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Research Article

Rocky reef fish assemblage structure in coastal islands of southern Brazil

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ABSTRACT. Within the Brazilian province, rocky reefs and submerged outcrops are among the most important habitats for reef fishes, providing suitable habitats for the development of reef fish communities and consequently sheltering a high ecological diversity. Rocky reef fish assemblages were sampled in seven coastal islands in South Brazil by strip transects of 40 m^2 by the underwater visual census to obtain density (fish 40 m^{-2}) and biomass (g 40 m^{-2}). Fish species were also categorized according to trophic category and geographical distribution. In total, 526 strip transects were performed, covering an area of 21,040 m^2, providing 19,377 fish, distributed among 73 species of 34 families. Itacolomis Island presented the highest density, followed by Veado Island. Regarding biomass, Itacolomis Island and Pedra da Baleia were the most representative rocky reefs. Mobile invertebrate predator was the trophic category with the highest density and biomass. A total of 60% of the species occur in the Western Atlantic, 20% are Transatlantic and 9.6% are endemic to the Brazilian Province. Our results indicate that despite the similarity in the taxonomic composition among islands, the observed differences in densities and biomass, highlight singular assemblage structures, whether by environmental and/or anthropogenic factors, and dominated by few species, both in density and biomass.

Keywords: rocky reef fish, taxonomic distinctness, trophic category, geographical distribution.

INTRODUCTION

The reef is a term used by the scientific community to describe environments with a predominance of the hard substratum and is usually associated with coral reef barriers. However, it should be assumed that they are not the only ones featuring a reef environment, once the hard substratum comprising the reef environment may have been originated not only from colonial polyploid organisms (*i.e.*, corals), but also from calcareous algae, sponges, bryozoans, rocks, artificial structures or even combinations of them (Hostim-Silva *et al.*, 2006), also including sandy/muddy, gravel bottom areas adjacent to the reef. These highly rich and complex environments allow fish communities to reach their highest level of diversity within the marine ecosystem (Sale, 1991), although this diversity varies according to geographical regions, being home for about 6300 species (Kulbicki *et al.*, 2013).

Any fish species that use or come nearby reefs' vicinity for refuge, feeding, breeding or just for displacement, can be characterized as a reef fish. In Brazil, at least 547 species (Freire & Carvalho-Filho, 2009) are assigned as reef fishes. They exhibit a wide

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variety of colors, shapes, feeding and reproductive strategies, and several intra- and interspecific associations (Monteiro-Neto *et al*., 2013). With such richness and diversity, reef fish makes up complex communities on rocky shores. Despite the lower topographic complexity when compared to coral reefs, rocky reefs may house a diverse fauna and flora associated (Bertoncini *et al.*, 2013).

Within the Brazilian province, rocky shore environments can be considered as one of the main habitats for reef biota is mainly present in the south-southeast region of the country (Ferreira *et al*., 2001). According to Floeter *et al*. (2001), rocky shores of the states of Paraná and Santa Catarina are part of southeastern Brazil, which covers the states from Espírito Santo to Santa Catarina.

There is an extensive literature on rocky shore fish communities for the south-southeast coast of Brazil (*e.g.*, Hostim-Silva *et al.*, 2006; Gibran & Mora, 2012; Simon *et al*., 2013), but only a few address the rock reefs of the coast of Paraná and north Santa Catarina states (Godoy *et al*., 2007; Hackradt & Felix-Hackradt, 2009; Daros *et al*., 2012). Sites with hard substrates such as coastal islands, rocky reefs, submerged outcrops, and limestone bottoms are scarce and barely mapped in this southern Brazilian continental platform. Thus, the study of these environments is of high ecological importance, once they provide suitable habitats for the development of communities with reef characteristics. The present study aimed to i) classify the species observed according to trophic category and geographical distribution, and ii) evaluate the rocky shore fish community structure of coastal islands of southern Brazil, by comparing the density, biomass and taxonomic distinctness among sampled islands.

MATERIALS AND METHODS

Study area

The study was performed along the islands in the southern coast of Brazil in the states of Paraná and Santa Catarina (Fig. 1). In Paraná, the study was conducted at two sites: Currais Archipelago (25º44'S, 48º22'W) comprised of three islands, about 11 km off the coast, with depths between 1.5 and 16.0 m; and Itacolomis Island (25º50'S, 48º24'W), located 13 km off the coast, with depths ranging from 3.0 to 17.0 m. In Santa Catarina, about 3.5 km off the coast and about 37 km from Itacolomis Island, Graças Archipelago (26º10'S, 48º29'W) consists of five islands and six outcrops. Within the archipelago, the study was conducted in the islands of Paz, Pirata, Veado and Velha and at Baleia outcrop. The depth around the archipelago varies from 1.5 to 18.0 m. Rocky shores of islands have a moderate slope, between 45º and 60º, mainly formed by blocks and boulders (<1 m diameter). Only Baleia outcrop has a larger area and boulders larger than 1 m covered mainly by macroalgae, *Palythoa* sp. and *Zoanthus* sp.

Data collection

Data were obtained by underwater visual census (UVC), using the strip transect technique (ST) of 40 m^2 (20×2 m) (see also Floeter *et al*., 2007), adopted as a sampling unit. Censuses were performed by SCUBA divers between October 2008 and January 2010, in the period from 07:00 to 15:00 h to avoid behavioral variation of species (Willis & Anderson, 2003). Strip transects were performed at an average depth of 6 m.

Species were identified based on the identification keys and descriptions from Figueiredo & Menezes (1980); Menezes & Figueiredo (1980, 1985); Randall (1996); Humann & Deloach (2002); Hostim-Silva *et al*. (2006) and Craig & Hastings (2007). During besides species identification of species, divers obtained density (fish 40 m^{-2}) and estimated total length in four size-classes (smaller than 10 cm; between 11 and 20 cm; between 21 and 30 cm; larger than 30 cm). Biomass (g 40 m^{-2}) was calculated using reference length-weight curves of each species, where coefficients were obtained from Froese & Pauly (2014), or when non-existent, for the species closest to the genus. For the conversion, we used mean values of each length class (*e.g.*, class 21-30 = 25 cm).

Trophic category

Fish observed in the study were grouped into eight trophic categories: carnivorous (CAR), mobile herbivorous (MOVH), territorial herbivorous (TERH), omnivorous (OMN), mobile invertebrate predator (MIP), sessile invertebrate predator (SIP), piscivorous (PIS), planktivorous (PLK), adapted from available literature (Randall, 1967; Opitz, 1996; Ferreira *et al*., 2004; Floeter *et al*., 2004, 2006).

Geographical distribution

Species zoogeographic affinities were classified as proposed by Luiz Jr. *et al*. (2008) as follows: Brazilian Province, Central Atlantic (Islands of St. Helena and Ascension), Circumtropical, Eastern Atlantic, Patagonia (occur mainly in temperate rocky reefs in Southern Argentina), Southern Caribbean (coast of Venezuela, Trinidad and Tobago and other islands below the Lesser Antilles), Southeastern Brazil (endemic to the region encompassing 20° to 27°S), Transatlantic (on both sides of the Atlantic Ocean), Western Atlantic

