

Comparative analysis of rocky reef fish community structure in coastal islands of south-eastern Brazil

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Reef fish community structures at three sites in the state of Rio de Janeiro (Pedra Vermelha (PV), Cabo Frio Island—Arraial do Cabo; Mãe Island (MI), Itaipu—Niterói; Comprida Island (CI), Cagarras Archipelago—Rio de Janeiro) were investigated to assess differences in fish species composition, density and distribution of trophic groups, between sites, correlating the observed patterns of fish distribution with environmental factors. Thirty-six visual strip-transects yielded 67 species of 34 families. Studied locations shared at least 40% of all species, mostly of western Atlantic distribution. The three sites presented significant differences on diversity, density and species dominance. CI presented the highest values, except for total density, which was higher at PV, probably due to its partial degree of protection. MI showed the lowest values, suggesting possible impacts from the proximity to the shore. The main trophic categories were omnivores followed by mobile invertebrate feeders, in similarity to what was previously observed for south-eastern Brazil. Inherent habitat features of each location regarding depth, declivity, visibility and rugosity resulted in different species distribution and dominance patterns.

Keywords: fish ecology, habitat complexity, rocky reefs, south-eastern Brazil

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INTRODUCTION

Reefs are the most diverse ecosystems among marine environments. One of the factors contributing to this high diversity is the variety of habitats and niches available for different species (Sale, 1980). Topographic complexity, under the predation hypothesis, is a possible explanation for fish diversity and richness, by providing refuge against predators (Hixon & Beets, 1993), modifying competitive interactions and survival rates (Holt, 1984; Jones, 1988; Syms & Jones, 2000; Gust, 2002). On the south-eastern Brazilian coast, rocky shores are the predominant habitat for reef associated organisms (Ferreira *et al.*, 2001, 2004; Floeter *et al.*, 2007). Ferreira *et al.* (2001) observed that rocky reefs, compared to coral reefs, still maintain a rich fauna and flora, but show less habitat complexity relying mostly on the presence or absence of holes.

The study of spatial pattern is essential for understanding the causes of the distribution and abundance of organisms (Levin, 1992). Understanding reef fish community organization may provide insights for management and conservation (Chittaro, 2004), and for monitoring their natural and human induced long-term changes (Underwood, 1990). Populations of the same species respond differently, according with local environmental cues, interspecific interactions and dispersal capacity (Genner *et al.*, 2004). The south-eastern Brazilian

coast is subjected to warm waters of the Brazil Current with coastal upwelling events occurring in summer and spring (Valentin, 1984), which provides an environment of mixed tropical and subtropical elements (Floeter *et al.*, 2001). Several studies have widely examined the effects of physical parameters on fish community structure (Luckhurst & Luckhurst, 1978; Chabanet *et al.*, 1997; Ornellas & Coutinho, 1998; Ferreira *et al.*, 2001; Arbuto-Oropeza & Balart, 2001). Ferreira *et al.* (2001) showed that some of the habitat complexity parameters widely used for describing other reef systems (e.g. benthic cover) was not compatible with fish community structure studies on rocky shores within this region.

Efforts in the last decade greatly increased our knowledge about Brazilian reef fish communities (Ferreira & Cava, 2001; Ferreira *et al.*, 2001, 2004; Floeter *et al.*, 2001; Rocha & Rosa, 2001; Floeter *et al.*, 2004; Floeter *et al.*, 2007; Mendonça-Neto *et al.*, 2008). Large-scale comparisons suggested that south-eastern rocky reefs show greater diversity than north-eastern coral reefs in the Brazilian coast (Floeter *et al.*, 2001), and herbivorous fish densities in the western Atlantic decrease from tropical to temperate latitudes (Floeter *et al.*, 2005).

Intermediate scales within region comparisons are few in the literature, but such studies may be important to predict geographically distinct communities. Patterns of community structure in the marine environment are strongly influenced by population relationships to biotic and physical gradients (Floeter *et al.*, 2007). Chittaro (2004) showed that both spatial variation and fish–habitat relationships at the community and population levels are largely independent of the spatial scales from 10 to 200 m². Nevertheless, considering the dimension of the Brazilian coast with nearly 8000 km,

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a limited set of scientific work on the ecology and community structure of reef fish is currently available for rocky reef environments. Therefore, new contributions should provide additional information and baseline data for the development of comparative studies and insights about the main ecological units and structuring processes at the local and regional scales.

The main goals of this work are to compare reef fish community structure, composition and distribution patterns between three sites and across levels of physical parameters, such as rugosity, temperature, declivity, depth and visibility. Understanding their effects on communities should improve our ability to predict the outcomes of alternative management strategies for reef fish and their habitats.

MATERIALS AND METHODS

Study sites

This study was conducted at three sites on the coast of Rio de Janeiro state, south-eastern Brazil, in order to compare reef fish communities across levels of environmental variables. (1) Enseada da Pedra Vermelha (PV— $22^{\circ}59'S$ $41^{\circ}59'W$) is located at Cabo Frio Island, Arraial do Cabo municipality (Figure 1-1). It is within a partial marine protected area (RESEX Arraial de Cabo) where only traditional fishing

techniques and historic fish colonies are allowed to use resources. The site is characterized by rocky shores with large boulders ending in a sand bottom. Massive cover of the zoantid *Palythoa caribaeorum* (Duchassaing & Michelotti, 1861) and meager colonies of the firecoral *Millepora alcicornis* Linné, 1758 are frequently found. Rocky rubble and sand are present in patches in some areas. (2) Mãe Island (MI— $22^{\circ}98'S$ $43^{\circ}06'W$) is located within Itaipu Sound, Niterói municipality (Figure 1-2). These shallow rocky shores present a gentle slope and small rocky rubble covering the bottom. Spaces between rocks are small and benthic diversity is relatively low with substrate mostly covered with turf algae. Great loads of mussel shells are observed at the bottom, which is a result of collection by artisanal fishermen. The degree of fishery activities is high, due to its proximity to the coast (~ 2 km). (3) Comprida Island (CI— $23^{\circ}02'S$ $43^{\circ}12'W$) is part of the Cagaras Archipelago, Rio de Janeiro, RJ (Figure 1-3). These rocky shores are characterized by large boulders, steep walls and rock rubble at some points, ending on a sandy bottom. This site presents a variety of habitats, where turf, crustose algae and sponges cover most of the substrate. Still, a high benthic diversity is found due to the presence of live brain-coral (e.g. *Mussismilia hispida* (Verrill, 1901), an endemic species), sea anemones and mussels. Shifts on dominance are observed, where two major habitats are clearly separated. On one side there is a steep wall with

