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Research Article

The rocky reef fishes of Vermelha Beach, a marine-estuarine transitional zone at Guanabara Bay, Brazil

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ABSTRACT. Rocky reefs are one of the most important biotopes in Guanabara Bay due to their broad distribution and high species diversity. This study aimed to describe the composition and structure of the fish assemblage associated with rocky reefs in Vermelha Beach (RJ/Brazil), an estuarine-marine transitional zone located at the entrance of Guanabara Bay. Fish were surveyed through underwater visual censuses, conducted by snorkeling divers along 10 m^2-linear transects (n = 90). A total of 2.487 fishes were recorded belonging to 29 species in 18 families. Except for *Atherinella brasiliensis*, all other species are intimately associated with rocky reefs. The present work also stresses the importance of further studies to evaluate the role of periodic influences of estuarine and oceanic waters as structuring factors of the fish assemblages associated with rocky reefs at Vermelha Beach and similar ecosystems.

Keywords: reef fishes, urban beach, transitional environment, underwater visual census, conservation, South Atlantic.

INTRODUCTION

The Guanabara Bay (22º24’-22º57’S, 42º33’-43º19’W), the second largest costal Bay in Brazil is characterized as an important estuary of approximately 400 km^2 in the state of Rio de Janeiro (Valentin *et al.*, 1999). It stands out not only for its environmental heterogeneity, with sandy beaches, rocky reefs, mangrove forests and many inflowing rivers, but also for its location, surrounded by one of the most urbanized areas of Brazil, inhabited by 11 million people (IBGE, 2015). As a consequence, Guanabara Bay has progressively become, throughout the years, one of the most eutrophic ecosystems in the world (Guenther *et al.*, 2008), functioning as a final receiver of high loads of both domestic and industrial non-treated effluents, that have been significantly changing its physical and chemical conditions and thus, adversely affecting habitats and organisms integrity (Jablonski *et al.,* 2006; Neves *et al.*, 2007; Seixas *et al.,* 2013).

Rocky reefs are one of the most relevant biotopes on coastal systems, sheltering a great diversity of organisms with ecological and economic importance (Ferreira *et al.*, 2001). They are amongst the prevalent submerged habitats in Guanabara Bay being, on the other hand, less common in its inner area where mangroves are dominant (Coutinho & Zalmon, 2009). In general, higher species richness is found at rocky reefs located in the entrance of Guanabara Bay (largely influenced by oceanic waters), in contrast to the lower species richness recorded in the inner areas where water circulation is limited (Kjerfve *et al.,* 1997; Veloso & Neves, 2009).

Since rocky shores have been recognized as good sensors of environmental conditions (Murray *et al.*, 2006), their associated fish assemblages mighty be used to assess the impacts posed on Guanabara Bay. Despite the high anthropic pressure, this bay plays an important role of nursery and feeding grounds for many fisheries resources, also harboring an intense commercial fishing activity (Jablonski *et al.,* 2006). While fish contamination by heavy metals and hydrocarbons have been documented (Kehrig *et al.,* 2002; Silva *et al.,* 2003), there are, surprisingly, no data about fish use patterns of the major submerged habitats in Guanabara Bay.

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In this context, the present study aimed to describe, through underwater visual censuses, the composition and structure of the fish assemblages associated to the rocky reefs of Vermelha Beach, Guanabara Bay. This area is located in a transitional zone between the estuarine and marine environment, undergoing influences of both oceanic nutrient rich and more saline waters, and inner bay oligohaline waters. In order to provide information on fish density and occurrence, trophic guilds were used to describe the functional structure of the reef fish assemblages and interactions between the major species and micro-scale habitat features.

MATERIALS AND METHODS

Study site

Vermelha Beach (22º57'S, 043º09'W) is located at the city of Rio de Janeiro, in the outer zone (entrance) of Guanabara Bay, undergoing direct influences of both transparent and more saline oceanic waters and more eutrophic and turbid estuarine bay waters (Fig. 1). Guanabara Bay hydrologic characteristics show a temporal pattern affected by a rainy season, tidal regime and by two spatial gradients: a) longitudinal, from the entrance of the bay towards the inner areas and b) vertical, from bottom to surface (Mayr *et al.*, 1989). The complex and often synergistic changes in these factors leads to a strong variability on environmental conditions. Vermelha Beach has no restriction for bathing and fishing throughout the year, being relatively exposed to SW swells.

Vermelha Beach has two rocky reefs (Fig. 1), separated by a sandy beach of 250 m. The left rocky reef (A) is composed of basalt rock boulders of various sizes, covered by sparse banks of *Codium* sp. and *Ulva* sp., two common green algae that prevail on both rocky reefs. The right rocky reef (B), on the other hand, has a steeper topography (between 45º and 60º), colonized by mussel beds mixed with patches of the both mentioned algae and frequently visited by fishermen due to its easier access.

