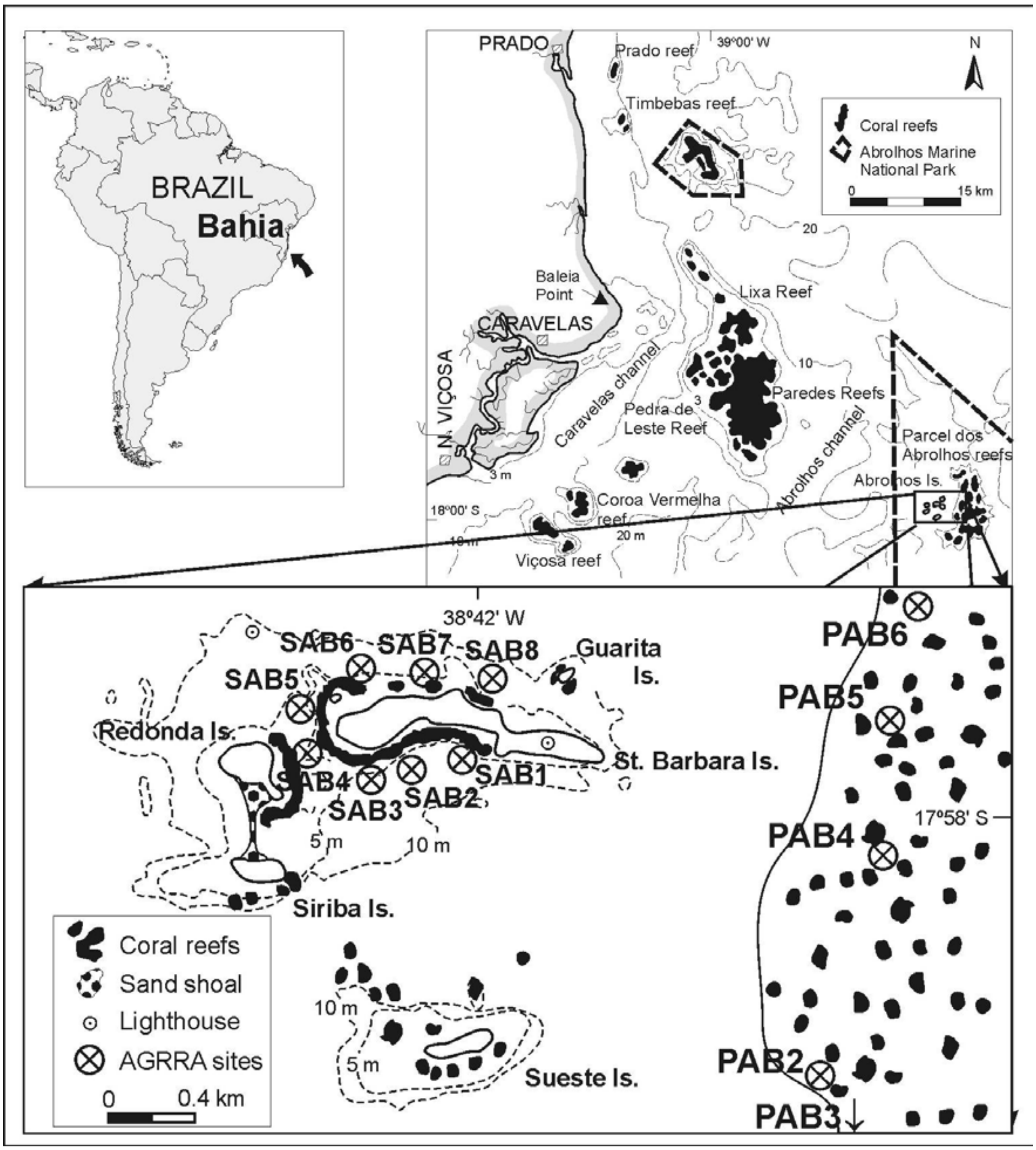

Figure 1. AGRRA survey sites off Santa Bárbara Island (SAB) and in the Parcel dos Abrolhos chapeirões (PAB), Abrolhos, Brazil. See Table 1 for site codes.

RAPID ASSESSMENT OF THE ABROLHOS REEFS, EASTERN BRAZIL (PART 2: FISH COMMUNITIES)

BY

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ABSTRACT

The first rapid assessment of fish communities in the Abrolhos Marine National Park was undertaken in three offshore chapeirões and at eight sites in the fringing reef off Santa Bárbara Island. Fish communities in the two habitat types differed at both the family and species levels. Total species numbers were higher in the chapeirões (38-40/site) than in the fringing reef (13-37/site). Total fish density was higher in the fringing reef than in the chapeirões, as were the densities of most surveyed families, except for pomacentrids, lutjanids and scarids. The most common size class for key herbivores (scarids ≥5 cm, acanthurids) and carnivores (lutjanids, large-sized serranids) was 11-20 cm. Herbivores grazing dead skeletal areas may accidentally damage stony corals, particularly in the chapeirões. Limited impacts from sewage discharge may affect the northern coast of Santa Bárbara Island; tourists or artisanal fishers may have reduced the density of carnivores in this fringing reef.