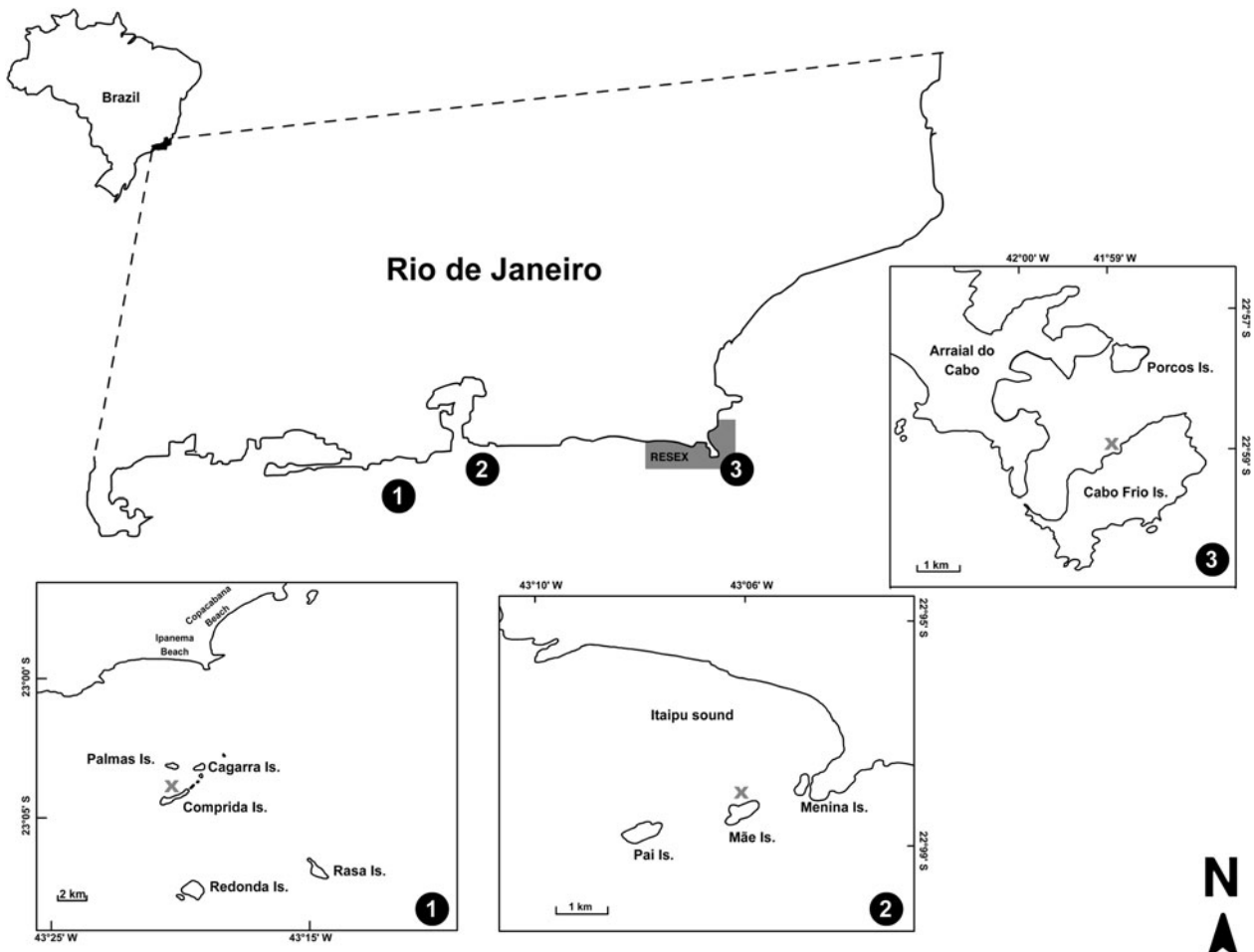


Fig. 1. Map of the study areas: 1, Pedra Vermelha (PV); 2, Mãe Island (MI); 3, Comprida Island (CI). Grey area represents the RESEX of Arraial do Cabo, a partial Marine Protected Area.

high densities of sponges and on the other side there is dominance of the zoantid *P. caribaeorum* (Villaça, unpublished data).

Physical parameters

Transects were laid haphazardly, always in the sheltered sides of the sites to reduce differences related to prevailing winds and wave exposure. Rugosity of the substrate was obtained using an adaptation of the chain-link method (Luckhurst & Luckhurst, 1978), which provided a comparative index (r). Shore slope was derived from the trigonometric relationship $\sin\alpha = \text{opposite side (a) hypotenuse (b)}$, where α , is the angle of the shore slope, 'a' is depth, since transects were performed from surface to bottom, and 'b' is the transect length. The slope angle was then obtained from the appropriate trigonometric tables. Depth was also recorded from the pressure gauge in the diving console. Horizontal visibility was obtained by measuring the maximum distance from which a white PVC plate was visible (Dominici-Arosemena *et al.*, 2005). Temperature was recorded for each sample with a mercury thermometer. Tide range for each sampling day was obtained from the tide tables available at the 'Departamento de Hidrografia e Navegação—DHN' website (www.dhn.mar.mil.br).

Fish community data

Underwater visual censuses (12 replicates per site; $N = 36$) were conducted between May and December 2005. All sites were sampled during the overall period in order to avoid different time effect among sites. Occurrence and abundance of fish species were recorded using the strip-transect method. In this work, transects were laid perpendicular to the shore, from the sand–rock interface towards the surface, covering all depths. Transect lengths varied according to depth and shore slope. In this manner, abundance data were later converted into density (fish/m²) to minimize differences between transects of different lengths.

Fish were counted within 2 m (1 m to each side of the observer) (Ferreira *et al.*, 2001) and recorded as a six-letter code (e.g. DIPARG: *Diplodus argenteus*). Censuses followed a predetermined sequence counting vagile species first, and cryptobenthic and sedentary species, with intensive search, on a second pass over the transect. The same diver conducted all counting to avoid bias related to different experience levels (Williams *et al.*, 2006).

Fish were grouped into major trophic categories following Ferreira *et al.* (2004) and Floeter *et al.* (2005) (see Appendix). Inclusion of species in categories was based on the available information from the literature (Randall, 1967; Ferreira *et al.*, 2004).

Statistical analysis

One-way analysis of variance was used to compare total fish density and environmental factors (rugosity, shore slope, water temperature, depth, visibility and tide range) between study sites (PV, MI and CI). A post hoc Student–Newman–Keuls (SNK) multiple comparison test was used to separate significantly different means. Data were log-transformed ($\log(\text{density} + 1)$) to satisfy ANOVA assumptions. A post hoc power analysis was conducted to assess whether the ANOVA test had a fair chance to reject an

incorrect H_0 (Cohen, 1988). Effect size was set to 0.4 (*sensu lato* Cohen, 1988), defining the minimum degree of violation of H_0 a researcher would like to detect with a probability not less than $(1-\beta)$ (Smith & Bayen, 2005). The post hoc power analysis for the one-way ANOVA, with $\alpha = 0.05$ was in the range of 0.52. Tests were performed using STATISTICA 6.0 software (Statsoft, Inc.), and G*Power 3 (Erdfelder *et al.*, 1996; Faul *et al.*, in press).

To assess the similarity patterns between samples and the formation of meaningful groups, non-metric multidimensional scaling ordination (nMDS) was performed. Species present in over 50% of samples were excluded from the matrix. This manoeuvre is used to decrease the value of stress considerably with no interference on the data spatial distribution pattern (J. L. Valentim, personal communication). Bray–Curtis dissimilarity was used to build the similarity matrix. Data were log-transformed.

A one-way analysis of similarity (ANOSIM), using the same data matrix, was performed to test for significant differences between groups formed in the previous analysis (Clarke, 1993). Both analyses were conducted using PRIMER 5.0 software (Clarke & Warwick, 2001).

Fish community and habitat relationships were analysed with 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). Significant environmental parameters were selected with the Monte Carlo permutation test (999 permutations). Species present in less than 8% of the samples were excluded to avoid noise. Data were log-transformed and the CANOCO for Windows 4.0 software was used for this analysis.

RESULTS

Environmental factors

Higher rugosity values were found at MI, where smaller boulders were present. Visibility was significantly higher and slopes steeper at the PV and CI sites. Also, CI transects were deeper whereas MI transects were shallower. Temperature and tide-range were not significantly different between sites (Table 1). The range of area covered by transects for each site was 30–68, 28–70 and 36–70 m², for PV, MI and CI, respectively. Nevertheless, differences between sampled areas in studied sites were not significant ($F = 2.228$; $P = 0.124$), which allowed a comparison.

Fish composition and trophic structure

Thirty-six visual censuses yielded sightings of 4236 fish belonging to 34 families and 67 species. The five most representative families in terms of relative abundance and number of species were Pomacentridae (30%, 6), Haemulidae (16%, 4), Monacanthidae (13%, 2), Sparidae (12%, 2) and Labridae (6%, 7). Together, they comprised three-quarters of all fish counted. Sixty-seven per cent of the fish species recorded in the three sites showed western Atlantic distribution, of which 13.5% are endemic to the Brazilian Province. At least 40% of all species recorded were shared between the three sites.