Samples

Underwater visual censuses (UVC) were conducted monthly from April 2011 to February 2012. from 10:00 to 16:00 h, through snorkeling dives along 5 m-strip transects over the rocky substrate**,** in depths ranging from 2 to 5 m. Fish located up to 1 m distance on each side of the transect (10 m^2) were identified to the lowest taxonomic level. Abundance and size of each species were estimated and recorded on PVC boards.

Data collection

Fish identification was based on Figueiredo & Menezes (1978, 1980, 2000), Menezes & Figueiredo (1980, 1985), complemented with Fishbase (Froese & Pauly, 2016) and Eschmeyer (2016). Fish species were grouped into six trophic categories (as in Ferreira *et al.*, 2004; Floeter *et al.*, 2004; Bertoncini *et al.*, 2010; Feitosa *et al.*, 2012) based on the main diet of adults as follows: CAR = carnivores (feed on a variety of mobile organisms, including invertebrates and fish), MIF = mobile invertebrate feeders (feed primarily on small benthic mobile invertebrates like mollusks, crustaceans and worms associated to the hard/soft bottoms), OMN = omnivores (feed on a variety of organisms, either animal and vegetal), PLA = planktivores (feed primarily on macro/micro zooplankton), HER = herbivores (small to large herbivores that include in their diet a large amount of detritus, turf algae and macroalgae) and SIF = sessile invertebrate feeders (feeds on a variety of sessile benthic invertebrates, like cnidarians, ascidians and sponges that are mostly associated with hard substrate).

RESULTS

Fish assemblage

Out of the 90 transects 2.487 fishes from 18 families and 29 species were recorded (Table 1). Haemulidae, Pomacentridae and Labrisomidae were the richest families, with three species each. The richest genera, with two species each were: *Haemulon, Stegastes, Labrisomus, Sphoeroides* and *Chilomycterus*.

Most species (51.7%) were mobile invertebrate feeders, followed by carnivores (17.2%), omnivores (13.8%) and herbivores (10.3%). Considering the relative abundance of each guild, omnivores represented 46.9% and mobile invertebrate feeders 43.0%, followed by carnivores (4.2%), herbivores (2.8%), planktivores (2.2%), and sessile invertebrate feeders (0.9%).

The most abundant species was *Diplodus argenteus*, followed by *Haemulon aurolineatum*, *Stephanolepis hispidus* and *Abudefduf saxatilis*. These four species accounted together for 69.7% of total abundance (Table 1). On the other hand, *S. hispidus* (71%), *D. argenteus* (50%), *Sphoeroides testudineus* (44%) and *Chilomycterus spinosus* (44%) were the most frequent species observed in transects.

Regarding size classes, the highest frequency of fish was observed in the size class 10-12 cm (45% of data) TL (total length), with a mode from 8-14 cm TL classes (86% of data) (Fig. 2). It is remarkable the low densities of commercially exploited species, such as the dusky grouper *Epinephelus marginatus* (0.33 ind 100 m^{-2}) (only juveniles), the cocoa damselfish *Stegastes variabilis* (1.00 ind 100 m^{-2}), exploited for ornamental purposes,