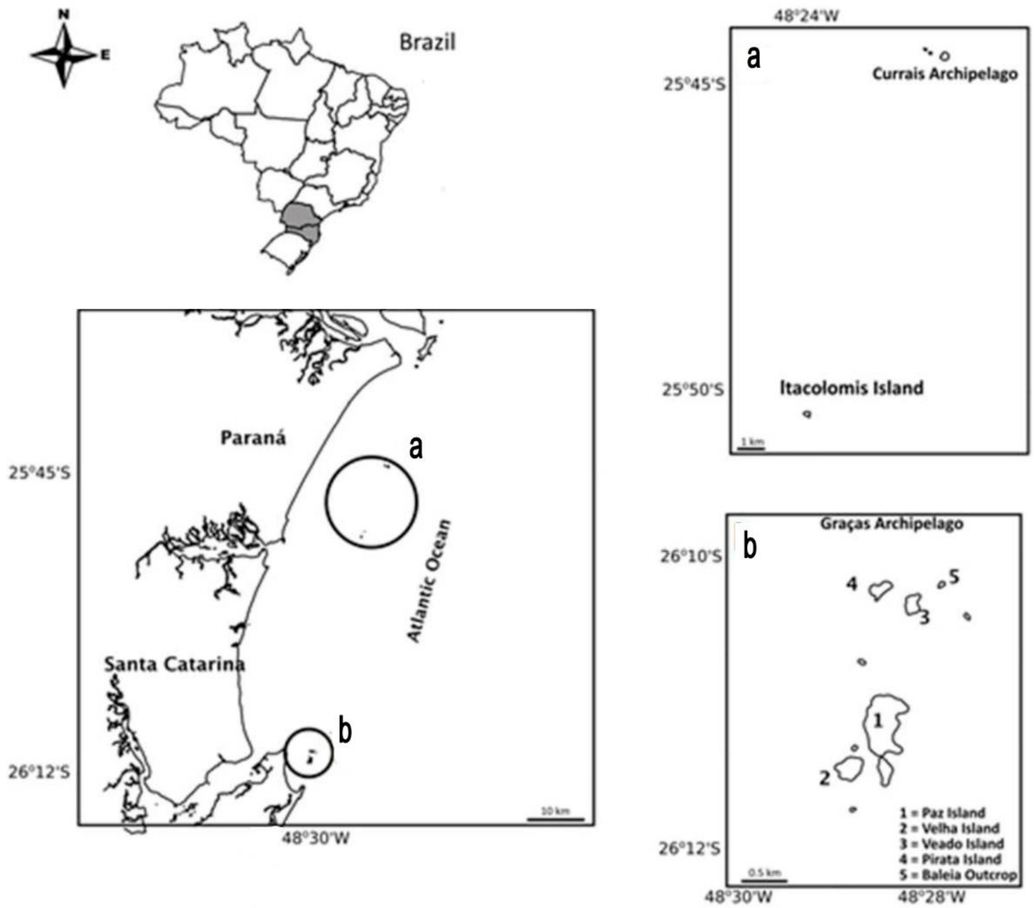

Figure 1. Map with location of the islands sampled in the states of Paraná and Santa Catarina. a) Currais Archipelago and Itacolomis Islands, b) Graças Archipelago.

(Western North and South Atlantic), Caribbean, South Atlantic and Northwest Atlantic (Azores).

Data analysis

In order to check for differences in taxonomic structure among locations, the indices of Average Taxonomic Distinctness (AvTD) (Δ^+) and Variation in Taxonomic Distinctness (VarTD) (Λ^+) were calculated as:

$$\Delta^+ = [\Sigma\Sigma_{i<j}\omega_{ij}]/[S\,(S-1)/2]$$

$$\Lambda^+ = \Sigma\Sigma_{i<j}(\omega_{ij} - \Delta^+)^2/[S\,(S-1)/2)]$$

where: ω_{ij} is the ''distinctness weight'' given to the path length linking species *i* and *j* in the taxonomy and *S* is the number of fish species found in a sample (Xiujuan *et al.*, 2010). The value of ω_{ij} =1 was used as a constant step weight between taxonomic levels (Clarke & Warwick, 1999).

The hierarchical classification associated with the data matrix was used to calculate the values of Δ^+ and Λ^+, built from 73 observed species and following Nelson (2006).

Comparisons of density (fish 40 m^{-2}), biomass (g 40 m^{-2}), AvTD, VarTD and trophic guilds between locations (fixed factor) were performed using a nonparametric Kruskal Wallis analysis of variance, with the package agricolae (Mendiburu, 2013). Analyses were run in Primer 6 software (Clarke & Gorley, 2006) and in R environment (R Development Core Team, 2011).

RESULTS

At Currais Archipelago and Itacolomis Island, 168 ST was performed in each area. On the other hand, at the islands of Paz, Pirata, and Velha, 48 ST were performed per island, and at Baleia outcrop and Veados Island, 23 ST in each, totaling 526 ST.

In total, 19,377 fish belonging to 73 species were observed, distributed among 34 families, 8 orders and 2 classes. The Itacolomis Island showed the highest number of species, followed by Currais Archipelago (49), Pirata Island (37), Paz and Velha islands (both with 34), Baleia Island (31) and Veado Island (27). The Blenniidae and Carangidae families had six species each, followed by Epinephelidae, Haemulidae, Pomacentridae, and Scaridae, with five species in each family. Considering 526 ST, *Stegastes fuscus, Malacoctenus delalandii, Parablennius marmoreus* and *Abudefduf saxatilis* exhibited the highest frequency of occurrence (92.59%, 85.74%, 51.52%, and 46.96%, respectively). In relation to density, *S. fuscus* (9.56 fish 40 m^{-2}), *A. saxatilis* (6.13 fish 40 m^{-2}), *Haemulon aurolineatum* (4.98 fish 40 m^{-2}) and *M. delalandii* (4.46 fish 40 m^{-2}) were the most abundant species. *Acanthurus chirurgus* (534.22 g 40 m^{-2}), *S. fuscus* (216.33 g 40 m^{-2}), *Kyphosus* spp. (195.55 g 40 m^{-2}), *Diplodus argenteus* (103.24 g 40 m^{-2}) and *Anisotremus virginicus* (100.47 g 40 m^{-2}) showed the highest values of estimated biomass (Table 1).

Geographical distribution

Among the observed species, approximately 60.27% (44) occur in the Western Atlantic, 20,54% (15) are Transatlantic and 9.58% (7) are endemic to Brazil. Species occurring in the Circumtropical Province, South Atlantic, and Southern Caribbean contributed with 5.48% (4), 2.74% (2) and 2.74% (2), respectively (Fig. 2).

Trophic category

The 73 species observed were grouped into eight trophic categories. Mobile invertebrate predators (MIIP) were the most diverse with 21 species (28.8%). Carnivorous (CAR) was the second category in a number of species (14), representing 19.2% of the total observed. The other categories together, omnivorous (OMN), mobile herbivorous (MOVH), piscivorous (PIS), planktivorous (PLK), territorial herbivorous (TERH) and sessile invertebrate predator (SIP) contributed with 52.5% of the number of species (11, 9, 6, 6, 4 and 2 respectively)

MIP was also the trophic category with the highest density, 12.57 fish 40 m^{-2}, followed by TERH and OMN with 9.61 and 8.25 fish 40 m^{-2}. Regarding the biomass, MOVH accounted to the highest biomass, 780.48 g 40 m^{-2}, followed by MIP (300.57 g 40 m^{-2}), TERH (217.42 g 40 m^{-2}) and OMN (217.41 g 40 m^{-2}).

Approximately 32% of the total density at Baleia outcrop consisted of MIP species, followed by OMN (29.12%), PLK (17.99%) and TERH (13.19%). The sum of the remaining categories accounted for 7.55%. At Currais Archipelago, species grouped into MIP, TERH, OMN represented respectively 41.42%, 24.94% and 15.75% of the total density, while CAR, MOVH, PIS, PLK, and SIP, together accounted for 17.89%. Thirty percent of the total density at Itacolomis Island was represented by MIP with TERH representing 29.81% and OMN with 27.29%. The other categories accounted for 11.23%.

In the Paz Island, the three categories with higher total density values accounted for 83.37%, where MIP contributed with 34.05%, OMN with 28.70% and TERH with 20.62%. At the Pirata Island, MIP and OMN were the trophic categories that contributed most to total density, with more than 30% each. Carnivorous and PLK accounted for 11.71 and 10.85%, respectively, of the total density in the island. On the other hand, TERH contributed with 42.77% of total density at Veado Island. MIP and PLK represented 20.93% and 17.19%, respectively. At the Velha Island, the trophic category that mostly contributed to the total density was MIP, with 35.25%, followed by TERH (26.11%) and PLK (19.04%). The other categories together contributed, in this island, with 19.60% (Fig. 3).

MIP was the most representative group in terms of total biomass at Currais Archipelago (31.55%) and Velha Island (36.27%). In the Itacolomis Island, MOVH showed the highest biomass, contributing with 70.17% of total biomass. Nonetheless, the category OMN was the group with greatest biomass at Baleia outcrop (48.61%), Paz Island (40.55%) and Pirata Island (37.26%) (Fig. 4).

Size class

Fishes in the length class of less than 10 cm accounted to a density of 25.96 fish 40 m^{-2} (70.47% of total). The length class between 11 and 20 cm showed a density of 9.37 fish 40 m^{-2}, 25.43%. Furthermore, the length classes, 21 to 30 cm and larger than 30 cm, sheltered densities of 0.94 fish 40 m^{-2} and 0.58 fish 40 m^{-2}, representing 2.54% and 1.56%, respectively.

As for biomass, the size class of individuals larger than 30 cm accounted for 929.18 g 40 m^{-2}, 51.90% of the total. Fish smaller than 10 cm presented only 50.64 g 40 m^{-2}, 2.83% of the total, while fish between 11 and 20 cm, 552.82 g 40 m^{-2} (30.88%) and fish between 21 and 30 cm presented 257.59 g 40 m^{-2} (14.39%).