Table 1. Environmental factors (mean \pm SE) and the one-way ANOVA results among localities (PV, Pedra Vermelha; MI, Mãe Island; CI, Comprida Island).

Factors	PV	MI	CI	P	F	SNK
Rugosity	1.30 \pm 0.26	1.44 \pm 0.20	1.38 \pm 0.21	0.02*	F = 4.16	IM > IC > PV
Declivity (°)	25 \pm 4	18 \pm 8	26 \pm 6	0.00**	F = 7.4	PV = IC > IM
Depth (m)	9.5 \pm 2.2	6.7 \pm 1.6	14 \pm 1.1	0.00**	F = 6.195	IC > PV > IM
Temperature (°C)	22 \pm 2.2	21 \pm 1.6	23 \pm 1.4	ns	F = 3.424	PV = IM = IC
Tide range	0.2 \pm 0.01	0.1 \pm 0.05	0.1 \pm 0.03	ns	F = 5.32	PV = IM = IC
Visibility	7 \pm 1.3	5.5 \pm 1.5	8 \pm 3.0	0.00**	F = 7.37	IM < PV = IC

* $P < 0.05$; ** $P < 0.01$; ns, non significant.

Total fish density varied significantly between sites ($F = 3.9044$; $P = 0.03^*$), but post hoc comparisons were not able to separate means. Ten species showing the highest densities were detected at all sites: *Abudefduf saxatilis* (Linnaeus, 1758) (0.31 fish/m²), *Stegastes fuscus* (Cuvier, 1830) (0.29 fish/m²), *Stephanolepis hispidus* (Linnaeus, 1766) (0.28 fish/m²), *Haemulon aurolineatum* Cuvier, 1830 (0.28 fish/m²), *Diplodus argenteus* (Valenciennes 1830) (0.25 fish/m²), *Halichoeres poeyi* (Steindachner, 1867) (0.13 fish/m²), *Chromis multilineata* (Guichenot, 1853) (0.08 fish/m²), *Stegastes pictus* (Castelnaud, 1855) (0.07 fish/m²), *Labrisomus nuchipinnis* (Quoy & Gaimard, 1824) (0.05 fish/m²) and *Chaetodon striatus* Linnaeus, 1758 (0.04 fish/m²). Nevertheless, *S. fuscus* predominated at PV and was nearly absent at the MI and CI sites. *Abudefduf saxatilis* and *H. aurolineatum* dominated at MI, and *S. hispidus* and *D. argenteus* at CI. Figure 2 shows the density distribution of these species at each site.

Mobile invertebrate feeders, mostly represented by *H. aurolineatum* and omnivores (*S. hispidus*, *D. argenteus* and *A. saxatilis*) predominated in all localities, but dominance patterns were reversed for MI as compared with PV and CI (Figure 3). Nevertheless herbivores (mostly territorial *Stegastes* spp.) were found at high relative abundances at PV. Planktivores, carnivores and sessile invertebrate feeders occurred in low numbers in the three sites.

Relationship between fish community and physical parameters

Non-metric multidimensional scaling analysis presented in Figure 4 showed three distinct sample groups. Group 1 included samples from MI, group 2 from PV and group 3 from CI. The low stress value indicated that the observed sample distribution in the two dimensional space provided a reliable interpretation of the differences between fish community structure at the study sites. One-way ANOSIM corroborated the formation of these groups, with minimal degree of overlap (global $R = 0.727$; $P = 0.001$).

Figure 5 shows the CCA ordination diagram with 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 42.1% and 34.5% of the variance between samples, species and variables. The first axis was positively related to shallow water, rugged, low visibility and gentle slope habitats. This axis clearly represented MI samples and mostly small site-attached species such as *Parablennius pilicornis* (Cuvier, 1829), *Scartella cristata* (Linnaeus, 1758), *P. marmoratus*, *Labrisomus nuchipinnis*, *Stegastes variabilis*, *Pareques acuminatus* (Bloch & Schneider,

1801) and *Mycteroperca acutirostris* (Valenciennes, 1828). Axis 2 was positively associated with steep slopes, and negatively associated with depth and water visibility. This axis represented mostly PV and CI samples, comprising greatest richness and highest density of vagile species such as *Acanthurus chirurgus* (Bloch, 1787), *Bodianus pulchellus* (Poey, 1860), *Balistes Vetula* Linnaeus 1758, *Acanthurus Bahianus* Castelnaud, 1855, *Holocentrus adscencionis* (Osbeck, 1765) and *D. argenteus*. PV samples also showed higher densities of sand-bottom associated species (*Synodus synodus* (Linnaeus, 1758), *Dactylopterus volitans*, *Serranus baldwini* (Evermann and Marsh, 1899) and *Coryphopterus glaucofraenum* Gill, 1863), mostly due to the presence of sand patches in this site. Species located in the centre of the plot had similar abundances in the studied sites, and showed little contribution for the CCA.

DISCUSSION

This work yielded a total of 67 species recorded at three different sites on the coast of Rio de Janeiro state. This number is considerably low when compared with other reef fish community studies conducted in localities near the studied sites. Probably, most differences were related to sampling effort and visual census methodology used in our work, since most reef fish species recorded showed a broad western Atlantic distribution. Such species are common in coastal rocky reefs, islands and mangroves. This was previously observed by Floeter *et al.* (2001) in a comprehensive study of the Brazilian coast.

Ferreira *et al.* (2001) recorded more than 91 species at Arraial do Cabo over one year of weekly sampling. Mendonça-Neto (unpublished data) recorded 42 species after one year of transect sampling in three islands of Itaipu Sound. Rangel *et al.* (2007) produced a list of 99 species at the Cagarras Archipelago using transect and rover diver sampling. Our study aimed to evaluate differences in species assemblages on three defined sites, whereas others usually addressed broader objectives within a wider studied area and time span. Also, our transects followed the depth gradient over the rocky reef, whereas other studies followed the depth stratified horizontal transect methodology.

Species dominance patterns were nearly the same, but species ranks changed between sites. These differences were also reflected on trophic groups. High densities of *Stegastes fuscus* representing 90% of the total of herbivores, were found at PV. Ferreira *et al.* (2001) reported similar findings in the region. At MI and CI, *S. fuscus* showed very low abundances. According to Ceccarelli (2004), former herbivores densities could be affected by abundance of large schools of

