SHALLOW REEF FISH COMMUNITIES OF SOUTH BAHIA COAST, BRAZIL*

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ABSTRACT

This study aims to describe for the first time the fish community structure of five shallow reefs located off the cities of Santa Cruz de Cabrália and Porto Seguro (Araripe-AR, Itacipanema-IT, Alagados-AL, Naufrágio-NA and Recife de Fora Marine Park-RF Reefs), South Bahia, Northeastern Brazil. Fish density and richness were assessed through stationary point counts of 2 m radius for small cryptic species and 3 m for more conspicuous species. A total of 1 802 fishes belonging to 23 families and 54 species were observed. The most abundant species were the pomacentrids *Stegastes fuscus* and *Abudefduf saxatilis*. No significant differences were found for species richness or density of conspicuous species, but density of small cryptic species was low on reefs with high bottom rugosity, where there were more holes and crevices available. Herbivores were dominant on AR, AL and RF, invertivores on AL and both groups were dominant on IT. Some habitat variables such as rugosity and benthic cover were strongly correlated to species and sites. High bottom heterogeneity was found among reefs but they still presented similar species composition, richness and density. Within small-scale studies, such similarities in composition and richness are to be expected for reef fish communities, as most of the species concerned have a wide distribution range.

RESUMO

Este trabalho descreve pela primeira vez as comunidades de peixes em cinco recifes rasos de Santa Cruz de Cabrália e Porto Seguro (Araripe-AR, Itacipanema-IT, Alagados-AL, Naufrágio-NA e Recife de Fora Marine Park-RF), sul da Bahia, nordeste do Brasil. A densidade e riqueza foram obtidas utilizando censos estacionários de 2 m de raio para espécies pequenas e criptobênticas e 3 m de raio para espécies conspícuas. Um total de 1802 peixes pertencentes a 23 famílias e 54 espécies foram registrados, sendo as espécies mais abundantes dos pomacentrídeos *Stegastes fuscus* e *Abudefduf saxatilis*. Nenhuma diferença significativa foi encontrada para a riqueza entre os recifes e também para a densidade de espécies vágeis. Entretanto, a densidade de espécies criptobênticas foi mais alta em lugares com maior rugosidade. Herbívoros foram dominantes nos recifes AR, AL e RF, invertívoros em AL e a dominância dos dois grupos ocorreram em IT. Algumas variáveis ambientais como rugosidade e cobertura bentônica estão fortemente relacionadas às espécies e diferentes recifes. Estes são fisicamente heterogêneos, mas a composição e riqueza de espécies similares, o que seria esperado em comunidades recifais abrangendo estudos em pequena-escala, pois peixes recifais estão amplamente distribuídos.

Descriptors: Fish Community, Reef Ecology, Bahia Reefs
Descritores:Comunidade de peixes, Ecologia de recifes, Recifes da Bahia

INTRODUCTION

Coral reefs present the most diverse natural communities. Such ecosystems are to be compared only with tropical forests in biodiversity and are nevertheless equally threatened by human activities

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(Prates, 2003). The most extensive reef formations of the Southwestern Atlantic (Abrolhos reef complex) are found off the northeastern coast of Brazil and provide a great diversity of reef fishes for this area (Guimarães *et al.*, 2001).

There has been an increase in the number of Brazilian reef fish studies over the last decade. Descriptions of new species (Gasparini *et al.*, 2001;

Feitoza, 2002; Guimarães and Barcelar, 2002; Moura and Castro, 2002; Gasparini *et al.*, 2003; Sampaio *et al.*, 2004), reports of the extension of species' geographical ranges (Moura *et al.*, 1999; Luiz Jr *et al.*, 2008), analyses of biogeographical patterns (Floeter and Gasparini, 2000; Joyeux *et al.*, 2001; Ferreira *et al.*, 2004; Floeter *et al.*, 2004, 2005, 2008) and natural history (Sazima *et al.*, 1998; Sazima and Sazima, 2001; Feitoza *et al.*, 2002; Nunes *et al.*, 2007a, 2007b; Sampaio *et al.*, 2007) are among the most prominent fields, whereas other works have been produced on reef fish community ecology, including that of coral reefs, rocky reefs and tide pools (Ferreira et al., 2001; Barreiros *et al.*, 2004; Moura and Francini-Filho, 2005; Cunha et al., 2007; Floeter *et al.,* 2007; Mendonça-Neto *et al.*, 2008; Chaves and Monteiro-Neto, 2009, Godinho and Lotufo, 2010).

In many tropical regions, reefs are well developed and reef fish feature as the most important source of income for traditional coastal communities. This is also true of the Bahia coast (Sampaio and Nunes, 2004), where these environments have been coming under intense pressure due to oil spills, sewage discharge, eutrophication and sedimentation (Leão and Kikuchi, 2005; Dutra *et al.*, 2005; Floeter *et al.*, 2006).

Bahia State presents the longest coastline in Brazil, extending for 1,188 km. It harbors the greatest and richest coral reef area of the Southwestern Atlantic (Leão and Dominguez, 2000), but little is known of its reef fish composition and ecology. With the increasing use of the coastal zone comes the urgent need for precise information on coral reefs. Understanding reef fish community organization may provide valuable insights for the management and conservation of this ecosystem (Chittaro, 2004). Despite their historical and touristic importance, the reefs of Porto Seguro and Santa Cruz de Cabrália have remained virtually unknown until recently (Castro and Segal, 2001) and knowledge of their ichthyofauna is still sparse. This is the first study of these coastal reefs, which describes the reef fish communities of five shallow coral reefs in South Bahia. These results were accomplished through the assessment of fish species´ density and richness and their association with environmental factors such as habitat complexity and benthic cover. Additional comments on fish trophic organization and distribution are made.