Density (fish 40 m^{-2})

Regarding fish density, the Kruskal-Wallis analysis of variance evidenced significant differences among locations (χ^2 = 96.64; P < 0.001). The highest density was found in the Itacolomis Island (48.18 ± 2.82 fish 40 m^{-2}), followed by Veado Island (43 ± 3.38 fish 40 m^{-2}), Currais Archipelago (36.40 ± 2.54 fish 40 m^{-2}), Baleia

Table 1. Mean density (Den = fish 40 m^{-2}), mean biomass (Bio = g 40 m^{-2}) and Trophic Category (TC) of the species observed in rocky shores in Southern Brazil. CAR: carnivorous, MOVH: mobile herbivorous, TERH: territorial herbivorous, OMN: omnivorous, MIP: mobile invertebrate predator, SIP: sessile invertebrate predator, PIS: piscivorous. PLK: planktivorous. Geographical distribution (GD). BR: Brazilian Province, CA: Central Atlantic (Islands of St. Helena and Ascension), CT: Cincumtropical, EA: Eastern Atlantic, PT: Patagonia (occur mainly in temperate rocky reefs in southern Argentina), SC: Southern Caribbean (coast of Venezuela, Trinidad and Tobago and other islands below the Lesser Antilles), SB: Southeastern Brazil (endemic to the region encompassing 20° to 27°S), TA: Transatlantic (on both sides of the ocean), WA: Western Atlantic (Western North and South Atlantic), CR: Caribbean, SA: South Atlantic, NA: Northwest Atlantic (Azores). *Species only observed.

Family and species	TC	GD	Currais		Itacolomis		Baleia		Paz		Pirata		Veado		Velha	
			Den	Bio	Den	Bio	Den	Bio	Den	Bio	Den	Bio	Den	Bio	Den	Bio
Myliobatidae																
Aetobatus narinari (Euphrasen, 1790)	CAR	CT			0.60	5.25										
Muraenidae																
Gymnothorax funebris (Ranzani, 1839)	CAR	WA	0.60	0.96	0.12	1.91			0.28	3.35						
Gymnothorax moringa (Cuvier, 1829)	CAR	WA+CA	0.30	4.20	0.12	1.68										
Gymnothorax vicinus (Castelnau, 1855)	CAR	TA	0.60	0.74	0.24	2.97										
Ophichthidae																
Myrichthys breviceps (Richardson, 1848)	MIP	WA	0.60	0.74												
Clupeidae																
Harengula clupeola (Cuvier, 1829)	PLK	WA					4.35	4.32			2.83	2.69				
Synodontidae																
Synodus synodus (Linnaeus, 1758)	PIS	TA			*											
Holocentridae																
Holocentrus adscensionis (Osbeck, 1765)	MIP	TA	0.15	32.37	0.45	68.27	0.52	181.66	0.29	35.57	0.28	32.29	0.43	1.42	0.63	4.65
Syngnathidae																
Micrognathus crinitus (Jenyns, 1842)	MIP	WA	0.60	0.54												
Pseudophallus mindii (Meek & Hildebrand, 1923)	MIP	CR+SA							0.42	0.38			0.43	0.39		
Fistulariidae																
Fistularia tabacaria (Linnaeus,1758)	PIS	TA	0.60	0.64												
Dactylopteridae																
Dactylopterus volitans (Linnaeus, 1758)	MIP	TA	*													
Scorpaenidae																
Scorpaena brasiliensis Cuvier, 1829	CAR	WA	0.24	0.89	0.12	1.94					0.28	1.49				
Serranidae																
Diplectrum radiale (Quoy & Gaimand, 1824)	CAR	WA	0.60	0.89											0.28	0.31
Serranus flaviventris (Cuvier, 1829)	MIP	WA	0.65	7.63	0.33	11.70	0.13	0.27	0.33	11.70	0.90	33.45	3.43	56.24	1.35	21.12

Continuation

Family and species	TC	GD	Currais		Itacolomis		Baleia		Paz		Pirata		Veado		Velha	
			Den	Bio	Den	Bio	Den	Bio	Den	Bio	Den	Bio	Den	Bio	Den	Bio
Epinephelidae																
Epinephelus marginatus (Lowe, 1834)	CAR	SB+PT+EA	0.42	17.14	0.95	66.42	0.43	33.67	0.83	4.16	0.13	6.35	0.34	96.99	0.28	1.58
Epinephelus morio (Valenciennes, 1828)	CAR	WA	*													
Hyporthodus niveatus (Valenciennes, 1828)	CAR	WA	0.60	0.16	0.24	0.62							0.13	0.35		
Mycteroperca acurtirostris (Valenciennes, 1828)	PIS	WA	0.22	36.19	0.83	4.19	0.22	31.62	0.14	5.81	0.28	45.46	0.22	6.47	0.25	13.62
Mycteroperca bonaci (Poey, 1860)	PIS	WA	0.60	1.51							0.28	3.68				
Priacanthidae																
Priacanthus arenatus Cuvier, 1829	CAR	TA													0.63	46.33
Carangidae																
Carangoides crysos (Mitchill, 1815)	PIS	TA	0.60	0.36	0.36	6.92										
Caranx latus Agassiz, 1831	PIS	TA			0.60	0.55										
Chloroscombrus chysurus (Linnaeus,1766)	PLK	TA	0.48	3.58	0.12	4.82	1.35	44.40			0.19	6.58	1.35	47.30	0.28	2.92
Pseudocaranx dentex (Bloch & Schemeider, 1801)	PLK	CT	0.68	73.16	0.29	29.98					0.42	12.22				
Selene setapinnis (Mitchill, 1815)	CAR	WA					0.43	17.60								
Selene vomer (Linnaeus, 1758)	PIS	WA			0.60	0.33										
Lutjanidae																
Lutjanus analis (Cuvier, 1828)	CAR	WA	0.12	0.35												
Haemulidae																
Anisotremus surinamensis (Bloch, 1791)	MIP	WA	0.17	46.54	0.18	17.50	1.48	143.20	0.19	16.36	0.28	11.98	0.87	16.64		
Anisotremus virginicus (Linnaeus, 1758)	MIP	WA	0.84	71.96	0.61	64.74	1.27	33.86	1.17	177.26	2.23	26.22	1.43	46.15	0.81	71.30
Haemulon aurolineatun Cuvier, 1830	MIP	WA	1.39	117.40	4.67	42.78	0.17	1.39	0.50	0.87	0.14	1.38	0.83	18.94	0.79	51.14
Haemulon steindachneri (Jordan & Gilbert, 1882)	MIP	WA	0.30	1.33	0.60	0.61	0.43	0.18			0.81	46.71	0.52	51.96	0.54	47.64
Orthopristis ruber (Cuvier, 1830)	MIP	WA	0.14	1.37	0.24	0.39	0.43	1.97	0.83	0.18	0.48	3.75	0.78	1.73	0.44	0.97
Sparidae																
Archosargus probatocephalus (Walbaum, 1792)	OMN	WA			0.60	2.16					0.28	7.37	0.43	18.68		
Archosargus rhomboidalis (Linnaeus, 1758)	OMN	WA					0.43	2.84								
Diplodus argenteus (Valenciannes, 1830)	OMN	WA	0.14	11.73	0.27	76.64	2.91	948.78	1.65	132.17	2.44	227.97			0.13	9.30

Continuation

Family and species	TC	GD	Currais		Itacolomis		Baleia		Paz		Pirata		Veado		Velha	
			Den	Bio	Den	Bio	Den	Bio	Den	Bio	Den	Bio	Den	Bio	Den	Bio
Sciaenidae																
Odontoscion dentex (Cuvier, 1830)	CAR	WA	2.27	6.73	2.15	81.34	1.17	37.86	1.78	36.59	3.28	91.49	3.27	26.45	0.90	46.64
Pareques acuminatus (Bloch & Schemeider, 1801)	MIP	WA	0.40	1.88	0.46	15.34	0.91	74.24	0.31	13.85	0.25	5.55	0.48	24.82	0.15	4.32
Mullidae																
Pseudupeneus maculatus (Bloch, 1793)	MIP	WA	0.27	18.94	0.11	8.86			0.25	28.33	0.28	6.51			0.31	22.36
Pempheridae																
Pempheris schomburgkii (Muller & Trschel, 1848)	PLK	WA	0.36	1.26	0.65	1.44										
Kyphosidae																
Kyphosus sp.	MOVH	TA	0.60	15.30	0.77	563.19	0.43	0.97			0.48	118.77				
Chaetodontidae																
Chaetodon striatus Linnaeus, 1758	SIP	WA	0.57	36.50	0.15	9.39	0.17	12.25	0.48	2.27	0.38	18.42	0.27	2.38	1.13	39.26
Pomacanthidae																
Pomacantus paru (Bloch, 1787)	OMN	WA	0.40	41.32	0.46	1.15	0.91		0.31	64.36	0.25		0.48		0.15	
Pomacentridae																
Abudefduf saxatilis (Linnaeus, 1758)	OMN	CT	4.74	24.53	11.29	7.94	2.65	73.98	2.94	53.38	5.00	226.96	2.34	12.47	0.73	21.60
Chromis multilineata (Guichenot, 1853)	PLK	TA			0.12	0.28							0.35	2.64	0.42	0.92
Stegastes fuscus (Cuvier, 1830)	TERH	BR	9.54	197.46	14.33	338.34	3.96	96.90	3.69	5.48	2.78	83.53	18.39	31.33	5.78	166.41
Stegastes pictus (Castelnau, 1855)	TERH	BR+SC	*													
Stegastes variabilis (Castelnau, 1855)	TERH	WA	0.24	0.92	0.24	0.57	0.22	0.52	0.83	0.24	0.23	8.99				
Labridae																
Bodianus rufus (Linnaeus, 1758)	MIP	WA			0.24	2.27										
Halicoeres poeyi (Steindachner, 1867)	MIP	WA	0.36	1.37	0.12	1.36					0.28	0.95			0.63	1.94
Scaridae																
Cryptotomus roseus (Cope, 1871)	MOVH	WA							0.28	1.16						
Sparisoma amplum (Ranzani, 1841)	MOVH	BR			0.60	1.85			0.42	12.94	0.63	19.43				
Sparisoma axilaris (Steindachner, 1878)	MOVH	BR	0.65	27.87	0.54	53.12	0.87	166.96	0.63	12.98					0.14	32.34
Sparisoma frondosus (Agassiz, 1831)	MOVH	BR+SC	0.30	7.44	0.24	15.54					0.42	7.79	0.43	2.77	0.28	6.47
Sparisoma radians (Valenciennes, 1840)	MOVH	WA			0.60	0.94										