INTRODUCTION

Brazilian coral reefs, which are the southernmost reefs in the western Atlantic Ocean, extend approximately 2,000 km between 0°50' S and 19° S latitude. Although they have been studied for over a century, many reef areas are still poorly known and there are few quantitative assessments of their condition (see Leão et al., 1999). The Abrolhos reef complex in the southern part of the eastern state of Bahia (between 17°S and 19°S) contains the largest and most thoroughly investigated coral reefs in the western South Atlantic (Fig. 1). The reefs are scattered over an area of approximately 6,000 km^2 on the inner and middle continental shelf of the Abrolhos Bank. There are three reef

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types: isolated nearshore bank reefs of varied shapes (e.g., elongated, circular) and sizes (<1 km to ~20 km) in depths of 10-20 m, offshore shallow (<10 m deep) fringing reefs that parallel the shorelines of the five volcanic islands of the Abrolhos Archipelago; and "chapeirões"– huge (15 to >25 m high), isolated mushroom-shaped reefs found in water depths greater than 20 m.

The northern coasts of the Abrolhos islands are exposed to relatively high wave energies between September and February, their southern sides to somewhat larger waves from April to August, while the western (leeward) coasts are protected from major wind trends. The fringing reef flats extend about 30 m from shore, are poorly developed, and, during low tides, are subaerially exposed. To seaward, the reefs gradually slope to their edges at depths of 4-5 m where they drop off to a sandy bottom at 8-10 m. The windward Parcel dos Abrolhos (PAB) chapeirões are located about 2 km east of the Abrolhos islands (Fig. 1). Due to the limited penetration of light beneath the overhangs around their sides, the maximum development of stony corals is at depths of 5-8 m on the crests of the chapeirões.

A marine protected area was established in the Abrolhos reef complex in 1983 in recognition of its unique reef morphology, the presence of endemic scleractinians, and because most Brazilian reefs occur in this region. As the focus of the Abrolhos Marine National Park (AMNP) was to preserve the isolated chapeirões, ninety percent is located approximately 60 km from the mainland in the offshore reefs, with only 10% of the Park in the coastal zone. Meanwhile, as urban expansion and deforestation have accelerated, the coastal reefs are being exposed to increasing amounts of river runoff and untreated sewage discharges. However, the offshore reefs are located beyond the reach of the turbid coastal waters.

It is important to note that endemism of fish species in the Brazilian province is about 18% to 20% (Floeter and Gasparini, 2000, 2001) and the Abrolhos area is the southernmost geographic limit of some endemic tropical Brazilian species (e.g., *Dasyatis marianne,* Gomes et al., 2000; Moura et al., 2001). Almost 20 years have passed since the AMNP was established, yet there have been only a few assessments of its fish communities (Telles, 1998; Ferreira and Gonçalves, 1999). While there has been, to date, no evidence of excessive harvesting in the offshore reefs, which are designated as "no-take" zones, the coastal reefs appear to have been overfished (Ferreira and Gonçalves, 1999).

Some of the fringing reefs that border the offshore Abrolhos islands have been intensively used by recreational divers and snorkelers since 1989 (Leão et al., 1994). Although tourists dive all around Santa Bárbara Island (SAB) in particular, its southern side is most heavily visited. The PAB chapeirões are less popular due to difficulty of navigation and rougher seas but its fish and coral populations are considered to be in relatively good condition (personal observations). Previous assessments of potential human disturbances in the AMNP have only referred to the anchorage of tourist boats in algal beds around the islands (Creed and Amado Filho, 1999).

Our initial purpose in using the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocols in the AMNP was to collect information on the condition of the offshore chapeirões and the SAB fringing reef in order to establish standards for a long-term monitoring program in the park. The results of the benthos assessment can be found in Kikuchi et al. (this volume).

METHODS

Fish surveys were conducted in eight fringing reef sites around SAB which are considered representative of its northern (three sites), southern (three sites) and western (two sites) coasts. The three southern sites were also strategically chosen because they are preferred recreational dive sites. Each site was located in shallow (3.5-5.5 m) water as close as possible to the seaward edge of the reef. The 6-6.5 m crests of three representative chapeirões were surveyed. Except for the leeward fringing reef, most of these sites are exposed to large waves, and the leeward sites experience strong tidal currents.

On each dive, two divers utilized the AGRRA Version 2.0 fish protocol (see Appendix One, this volume), which was modified as follows. As many of the chapeirões are less than 30 m in width, we made 30 transects/site, each 10 m long by 2 m wide. Except for the absence of a T-bar for estimating fish lengths, the transects were swum in the AGRRA manner. Juvenile grunts (haemulids) and parrotfishes (scarids) less than 5 cm in total length were tallied, as were all species of common reef fishes. Any juvenile that could not be identified to species was only assigned a genus name. The name *Scarus trispinosus* Valenciennes, 1840 was substituted for *Scarus coelestinus* which is no longer thought to occur in Brazil (Moura et al. 2001). Other identifications were based on the descriptions of Humann (1994), Smith (1997), Carvalho-Filho (1999) and Rocha and Rosa (2001).

Roving Diver Technique surveys were not made. Therefore, the number of fish species at each site is taken from the transect results. To ensure consistency, all analyses are based on the data collected by Sampaio. Juvenile grunts and parrotfishes <5 cm in length were excluded from calculations of AGRRA fish densities. Scatterplots and regression plots were used to investigate possible relationships between fish characteristics [total densities and densities of key carnivores, key herbivores, surgeonfishes (acanthurids), and parrotfishes] and some ecological parameters [live stony coral cover, height or partial-colony mortality of "large" (≥25cm diameter) stony corals, macroalgal index = macroalgal relative abundance x macroalgal height] that are given in Kikuchi et al. (this volume). Comparisons were made with both reef types (SAB fringing reef and the PAB chapeirões) grouped together and separately. Regression coefficients of determination and significance probability based on ANOVAs are presented for the best relationships. Densities of surgeonfishes, parrotfishes ≥5 cm, and both herbivores combined showed a rather good fit to a normal distribution model; hence fish densities and numbers of species were used without transformation. Cluster dendrogram and MDS diagrams were plotted based on Bray-Curtis similarity coefficients between the mean total density of fishes grouped by family at each site after the mean densities were square-root transformed. The complete linkage option was chosen in hierarchical agglomerative clustering (Clarke and Warwick, 1994).

