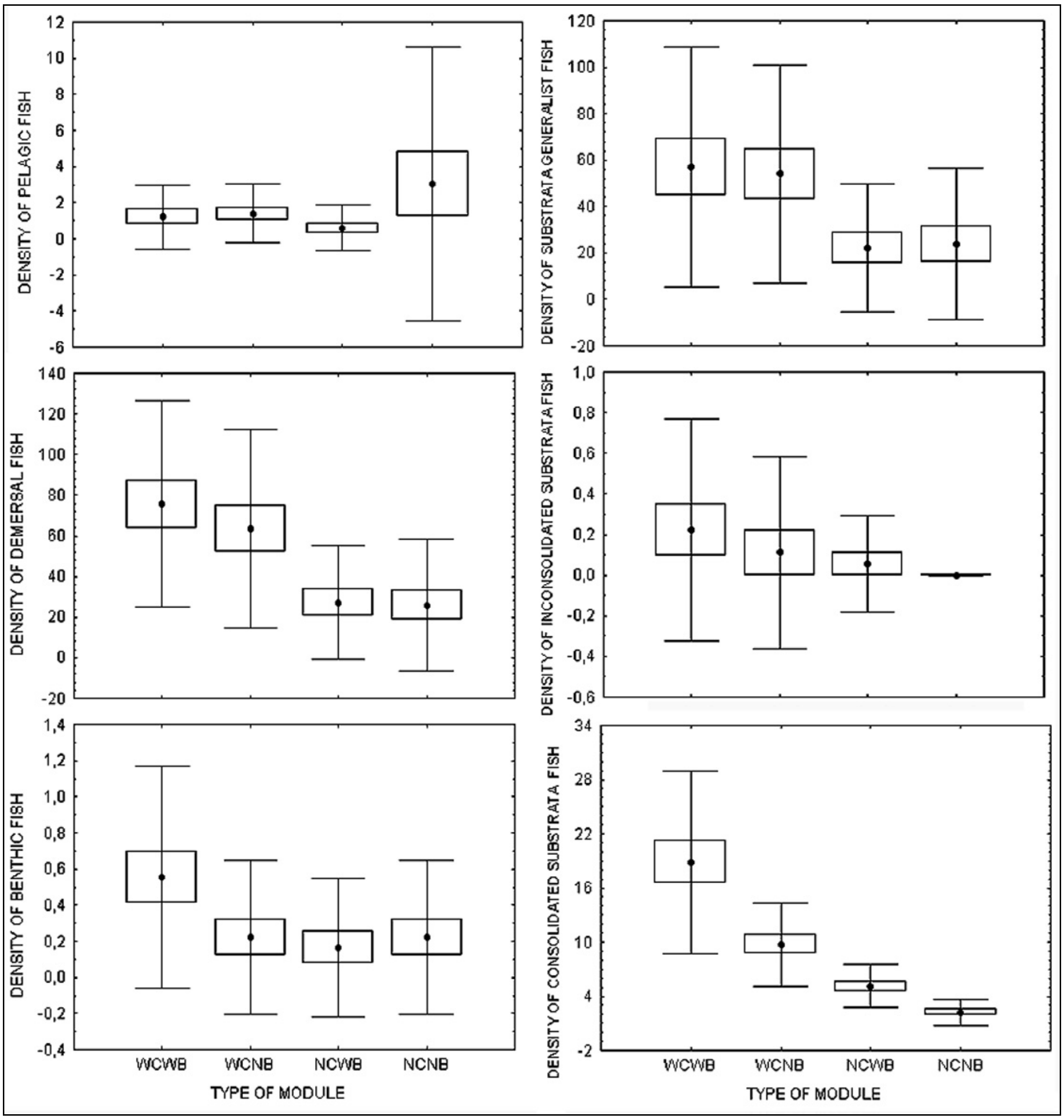

Fig. 5. Fish density mean values according to vertical position (left) and preferential substrata (right) on different modules. Vertical bars and lines represent standard error and standard deviation (WCWB – with complexity/with benthos, WCNB – with complexity/no benthos, NCWB – no complexity/with benthos and NCNB – no complexity/no benthos).