MATERIAL AND METHODS

Study Area

The study area comprises five coastal reefs along the coast of Porto Seguro and Santa Cruz de Cabrália municipalities, South Bahia, Brazil (Fig. 1): 1) AR-Araripe reef (16º10'S, 38º54'W); 2) IT-Itacipanema reef (16º15'S, 38º57'W); 3) AL-Alagados reef (16º16'S, 38º58'W); 4) NA-Naufrágio reef (16º20'S, 38º58'W) and, 5) RF-Recife de Fora Marine Park reef (16º24'S, 38º59'W). Reefs 1-4 never emerge at low tide. Naufrágio reef is the smallest of those studied and was thus named after the shipwreck of the 'Castor', found close to the reef. The Recife de Fora Marine Park was created in December 1997. It is located off the city of Porto Seguro, and covers an area of 17.5 km². Depths around these reefs varied between 6 and 18m. In the Marine Park, water transparency is normally greater than that of the other reefs, which are closer to the coast and more affected by fluvial discharges. All the sites, except for Recife de Fora Municipal Marine Park, are characterized by high abundance of crustose and filamentous algae. Other organisms such the sea urchin *Echinometra lucunter* and the coral species: *Siderastrea* spp., *Millepora* spp., *Mussismilia* spp. and *Montastrea cavernosa*, are frequently observed. As for the Recife de Fora Marine Park, corals cover the greater part of the reef surface. For further details, all the reef sites studied are included in sector 3 of the Brazilian Reefs Area described by Castro and Pires (2001).

Community Data

Access was gained to the Reefs using local fishing vessels. The study was carried out in January 2007, using SCUBA diving equipment. The stationary point counts method was adapted from Bohnsack and Bannerot (1986) as in Moura (2003), where a 2m-radius was used for small cryptobenthic fishes (Families Labrisomidae, Cirrithidae, Grammatidae, Chaenopsidae, Gobiidae and Blenniidae) and a 3m-radius was used for conspicuous species, comprising larger home range species and other site attached fish, such as territorial pomacentrids. Sampling stations were located on the reef tops. The study design included 150 diurnal samples, 30 for each reef. Records were made first for mobile species and then for cryptobenthic fish. Species density was recorded on PVC plates, each sampling taking around five minutes. An experienced observer (J.A.C.C. Nunes) was responsible for making all the counts in order to minimize any possible effect related to individual performance. Specialized literature was used for fish identification (Carvalho-Filho, 1999; Humman and DeLoach, 2003).

The species checklist is placed in order of family phylogeny following Nelson (2006). Recent changes in the classification of the Serranidae were also modified as proposed by Craig and Hastings (2007) and Smith and Craig (2007).
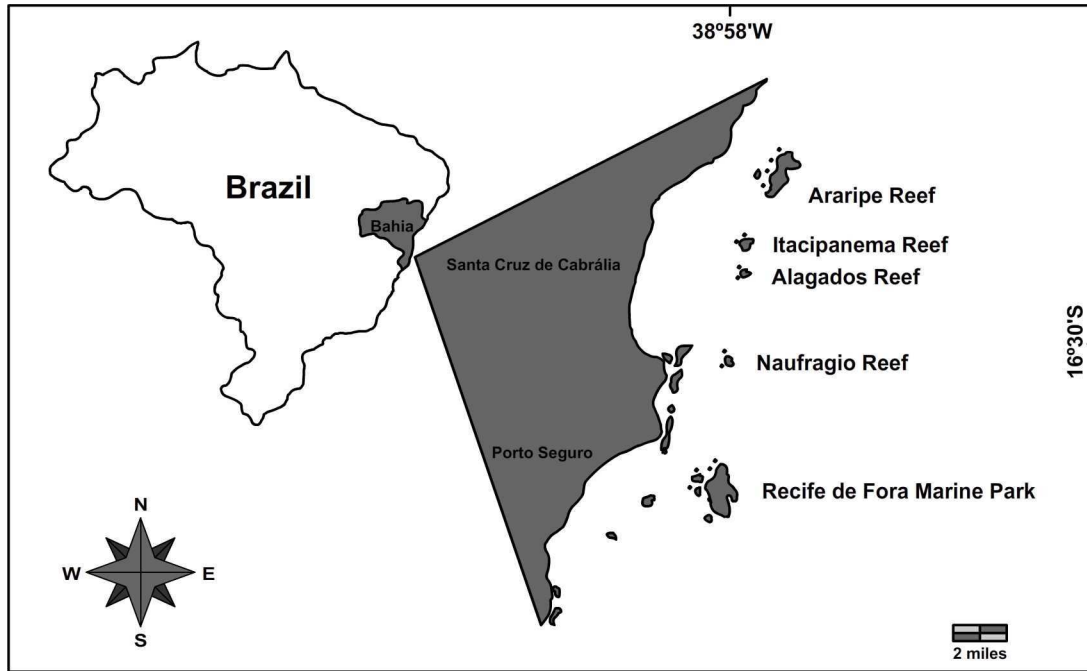
Fig. 1. Map indicating sites within the reefs studied.

Environmental Variables

Rugosity (topographical complexity) was measured using the link-chain method proposed by Luckhurst and Luckhurst (1978) as a rugosity index for each site. Depth was also measured and benthic cover obtained using replicates of a 25x25cm grid (100% cover). Functional groups were used for benthic organisms (foliage algae, filamentous algae, crustose algae, corals, octocorals, sponges, echinoderms and zoantids). For each sample area two measurements of these parameters were taken at random.

Trophic Organization and Biogeographical Affinities

Trophic organization was adapted from Ferreira et al., 2004, but only 5 of their categories are used here: CAR = Carnivores (which eat a variety of invertebrates and/or fishes), INV = Invertebrate feeders (feed primarily on benthic mobile and sessile invertebrates associated with the hard- or nearby soft-substrate), OMN = Omnivores (feed on a variety of organisms, animal and vegetal), PLK = Planktivores (feed primarily on macro- and micro-zooplankton) and HER =Herbivores (territorial and roving herbivores which include a rich mass of detritus, turf algae and/or macroalgae in their diet).