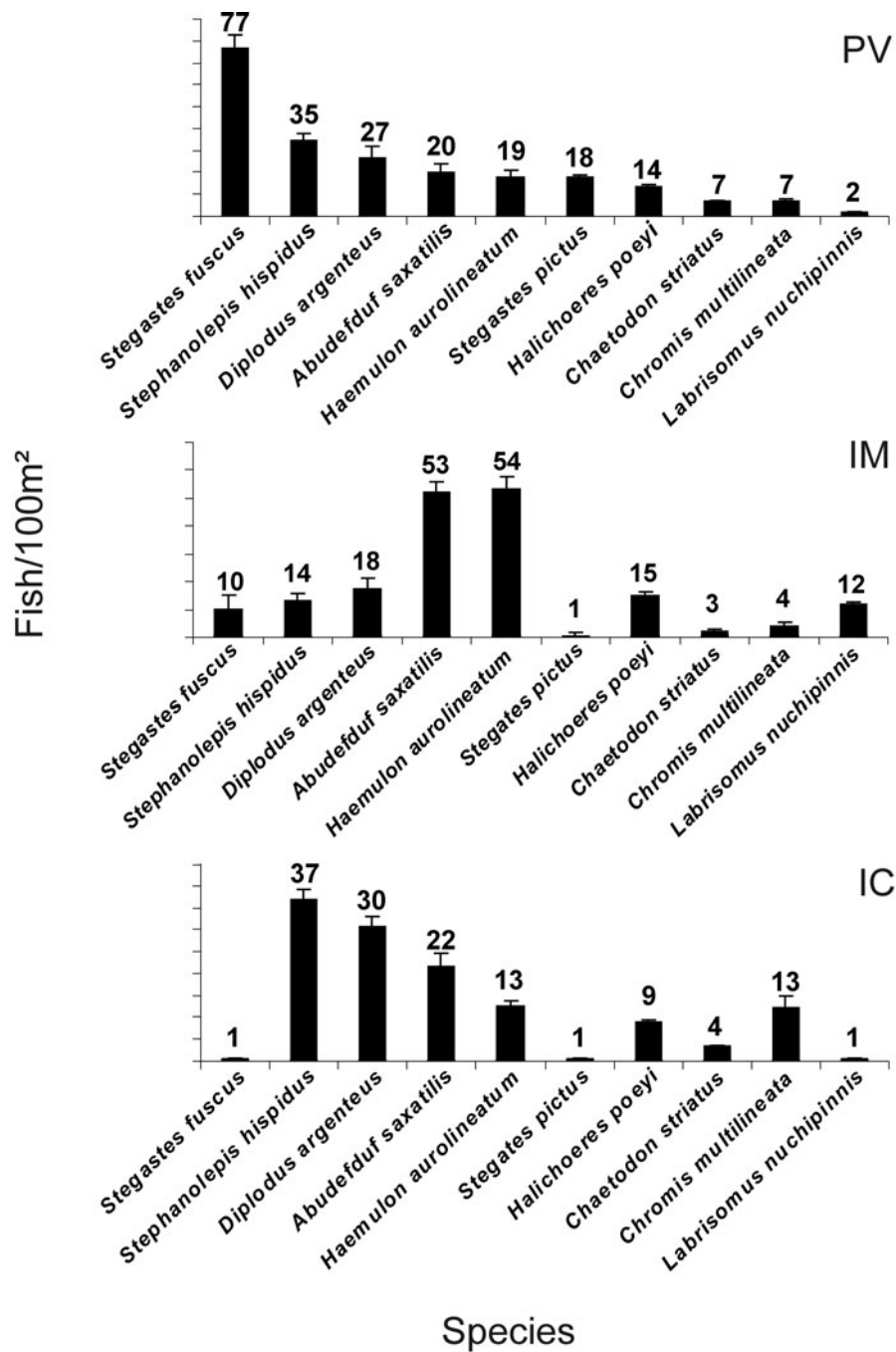


Fig. 2. Density (mean \pm SE) of ten more abundant species. PV, Pedra Vermelha; MI, Mãe Island; CI, Comprida Island.

roving herbivores, which was found only in IC, but such a conclusion needs further studies addressing this question.

Omnivores *Abudefduf saxatilis*, *Stephanolepis hispidus* and *Diplodus argenteus*, and the mobile invertebrate feeder *Haemulon aurolineatum* predominated at MI and CI, a pattern previously observed in other studies in subtropical Brazilian waters (Ferreira *et al.*, 2004). Dominance of these groups in higher latitudes may be associated with the better use of low-quality food (Harmelin-Vivien, 2002).

Large predators are expected to be less frequent, but their large sizes compensate the low abundance, representing a large portion of fish biomass (Rocha & Rosa, 2001). This was previously found at Arraial do Cabo, RJ (Ferreira *et al.*,

2001). Nevertheless, in some cases, intensive fishing over target mobile top predators, may be responsible for their low abundances. The presence of the small sized carnivore *Labrisomus nuchipinnis* at MI may be further evidence that fisheries have removed top predators. In fact, Turbino *et al.* (2007) suggested that the proximity to the coast magnifies fisheries impacts at the islands within Itaipu Sound, including MI. Many of the species recorded in this work were present in the local artisanal fisheries landings at Itaipu, but the scarcity of top predators (snappers and groupers) was striking.

Topographic complexity along with other habitat variables played an important role in structuring fish communities at the studied sites, but its contribution had a lesser

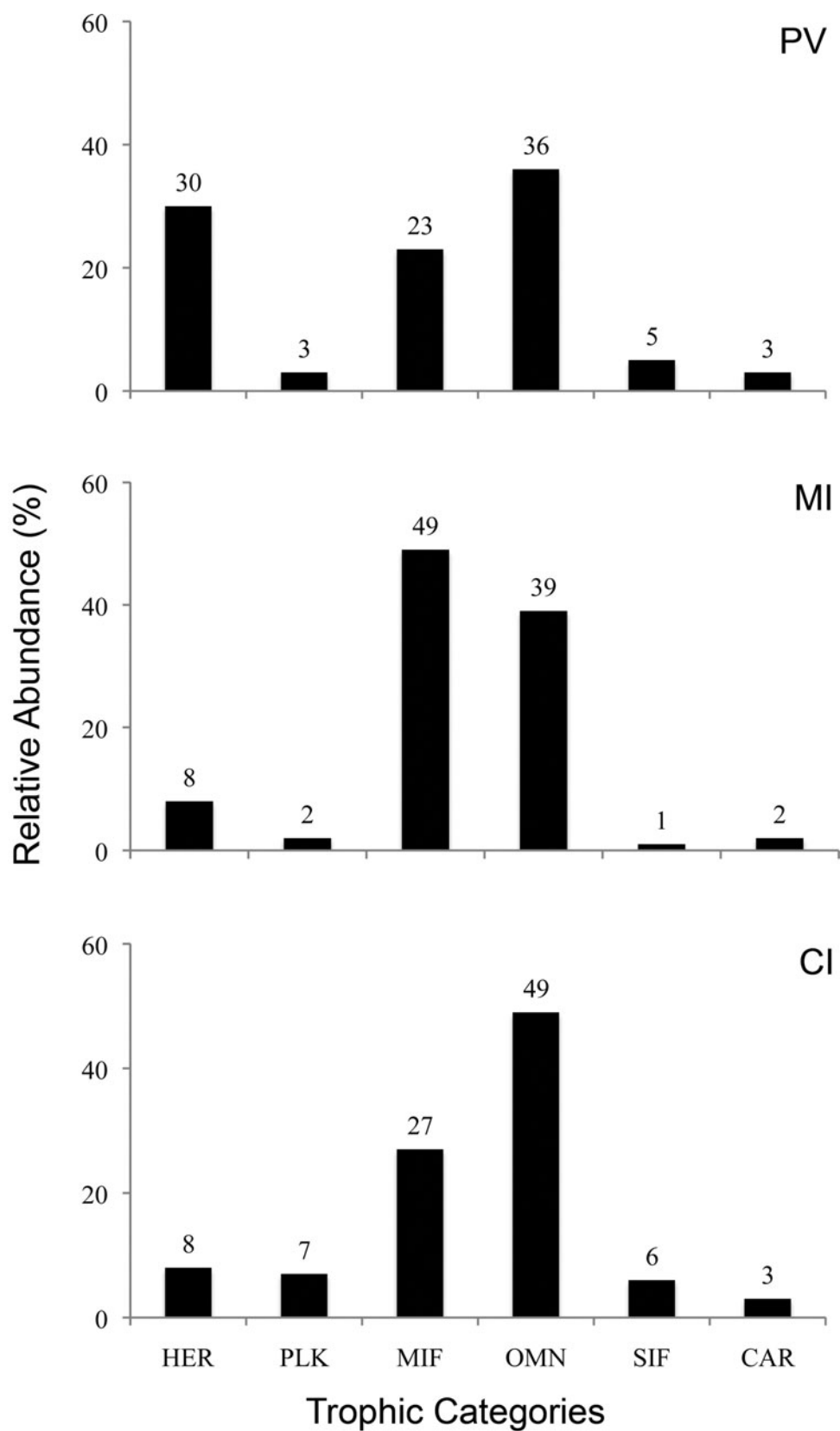


Fig. 3. Relative abundance of fish trophic groups within the study localities. PV, Pedra Vermelha; MI, Mãe Island; CI, Comprida Island; HER, herbivores; PLK, planktivores; MIF, mobile invertebrate feeders; OMN, omnivores; SIF, sessile invertebrate feeders; CAR, carnivores.