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RESULTS

The total fish community at many (7/11) sites had over 30 species of common reef fishes, and three of the remaining sites had more than 20 species (Table 1). Total species numbers were consistently higher at 6.5 m in the chapeirões (39-40/site, n=3) than at 3.5-5.5 m in the fringing reef (13-37/site, n=8). In contrast, 6/8 of the SAB sites had 17-19 of the species on the AGRRA list, whereas corresponding numbers in the PAB were somewhat lower (14-16/chapeirão).

Fish densities (AGRRA species only) were higher off SAB than in the chapeirões (Fig. 2, Table 2) as were densities of the numerically dominant grunts (all sizes) and surgeonfishes. When all sites are considered together, the small omnivorous grunt, *Haemulon aurolineatum,* had the highest density, followed by another omnivore (and non-AGRRA-listed fish) the sergeant major, *Abudefduf saxatilis*, damselfishes (*Stegastes* spp.), two surgeonfishes *(Acanthurus chirurgus and A. coeruleus)* and, in sixth position, the carnivorous snapper (lutjanid), *Ocyurus chrysurus* (Table 3). Densities of parrotfishes (≥5 cm) were about 20 individuals/100 m^2 in both habitat types (Fig. 2). Acanthurids were more plentiful off SAB (~60 individuals/100 m^2) than in the chapeirões (35 individuals/100 m^2). Snapper densities in the PAB were double those in the fringing reef (30 versus 15 individuals/100 m^2, respectively). Groupers were fewer than about 5 individuals/100 m^2 everywhere.

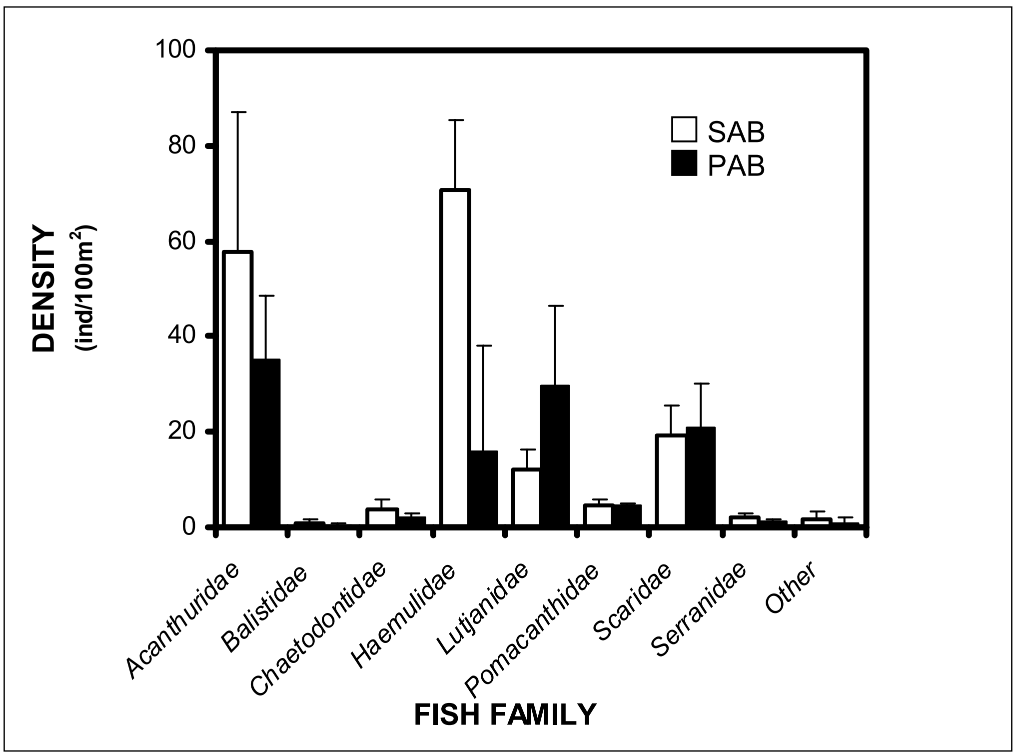

Figure 2. Mean fish density (no. individuals/100 m^2 ± sd) for all species (and all sizes of fish) in 11 fish families in the SAB fringing reef and PAB chapeirões, Abrolhos, Brazil. Other = *Caranx ruber, Caranx crisus, Sphyraena barracuda.*