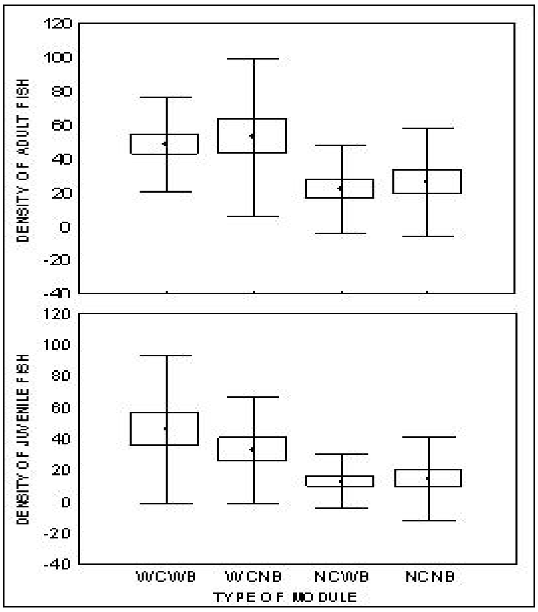

Fig. 6. Fish density mean values according to ontogenetic stages on different modules. Vertical bars and lines represent standard error and standard deviation (WCWB – with complexity/with benthos, WCNB – with complexity/no benthos, NCWB – no complexity/with benthos and NCNB – no complexity/no benthos).

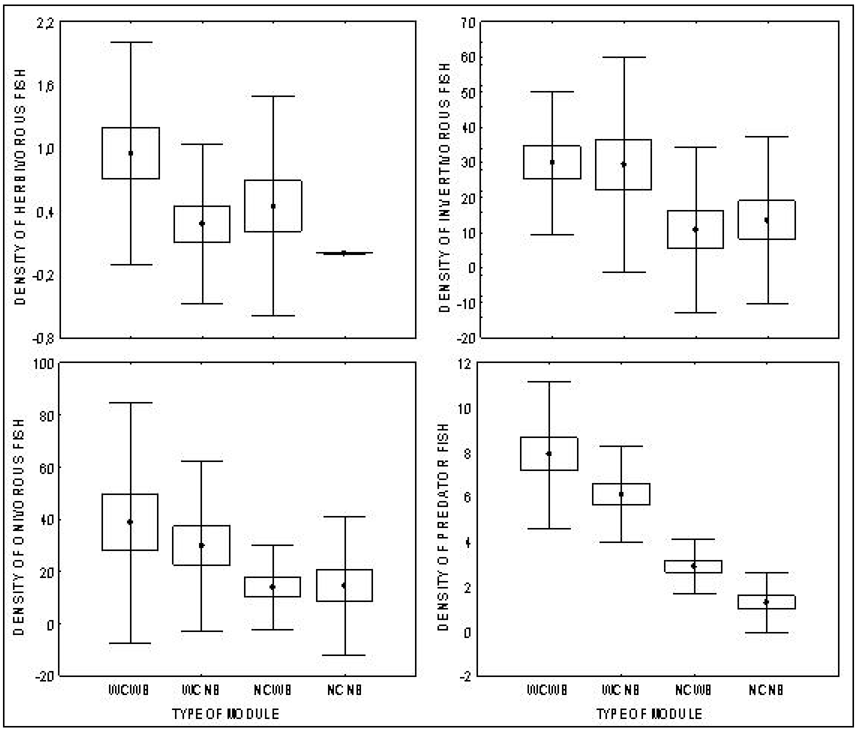

Fig. 7. Fish density mean values according to feeding habit on different modules. Vertical bars and lines represent standard error and standard deviation (WCWB – with complexity/with benthos, WCNB – with complexity/no benthos, NCW – no complexity/with benthos and NCNB – no complexity/no benthos).