In the section Biogeographical range of the species the following codes were adopted, following Luiz Jr. *et al*., 2008, where Br = Brazilian province (*sensu* Briggs 1974), CE = Central Atlantic (Islands of St. Helena and Ascension), CT = Circumtropical, SCa = Southern Caribbean (Coast of Venezuela, Trinidad and Tobago and other islands of the lesser Antilles), AA = Amphi-Atlantic (occurring in both sides of the Atlantic Ocean), and WA = Western Atlantic (occurring in both the Northern and Southern West Atlantic).

Statistical Analysis

One-Way Analysis of Variance was used to compare richness, density and physical parameters (rugosity, depth and benthic cover) between study sites. Data of conspicuous and cryptobenthic species were treated separately for the purpose of this analysis, due to the different radius sizes of the samples. The Student-Newman-Keuls (SNK) *post hoc* multiple comparison test was used to separate significantly different means. Data were log-transformed [log (density + 1)] to satisfy ANOVA assumptions (Zar, 1996). Tests were performed using STATISTICA 6.0 software (Statsoft, Inc.).

Cluster analysis was used to observe patterns of similarity of fish density between study sites. Density data of all species was log-transformed and Bray-Curtis similarity was used for matrix construction. Primer 5.0 software was used for this analysis.

Additionally, fish community and habitat relationships were analyzed using Canonical Correspondence Analysis (CCA) ordination. This analysis is a powerful technique used to understand how multiple species respond simultaneously to environmental factors, extracting significant gradients from ecological matrices (Ter Braak, 1987). Species present in less than 5% of the samples were excluded and only significant variables were used. This analysis was performed on CANOCO *for Windows* 4.0 (ter Braak and Verdonschot, 1995).

RESULTS

In the present study 1 802 fishes belonging to 23 families and 54 species were observed (Table 1). The most abundant species are represented in Figures 1-2.

Table 1. Species composition, abundance, geographical range and trophic category of the reef fishes recorded at Santa Cruz de Cabrália and Porto Seguro. Teleost fishes are arranged in accordance with Nelson (2006); genera and species are arranged in alphabetical order. Geographical Range: AA=Amphi-Atlantic; Br = Brazilian Province; CT = Circumtropical; EA = Eastern Atlantic; SCa =South Caribbean; WA=Western Atlantic; WA-CE=Western-Central-Eastern Atlantic. Trophic category: CAR=Carnivore; INV=Invertebrate Feeder; OMN=Omnivore; PIS=Piscivore; PLK=Planktivore; HER=Herbivore. * Cryptobenthic species; # Species observed on dives but not included in Stationary Visual Census.

Species	Trophic Category	Biogeographic Distribution	Araripe Reef	Itacipanema Reef	Alagados Reef	Naufrágio Reef	Recife de Fora Marine Park
Muraenidae							
Gymnothorax funebris Ranzani, 1839	CAR	WA	-	#	#	-	-
Gymnothorax moringa (Cuvier, 1829)	CAR	WA-CE	0.06±0.02	-	-	-	0.06±0.02
Ophichthidae							
Myrichthys ocellatus (LeSueur, 1825)	INV	WA	#	-	#	-	#
Mugilidae							
Mugil sp	OMN	???	-	-	-	#	-
Holocentridae							
Holocentrus adscensionis (Osbeck, 1765)	CAR	AA	-	0.13±0.02	-	-	0.06±0.02
Myripristis jacobus Cuvier, 1829	PLK	AA	-	#	-	-	-
Dactylopteridae							
Dactylopterus volitans L., 1758	INV	AA	-	#	-	#	#
Scorpaenidae							
Scorpaena plumieri Bloch, 1789	CAR	WA-CE	#	#	#	-	-
Serranidae							
Serranus flaviventris (Cuvier, 1829)	CAR	WA	#	#	0.06±0.02	0.06±0.02	0.06±0.02
Epinephelidae							
Cephalopholis fulva (L., 1758)	CAR	WA	0.06±0.02	-	#	#	#
Myctoroperca bonaci (Poey, 1860)	CAR	WA	-	-	-	-	#
Grammatidae*							
Gramma brasiliensis Sazima, Gasparini and Moura, 1998	PLK	BR	-	0.06±0.02	-	-	0.06±0.02

Table 1. Continuation.