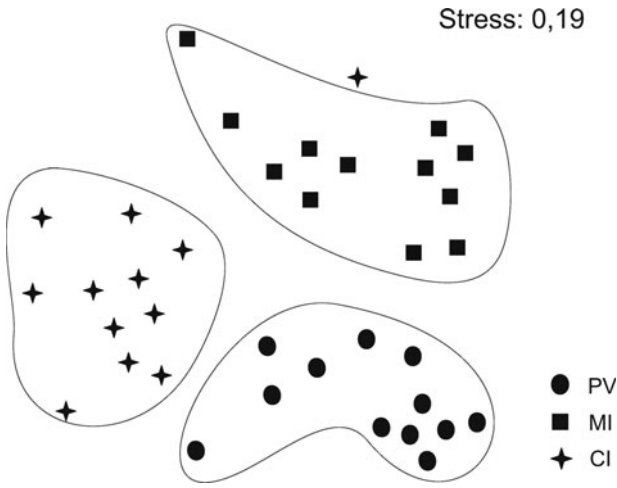


Fig. 4. NMDS analysis within study sites: PV, Pedra Vermelha; MI, Mãe Island; CI, Comprida Island.

importance than the others. Sale (1991) observed that fish communities are not predictable for every location, as structuring factors may differ in their relative importance from one location to another. For instance, recent studies (Ferreira *et al.*, 2001; Gratwicke & Speight, 2005) showed that other physical parameters instead of rugosity were of greater importance for structuring reef fish communities, as opposed to previous studies (Bell & Galzin, 1984; Charton & Ruzafa, 1998).

Each site showed distinct features regarding total fish composition and diversity, despite the fact that they lay within a narrow latitudinal range, and shared similar environmental characteristics. A higher diversity at CI could be associated with the larger sampled area in this site. The positive relationship between diversity and reef size was previously observed by Galzin *et al.* (1994). Nevertheless, fish density in this locality was surprisingly low. PV was the smallest sampled area but presented the highest fish density, possibly due to the fact that the area is a marine sanctuary, providing

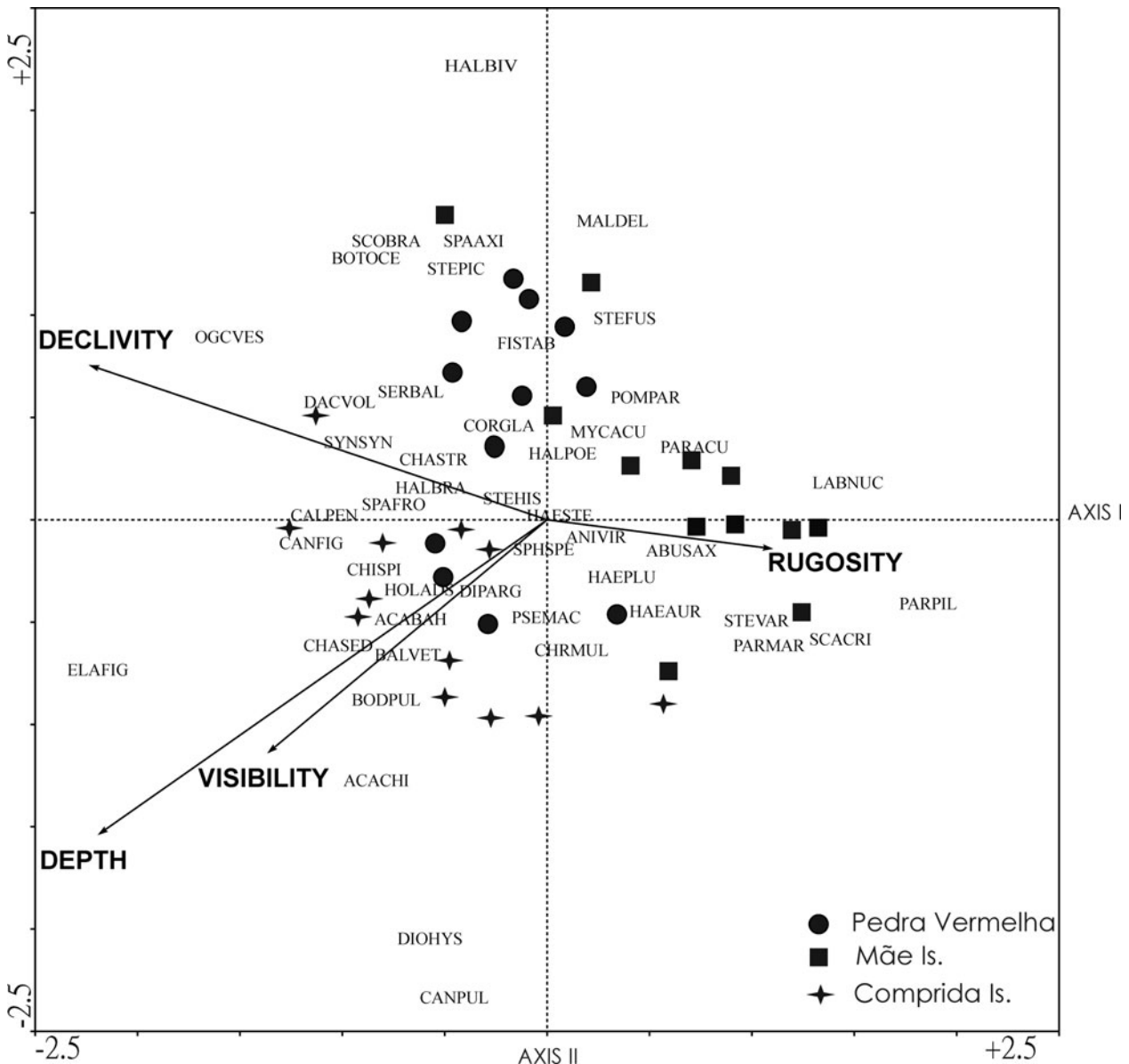


Fig. 5. Canonical correspondence analysis (CCA) ordination. Species are represented by six-letter codes.

species refuge and protection. Future studies comprising the effects of oceanographic features on larval dispersion and recruitment should explain such findings.

Our work showed that habitat partitioning was partly explained by the studied environmental variables at each site. Also, the results showed that fish communities of these sites presented similarities mostly for the ubiquitous groups with wide distribution ranges, but not for all species. Some species were associated to shallower habitats with higher rugosity such as those at MI. Such habitats may provide species protection against potential predators (Willis & Anderson, 2003). Most of them are small, site-attached and habitat-specialist fish such as blennies, often underestimated on visual census (Sale & Douglas, 1981; Brock, 1982; Bellwood & Alcala, 1988; Ackerman & Bellwood, 2000). Also, the great amount of organic matter and detritus available from the Guanabara Bay (van Weerelt, personal communication) could provide additional food sources for the success of blennies at this site (Wilson, 2001, 2002).

Other species were associated to clear, deeper waters or to sandy-patches, such as *Serranus baldwini* and *Coryphopterus glaucofraenum* found at CI and PV, respectively. Some species with wider range of distribution along the reef were observed in deeper waters such as *Bodianus pulchellus* found in our work and a similar pattern was observed by Ferreira *et al.* (2001). According to Letourneur *et al.* (2003), deeper sites present more niches to be explored and can aggregate a wider range of species.