Species diversity and total density showed a higher similarity among modules with structural complexity (Fig. 8). Numerical descriptors showed a clear fish association pattern to the complex modules (Fig. 8, Table 3).

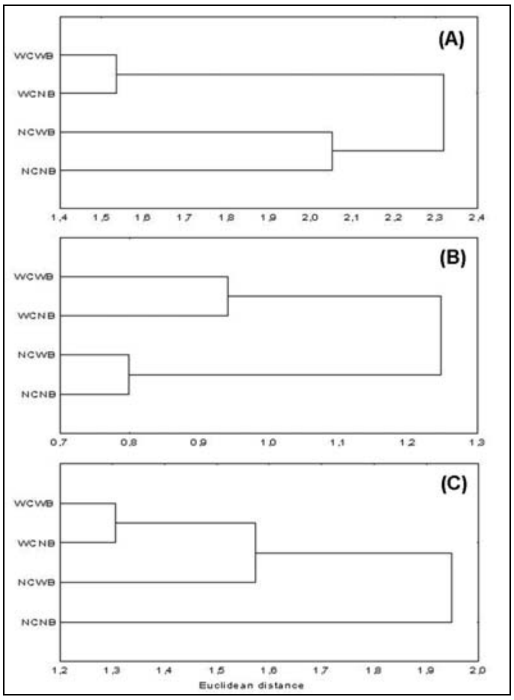

Fig. 8. Cluster analysis between modules according to specific fish density (A), species richness (B) and species diversity (C) (dissimilarity index Euclidean distance – UPGMA) (WCWB – with complexity/with benthos, WCNB – with complexity/no benthos, NCWB – no complexity/with benthos and NCNB – no complexity/no benthos).

Table 3. Analysis of variance (ANOVA) and a posteriori Tukey test (HSD) among sample units and module types (WCWB – with complexity/with benthos; WCNB – with complexity/no benthos; NCWB – no complexity/with benthos; NCNB – no complexity/no benthos), NS: non significant $p < 0.05$.

	Sample independence analysis
Total density	NS
Species richness	NS
Species diversity	NS
	Among modules analysis
Total density	WCWB and WCNB > NCWB and NCNB
Species richness	WCWB and WCNB > NCWB and NCNB
Species diversity	WCWB > WCNB, NCCB and NCNB
	Position in water column analysis
Benthic	NS
Demersal	WCWB and WCNB > NCWB and NCNB
Pelagic	NS
	Preferential type of substrata analysis
Hard bottom	WCWB > WCNB, NCWB and NCNB
Unhard bottom	NS
Generalists	WCWB and WCNB > NCWB and NCNB
	Feeding habit analysis
Invertivorous	WCWB and WCNB > NCWB and NCNB
Onivorous	WCWB and WCNB > NCWB and NCNB
Herbivorous	NS
Predators	WCWB and WCNB > NCWB and NCNB
	Ontogenetic stages analysis
Adult/Juvenile rate	((WCWB: 857/826) ≠ (WCNB: 941/590)) ≠ (NCWB: 385/226 = NCNB: 460/256)
Adults	WCWB and WCNB > NCWB and NCNB
Juveniles	WCWB and WCNB > NCWB and NCNB

DISCUSSION

Underwater visual fish census is surely the most common method for fish community assessment in reef environments (Samoilys, 1997; Seaman, 2000; Labrosse, 2002). It allows demersal, benthic and especially cryptic fish sampling in hard and heterogeneous bottoms and generates conclusive knowledge about the role of structural complexity and benthic community as reef fish assemblages modeling agents.

Other sampling methods such as gill nets or trammel nets present positive aspects since they might be applied even in extremely turbid water and allow feeding and reproductive data from fish community. The main disadvantage of this fishing gear is its selectivity for pelagic and demersal fish from homogeneous bottom (Zalmon *et al.*, 2002; Godoy *et al.*, 2002). Thereafter, visual census samplings would provide the knowledge about usage patterns of the habitat by reef fish communities.