Species	Trophic Category	Biogeographic Distribution	Araripe Reef	Itacipanema Reef	Alagados Reef	Naufrágio Reef	Recife de Fora Marine Park
Carangidae							
Carangoides bartholomaei (Cuvier, 1833)	CAR	WA	0.06±0.01	-	-	-	0.13±0.03
Caranx crysos (Mitchill, 1815)	CAR	AA	#	-	0.53±0.13	-	0.13±0.03
Caranx latus Agassiz, 1831	CAR	AA	#	-	-	-	#
Caranx ruber (Bloch, 1793)	CAR	WA	-	-	#	-	#
Lutjanidae							
Lutjanus jocu (Bloch and Schneider, 1801)	CAR	WA	0.13±0.03	#	#	-	#
Lutjanus synagris (Linnaeus, 1758)	CAR	WA	-	-	-	#	-
Ocyurus chrysurus (Bloch, 1791)	CAR	WA	-	-	-	-	0.73±0.07
Haemulidae							
Anisotremus moricandi (Ranzani, 1842)	INV	BR	#	0.33±0.08	#	-	-
Anisotremus surinamensis (Bloch, 1791)	INV	WA	#	2.00±0.30	#	0.06±0.02	-
Anisotremus virginicus (L., 1758)	INV	WA	0.13±0.02	0.26±0.04	0.40±0.04	#	0.26±0.04
Haemulon aurolineatum Cuvier, 1830	INV	WA	#	#	#	#	1.86±0.18
Haemulon plumierii (Lacepède, 1801)	INV	WA	#	0.60±0.14	#	-	-
Sciaenidae							
Odontoscion dentex (Cuvier, 1830)	CAR	WA	-	0.13±0.03	-	-	-
Pareques acuminatus (Bloch and Schneider, 1801)	CAR	WA	-	-	-	0.06±0.02	0.06±0.02
Mullidae							
Mulloidichthys martinicus (Cuvier, 1829)	INV	AA	-	-	#	#	-
Pseudupeneus maculatus (Bloch, 1793)	INV	WA	#	-	-	0.26±0.05	-
Chaetodontidae							
Chaetodon striatus L., 1758	INV	WA	-	#	0.06±0.02	0.06±0.02	0.13±0.02
Pomacanthidae							
Holacanthus ciliaris (L., 1758)	INV	WA	-	0.06±0.02	-	-	-
Pomacanthus arcuatus	OMN	WA	-	-	0.06±0.02	#	-
Pomacanthus paru (Bloch, 1787)	OMN	WA	0.06±0.02	0.40±0.05	#	#	0.13±0.03
Cirrhitidae*							
Amblycirrhitus pinos (Mowbray, 1927)	CAR	AA	0.06±0.02	-	0.06±0.02	-	-
Pomacentridae							
Abudefduf saxatilis (L., 1758)	OMN	CT	3.40±0.14	2.60±0.14	3.06±0.23	4.20±0.36	0.20±0.03
Microspathodon chrysurus (Cuvier, 1830)	HER	WA	0.13±0.03	0.06±0.02	0.33±0.05	0.40±0.04	0.86±0.06
Stegastes fuscus (Cuvier, 1830)	HER	BR	9.80±0.28	9.00±0.20	8.80±0.16	6.40±0.27	9.20±0.27
Stegastes cf. variabilis (Castelnau, 1855)	HER	WA	#	-	#	0.13±0.02	-
Labridae							
Bodianus rufus (L., 1758)	INV	WA	0.60±0.05	#	0.13±0.04	0.06±0.02	-
Halichoeres brasiliensis (Bloch, 1791)	INV	BR	0.33±0.03	0.20±0.04	0.26±0.04	-	-
Halichoeres penrosei (Starks, 1913)	INV	BR	-	-	-	#	-
Halichoeres poeyi (Steindachner, 1867)	INV	WA	0.13±0.04	1.80±0.14	0.53±0.07	1.13±0.08	0.06±0.02

Table 1. Continuation.