Differences among vicinal coastal islands were defined in this work through several physical parameters of each selected site, such as rugosity, depth, declivity and visibility. This suggests that rugosity works synergistically with other factors, which are extremely important for the fish community structure in rocky reefs.

Logistical limitations prevented us from obtaining more replica within sites as expected. Sampling on reefs usually relies on 10 to 20 samples, depending on the number of sites and the size of transects (Chittaro, 2004). Our significant results suggested that differences between sites exist, but we could not draw any further conclusions regarding group means, especially for species densities. Problems may have arisen because our experimental design had a 50% chance of type II error, especially for non-significant findings. Despite these limitations, our results may be taken as exploratory, suggesting regional patterns of distribution, abundance and diversity of reef fish between separate sites in south-eastern Brazil.

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REFERENCES

- Ackerman J.L. and Bellwood D.R. (2000) Reef fish assemblages: a re-evaluation using enclosed rotenone stations. *Marine Ecology Progress Series* 206, 227–237.
- Arbuto-Oropeza O. and Balart E.F. (2001) Community structure of reef fish in several habitats of a rocky reef in the Gulf of California. *Marine Ecology* 22, 283–305.
- Bell J.D. and Galzin R. (1984) Influence of live coral cover on coral reef fish communities. *Marine Ecology Progress Series* 15, 265–274.
- Bellwood D.R. and Alcala A.C. (1988) The effect of a minimum length specification on visual estimates of density and biomass of coral reef fishes. *Coral Reefs* 7, 23–27.
- Brock R.E. 1982. A critique of the visual census method for assessing coral reef fish populations. *Bulletin of Marine Science* 32, 269–276.
- Ceccarelli D.M. (2004) *Herbivorous fishes as determinants of the structure of coral reef communities: farmers, foragers and their interactions*. PhD thesis. James Cook University, Townsville, Queensland.
- Chabanet P., Ralambondrainy H., Amanieu M., Faure G. and Galzin R. (1997) Relationships between coral reef substrata and fish. *Coral Reefs* 16, 93–102.
- Charton J.A.G. and Ruzafa A.P. (1998) Correlation between habitat structure and a rocky reef fish assemblage in the southwestern Mediterranean. *Marine Ecology* 19, 111–128.
- Chittaro P.M. (2004) Fish–habitat associations across multiple spatial scales. *Coral Reefs* 23, 235–244.
- Clarke K.R. (1993) Non-parametric multivariate analysis of changes in community structure. *Australian Journal of Ecology* 18, 117–143.
- Clarke K.R. and Warwick R.M. (2001) *Changes in marine communities: an approach to statistical analysis and interpretation*. 2nd edition. Plymouth: Plymouth Marine Laboratory, PRIMER-E.
- Cohen J. (1988) *Statistical power analysis for the behavioral sciences*. 2nd edition. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Dominici-Arosemena A., Brugnoli-Oliveira E., Cortés-Núñez J., Molina-Ureña H. and Quesada-Alpizar M. (2005) Community structure of Eastern Pacific reef fishes (Gulf of Papagayo, Costa Rica). *Tecnociencia* 7, 19–41.
- Erdfelder E., Faul F. and Buchner A. (1996) GPOWER: a general power analysis program. *Behavior Research Methods, Instruments and Computers* 28, 1–11.
- Faul F., Erdfelder E., Lang A.G. and Buchner A. (in press) G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*.
- Ferreira B.P. and Cava F. (2001) Ictiofauna marinha da APA Costa dos Corais: Lista de espécies através de levantamento da pesca e observações subaquáticas. *Boletim Técnico-Científico do CEPENE, Tamandaré (PE)* 9, 14 pp.
- Ferreira C.E.L., Gonçalves J.E.A. and Coutinho R. (2001) Community structure of fishes and habitat complexity on tropical rocky shores. *Environmental Biology of Fishes* 61, 353–369.
- Ferreira C.E.L., Floeter S.R., Gasparini J.L., Joyeux J.C. and Ferreira B.P. (2004) Trophic structure patterns of Brazilian reef fishes: a latitudinal comparison. *Journal of Biogeography* 31, 1093–1106.

- Floeter S.R., Guimarães R.Z.P., Rocha L.A., Ferreira C.E.L., Rangel C.A. and Gasparini J.L. (2001) Geographic variation in reef-fish assemblages along the Brazilian Coast. *Global Ecology and Biogeography* 10, 423–431.
- Floeter S.R., Behrens M.D., Ferreira C.E.L., Paddock M.J. and Horn M.H. (2005) Geographical gradients of marine herbivorous fishes: patterns and processes. *Marine Biology* 147, 1435–1447.
- Floeter S.R., Krohling W., Gasparini J.L., Ferreira C.E.L. and Zalmon I.R. (2007) Reef fish community structure on coastal islands of south-eastern Brazil: the influence of exposure and benthic cover. *Environmental Biology of Fishes* 78, 147–160.
- Galzin R., Planes S., Dufour V. and Salvat B. (1994) Variation in diversity of coral reef fish between French Polynesian atolls. *Coral Reefs* 13, 175–180.
- Genner M.J., Sims D.W., Wearmouth V.J., Southall E.J., Southward A.J., Henderson P.A. and Hawkins S.J. (2004) Regional climatic warming drives long-term community changes of British marine fish. *Proceedings of the Royal Society of London, Series B* 271, 655–661.
- Gratwicke B. and Speight M.R. (2005) The relationship between fish species richness, abundance and habitat complexity in a range of shallow tropical marine habitats. *Journal of Fish Biology* 66, 650–667.
- Gust N. (2002) Scarid biomass on the northern Great Barrier Reef: the influence of exposure, depth and substrata. *Environmental Biology of Fishes*, 64, 353–366.
- Harmelin-Vivien M.L. (2002) Energetics and fish diversity on coral reefs. In Sale P.F. (ed.) *The ecology of fishes on coral reefs*. San Diego, CA: Academic Press, pp. 265–274.
- Hixon M.A. and Beets J.P. (1993) Predation, prey refuges and the structure of coral reef fish assemblages. *Ecological Monographs* 63, 77–101.
- Holt R.D. (1984) Spatial heterogeneity, indirect interactions, and the coexistence of prey species. *American Naturalist* 124, 377–406.
- Jones G.P. (1988) Experimental evaluation of the effect of habitat structure and competitive interactions on the juveniles of two coral reef fishes. *Journal of Experimental Marine Biology and Ecology* 12, 115–126.
- Letourneur Y., Ruitton S. and Sartoretto S. (2003) Environmental and benthic habitat factors structuring the spatial distribution of a summer infra-littoral fish assemblage in the north-western Mediterranean Sea. *Journal of the Marine Biological Association of the United Kingdom* 83, 193–204.
- Levin S.A. (1992) The problem of pattern and scale in ecology. *Ecology* 73, 1943–1967.
- Luckhurst B.E. and Luckhurst K. (1978) Analysis of the influence of substrate variables on coral reef fish communities. *Marine Biology* 49, 317–324.
- Mendonça-Neto J.P., Monteiro-Neto C. and Moraes L.E. (2008) Reef fish community structure on three islands of Itaipu, Southeast Brazil. *Neotropical Ichthyology* 6, 267–274.
- Ornellas A.B. and Coutinho R. (1998) Spatial and temporal patterns of distribution and abundance of a tropical fish assemblage in a seasonal *Sargassum* bed, Cabo Frio Island, Brazil. *Journal of Fish Biology* 53, 198–208.
- Randall J.E. (1967) Food habits of reef fishes of the West Indies. *Studies in Tropical Oceanography* 5, 665–847.
- Rangel C.A., Chaves L.C.T. and Monteiro-Neto C. (2007) Baseline assessment of the reef fish assemblage from Cagarras Archipelago, Rio de Janeiro, southeastern Brazil. *Brazilian Journal of Oceanography* 55, 7–17.
- Rocha L.A. and Rosa I.L. (2001) Baseline assessment of reef fish assemblage of Parcel Manuel Luiz Marine State Park, Maranhão, Northeast Brazil. *Journal of Fish Biology* 58, 985–998.
- Sale P.F. (1980) The ecology of fishes on coral reefs. *Oceanography and Marine Biology: an Annual Review* 18, 367–421.
- Sale P.F. (1991) Reef fish communities: open non-equilibrial systems. In Sale P.F. (ed.) *The ecology of fishes on coral reefs*. San Diego, CA: Academic Press, pp. 564–598.
- Sale P.F. and Douglas W.A. (1981) Precision and accuracy of visual census technique for fishes assemblages on coral patch reefs. *Environmental Biology of Fishes* 6, 333–339.
- Smith R.E. and Bayen U.J. (2005) The effects of working memory resource availability on prospective memory: A formal modeling approach. *Experimental Psychology* 52, 243–256.
- Syms C. and Jones G.P. (2000) Disturbance, habitat structure and the dynamics of a coral-reef fish community. *Ecology* 81, 2714–2729.
- Ter Braak C.F. (1987) Ordination. In Jongman H., ter Braak C.J. and van Tongeren O.F. (eds) *Data analysis in community and landscape ecology*. Wageningen, The Netherlands: Backhuys Publishers, pp. 91–173.
- Turbino R.A., Monteiro-Neto C., Moraes L.E.S. and Paes E.T. (2007) Artisanal fisheries production in the coastal zone of Itaipu, Niterói, RJ, Brazil. *Brazilian Journal of Oceanography* 55, 187–197.
- Underwood A.J. (1990) Experiments in ecology and management: their logics, functions and interpretations. *Australian Journal of Ecology* 15, 365–389.
- Valentin J.L. (1984) Analyse des paramètres hydrobiologiques dans la remontée de Cabo Frio (Brésil). *Marine Biology* 82, 259–276.
- Williams I.D., Walsh W.J., Tissot B.N. and Hallacher L.E. (2006) Impact of observers' experience level on counts of fishes in underwater visual surveys. *Marine Ecology Progress Series* 310, 185–191.
- Willis T.J. and Anderson M.J. (2003) Structure of cryptic reef fish assemblages: relationships with habitat characteristics and predator density. *Marine Ecology Progress Series* 257, 209–221.
- Wilson S. (2001) Multiscale habitat associations of detritivorous blennies (Blenniidae: Salarini). *Coral Reefs* 20, 245–251.
- and
- Wilson S. (2002) Nutritional value of detritus and algae in blenny territories on the Great Barrier Reef. *Journal of Experimental Marine Biology and Ecology* 271, 155–169.