The reef complex on the north coast of Rio de Janeiro showed increased structural complexity favoring higher abundance, species richness and diversity. Fish density according to vertical position, feeding habits and ontogenetic stages presented the same pattern, suggesting the shelter influence on structure and composition of the local fish assemblage. Also, in artificial reef environments Charbonnel *et al.* (2002), Sherman *et al.* (2002) and Kawasaki *et al.* (2003) related higher fish density and richness to higher structural complexity habitats.

Eklund (1997) in a similar experiment with fish assemblages at artificial reefs observed that fish density and richness did not differ between modules with and without benthos in opposition to those complex and non-complex.

Ferreira *et al.* (2001) studying fish assemblages at natural rock shores in Rio de Janeiro coast, SE-Brazil, considered the structural complexity offered by the benthic organisms as the major modeling agent to local fish community. Holbrook *et al.* (1990) observed that the fish assemblages are also influenced by the biogenic structural complexity of the reef referring to engineer species (Jones *et al.*, 1997) as bivalves, balanids and polychaete, which could be understood as structural complexity generators. Jacobi & Langevin (1994) also suggest that higher structural complexity bottoms generate superior trophic resources amounts, due to increasing microhabitats heterogeneity.

According to Luckhurst & Luckhurst (1977), Russell *et al.* (1978), Brock & Kam (1994) and Herrera *et al.* (2002), fish recruitment at reef environments is highly variable due to the unpredictability in production and survival of reef fish larvae, sea current dispersal patterns, and distances from larvae source areas, microhabitat requirements and predation rates. Chou *et al.* (1991) suggest that juvenile fishes are an important link in trophic relations of reef environments because they transfer energy from -scattered food resource as plankton to higher levels in the food chain.

Out of 57 families of Brazilian reef fish (Floeter & Gasparini, 2000), 14 occurred in the reef complex: Acanthuridae, Serranidae, Holocentridae, Lutjanidae and Sciaenidae as juveniles and Labridae, Ephippidae, Haemulidae e Chaetodontidae as juveniles and also adults. Carangidae, Muraenidae, Diodontidae, Ostraciidae and Sparidae occurred only as adults. The main reason for the low number of reef fish family recruits might be the lack of natural reefs in the area.

Adults and juvenile fish were more abundant in complex modules since habitats of higher structural complexity represent sheltering from predation or environmental stress as the local strong bottom currents. Higher density of juveniles in complex modules suggests these modules as a proper recruitment site. Predator fish (mainly Serranidae and Lutjanidae juveniles) although not abundant in visual census sample were always associated with complex modules, where presumably they prey on invertebrates and juvenile fishes. Adults of these predator fish were not observed in the reef complex, possibly because their natural habitat is located in deeper areas as stated by Bohnsack. Bohnsack *et al.* (1994).

Considering the food habits, herbivorous fish did not present a clear pattern of distribution between the different modules. The four reef types were not colonized by macroalgae probably due to the low water visibility (Krohling *et al.*, 2006). The local herbivorous fishes were surely associated to the drifted algae brought to the reef by strong bottom currents. Invertivorous fishes were the most frequent feeding category in all kind of modules, suggesting that their food requisitions were homogeneously distributed in the reef and at the adjacent bottom, where they could find abundant prey as small invertebrates of hard bottom (Frazer & Lindberg, 1994).

These results are similar to those obtained by gill net sampling performed at the same reef complex from March 2002 to March 2003 (Brotto *et al.*, 2006). Both techniques indicate the highest similarity for density and diversity between fish assemblages at modules with complexity and higher similarity for species richness between non-complex ones. Thereafter, structural factor plays a major role as a fish community modeling agent and benthic community a secondary one. This work indicates that trophic relations and different habitat selection according to ontogenetic stag e are also modeling factors of the community structure since juvenile fishes have been actively seeking the experimental complex modules.

ACKNOWLEDGEMENTS

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