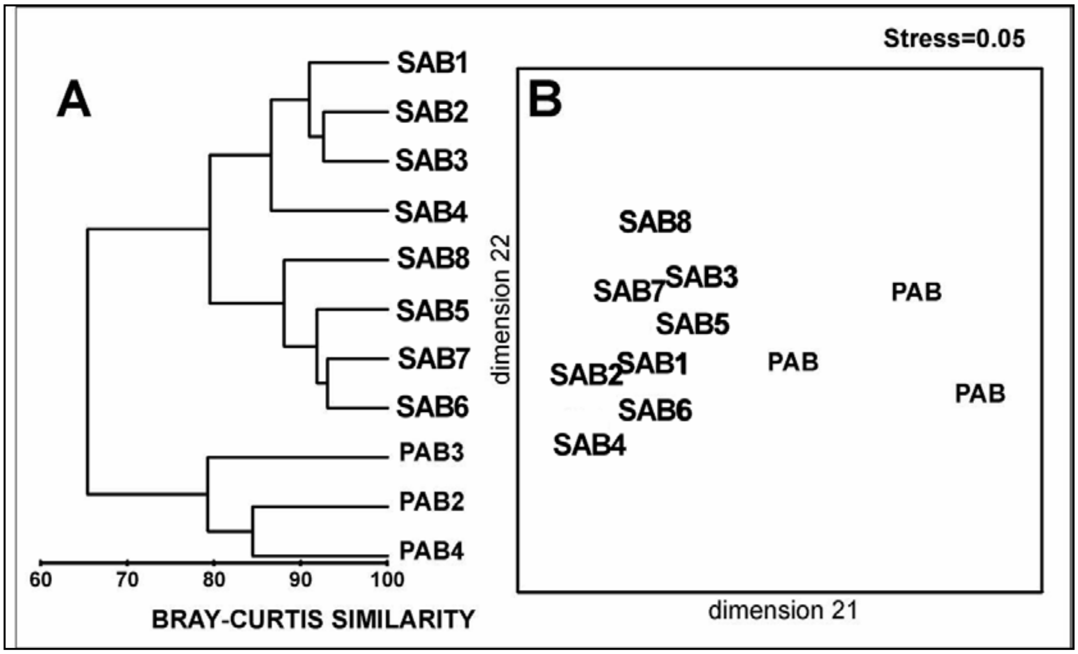

Figure 3. (**A**) Hierarchical cluster analysis and (**B**) MDS ordination plot of all common reef fishes (based on belt transect data), by site in the Abrolhos, Brazil.

Site comparisons at the family level clearly separated the fringing reef from the chapeirões (Fig. 3) on the basis of both the Bray-Curtis similarity matrix and the MDS analyses.

The size-frequency distributions of the key carnivores (snappers and large groupers) were similar in the two habitats (Fig. 4A), the most common length class being 11-20 cm. The mean size of the key herbivores, parrotfishes ≥5 cm, and surgeonfishes (the damselfish *Microspathodon chrysurus* was not seen despite its known presence in Brazilian waters) was a little larger in the chapeirões than in the fringing reef, even though the most common length class at both was 11-20 cm (Fig. 4B). Carnivore sizes in both environments (fringing reef and chapeirões) were normally distributed, as were herbivores in the chapeirões, however, the size distribution of the SAB herbivores was slightly skewed towards larger fishes.

When all sites are included in the analysis, regardless of whether or not juvenile scarids (<5 cm in length) are retained, herbivore density showed no relationship to macroalgal index (Fig. 5A). However, when the two island sites with the highest macroalgal indices (SAB5, SAB8) and the chapeirões reefs are removed, herbivore (scarids ≥5 cm long, acanthurids) density was inversely related (R^2=0.800, p=0.016) to the macroalgal index of the remaining six SAB sites (Fig. 5B). A separate test of surgeonfish density versus macroalgal index in these six sites also produced good fit (R^2=0.910, p=0.003), but there was no relationship between parrotfish (≥5 cm) density and macroalgal index in these same six sites. Despite the moderately good fit between herbivore density and macroalgal index in the chapeirões, the significance test indicates a high probability that the curve is horizontal (R^2=0.619, p=0.423).

The total number of fish species/site showed no relationship with the density of large (≥25 cm in diameter) stony corals when all sites are taken into consideration

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(Fig.6), and the positive regression for the chapeirões sites is not significant (R^2=0.881, p=0.224). No relationship emerged from the comparison of live stony coral cover and fish density. Neither was fish density related to the density of large stony corals nor to their average maximum height (which was used to approximate the rugosity of the reef surface, Kikuchi et al., this volume).

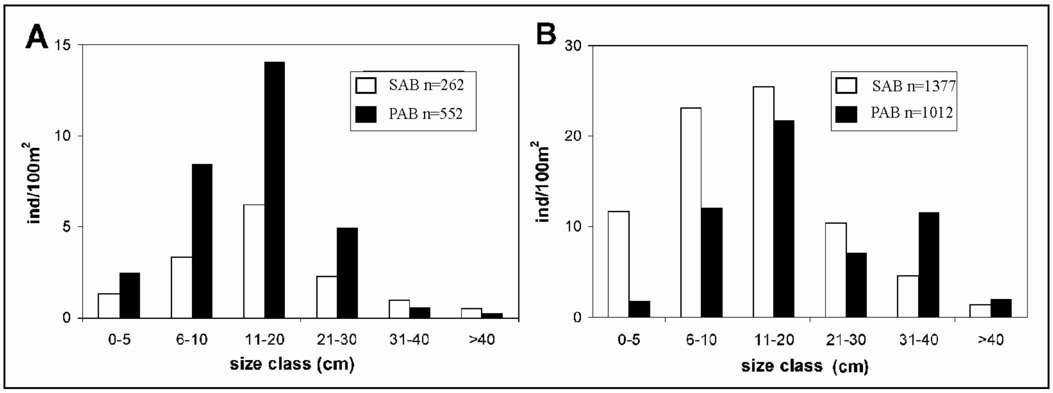

Figure 4. Size frequency distribution of (**A**) carnivores (all lutjanids, select serranids) and (**B**) herbivores (all acanthurids, scarids ≥5 cm) in the SAB fringing reef and PAB chapeirões, Abrolhos, Brazil.

When all sites are considered, no relationship was found between the total density of the AGRRA fishes and values for old partial-colony mortality of the large stony corals. Amongst the herbivores, only in the chapeirões (Fig. 7A, B, C) was old (but not recent) partial mortality positively related to the density of parrotfishes (R^2=0.978, p=0.031) and surgeonfishes (R^2=0.997, p=0.037).