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Appendix Checklist of species. Density (mean \pm SE), total number of specimens (n) and relative abundance (%) of individuals per species at Pedra Vermelha (PV), Mãe Island (MI) and Comprida Island (CI).

Family/name	Trophic category	PV			MI			CI		
		Density	n	%	Density	n	%	Density	n	%
Acanthuridae										
<i>Acanthurus bahianus</i> (ACABAFI)	HER	4.9 \pm 0.3	29	1.82	1.2 \pm 0.3	7	0.53	6.2 \pm 0.7	38	2.89
<i>Acanthurusehirurgus</i> (ACACFII)	HER	0.9 \pm 0.2	7	0.44	0.1 \pm 0.1	2	0.15	5.8 \pm 0.9	37	2.82
<i>Acanthurus coeruleus</i> (ACACOE)	HER	—	—	—	—	—	—	1.6 \pm 0.2	3	0.23
Apogonidae										
<i>Apogon americanus</i> (APOAME)	PLK	0.4 \pm 0.1	2	0.13	—	—	—	—	—	—
Balistidae										
<i>Balistes vetula</i> (BALVET)	MIF	1 \pm 0.2	7	0.44	1.7 \pm 0.1	10	0.75	5 \pm 0.4	31	2.36
Blennidae										
<i>Parablenniusmarmoreus</i> (PARMAR)	OMN	0.1 \pm 0.04	1	0.06	10.4 \pm 0.7	62	4.65	2.4 \pm 0.3	17	1.29
<i>Parablennius pilicornis</i> (PARPIL)	—	—	—	—	9.5 \pm 0.6	57	4.28	0.6 \pm 0.1	5	0.38
<i>Scartella cristata</i> (SCACRI)	HER	—	—	—	2.3 \pm 0.2	14	1.05	0.5 \pm 0.06	4	0.3
Bothidae										
<i>Bothus ocellatus</i> (BOTOCE)	CAR	1.1 \pm 0.2	7	0.44	0.3 \pm 0.1	1	0.08	—	—	—
Carangidae										
<i>Caranx crysos</i> (CARCRY)	CAR	—	—	—	—	—	—	3.6 \pm 0.7	12	0.91
Chaetodontidae										
<i>Chaetodon sedentarius</i> (CHASED)	SIF	3.2 \pm 0.3	22	1.38	—	—	—	6.3 \pm 0.2	38	2.89
<i>Chaetodon striatus</i> (CHASTR)	SIF	7.1 \pm 0.5	42	2.64	2.5 \pm 0.4	14	1.05	3.5 \pm 0.3	20	1.52
Dactylopteridae										
<i>Dactylopterus volitans</i> (DACVOL)	MIF	2.7 \pm 0.4	19	1.19	—	—	—	—	—	—
Diodontidae										
<i>Chilomycterus spinosus</i> (CHISPI)	MIF	1.1 \pm 0.2	7	0.44	0.1 \pm 0.1	1	0.08	0.4 \pm 0.07	2	0.15
<i>Diodon hystrix</i> (DIOHYS)	MIF	0.1 \pm 0.03	1	0.06	—	—	—	0.2 \pm 0.04	2	0.15
Fistularidae										
<i>Fistularia tabacaria</i> (FISTAB)	CAR	1.3 \pm 0.2	8	0.50	0.1 \pm 0.1	1	0.08	—	—	—
Gobiidae										
<i>Coryphopterus glaucofraenum</i> (CORGLA)	OMN	2.5 \pm 0.3	13	0.82	0.2 \pm 0.2	1	0.08	0.8 \pm 0.1	6	0.46
<i>Elacatinus Figaro</i> (ELAFIG)	SIF	—	—	—	—	—	—	0.8 \pm 0.1	6	0.46
Grammistidae										
<i>Rypticus saponaceus</i> (RYPSPAP)	CAR	0.2 \pm 0.04	1	0.06	—	—	—	—	—	—
Haemulidae										
<i>Anisotremus virginicus</i> (ANIVIR)	MIF	0.8 \pm 0.2	4	0.25	5.2 \pm 0.3	28	2.10	4.2 \pm 0.3	29	2.21
<i>Haemulon aurolineatum</i> (HAEAUR)	MIF	18.5 \pm 2.4	132	8.29	53.4 \pm 4.7	297	22.28	12.7 \pm 1	90	6.85
<i>Haemulon plumieri</i> (HAEPLU)	MIF	2.6 \pm 0.5	19	1.19	5.7 \pm 0.6	33	2.48	1.7 \pm 0.2	9	0.69
<i>Haemulon steindachneri</i> (HAEESTE)	MIF	0.6 \pm 0.1	3	0.19	4.7 \pm 0.3	28	2.10	2.9 \pm 0.4	18	1.37
Holocentridae										
<i>Holocentrus adscensionis</i> (HOLADS)	CAR	4.6 \pm 0.6	22	1.38	0.8 \pm 0.4	6	0.45	4.5 \pm 0.4	30	2.28
Kyphosidae										
<i>Kyphosus sectatrix</i> (KYPSEC)	HER	—	—	—	—	—	—	0.1 \pm 0.04	1	0.08
Labridae										
<i>Bodianus pulchellus</i> (BODPUL)	MIF	1.3 \pm 0.2	9	0.56	—	—	—	2.5 \pm 0.2	22	1.68
<i>Bodianus rufus</i> (BODRUF)	MIF	—	—	—	—	—	—	0.3 \pm 0.05	2	0.15
<i>Clepticus brasiliensis</i> (CLEBRA)	PLK	—	—	—	—	—	—	0.4 \pm 0.1	2	0.15
<i>Halichoeres brasiliensis</i> (HALBRA)	MIF	0.1 \pm 0.04	1	0.06	0.2 \pm 0.04	1	0.08	0.1 \pm 0.04	1	0.08
<i>Halichoeres dimidiatus</i> (HALDIM)	MIF	—	—	—	—	—	—	1 \pm 0.1	4	0.30
<i>Halichoeres penrosei</i> (HALPEN)	MIF	—	—	—	2.7 \pm 0.6	9	0.68	0.2 \pm 0.06	1	0.08
<i>Halichoeres poeyi</i> (HALPOE)	MIF	13.6 \pm 0.7	69	4.33	15.3 \pm 0.9	82	6.15	9 \pm 0.5	53	4.04
Labrisomidae										
<i>Labrisomus nuchipinnis</i> (LABNUC)	CAR	1.9 \pm 0.1	10	0.63	12.1 \pm 0.8	70	5.25	0.6 \pm 0.1	5	0.38
<i>Malacoctenus delalandii</i> (MALDEL)	MIF	—	—	—	3 \pm 0.2	14	1.05	0.6 \pm 0.1	4	0.30
Lutjanidae										
<i>Ocyurus chrysurus</i> (OCYCHR)	CAR	—	—	—	—	—	—	0.1 \pm 0.04	1	0.08
Monacanthidae										
<i>Cantherhines pullus</i> (CANPUL)	OMN	—	—	—	—	—	—	—	—	—
<i>Stephanolepis hispidus</i> (STEHIS)	OMN	35 \pm 3	208	13.06	13.4 \pm 2.3	70	5.25	37.1 \pm 2.2	248	18.89
Mulidae										
<i>Pseudupeneus maculatus</i> (PSEMAC)	MIF	1.7 \pm 0.2	12	0.75	2 \pm 0.2	12	0.90	5.6 \pm 0.4	41	3.12
Muraenidae										
<i>Gymnothorax funebris</i> (GYMFUN)	CAR	0.2 \pm 0.04	1	0.06	—	—	—	—	—	—