Continuation

Family and species	TC	GD	Currais		Itacolomis		Baleia		Paz		Pirata		Veado		Velha	
			Den	Bio	Den	Bio	Den	Bio	Den	Bio	Den	Bio	Den	Bio	Den	Bio
Sciaenidae																
Odontoscion dentex (Cuvier, 1830)	CAR	WA	2.27	6.73	2.15	81.34	1.17	37.86	1.78	36.59	3.28	91.49	3.27	26.45	0.90	46.64
Pareques acuminatus (Bloch & Schemeider, 1801)	MIP	WA	0.40	1.88	0.46	15.34	0.91	74.24	0.31	13.85	0.25	5.55	0.48	24.82	0.15	4.32
Mullidae																
Pseudupeneus maculatus (Bloch, 1793)	MIP	WA	0.27	18.94	0.11	8.86			0.25	28.33	0.28	6.51			0.31	22.36
Pempheridae																
Pempheris schomburgkii (Muller & Trschel, 1848)	PLK	WA	0.36	1.26	0.65	1.44										
Kyphosidae																
Kyphosus sp.	MOVH	TA	0.60	15.30	0.77	563.19	0.43	0.97			0.48	118.77				
Chaetodontidae																
Chaetodon striatus Linnaeus, 1758	SIP	WA	0.57	36.50	0.15	9.39	0.17	12.25	0.48	2.27	0.38	18.42	0.27	2.38	1.13	39.26
Pomacanthidae																
Pomacantus paru (Bloch, 1787)	OMN	WA	0.40	41.32	0.46	1.15	0.91		0.31	64.36	0.25		0.48		0.15	
Pomacentridae																
Abudefduf saxatilis (Linnaeus, 1758)	OMN	CT	4.74	24.53	11.29	7.94	2.65	73.98	2.94	53.38	5.00	226.96	2.34	12.47	0.73	21.60
Chromis multilineata (Guichenot, 1853)	PLK	TA			0.12	0.28							0.35	2.64	0.42	0.92
Stegastes fuscus (Cuvier, 1830)	TERH	BR	9.54	197.46	14.33	338.34	3.96	96.90	3.69	5.48	2.78	83.53	18.39	31.33	5.78	166.41
Stegastes pictus (Castelnau, 1855)	TERH	BR+SC	*													
Stegastes variabilis (Castelnau, 1855)	TERH	WA	0.24	0.92	0.24	0.57	0.22	0.52	0.83	0.24	0.23	8.99				
Labridae																
Bodianus rufus (Linnaeus, 1758)	MIP	WA			0.24	2.27										
Halicoeres poeyi (Steindachner, 1867)	MIP	WA	0.36	1.37	0.12	1.36					0.28	0.95			0.63	1.94
Scaridae																
Cryptotomus roseus (Cope, 1871)	MOVH	WA							0.28	1.16						
Sparisoma amplum (Ranzani, 1841)	MOVH	BR			0.60	1.85			0.42	12.94	0.63	19.43				
Sparisoma axilaris (Steindachner, 1878)	MOVH	BR	0.65	27.87	0.54	53.12	0.87	166.96	0.63	12.98					0.14	32.34
Sparisoma frondosus (Agassiz, 1831)	MOVH	BR+SC	0.30	7.44	0.24	15.54					0.42	7.79	0.43	2.77	0.28	6.47
Sparisoma radians (Valenciennes, 1840)	MOVH	WA			0.60	0.94										

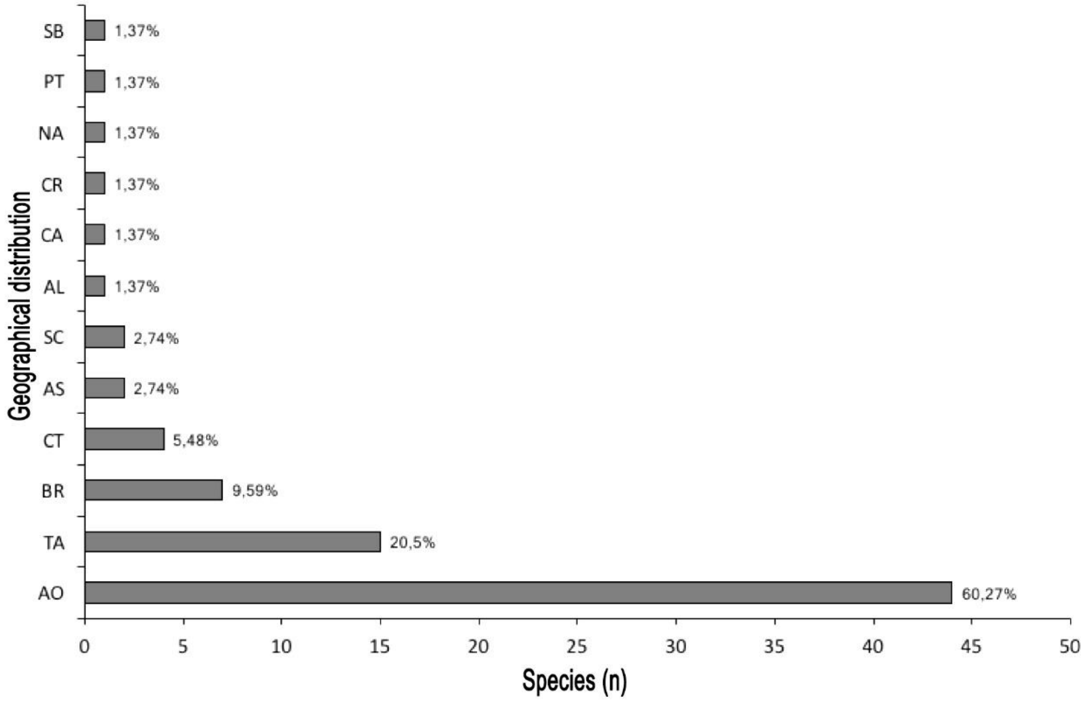

Figure 2. Geographical distribution of the species (n) observed on rocky shores in Southern Brazil, and their percentages. BR: Brazilian Province, CA: Central Atlantic (St. Helena and Ascension islands), CT: Circumtropical, EA: Eastern Atlantic, PT: Patagonia (occur mainly in temperate rocky reefs in southern Argentina), SC: Southern Caribbean (coast of Venezuela, Trinidad and Tobago and other islands below the Lesser Antilles), SB: Southeastern Brazil (endemic to the region encompassing 20° to 27°S), TA: Transatlantic (on both sides of the ocean), WA: Western Atlantic (western North and South Atlantic), CR: Caribbean, SA: South Atlantic, NA: Northwest Atlantic (Azores).