DISCUSSION

The structure of the SAB reef fish community seems representative of the offshore insular fringing reefs in the Abrolhos Archipelago as a whole. Our results are very similar at the family level to those of Telles (1998) who, in 1995, quantified 20 common fish taxa in sites that were evenly distributed among the fringing reefs of all five islands. (Four of these sites were located in SAB, three were in Sueste, two each were in Redonda and Siriba and one was in Guarita.) Telles' (1998) belt transects, which were 50 m x 4 m, each being surveyed three times (i.e., there were three replicates of each 200 m^2 transect), were swum at depths of 2-6 m.

As in our SAB surveys, grunts, surgeonfishes and damselfishes were the most common families found by Telles (1998) when the data from all five islands are combined (Fig. 8). The SAB fish community also seems to be representative of the archipelago's five fringing reefs at the species level, given the similarities in the relative frequency of Telles' (1998) 20 target taxa in the two studies (Table 4). *Haemulon aurolineatum* is the most abundant of these species in both surveys.

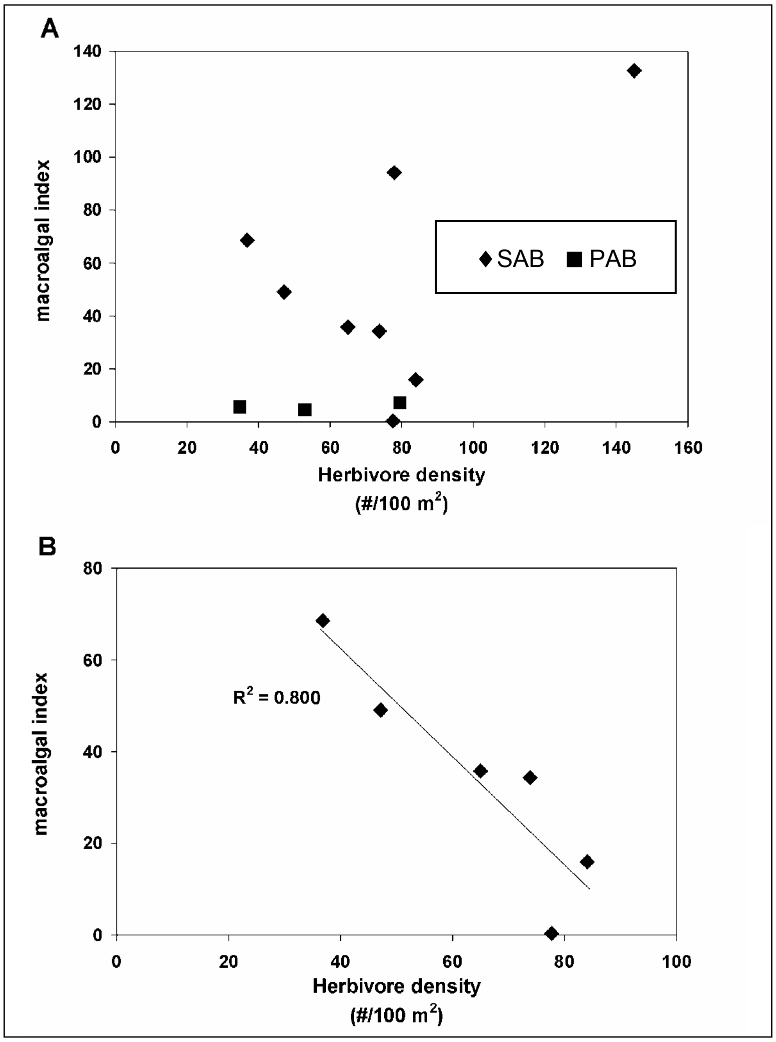

Figure 5. Regression plots between mean herbivore density (no. individuals/100 m^2) and macroalgal index (**A**) by site, (**B**) for six of the SAB sites (with the significant regression line), in the Abrolhos, Brazil.

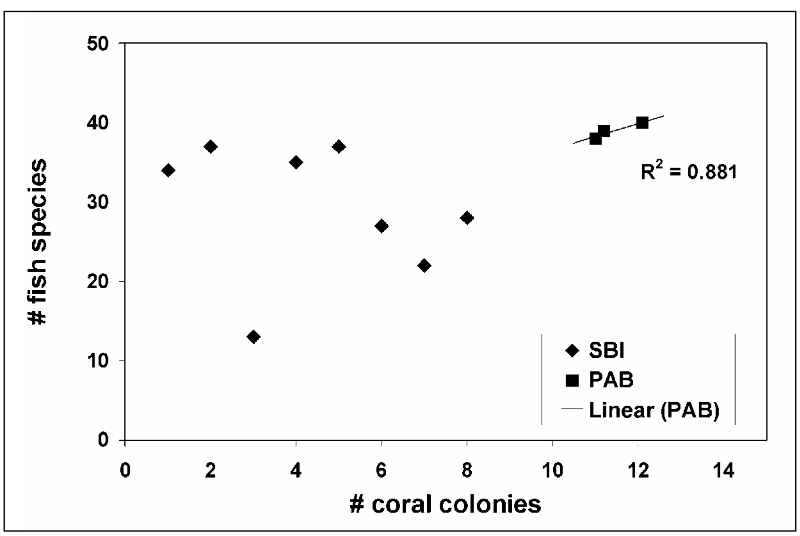

Figure 6. Regression plot between total fish species number and mean density of stony corals (≥ 25 cm diameter)/10 m, by site in the Abrolhos, Brazil. Regression line shown for the PAB chapeirões sites is not significant.