| Species	Trophic Category	Biogeographic Distribution	Araripe Reef	Itacipanema Reef	Alagados Reef	Naufrágio Reef	Recife de Fora Marine Park
Scaridae							
Scarus trispinosus Valenciennes, 1840	HER	BR	-	-	-	#	0.13±0.02
Sparisoma amplum (Ranzani, 1842)	HER	BR	-	-	-	-	0.06±0.02
Sparisoma axillare (Steindachner, 1878)	HER	BR	3.26±0.48	0.46±0.07	0.60±0.05	0.60±0.05	0.20±0.03
Sparisoma frondosum (Agassiz 1831)	HER	BR+Sca	0.13±0.03	0.20±0.04	#	-	-
Sparisoma radians (Valenciennes, 1840)	HER	BR	0.06±0.02	-	-	-	0.06±0.02
Blenniidae*							
Hypleurochilus pseudoaequipinnis Bath, 1994	HER	WA	#	-	-	-	-
Ophioblennius trinitatis Miranda-Ribeiro,1919	HER	BR	1.06±0.10	2.30±0.14	2.30±0.13	1.33±0.08	0.20±0.08
Parablennius marmoreus (Poey, 1876)	INV	WA	-	#	-	-	0.06±0.01
Scartella cristata (L., 1758)	HER	CT	0.06±0.02	0.06±0.02	0.06±0.02	-	-
Labrisomidae*							
Labrisomus nuchipinnis (Quoy and Gaimard, 1824)	CAR	AA	0.53±0.05	0.53±0.05	0.26±0.03	0.26±0.03	0.13±0.02
Malacoctenus sp	INV	BR	0.60±0.06	1.06±0.05	2.00±0.02	1.46±0.08	0.66±0.05
Paraclinus sp	INV	BR	#	-	-	-	-
Starksia brasiliensis (Gilbert, 1900)	INV	BR	-	-	-	-	0.06±0.02
Chaenopsidae*							
Emblemariopsis signifera (Ginsburg, 1942)	INV	WA	-	-	-	-	0.20±0.03
Gobiidae*							
Coryphopterus glaucofraenum Gill, 1863	OMN	WA	#	-	#	#	0.06±0.02
Elacatinus figaro Sazima, Moura and Rosa, 1997	INV	BR	-	0.06±0.02	-	0.06±0.02	0.06±0.02
Gnatholepis thompsoni Jordan, 1902	OMN	AA	-	#	-	-	#
Ephippidae							
Chaetodipterus faber (Broussonet, 1782)	INV	WA	-	#	-	#	-
Acanthuridae							
Acanthurus bahianus Castelnau, 1855	HER	WA	2.20 ±0.50	#	-	0.30±0.05	0.13±0.02
Acanthurus chirurgus (Bloch, 1787)	HER	AA	2.00±0.50	0.06±0.01	-	0.06±0.02	0.13±0.02
Acanthurus coeruleus Bloch and Schneider, 1801	HER	WA	0.13±0.02	0.20±0.03	0.20±0.02	0.06±0.01	0.20±0.03
Sphyraenidae							
Sphyraena barracuda (Edwards, 1771)	CAR	CT	-	-	-	-	#
Scombridae							
Scomberomorus brasiliensis Collette, Russo and Zavala-Camin, 1978	CAR	WA	#	-	#	-	-
Scomberomorus regalis (Bloch, 1793)	CAR	WA	-	-	-	#	#
Monacanthidae							
Cantherhines macrocerus (Hollard, 1853)	INV	WA	-	#	0.13±0.02	#	-
Cantherhines pullus (Ranzani, 1842)	OMN	AA	-	-	0.06±0.02	0.06±0.02	-
Tetraodontidae							
Sphoeroides greeleyi Gilbert, 1900	INV	WA	#	-	#	-	#
Sphoeroides spengleri (Bloch, 1785)	INV	WA	-	-	#	-	#
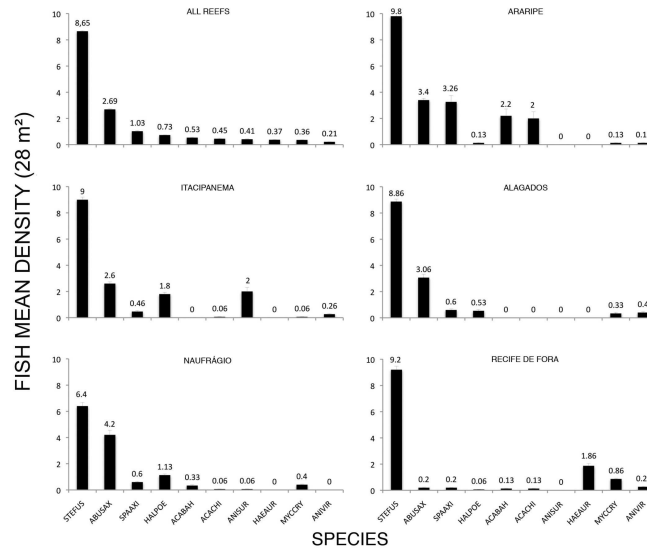
Fig. 2. Mean density per sample of conspicuous species. (⊤) represents Standard Error. STEFUS = *Stegastes fuscus*; ABUSAX= *Abudefduf saxatilis*; HALPOE= *Halichoeres poeyi*; SPAAXI= *Sparisoma axillari*; ACABAH= *Acanthurus bahianus*; ACACHI= *Acanthurus chirurgus*; CARCRY= *Carangoides crysos*; HAEPLU= *Haemulon plumieri*; HAEAUR= *Haemulon aurolineatum*; ANISUR= *Anisotremus surinamensis*; ANIVIR= *Anisotremus virginicus*; MICCHR= *Microspathodon chrysurus* and OCYCHR= *Ocyurus chrysurus*.
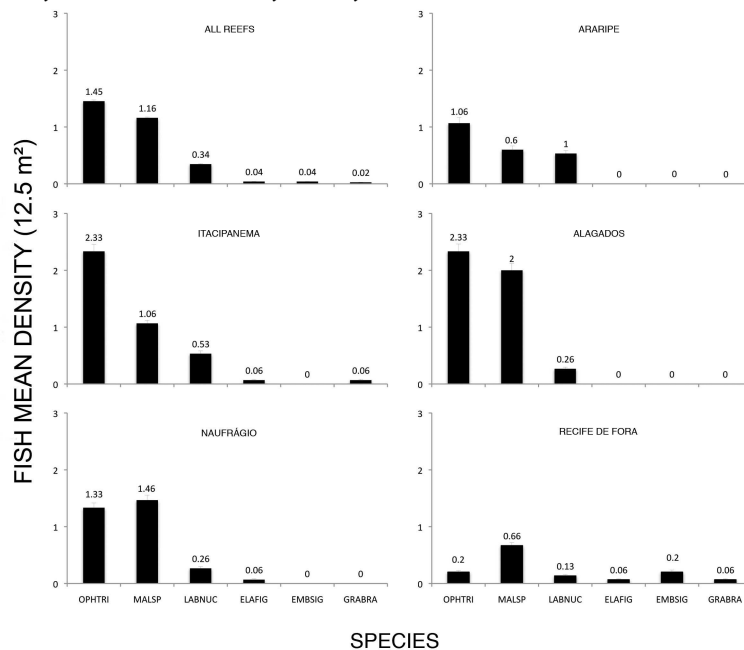

Fig. 3. Mean density per sample of small cryptobenthic species. (⊤) represents Standard Error. MALSPN = *Malacoctenus* spn; OPHTRI= *Ophioblennius trinitatis*; EMBSIG = *Emblemariopsis signifera*; LABNUC= *Labrisomus nuchipinnis*; GRABRA= *Gramma brasiliensis*; ELAFIG= *Elacatinus fígaro*. AR= Araripe Reef; IT= Itacipanema Reef, AL = Alagados Reef; NA=Naufrágio Reef and RF= Recife de Fora Marine Park.

No significant differences were observed for the cryptobenthic species richness between sites (F=1.24; p=0.3), whereas the densities for this group differed clearly (F=3.43; p=0.02; SNK: Al=IT>AR=NA>RF). Cryptobenthic fish were more abundant on the Alagados and Itacipanema Reefs. The density and richness of conspicuous species were homogeneous for all sites (F=1.2; p=0.15 and F=1.91; p=0.11, respectively). *Stegastes fuscus*, *Abudefduf saxatilis*, *Halichoeres poeyi* and *Sparisoma axillare* were among the five most abundant species (Fig. 3).

Cluster analysis showed clearly that the Recife de Fora Marine Park formed one distinct group and the other sites formed another (Fig. 4). This result reflects the low density recorded for cryptobenthic species, due both to the reef structure of this site and the methodology applied, as will be discussed further. However, the richness was higher for this group (n=9). Alagados and Naufrágio reefs were grouped together, mostly because of the lower density of *S. fuscus*, the most abundant on all the reefs, and the higher densities of *A. saxatilis*.
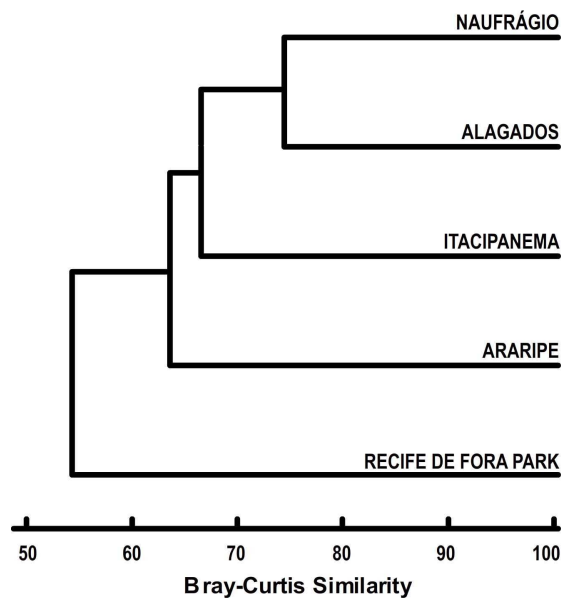

Fig. 4. Cluster Analysis indicating similarity patterns in fish abundance between sample sites. Bray-Curtis Similarity was used.