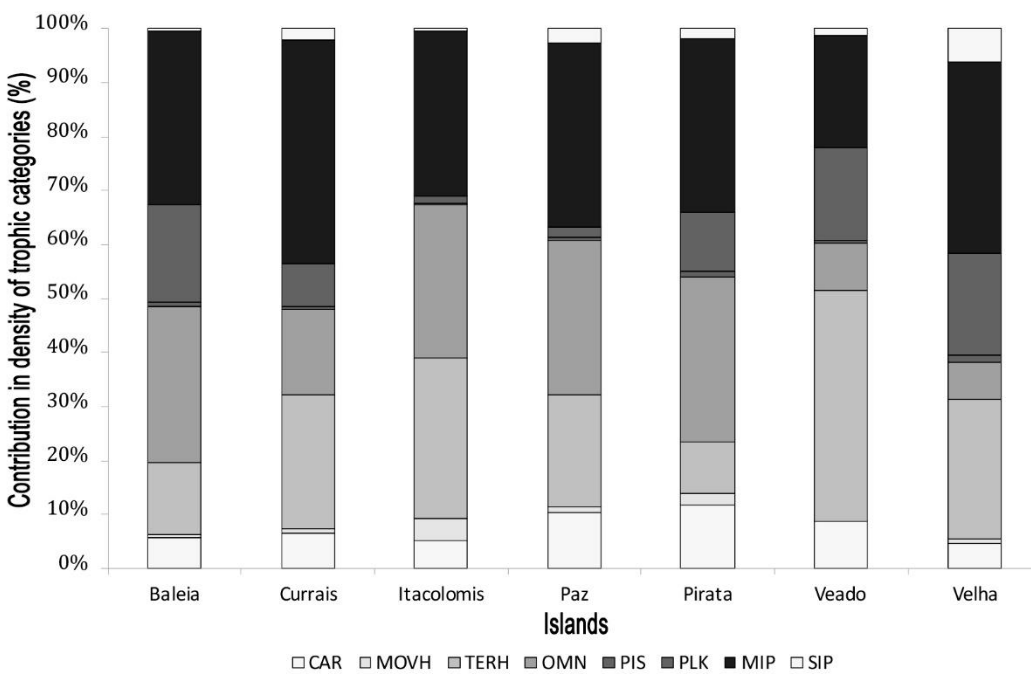

Figure 3. Density (fish 40 m^{-2}) of trophic categories for each location. CAR: carnivorous, MOVH: mobile herbivorous, TERH: territorial herbivorous, OMN: omnivorous, PIS: piscivorous, PLK: planktivorous, MIP: mobile invertebrate predator, SIP: sessile invertebrate predator.

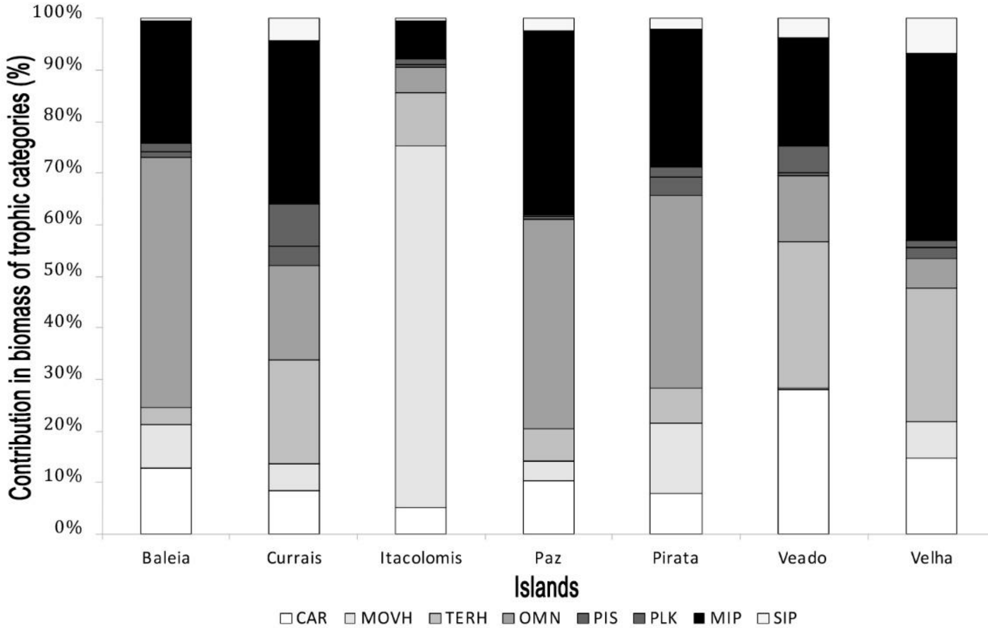

Figure 4. Contribution in biomass (g 40 m^{-2}) of trophic categories for each location. CAR: carnivorous, MOVH: mobile herbivorous, TERH: territorial herbivorous, OMN: omnivorous, PIS: piscivorous, PLK: planktivorous, MIP: mobile invertebrate predator, SIP: sessile invertebrate predator.

outcrop (31.65 ± 4.75 fish 40 m^{-2}), Pirata Island (31.47 ± 4.12 fish 40 m^{-2}), Velha Island (22.10 ± 1.40 fish 40 m^{-2}) and Paz Island (18.29 ± 1.75 fish 40 m^{-2}) (Fig. 5).

Biomass (g 40 m^{-2})

The analysis of variance evidenced that the estimated biomass (g 40 m^2) was also significantly different among locations (χ^2 = 30.47; P < 0.001). The highest mean biomass values were observed at Itacolomis Island (3,253.09 ± 1,187.25 g 40 m^{-2}) and Baleia outcrop (3,028.65 ± 754.12 g 40 m^{-2}), following lower values at Pirata Island (1,333.58 ± 259.12 g 40 m^{-2}), Veado Island (1,087 ± 247.24 g 40 m^{-2}), Currais Archipelago (994.04 ± 150 g 40 m^{-2}), Paz Island (836.38 ± 114.84 g 40 m^{-2}) and Velha Island (639.82 ± 11.07 g 40 m^{-2}) (Fig. 6).

Taxonomic distinctness

The results of the Average Taxonomic Distinctness Δ^+ (AvTD) and the Variation in Taxonomic Distinctness Λ^+ (VarTD) for each sampled area were within the 95% confidence interval. For Δ+, the values were very close to the index expected mean, corroborated by the analysis of variance (χ^2 = 3.53; P = 0.7394), differing only in species number, in which Itacolomis Island contributed with 51 species, Currais Archipelago, 49, Pirata Island, 37, Paz and Velha, 34 each, Baleia outcrop, 31, and Velha Island, 27 species (Fig. 7).

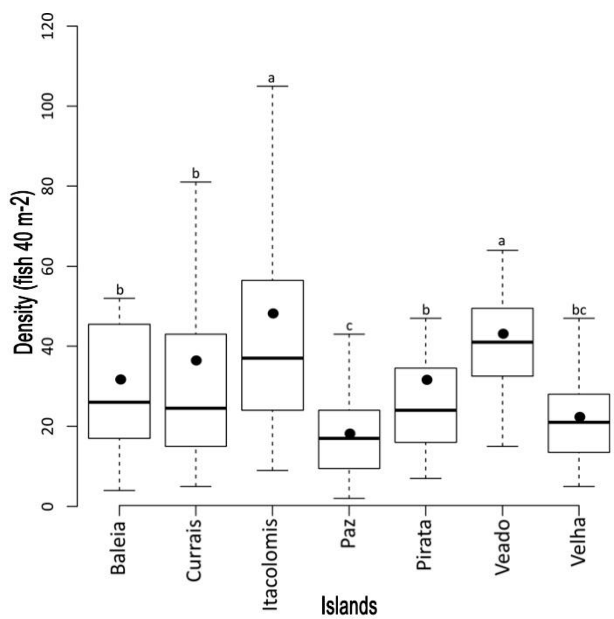

Figure 5. Boxplots of density (fish 40 m^{-2}) in the studied islands. Similar letters indicate statistically similar densities. average.

The Variation in Taxonomic Distinctness (Λ^+) also showed values within the 95% confidence interval. However, significant differences were detected between locations ($\chi^2_{38,58}$ = 1.1662; P = 8.63e-07); the Itacolomis Island was the farthest from the expected

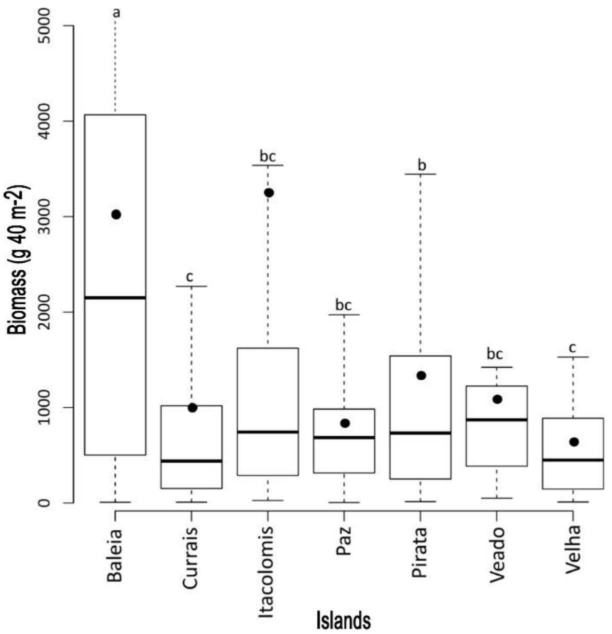

Figure 6. Boxplots of estimated biomass (g 40 m^{-2}) of fish in the studied islands. Similar letters indicate statistically similar biomass. average.