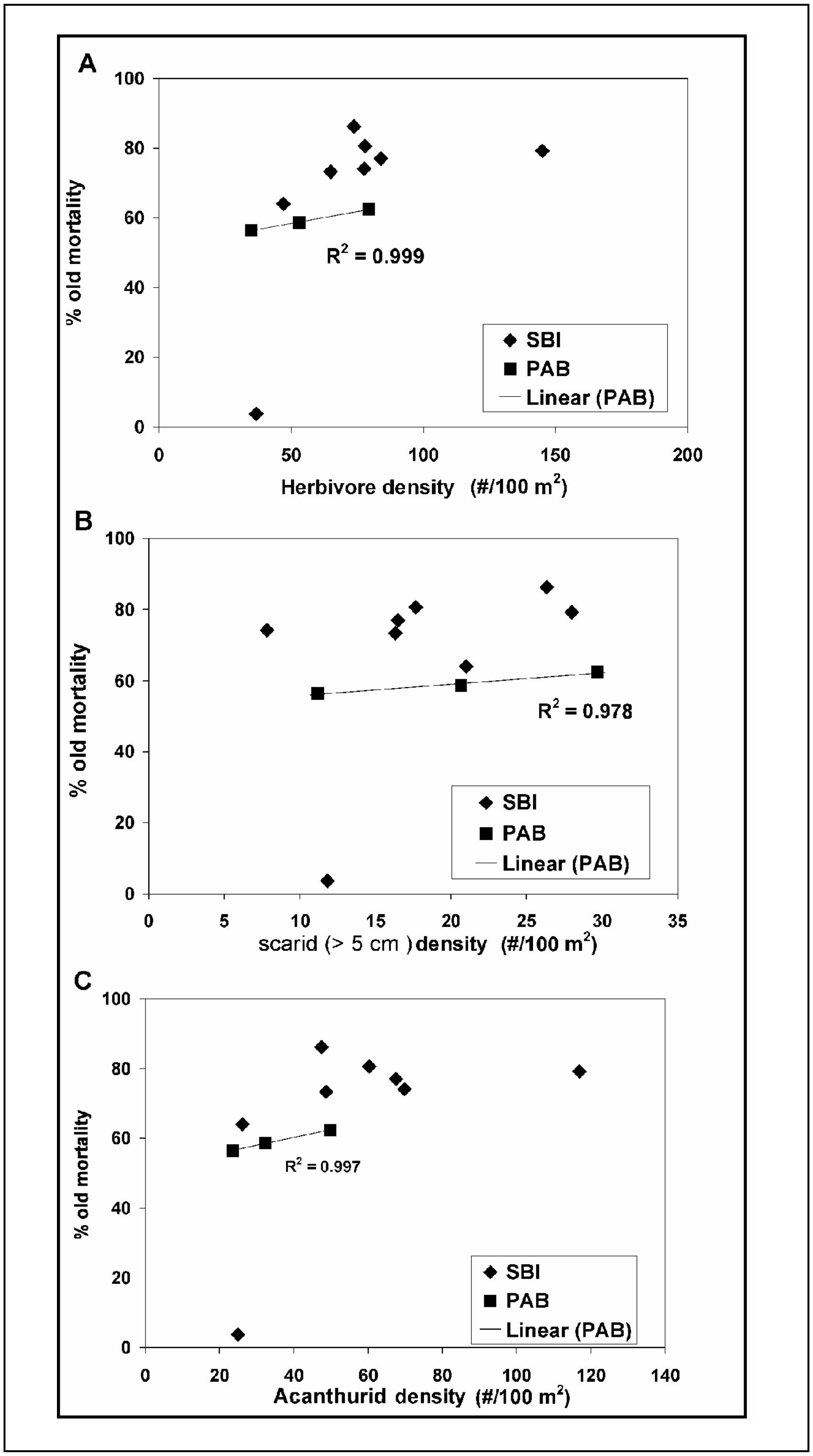

Figure 7. Regression plots between old partial colony mortality of stony corals and density of (**A**) key herbivores, (**B**) scarids ≥5 cm, (**C**) acanthurids, by site in the Abrolhos. Regression lines shown for the PAB chapeirões sites are significant.

However, there are marked differences, at least at the family level, between the fish communities of the SAB fringing reef and the PAB chapeirões (Figs. 2, 3). The positive (but non-significant) relationship between the number of fish species and the density of large stony corals in the chapeirões might be explained by an attendant increase in the variety of habitats and niches associated with the latter. Like the large chapeirões, massive colonies of *Mussismilia braziliensis* are mushroom shaped. Their upper (illuminated) surfaces are larger in diameter than their shaded bases, which are dead and overgrown by crustose coralline algae, turf algae, macroalgae, and sponges. As the number of colonies increases, concomitant increases in the microtopographic complexity may enhance fish species richness by increasing the number of ecological interactions among stony corals, other benthic species, and fishes.