Table 2. Result of the analysis of variance carried out on the reef organisms and the physical variables considered. SNK-Student-Newman-Keuls test.

Variables (%)	Araripe	Itacipanema	Alagados	Naufrágio	Recife de Fora	F	p	Post-hoc SNK test
Coral cover	10.84±0.30	5.83±0.27	5.95±0.28	1.26±0.28	32.8±0.83	15.13	**0.00**	RF>AR>IT=AL>NA
Foliage algae	4.57±0.42	17.08±0.41	-	5.83±0.10	3.33±0.43	2.35	ns	-
Urchins	0.42±0.09	1.67±0.07	3.93±0.08	2.09±0.03	0.67±0.09	1.08	ns	-
Octocorals	-	4.16±0.19	-	7.91±0.14	-	2.88	**0.02**	NA>IT
Sponges	-	0.42±0.18	-	6.67±0.12	-	0.96	ns	-
Zoantids	-	24.99±0.78	40.15±0.81	10.41±0.19	0.41±1.15	8.39	**0.00**	AL>IT>NA>RF
Filamentous algae	25.43±0.31	16.66±0.33	14.95±0.38	16.67±0.37	47.07±0.90	5.27	**0.00**	RF>AR>IT=NA>AL
Crustose algae	58.74±1.10	29.2±0.91	35.01±1.02	49.16±1.0	15.72±1.12	8.03	**0.00**	AR>NA>AL>IT>RF
Depth (m)	2.76±0.07	2.08±0.07	2.45±0.07	3.17±0.07	3.59±0.04	11.64	**0.00**	RF>NA>AR=AL>IT
Rugosity index	1.56±0.04	1.48±0.04	1.51±0.04	1.43±0.03	2±0.02	6.01	**0.00**	RF>AR=AL>IT=NA

The fish community showed a degree of similarity for density and species richness between all the sites, but trophic composition showed some divergence (Fig.5). Herbivores are dominant in the Recife de Fora Marine Park (35.4%) and on the Araripe (41.1%) and Naufrágio Reefs (40%), whereas Invertebrate feeders were dominant on the Alagados Reef (33.5%). Both categories were balanced on the Itacipanema Reef, where they represented about 36% of the species recorded.

The Recife de Fora Marine Park and Araripe Reef presented higher numbers for carnivore species (n=8 and 6, respectively) whereas the others only presented 3 species each. Omnivores presented greater species richness on the Araripe (n=6) and Alagados (n=4) Reefs.

Some variables showed that the sites are heterogeneous (Table 2). Depth, rugosity, percentage cover of corals, octocorals, filamentous algae, zoantids and crustose algae presented significant differences, whereas echinoderms, sponges and foliage algae cover were similar among sites.

The CCA ordination diagram (Fig. 6) shows significant environmental variables represented by arrows, species by six-letter codes, and samples by symbols. The first two axes were significant (p=0.001) and accounted respectively for 47.4% and 30.2% of the variance between samples, species and variables.

The first axis was positively related to coral, filamentous algae and rugged habitats. This axis clearly represented RF marine park samples where both roving and territorial herbivores, represented respectively by species such as *Acanthurus* spp and *Microspathodon chrysurus*, occur in higher densities. Haemulids and Lutjanids such as *Anisotremus virginicus* and *Lutjanus chrysurus* are also more commonly found. To a lesser degree AR sites were also correlated to these parameters. The higher similarity between these reefs would be unexpected, considering the distance between them, but they cover larger surface areas and thus offer more available space to a wider range of species (e.g., large home range species). Axis 2 was positively associated with crustose algae and coral cover. Apparently, crustose algae cover was similarly distributed among reefs. Zoantids, which were negatively associated with Axis 2 were more abundant on the IT, AL and NA reefs. *Abudefduf saxatilis* was also more abundant on the latter reefs.

Fifty-five percent of the species occur throughout the Western Atlantic, 21% are endemic to the Brazilian coast, 16% are Amphi-Atlantic, 4% are circumtropical, 3% are found in the Western Atlantic and the mid-Atlantic islands, Ascension and Sta. Helena, and 1% are found in the Brazilian Province and the Caribbean.
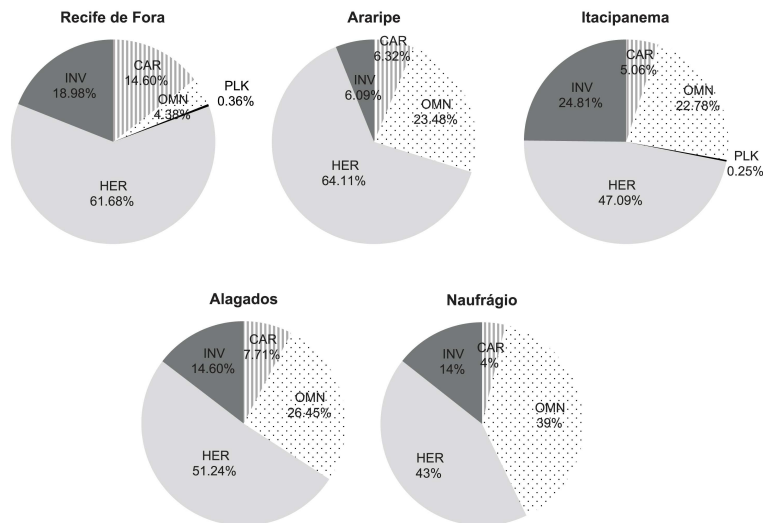