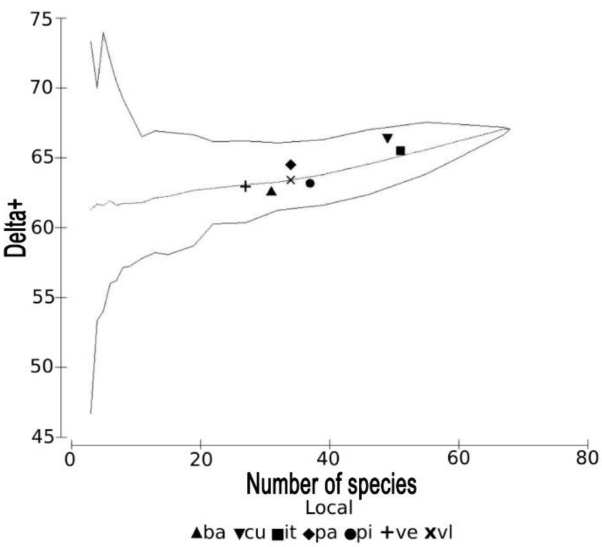

Figure 7. Average Taxonomic Distinctness (Δ^+) calculated for each sampled location. The expected mean is represented by the central dotted line and the 95% confidence interval is represented by the funnel-shaped solid line. Ba: Baleia outcrop, cu: Currais Archipelago, it: Itacolomis Island, pa: Paz Island, pi: Pirata Island, ve: Veado Island, vl: Velha Island.

mean, but still within the 95% confidence interval. Pairwise comparisons between locations in Λ+ pointed out that the Baleia outcrop, Itacolomis Island, Pirata Island and Veado Island were not significantly different from each other. The results also evidenced that Itacolomis

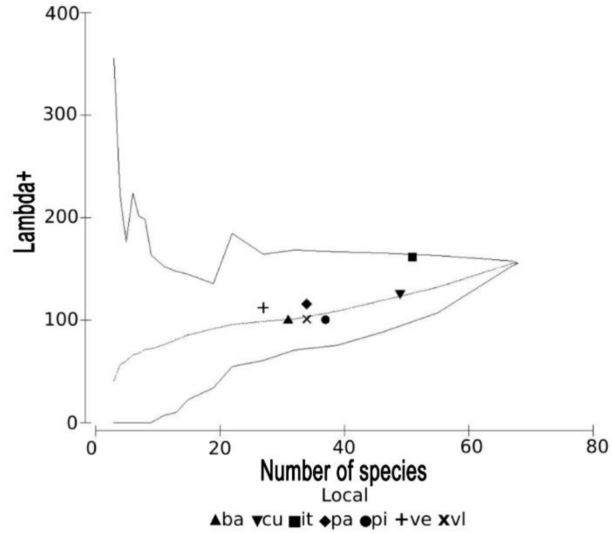

Figure 8. Variation in Taxonomic Distinctness (Λ+) calculated for each sampled location. The expected mean is represented by the central dotted line and the 95% confidence interval is represented by the funnel-shaped solid line. ba: Baleia outcrop, cu: Currais Archipelago, it: Itacolomis Island, pa: Paz Island, pi: Pirata Island, ve: Veado Island, vl: Velha Island.

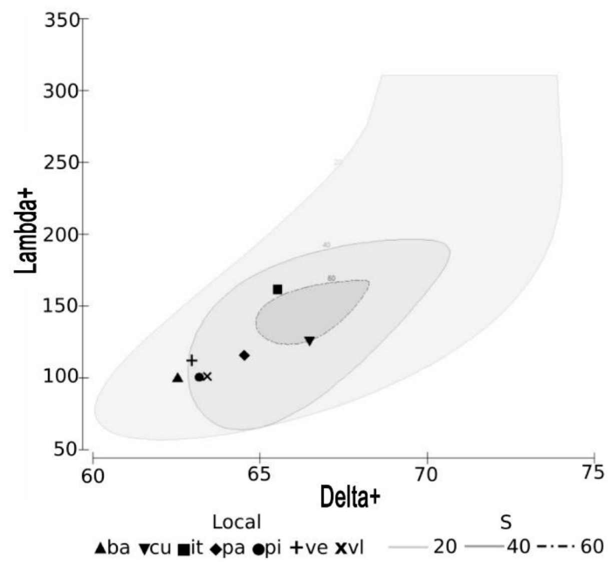

Figure 9. Average Taxonomic Distinctness (Δ^+) of the locations according to the corresponding values of Variation in Taxonomic Distinctness (Λ^+). The ellipse represents the 95% confidence interval of paired values, obtained from 60 independent random simulations. ba: Baleia outcrop, cu: Currais Archipelago, it: Itacolomis Island, pa: Paz Island, pi: Pirata Island, ve: Veado Island, vl: Velha Island.

Island was statistically similar to Paz Island, which was also observed between Currais Archipelago, Paz Island and Velha Island (Fig. 8).

The bivariate simulations for Δ^+ and Λ^+ demonstrated that the values of all sampling sites were within the 95% confidence interval. The ellipse shape and the distribution of means suggested a positive correlation between Δ^+ and Λ^+ (Fig. 9).

DISCUSSION

This study encompassed the rocky shores of Currais Archipelago, Itacolomis Island and the Graças Archipelago covering an area of 21,040 m^2 through 526 40 m^2-strip-transects. We observed 73 species, representing 13% of the total (547 species) registered along the Brazilian coast, according to Freire & Carvalho-Filho (2009). For the islands of the State of Paraná, Hackradt & Félix-Hackradt (2009) and Daros *et al*. (2012) observed 77 species, of which 66% and 64% were observed only in the Itacolomis Island and Currais Archipelago, respectively. Godoy *et al*. (2007) conducted an underwater visual census, using the same methodology of this study, and only at Paz Island, the authors observed 33 species, one less than in the present survey. Considering the total number of species, Graças Archipelago had an absolute richness of 53 species.

Comparing the species richness of the present study with other studies performed in the south-southeastern Brazil, including our study area, the richness observed herein is close to that observed by Alves & Pinheiro (2011) in the islands of Balneário Barra do Sul (State of Santa Catarina) and Mendonça-Neto *et al*. (2008) in rocky shores of Rio do Janeiro. On the other hand, surveys carried out in rocky shores of the south-southeast region by Ferreira *et al.* (2001) (State of Rio de Janeiro); Hostim-Silva *et al*. (2006) (State of Santa Catarina); Floeter *et al*. (2007) (State of Espírito Santo); Rangel *et al*. (2007) and Monteiro-Neto *et al*. (2013) (State of Rio de Janeiro); Luiz Jr. *et al*. (2008) and Gibran & Moura (2012) (State of São Paulo) demonstrated a higher richness. These differences between study areas are not only related to the morphology of each site or longitudinal variation, but also to the sampling effort applied for data acquisition, as well as, visual census methods, differences in sampled depths, sampling of different areas (protected from wave action) and degree of protection (no-take areas) and, different seasons along the year. Due to the proximity of the islands to large estuaries, strip transects were only conducted at an average depth of 6 m, where visibility is generally more favorable to the full accomplishment of the sampling procedures.

As to the number of species per family, Blenniidae, Carangidae, Haemulidae, Pomacentridae, and Scaridae showed the higher richness, which was also verified by Floeter *et al.* (2001), who considered these families as the most representatives in species richness for the south-southeastern Brazil. According to these authors, the family Serranidae presented the highest richness. Craig & Hasting (2007) proposed an alteration in the family Serranidae, moving up the subfamily Epinephelinae to the family Epinephelidae, which shelters important large size genera (*i.e.*, *Epinephelus, Mycteroperca, Hyporthodus*), which showed a significant number of species (5) in the present study.

The rocky shore fish assemblage observed herein is mainly composed of species occurring in the Western Atlantic and Northeast Brazil, despite the fact that the studied islands are located at subtropical latitudes. Even with a lower species richness compared with Laje de Santos State Marine Park (24º15'S, 46º10'W State of São Paulo) (Luiz Jr. *et al*., 2008), the species composition in relation to geographical distribution is very similar. This distribution is mainly influenced by the Brazilian Current, warm and shallow waters, transporting tropical fish larvae to the coast of Santa Catarina, which according to Floeter *et al*. (2008) is the southernmost limit of reef fish distribution in Brazil.