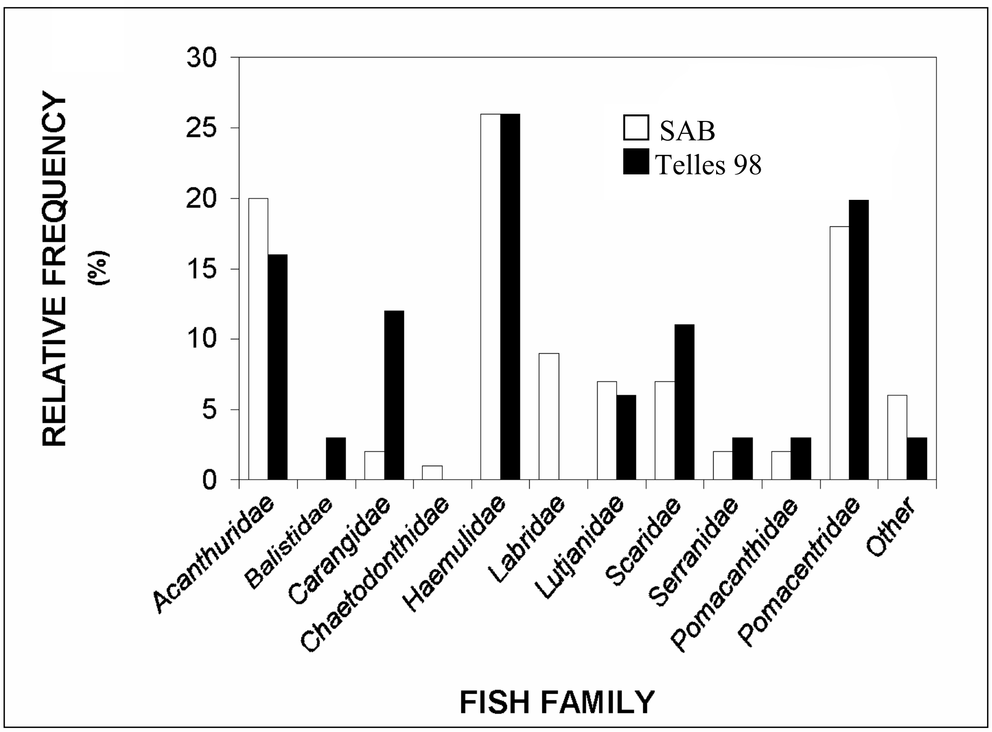

Figure 8. Percent relative frequency (number of fishes belonging to each family divided by the total number of fish counted) for 20 common fish taxa, by familiy, in the SAB fringing reef (this study) and all five offshore fringing reefs (Telles 1998) in the Abrolhos, Brazil. Other = *Caranx ruber, Caranx crisus, Sphyraena barracuda.*

Local nutrient enrichment is possibly responsible for the unexpectedly high algal biomass at the two fringing reef sites in which the inverse relationship elsewhere found between herbivores and macroalgae at SAB is lacking (Fig. 5). One of these sites (SAB5) is located near an area known as Bird's Cemetery where dead bodies of masked booby (*Sula dactylatra*), brown booby (*Sula leucogaster),* and magnificent frigatebird (*Fregata magnificens*) are frequently found. The other site (SAB8) is seaward of the seven houses occupied by Navy and Park personnel where sewage either seeps from septic tanks or is discharged directly into the ocean.

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Relative to the chapeirões, snapper densities in the SAB fringing reef are strikingly low (Fig. 2) and the size-frequency distributions of herbivores are shifted toward smaller individuals (Fig. 4). As these patterns are not what we would expect in an area lacking direct human exploitation, tourists may simply chase carnivores away and/or illegal fishing (by tourists or artisanal fishermen) may occur at night.

Recent partial mortality of large (≥25 cm in diameter) stony corals was rare and bore no relationship to fish densities. In the chapeirões, however, there seems to be a relationship between the densities of parrotfishes and surgeonfishes and old partial-colony mortality. Herbivorous fishes graze intensively on the dead surfaces of stony corals and may occasionally destroy some live tissues. Schools of the endemic greenbeak parrotfish, *Scarus trispinosus*, and of surgeonfishes are commonly seen engaged in this activity (personal observations of all co-authors).

The species richness of the common and AGRRA-listed reef fishes and the sizes of key herbivores and carnivores was higher in the PAB than off SAB, reinforcing our interpretation from the benthos assessment that the chapeirões are in better condition overall than the fringing reef (Kikuchi et al., this volume). The role of tourism in depressing carnivore, and possibly parrotfish, density in the SAB fringing reef can only be tested by assessing other areas of the AMNP, such as the islands of Sueste and Guarita, where tourist activities are prohibited.

If Telles' (1998) data are any guide, carnivorous snappers and groupers are slightly more common in the five islands as a whole than off SAB. Anthropogenic effects are possibly reflected in the AGRRA fish indicators in what is supposed to be a protected fringing reef. To test this hypothesis is one of the aims of future AGRRA assessments in the AMNP. We also plan to survey fish communities in its coastal reefs where artisanal and recreational harvesting is known to be intense. In sum, park management practices should be evaluated, and some changes may be needed to conserve the endemic species and other fishes in the Abrolhos Marine National Park.

ACKNOWLEDGMENTS

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Table 1. Site information for AGRRA fish surveys in the Abrolhos, Brazil.

Site name	Site code	Relative exposure/ Reef type	Latitude (º ′ S)	Longitude (º ′ W)	Survey date(s)	Depth (m)	>25 cm stony corals[1] (#/10 m)	Height (cm)	% live stony coral cover (mean ± sd) [1]	10 m fish transects (#)	Fish species (#) All common	AGRRA
Santa Bárbara Island												
South 1	SAB1	exposed/fringing	17 58.89	38 41.71	Mar 28 00	4	3	14.0	3.5 ± 1.3	30	34	18
South 2	SAB2	exposed/fringing	17 57.82	38 42.06	Mar 29 00	5.5	4	23.5	6.5 ± 4.3	30	37	18
South 3	SAB3	exposed/fringing	17 57.92	38 42.22	Mar 30 00	5.5	5.5	20.0	8.0 ± 6.3	30	13	17
Leeward 1	SAB4	sheltered/fringing	17 57.75	38 42.40	Mar 31-Apr 1 00	3.5	10.5	20.5	7.5 ± 5.0	30	35	15
Leeward 12	SAB5	sheltered/fringing	17 57.85	38 42.20	Apr 1-2 00	4.5	12	17.0	12.0 ± 4.9	30	37	18
North 3	SAB6	exposed/fringing	17 57 60	38 42 11	Apr 4-5 00	3.5	6	26.0	7.0 ± 5.2	30	28	19
North 2	SAB7	exposed/fringing	17 57.68	38 41.98	Apr 5-6 00	4.5	12.5	25.0	11.5 ± 6.1	30	22	16
North 1	SAB8	exposed/fringing	17 58 04	38 41.54	Apr 9-10 00	4	7	23.0	7.0 ± 4.3	30	27	18
Parcel dos Abrolhos												
Chapeirões 2	PAB2	exposed/chapeirões	17 59.00	38 40.04	Mar 21 00	6.5	11	26.5	20.0 ± 10.5	30	39	16
Chapeirões 3	PAB3	exposed/chapeirões	17 57.52	38 40.17	Mar 22 00	6.5	11	30.5	23.0 ± 8.1	30	38	14
Chapeirões 4	PAB4	exposed/chapeirões	17 58.08	38 39.34	Mar 23 00	6.5	12	30.0	22.0 ± 7.5	30	40	16