Fig. 5. Trophic composition of reef fish within reefs. INV=Invertivores, CAR = Carnivores, OMN=Omnivores, PLK=Planktivores, HER = Herbivores.
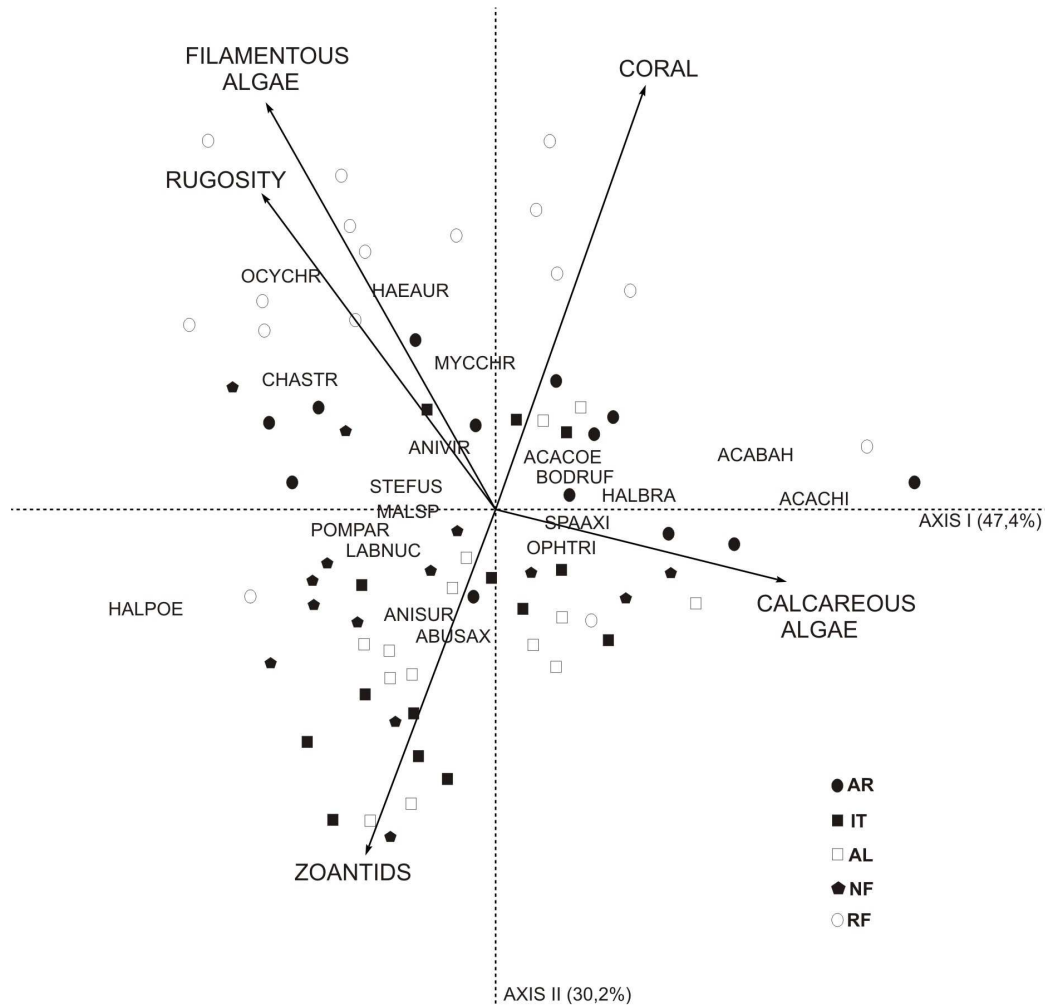
Fig. 6. Canonical Correspondence Analysis (CCA) ordination. Species are represented by six-letter codes. AR=Araripe Reef; IT=Itacipanema Reef; AL=Alagados Reef; NA=Naufrágio Reef; and RF= Recife de Fora Marine Park. STEFUS = *Stegastes fuscus*; ABUSAX= *Abudefduf saxatilis*; HALPOE= *Halichoeres poeyi*; SPAAXI= *Sparisoma axillari*; ACABAH= *Acanthurus bahianus*; ACACHI= *Acanthurus chirurgus*; CARCRY= *Carangoides crysos*; HAEPLU= *Haemulon plumieri*; HAEAUR= *Haemulon aurolineatum*; ANISUR= *Anisotremus surinamensis*; ANIVIR= *Anisotremus virginicus*; MICCHR= *Microspathodon chrysurus*; OCYCHR= *Ocyurus chrysurus*; BODRUF=*Bodianus rufus*; POMPAR=*Pomacanthus paru*; MALSPN = *Malacoctenus* spn; OPHTRI= *Ophioblennius trinitatis*; HALBRA = *Halichoeres brasiliensis*; LABNUC= *Labrisomus nuchipinnis*.

DISCUSSION

Fish Community

Porto Seguro and Santa Cruz de Cabrália reefs presented lower density and richness of fishes than those reported in other studies on the reef systems of northeastern Brazil, such as Risca do Zumbi, PB (154 spp. – Feitoza, unpublished data), Tamandaré, PE (185 spp. – Ferreira *et al.*, 2001), and especially the Abrolhos Complex, the southernmost reef formations in Bahia (Moura and Francini-Filho., 2005) and also as compared with the rocky reefs of southeastern Brazil (Ferreira et al., 1998, 2001; Floeter et al., 2006; Rangel et al., 2007). In these cases, such differences may be due to different sampling methodologies, the area covered by the respective survey, and sampling effort. Additionally, the combination of different conditions in a transitional ecological area is regarded as a major factor accounting for the high diversity in SE Brazilian reef systems (Floeter et al. 2001).