The trophic categorization of species is a useful tool, which beyond taxonomic grouping, is a suitable way to infer ecological attributes like food availability and use of resources (Bellwood & Wainwright, 2002). Considering the species grouped into trophic categories, mobile invertebrate predators (MIP) showed the highest species richness, followed by carnivorous (CAR) and omnivorous (OMN). According to Ferreira *et al*., 2004, the dominance of these groups in subtropical regions is a result of the decrease of mobile herbivorous (*e.g.*, families Acanthuridae and Scaridae), considered a dominant group at lower latitudes, especially in densities.

Moreover, MIP is described as the main trophic group in reef environments (Wainwright & Bellwood, 2002) due to a large amount of available food at consolidated and unconsolidated bottoms (Harmelin-Vivien, 2002). This group accounted for the highest densities observed, being *Malacoctenus delalandii* and *Haemulon aurolineatun* the species with the highest values within MIP. Accordingly, the biomass of MIP species had *Anisotremus virginicus*, *H. aurolineatun* and *H. steindachneri* (Haemulidae) as the most representative ones.

In relation to density and biomass, *Odontoscion dentex* was the main representative of the category CAR in the study area. This result differs from the observed in the southeastern Brazil, where Serranidae species were the most abundant (Ferreira *et al*., 2004). On the other hand, Chaves & Monteiro-Neto (2009) reported *Labrisomus nuchipinnis* as the most abundant among carnivorous species, ascribing the low abundance of Serranidae to the historical fishing pressure along the coast of Rio de Janeiro. Similarly, the low abundance of (large) Serranidae species in the islands reflects the growing demand and intensification of fishing effort for these valuable species (Medeiros *et al*., 1997; Gerhardinger *et al*., 2006).

Besides that, omnivorous (OMN) was the group with the third highest density, differing from that observed along the coast of Rio de Janeiro, where OMN was the most abundant (Ferreira *et al.*, 2004; Chaves & Monteiro-Neto, 2009). *Abudefduf saxatilis* and *Diplodus argenteus* were the main species, both for density and biomass, showing great plasticity, inhabiting different reef environments and feeding on a wide range of resources (Carvalho-Filho, 1999; Harmelin-Vivien, 2002; Ferreira *et al*., 2004).

In agreement with Ferreira *et al.* (2004), *Stegastes fuscus* is the most abundant territorial herbivorous (TERH) species in reefs from the State of Pernambuco (NE Brazil) to the rocky shores of the north-central coast of the State of Santa Catarina. Among TERH, this species was the most frequent, abundant and the accounted for the second highest biomass contribution in our study.

Mobile herbivorous category (HOVH) had the lowest abundance in the southeast region compared with the North and Northeast Brazil, and exhibited the highest biomass, due to the presence of *Acanthurus chirurgus* and *Kyphosus* spp. Ferreira *et al*. (2004) compared trophic categories between latitudes and indicated that Acanthuridae was the most abundant from NE Brazil until Arraial do Cabo (State of Rio de Janeiro) and Kyphosidae dominated this niche down south to Santa Catarina. The geographical gap addressed by this study demonstrates that, in fact, with an adequate sampling effort, species like *A. chirurgus* shows a higher relative contribution to the reefs further south, differently than suggested by Ferreira *et al*. (2004). Data from this study referring to herbivorous are consistent with Floeter *et al*. (2005), who described a decrease in richness and abundance towards high latitudes, and the replacement of mobile by territorial herbivorous.

All other categories, piscivorous (PIS), planktivorous (PLK) and sessile invertebrate predators (SIP) had lower densities and biomass, compared with other categories. The main species were: *Mycteroperca acutirostris* (PIS), *Coryphopterus glaucofraenum* and *Harengula clupeola* (PLK) and *Chaetodon striatus* (SIP). Some studies (*e.g.*, Floeter *et al*., 2007; Rangel *et al*., 2007; Chaves & Monteiro-Neto, 2009) have reported low richness and abundance of PLK on the coast, once greater abundances are observed on oceanic islands (Ferreira *et al*., 2004).

The vast majority of fish observed were smaller than 11 cm. This result was expected, once most species observed in this study had their maximum length close to 10 cm. Another factor is the ontogenetic migration of some species, such as *E. marginatus* (Machado *et al*., 2003), in which juveniles inhabit shallow areas, seeking refuge/larger prey in deeper places while growing, thus reducing competition for space and food.

In our study, 40 m^2-samples can be easily converted and comparable with any other unit of measurement that involves area. Regarding the number of fish per 40 m^2, Itacolomis Island showed the highest density, which was statistically similar to Veado Island. Baleia outcrop, Currais Archipelago, Pirata Island and Velha Island showed no significant differences regarding fish density. Paz Island exhibited the lowest density. Biomass per 40 m^2 also differed between locations, with higher values in the Itacolomis Island and Baleia outcrop.

The Average Taxonomic Distinctness (AvTD) and the Variation in Taxonomic Distinctness (VarTD) provided a consistent picture of the taxonomic relationship within the reef fish assemblage (Clarke & Warwick, 2001), based on the uniformity of taxa distribution in a hierarchical taxonomic tree (Xiujuan *et al*., 2010).

Such indices pointed out to a uniform taxonomic relationship pattern within the reef fish assemblage in Southern Brazil (Clarke & Warwick, 2001; Shan *et al*., 2010), which was expected given the proximity between the islands and the similar geomorphology of the rocky reef sites. The index VarTD evidenced no differences in the taxonomic structure between islands *i.e.*, an assemblage made up of few genera (with several species), while other higher taxa are represented by only one (or few) taxa (Clarke & Warwick, 2001). Indices also showed a positive correlation, that is, the higher the average taxonomic distinctness the higher the variation thereof.

Besides being a tool for monitoring environmental stress, the use of these indices can support the selection of specific sites for conservation, indicating locations with higher values of Average Taxonomic Distinctness, which consequently have higher ecological resilience. Our results evidenced that the rocky fish fauna that inhabits south Brazilian coastal islands' is dominated by few species, and contains taxa geographically widely distributed, with a predominance of generalist species; and although differing in richness, density and biomass, the islands do have a very similar taxonomic composition.

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REFERENCES

Alves, J.A.A. & P.C. Pinheiro. 2011. Peixes recifais das ilhas costeiras do Balneário Barra do Sul, Santa Catarina, Brasil. Rev. Cepsul, 2(1): 10-21.

Bellwood, D.R. & P.C. Wainwright. 2002. The history and biogeography of fishes on coral reefs. In: P.F. Sale (ed.). Coral reef fishes: dynamics and diversity in a complex ecosystem. Academic Press, San Diego, pp. 5-32.

Bertoncini, A.A., C.A. Rangel L.C.T. Chaves, J.P. Mendonça-Neto & C. Monteiro-Neto. 2013. Peixes recifais do monumento natural das Ilhas Cagarras. História, pesquisa e biodiversidade do Monumento Natural das Ilhas Cagarras, Rio de Janeiro, Museu Nacional, 1: 107-137.

Carvalho-Filho, A. 1999. Peixes: costa Brasileira. Marca D'água, São Paulo, 304 pp.

Chaves, L.C.T. & C. Monteiro-Neto. 2009. Comparative analysis of rocky reef fish community structure in coastal islands of south-eastern Brazil. J. Mar. Biol. Assoc. U.K., 89(3): 609-619.

Clarke, K.R. & R.N. Gorley. 2006. PRIMER. User Manual/Tutorial. PRIMER-E, Plymouth, 6: 192 pp.

Clarke, K.R. & R.M. Warwick. 1999. The taxonomic distinctness measure of biodiversity: weighting of step lengths between hierarchical levels. Mar. Ecol. Progr. Ser., 184: 21-29.

Clarke, K.R. & R.M. Warwick. 2001. A further biodiversity index applicable to species lists: validation in taxonomic distinctness. Mar. Ecol. Progr. Ser., 216: 265-278.

Craig, M.T. & P.A. Hastings. 2007. A molecular phylogeny of the groupers of the subfamily Epinephelinae (Serranidae) with a revised classification of Epinephelini. Ichthyol. Res., 54: 1-17.

Daros, F.A., L.S. Bueno, C.C. Vilar, A.C. Passos & H.L. Spach. 2012. Checklist of rocky reef fishes from the Currais Archipelago and Itacolomis Island, Paraná state, Brazil. Check List, 8(3): 349-354.

Ferreira, C.E.L., J.E.A. Gonçalves & R. Coutinho. 2001. Community structure of fish and habitat complexity on a tropical rocky shore. Environ. Biol. Fish., 61: 353-369.

Ferreira, C.E.L., S.R. Floeter, J.L. Gasparini, B.P. Ferreira & J.C. Joyeux. 2004. Trophic structure patterns of Brazilian reef fishes: a latitudinal comparison. J. Biogeogr., 31: 1093-1106.

Figueiredo, J.L. & N.A. Menezes. 1980. Manual de peixes marinhos do sudeste do Brasil. III. Teleostei (2). São Paulo, Museu de Zoologia, Universidade de São Paulo, 90 pp.