[1]From Kikuchi et al. (this volume)

Table 2. Density (mean ± standard deviation) of AGRRA fishes and macroalgal index, by site in the Abrolhos, Brazil

Site code	Herbivores (#/100 m²)		Carnivores (#/100 m²)			Macroalgal Index[2]
	Acanthuridae	Scaridae ≥5 cm	Haemulidae ≥5 cm	Lutjanidae	Serranidae[1]	
SAB1	48.67±41.88	16.33±12.04	62.33±59.77	10.50±7.29	2.33±1.41	36
SAB2	26.17±19.80	21.00±12.82	72.17±105.58	16.33±8.34	3.83±3.05	49
SAB3	25.00±13.72	11.83±9.01	42.83±40.47	13.00±18.46	2.00±2.05	69
SAB4	47.50±37.16	26.33±17.72	55.00±41.20	9.50±7.62	2.83±2.23	34
SAB5	60.33±39.98	17.67±15.46	79.00±72.48	17.00±8.88	1.50±3.19	94
SAB6	69.83±61.66	7.83±7.20	45.17±31.84	15.17±20.27	1.33±1.53	<1
SAB7	67.50±36.47	16.50±21.03	74.83±71.88	10.83±14.70	2.67±3.44	16
SAB8	117.00±92.26	28.00±30.73	32.67±56.33	5.50±4.97	1.00±1.41	133
PAB2	49.83±40.40	29.67±12.79	3.50±5.18	40.00±29.06	0.67±0.86	7
PAB3	23.67±24.57	11.17±12.67	2.67±1.61	9.83±5.47	0.83±0.88	6
PAB4	32.33±31.14	20.67±12.40	41.50±66.58	38.83±32.46	1.83±2.28	5

[1] *Epinephelus* spp. and *Mycteroperca* spp.
[2] From Kikuchi et al. (this volume)

Pp. 188-203 in J.C. Lang (ed.), Status of Coral Reefs in the western Atlantic: Results of initial Surveys, Atlantic and Gulf Rapid Reef Assessment (AGRRA) Program. Atoll Research Bulletin 496.

Table 3. Twenty-five most frequently sighted fishes and the mean densities for species seen in belt transect surveys in the Abrolhos, Brazil.

Scientific name	Sighting frequency (%)[2]	Density (#/100 m^2)
Abudefduf saxatilis	100	28.95
Stegastes spp.	100	23.77
Acanthurus chirurgus	100	20.06
Acanthurus coeruleus	100	17.79
Ocyurus chrysurus	100	16.88
Scarus trispinosus[1]	100	11.77
Sparisoma spp.	100	7.9
Anisotremus virginicus	100	4.89
Chaetodon striatus	100	3.33
Holocentrus adscensionis	100	2.21
Acanthurus bahianus	96	13.77
Pomacanthus paru	96	2.98
Mycteroperca bonaci	96	1.86
Gramma braziliensis	96	1.59
Haemulon plumieri	92	5.32
Balistes vetula	88	0.83
Haemulon aurolineatum	83	35.68
Halichoeres radiatus	79	1.61
Elacatinus figaro	75	5.68
Holocanthus ciliaris	75	1.05
Haemulon parra	71	9.73
Scarus zelindae	71	1.48
Caranx chrysus	67	1.36
Caranx ruber	50	0.86
Caranx bartholomaei	46	1.02

[1]formerly *Scarus coelestinus*.
[2]Sighting frequency (%) = percentage of dives in which the taxon was recorded.

Table 4. Relative frequency of the most common fishes in the Abrolhos Archipelago (Telles, 1998) and in Santa Bárbara Island (this survey).

Scientific name	Relative frequency (%)[2]	
	(Telles, 1998)	(this survey)
Haemulon aurolineatum	19	14
Stegastes variabilis	13	9
Acanthurus chirurgus	11	8
Scarus trispinosus[1]	8	4
Abudefduf saxatilis	7	11
Chaetodon striatus	5	1
Caranx latus	5	0
Ocyurus chrysurus	4	7
Acanthurus coeruleus	4	7
Pomacanthus arcuatus	3	0.2
Anisotremus virginucus	3	2
Haemulon parra	3	4
Sparisoma spp.	3	3
Mycteroperca bonaci	3	1
Balistes vetula	3	0.3
Lutjanus jocu	2	0.3
Caranx rubber	2	0.3
Holocentrus adscensionis	1	1
Kyphosus sectatrix	1	4
Sphyraena barracuda	1	0.1

[1]formerly *Scarus coelestinus*.
[2]Relative frequency = number of individuals/taxon relative to the total number of individuals.

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