Continued

Appendix. Continued

Family/name	Trophic category	PV			MI			CI		
		Density	n	%	Density	n	%	Density	n	%
Ogecocephalidae										
<i>Ogecocephalus vespertilio</i> (OGCVES)	MIF	0.2 ± 0.05	1	0.06	—	—	—	0.4 ± 0.07	2	0.15
Ophichthidae										
<i>Myrichthys breviceps</i> (MYRBRE)	MIF	—	—	—	0.5 ± 0.1	2	0.15	—	—	—
Ostraciidae										
<i>Acanthostracion quadricornis</i> (ACAQUA)	OMN	0.6 ± 0.1	4	0.25	—	—	—	—	—	—
Pempheridae										
<i>Pempheris schomburgki</i> (PEMSH)	PLK	—	—	—	1 ± 0.2	6	0.45	—	—	—
Pomacanthidae										
<i>Centropyge aurantonotus</i> (CENAUR)	SIF	0.3 ± 0.7	1	0.06	—	—	—	—	—	—
<i>Holacanthus ciliaris</i> (HOLCIL)	SIF	0.2 ± 0.04	1	0.06	—	—	—	—	—	—
<i>Pomacanthus paru</i> (POMPAR)	OMN	—	—	—	0.3 ± 0.07	1	0.08	—	—	—
Pomacentridae										
<i>Abudefduf sexatilis</i> (ABUSAX)	OMN	20 ± 3.8	151	9.48	52.6 ± 3.5	286	21.46	21.6 ± 2.9	146	11.12
<i>Chromis multilineata</i> (CHRMUL)	PLK	6.9 ± 1.4	52	3.26	4.2 ± 1	21	1.58	12.5 ± 2.3	91	6.93
<i>Stegastes fuscus</i> (STEFUS)	HER	77 ± 6	340	21.34	10.1 ± 4.9	55	4.13	0.7 ± 0.08	5	0.38
<i>Stegastes pictus</i> (STEPIC)	HER	18.1 ± 1	87	5.46	0.7 ± 1	3	0.23	0.7 ± 1	5	0.38
<i>Stegastes variabilis</i> (STEVAR)	HER	0.8 ± 0.1	5	0.31	3.5 ± 0.3	21	1.58	0.7 ± 0.1	5	0.38
Priacanthidae										
<i>Heteropriacanthus cruentatus</i> (HETCRU)	CAR	—	—	—	0.2 ± 0.04	1	0.08	—	—	—
Scaridae										
<i>Sparisoma axillare</i> (SPAAXI)	HER	1.7 ± 0.2	9	0.56	—	—	—	—	—	—
<i>Sparisoma frondosum</i> (SPAFRO)	HER	1 ± 0.1	6	0.38	—	—	—	0.4 ± 0.05	3	0.23
<i>Sparisoma tuiupiranga</i> (SPATUI)	HER	—	—	—	—	—	—	0.5 ± 0.07	3	0.23
Scianidae										
<i>Pareques acuminatus</i> (PARACU)	CAR	2.9 ± 0.7	13	0.82	3.3 ± 0.5	16	1.20	1.8 ± 0.3	12	0.91
Scorpaenidae										
<i>Scorpaena brasiliensis</i> (SCOBRA)	SIF	0.7 ± 0.2	3	0.19	—	—	—	0.1 ± 0.04	1	0.08
<i>Scorpaena plumieri</i> (SCOPLU)	CAR	0.8 ± 0.1	4	0.25	—	—	—	—	—	—
Serranidae										
<i>Mycteroperco acutirostris</i> (MYCACU)	CAR	—	—	—	0.5 ± 0.06	2	0.15	0.3 ± 0.08	2	0.15
<i>Serranus baldwini</i> (SERBAL)	SIF	7.7 ± 0.4	42	2.64	0.1 ± 0.4	1	0.08	0.9 ± 0.09	5	0.38
Sparidae										
<i>Calamus pennatula</i> (CALPEN)	MIF	—	—	—	—	—	—	0.4 ± 0.07	2	0.15
<i>Diplodus argenteus</i> (DIPARG)	OMN	27.2 ± 4.7	196	12.30	17.5 ± 3.9	92	6.90	30.7 ± 2.4	208	15.84
Synodontidae										
<i>Synodus intermedius</i> (SYNINT)	CAR	0.2 ± 0.04	1	0.06	—	—	—	—	—	—
<i>Synodus synodus</i> (SYNSYN)	CAR	1.4 ± 0.2	6	0.38	—	—	—	1.4 ± 0.2	7	0.53
Tetraodontidae										
<i>Canthigaster figueiredoi</i> (CANFIG)	SIF	1.8 ± 0.1	10	0.63	—	—	—	2.3 ± 0.2	16	1.22
<i>Sphoeroides greeley</i> (SPHGRE)	MIF	0.2 ± 0.04	1	0.06	—	—	—	—	—	—
<i>Sphoeroides spengleri</i> (SPHSPE)	MIF	0.3 ± 0.07	1	0.06	1.4 ± 0.1	7	0.53	1.7 ± 0.1	11	0.84
Total observed			1593	100.0		1333	100.0		1313	100.0