Although shallow reefs are known to offer refuge to a great diversity and abundance of small and cryptobenthic species (Williams and Tyler, 2003), the low density of the former group in the Recife de Fora Park was unexpected. This reef presented high values for the rugosity index and coral covering, which confer habitat complexity. The record of *Emblemariopsis signifera* in the park, where a high coverage of braincorals (*Mussismilia* spp.) is found, is worth noting - such a relationship has previously been reported by Carvalho-Filho (1999).

Together with the presence of holes, habitat complexity provides more available refuge for cryptobenthic species. Ackerman and Bellwood (2000) recorded 95 individuals of 36 cryptobenthic species in a 10 m^2 area of a specific location. This represented approximately 50% of the individuals and 40% of all reef fish species at this location (Depczynski and Bellwood, 2003), which demonstrates once again the limitations of methods such as the use of non-destructive visual censuses, already known to underestimate the density of cryptobenthic fishes (Smith-Vaniz et al., 2006). The methodology applied and shallow depths assessed (~2 m) are also reasonable explanations for the lower densities of wandering species with large home ranges. Nevertheless, we assessed the more common and frequent species. Species commonly found at greater depths were excluded from the study, thus leading to an underestimation of the potential diversity expected for these reefs.

Habitat Heterogeneity

The results presented by this study show the influence of habitat complexity mainly as regards cryptobenthic species. The structure of reefs had a positive influence for richness, but as has been discussed above, underestimated their density. Several studies have examined the effects of biotic and abiotic parameters on fish community structure over extensive areas (Luckhurst and Luckhurst, 1978; Chabanet et al., 1997; Ornellas and Coutinho, 1998; Arbuto-Oropeza and Balart, 2001; Ferreira et al., 2001). Such studies regarding the Brazilian coast are increasing (Ferreira et al., 2001; Francini-Filho, 2005; Floeter et al., 2007; Chaves and Monteiro-Neto, 2009, Medeiros et al., 2010) and the great variability found suggests that the factors potentially influencing reef fish composition are highly site-dependent and variable.

Trophic Organization and Biogeographical Affinities

The reefs presented some physical heterogeneity, but their fish composition and richness were very similar. This was expected in view of the scale applied, seeing that most reef fish species are widely distributed along the coast, which reflects the high potential for dispersal among reef fishes and their ability to reach distant areas (Luiz-Jr. et al., 2008). Nevertheless, many species reported in the present study (e.g., *Pomacanthus arcuatus*, *Anisotremus moricandi*, *Microspathodon chrysurus*) are characteristic of the Brazilian northeastern coastal reef, but as with many of the others found, they exhibit major contributions of components of the Brazilian province.

Trophic organization in the area studied is very similar to that of the SE rocky reefs (Ferreira et al., 2001), where invertebrate feeders, herbivores and omnivores are the most abundant and speciose groups. According to Floeter et al., 2004, the density of herbivorous fishes (the dominant group relying on low-quality food resources) in the Western Atlantic decreases from tropical to temperate latitudes. The similarity observed with southeastern rocky reefs for herbivores is due to a high density of the territorial damselfish *S. fuscus* in the study conducted by Ferreira et al. (2001). Moreover, Moura and Francini-Filho (2005) found that carnivores were the most abundant group, followed by omnivores, herbivores and planktivore fishes in Southern Bahia. In the latter study, the trophic category for carnivores included invertebrate feeders, thus contributing to the differences observed in this study.

Marine Protected Areas and Conservation Remarks

Floeter et al. (2006) and Francini-Filho and Moura (2008b) show the effects of no-take areas on the abundance and size of reef fish as compared with those of the fishing areas on Brazilian reefs. Top predators and roving herbivores clearly presented higher abundances and sizes in areas closed to fisheries.

According to our data, the Recife de Fora Marine Park, compared to other protected reefs, presented a low abundance of top predators such as epinephelids and lutjanids, and Roving Herbivores, families of high economic value. Thus, indicating its conservation status had little or no effect as regards the protection it affords to large roving herbivores and carnivores. Although a Marine Protected Area can be a powerful tool for the replenishment of fish stocks (Francini-Filho, 2005; Francini-Filho and Moura, 2008a), it is still difficult to estimate when fish populations will attain a healthy status or whether effective management actions are being taken. Fisheries management using small-scale marine protected areas has shown positive results (e.g. McClanahan et al., 1997; Ferreira and Maida, 2001). However, only some species respond positively to protection (Micheli et al., 2005; Dulvy et al., 2004a).

A general abundance increase of non-target species, particularly in small-sized classes, could be an indirect effect of local top predator extinction, as has been documented for several regions (Dulvy et al., 2004b; Ashworth and Ormond, 2005).

Threatened species such as *Elacatinus figaro*, *Anisotremus moricandi* and *Gramma brasiliensis* (MMA, 2004) reinforce the need for conservation on the reefs studied. Some efforts suggest that commercial fisheries and the ornamental fish trade has effects on the diversity and abundance of species, leading to significant changes in the local fish community structure (Costa *et al.*, 2003; Gasparini *et al.*, 2005; Ferreira *et al.*, 2006). Nonetheless, past data would be needed to draw a more precise scenario. The lack of effective enforcement observed by Prates (2003) and the increasing fishing pressure inside the Park are indicative of the great need of protection in the area, that might be considered at this point in time as a mere "paper park".

This article presents a pioneer study of the composition and community structure of reef fishes in the Santa Cruz de Cabrália and Porto Seguro reefs. Baseline data are essential for biodiversity evaluations, improving our ability to predict the outcomes of alternative management strategies for reef fishes and their habitats. Given the high endemism level (10.5%), according to Floeter *et al.* (2008), and a coastline extending for approximately 8,000 km, a large-scale management plan covering the whole Marine reserves network would be an alternative for the conservation of Brazilian reef systems.

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