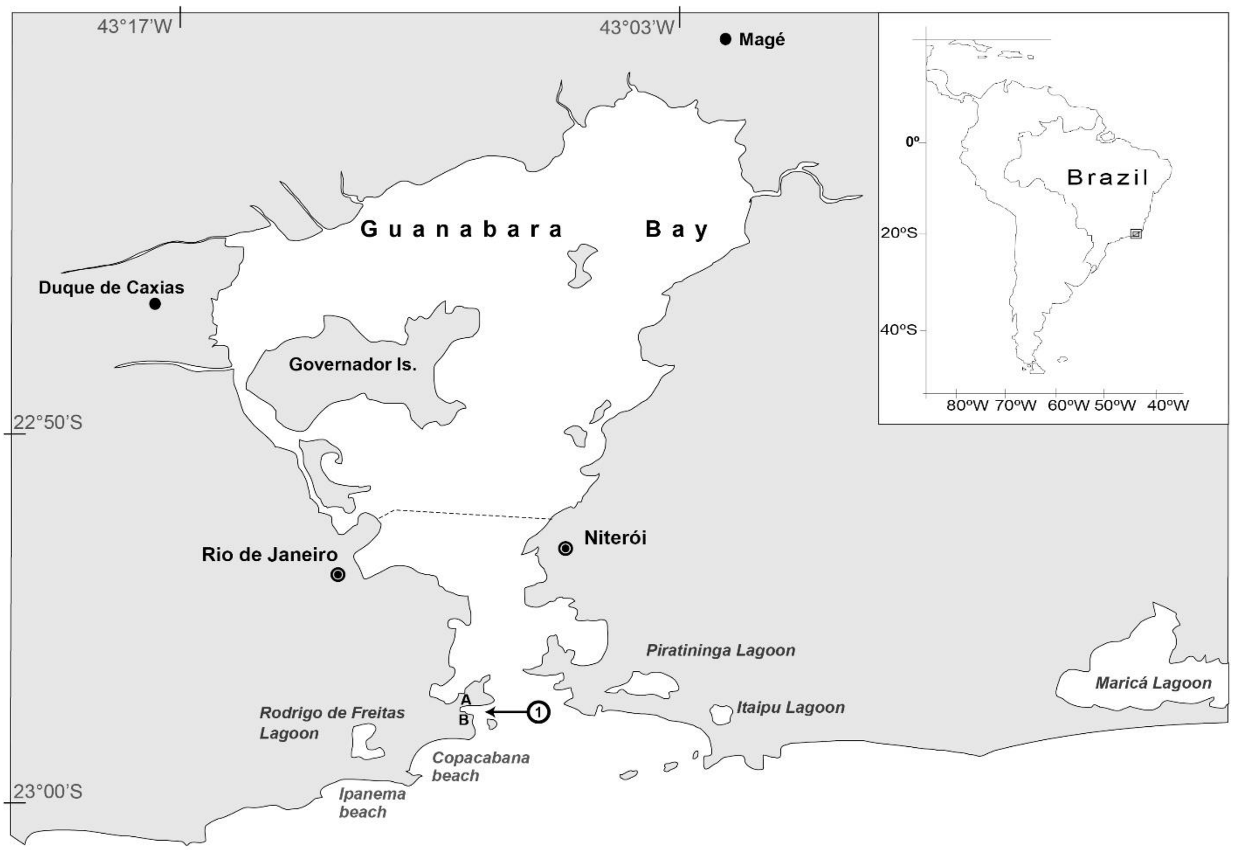

Figure 1. Geographic location of the studied site showing Guanabara Bay, Rio de Janeiro, Brazil, with the location of Vermelha Beach (1) at the outer zone of the Bay and its rocky reefs (A: left, and B: right).

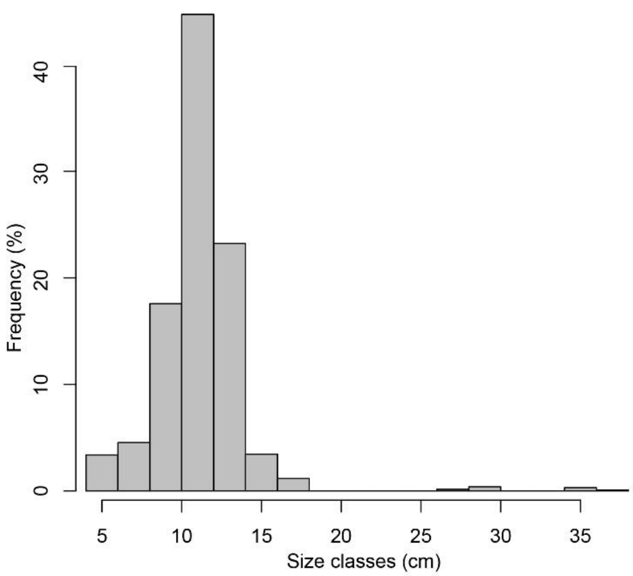

Figure 2. Frequency (%) of fish by size classes (cm) at rocky shores of Vermelha Beach, Rio de Janeiro, Brazil.

and the queen trigger fish *Balistes vetula* (0.44 ind 100 m^{-2}), also targeted by the aquarium market and gamefish.

Although *S. testudineus* and *C. spinosus* were recorded in 44% of all transects, their mean densities were considered moderate, 10.89 ind 100 m^{-2} and 8.11 ind 100 m^{-2}, respectively. Two cryptic species deserve special attention, *Labrisomus nuchipinnis* (8.88 ind 100 m^{-2}) and *Parablennius pilicornis* (7.55 ind 100 m^{-2}) once they are among the top-ten most abundant species.