Floeter, S.R., B.S. Halpern & C.E.L. Ferreira. 2006. Effects of fishing and protection on Brazilian reef fishes. Biol. Conserv., 128: 391-402.

Floeter, S.R., C.E.L. Ferreira, A. Dominici-Arosemena & I.R. Zolmon. 2004. Latitudinal gradients in Atlantic reef fish communities: trophic structure and spatial use patterns. J. Fish. Biol., 64: 1680-1699.

Floeter, S.R., M.D. Behrens, C.E.L. Ferreira, M.J. Paddack & M.H. Horn. 2005. Geographical gradients of marine herbivorous fishes: patterns and processes. Mar. Biol., 147: 1435-1447.

Floeter, S.R., W. Krohling, J.L. Gasparini, C.E.L. Ferreira & I.R. Zalmon. 2007. Reef fish community structure on coastal islands of southeastern Brazil: the influence of exposure and benthic cover. Environ. Biol. Fish., 78: 147-160.

Floeter, S.R., R.Z.P. Guimarães, L.A. Rocha, C.E.L. Ferreira, C.A. Rangel & J.L. Gasparini. 2001. Geographic variation in reef-fish assemblage along the Brazilian coast. Glob. Ecol. Biogeogr., 10: 423-431.

Floeter, S.R., L.A. Rocha, D.R. Robertson, J.C. Joyeux, W.F. Smith-Vaniz, P. Wirtz, A.J. Edwards, J.P. Barreiros, C.E.L. Ferreira, J.L. Gasparini, A. Brito, J.M. Falcón, B.W. Bowen & G. Bernardi. 2008. Atlantic reef fish biogeography and evolution. J. Biogeogr., 35: 22-47.

Freire, K.M.F & A. Carvalho-Filho. 2009. Richness of common names of Brazilian reef fishes. Pan-Am. J. Aquat. Sci., 4(2): 96-145.

Froese, R. & D. Pauly (eds.). 2014. FishBase. World Wide Web electronic publication. Available from [www.fishbase.org]. Reviewed: 12 December 2016.

Gerhardinger, L.C., M.O. Freitas, A.A. Bertoncini, M. Borgonha & M. Hostim-Silva. 2006. Collaborative approach in the study of the reproductive biology of the dusky grouper *Epinephelus marginatus* (Lowe, 1834) (Perciformes: Serranidae). Acta. Sci. Biol. Sci., 28(3): 219-226.

Gibran, F.Z. & R.L. Moura. 2012. The structure of rocky reef fish assemblage across a nearshore to coastal island's gradient in Southeastern Brazil. Neotrop. Ichthyol., 10(2): 369-382.

Godoy, E.A.S., F.A. Daros, L.C. Gerhardinger, P.R.K. Bertuol, L.F. Machado, A.B. Andrade & M. Hostim-

Silva. 2007. Projeto peixes de costão rochoso de Santa Catarina: subsídios para conservação. In: A.P. Prates & D. Blanc (org.). Brasília/MMA/SBF. Áreas Marinhas Protegidas como instrumento de gestão pesqueira. Série Áreas Marinhas Protegidas 4: 99-116.

Hackradt, C.W. & F.C. Félix-Hackradt. 2009. Assembleia de peixes associados a ambientes consolidados no litoral do Paraná, Brasil: uma análise qualitativa com notas sobre sua bioecologia. Pap. Avulsos Zool., 49(31): 389-403.

Harmelin-Vivien, M.L. 2002. Energetics and fish diversity on coral reefs. In: P.F. Sale (ed.). Coral reef fishes: dynamics and diversity in a complex ecosystem. Academic Press, San Diego, pp. 265-273.

Hostim-Silva, M., A.A. Bertoncini, L.F. Machado, L.C. Gerhardinger, F.A. Daros, J.P. Barreiros & E.A.S. Godoy. 2006. Peixes de costão rochoso de Santa Catarina: I. Arvoredo. Universidade do Vale do Itajaí, Itajaí, 134 pp.

Humann, P. & N. Deloach. 2002. Reef fish identification: Florida, Caribbean, Bahamas. New World Publications, Jacksonville, 481 pp.

Kulbicki, M., V. Parravicini, D.R. Bellwood, E. Arias-Gonzalez, P. Chabanet, S.R. Floeter, A. Friedlander, J. Mcpherson, R.E. Myers, L. Vigliola & D. Mouillot. 2013. Global biogeography of reef fishes: a hierarchical quantitative delineation of regions. PLoS ONE, 8(12): e81847.

Luiz-Jr, O., A. Carvalho-Filho, C.E.L. Ferreira, S.R. Floeter, J.L. Gasparini & I. Sazima. 2008. The reef fish assemblage of the Laje de Santos Marine State Park, Southwestern Atlantic: annotated checklist with comments on abundance, distribution, trophic structure, symbiotic associations, and conservation. Zootaxa, 1807: 1-25.

Machado, L.F., A.A. Bertoncini, M. Hostim-Silva & J.P. Barreiros. 2003. Habitat use by the juvenile dusky grouper *Epinephelus marginatus* and its relative abundance, in Santa Catarina, Brazil. Aquaculture, 6(4): 133-138.

Medeiros, R.P., S.C. Vizinho, C.X. Macedo & M. Polette. 1997. Diagnóstico sócio econômico e cultural das comunidades pesqueiras artesanais do litoral centro-norte do Estado de Santa Catarina. Notas Técnicas da FACIMAR, 1: 33-42.

Mendiburu, F. 2013. Agricolae: statistical procedures for agriculture research. R package version 1.1-4. [http://cran.at.r-project.org/web/packages/agricolae/index.html]. Reviewed: 10 October 2016.

Mendonça-Neto, J.P., C. Monteiro-Neto & L.E. Moraes. 2008. Reef fish community structure on three islands of Itaipu, Southeast Brazil. Neotrop. Ichthyol., 6(2): 267-274.

Menezes, N.A. & J.L. Figueiredo. 1980. Manual de Peixes Marinhos do Sudeste do Brasil. IV. Teleostei (3). São Paulo: Museu de Zoologia, Universidade de São Paulo, São Paulo, 96 pp.

Menezes, N.A. & J.L. Figueiredo. 1985. Manual de peixes marinhos do Sudeste do Brasil. V. Teleostei (4). Museu de Zoologia, Universidade de São Paulo, São Paulo, 105 pp.

Monteiro-Neto, C., A.A. Bertoncini L.C.T. Chaves, R. Noguchi, J.P. Mendonça-Neto & C.A. Rangel. 2013. Checklist of marine fish from coastal islands of Rio de Janeiro, with remarks on marine conservation. Mar. Biodivers. Rec., 6: 1-13.

Nelson, J.S. 2006. Fishes of the world. John Wiley and Sons, New York, 601 pp.

Opitz, S. 1996. Trophic interactions in Caribbean coral reefs. ICLARM Tech. Rep., 43: 341 pp.

R Development Core Team. 2011. R: a language and environmental for statistical computing. R. Foundation for Statistical Computing, Vienna, Austria. ISBM 3-900051-07-0, [http://www.R-project.org/].

Randall, J.E. 1967. Food habits of reef fishes of the west Indies. Stud. Trop. Oceanogr., 5: 665-847.

Randall, J.E. 1996. Caribbean reef fish. T.F.H. Publications, Neptune City, 368 pp.

Rangel, C.A., L.C.T. Chaves & C. Monteiro-Neto. 2007. Baseline assessment of the reef fish assemblage from Cagarras Archipelago, Rio de Janeiro, Southeastern Brazil. Braz. J. Oceanogr., 55(1): 7-17.

Sale, P.F. 1991. The ecology of fishes on coral reefs. Academic Press, San Diego, 754 pp.

Simon, T., J.C. Jouyeux & H.T. Pinheiro. 2013. Fish assemblage on shipwrecks and natural rocky reefs strongly differ in trophic structure. Mar. Environ. Res., 90: 55-65.

Shan, X., X. Jin & W. Yuan. 2010. Taxonomic diversity of fish assemblages in the Changjiang Estuary and its adjacent waters. Acta Oceanol. Sin., 29: 70-80.

Wainwright, P.C. & D.R. Bellwood. 2002. Ecomorphology of feeding. In: P.F. Sale (ed.). Coral reef fishes: dynamics and diversity in a complex ecosystem. Academic Press, San Diego, 549 pp.

Willis, T.J. & M.J. Anderson. 2003. Structure of cryptic reef fish assemblages: relationships with habitat characteristics and predator density. Mar. Ecol. Progr. Ser., 257: 209-221.

Xiujuan, S., J. Xianshi & Y. Wei. 2010. Taxonomic diversity of fish assemblages in the Changjiang Estuary and its adjacent waters. Acta Oceanol. Sin., 29(2): 70-80.

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