Photographs taken at Vermelha Beach provided insights on inter and intraspecific interactions of the major fish species, as well as, some of their different uses of the rocky bottoms. *Anisotremus virginicus. A. saxatilis* and *D. argenteus* were commonly seen in association with large boulders (130 cm diameter) of the left rocky reef (Fig. 3a). Small shoals (n < 5) of the high-hat *Pareques acuminatus* (Fig. 3b) were often seen in gregarious behavior, probably for protection, under rocky slabs and small holes. The aggressive territorial damselfish *S. fuscus* was photographed attacking a young dusky grouper (*E. marginatus*), a potential juvenile predator (Fig. 3c). The banded butterflyfish *Chaetadon striatus* were observed foraging on the rocky bottoms (Fig. 3d), usually in pairs. The ringneck blenny *P. pilicornis* presented a variety of

Table 1. Family and fish species recorded though underwater visual census (n = 90) on both rocky reefs of Vermelha Beach, Guanabara Bay, Rio de Janeiro. Tcat: Trophic categories (CAR: carnivores, MIF: mobile invertebrate feeders, OMN: omnivores, PLA: planktivorous, HER: herbivores, SIF: sessile invertebrate feeders), DEN: mean density (ind $100m^2$), SE: standard error. RA: relative abundance (%) and FO: frequency of occurrence (%). Bold values are the top-four-abundant species.

Family/species	Tcat	DEN		SE	RA	FO
Atherinopsidae						
Atherinella brasiliensis (Quoy & Gaimard, 1825)	PLA	6.11	±	0.72	2.21	2.22
Holocentridae						
Holocentrus adscensionis (Osbeck, 1765)	MIF	15.44	±	0.94	5.59	20.00
Fistulariidae						
Fistularia tabacaria Linnaeus, 1758	CAR	0.11	±	2.69	0.04	1.11
Dactylopteridae						
Dactylopterus volitans (Linnaeus, 1758)	MIF	1.44	±	0.54	0.52	12.22
Serranidae						
Epinephelus marginatus (Lowe, 1834)	CAR	0.33	±	0.32	0.12	2.22
Haemulidae						
Anisotremus virginicus (Linnaeus, 1758)	MIF	0.11	±	16.85	0.04	1.11
Haemulon aurolineatum Cuvier, 1830	MIF	**38.44**	±	1.78	13.91	32.22
Haemulon steindachneri (Jordan & Gilbert, 1882)	MIF	1.56	±	1.21	0.56	6.67
Sparidae						
Diplodus argenteus (Valenciennes, 1830)	OMN	**94.67**	±	2.95	34.26	50.00
Sciaenidae						
Pareques acuminatus (Bloch & Schneider, 1801)	CAR	1.44	±	0.25	0.52	8.89
Mullidae						
Mullus argentinae Hubbs & Marini, 1933	MIF	0.11	±	5.64	0.04	1.11
Pseudupeneus maculatus (Bloch, 1793)	MIF	0.22	±	0.60	0.08	1.11
Chaetodontidae						
Chaetodon striatus Linnaeus, 1758	SIF	2.56	±	0.69	0.92	17.78
Pomacentridae						
Abudefduf saxatilis (Linnaeus, 1758)	OMN	**24.89**	±	10.85	9.01	20.00
Stegastes fuscus (Cuvier, 1830)	HER	2.44	±	0.43	0.88	18.89
Stegastes variabilis (Castelnau, 1855)	HER	1.00	±	4.46	0.36	6.67
Labridae						
Halichoeres poeyi (Steindachener,1867)	MIF	1.67	±	1.83	0.60	7.78
Labrisomidae						
Labrisomus nuchipinnis (Quoy & Gaimard, 1824)	CAR	8.89	±	0.56	3.22	21.11
Labrisomus kalisherae (Jordan, 1904)	CAR	0.78	±	0.68	0.28	6.67
Malacoctenus delalandii (Valenciennes, 1836)	MIF	1.44	±	0.11	0.52	8.89
Blenniidae						
Scartella cristata (Linnaeus, 1758)	HER	4.33	±	0.11	1.57	25.56
Parablennius pilicornis (Cuvier, 1829)	OMN	7.56	±	0.45	2.73	17.78
Balistidae						
Balistes vetula Linnaeus, 1758	MIF	0.44	±	5.82	0.16	3.33
Tetraodontidae						
Sphoeroides greeleyi Gilbert, 1900	MIF	4.00	±	0.22	1.45	14.44
Sphoeroides testudineus (Linnaeus, 1758)	MIF	10.89	±	0.16	3.94	44.44
Monacanthidae						
Monacanthus ciliatus (Mitchill, 1818)	OMN	2.44	±	7.70	0.88	8.89
Stephanolepis hispidus (Linnaeus, 1766)	MIF	**34.67**	±	0.11	12.55	71.11
Diodontidae						
Chilomycterus reticulatus (Linnaeus, 1758)	MIF	0.22	±	0.99	0.08	3.33
Chilomycterus spinosus (Linnaeus, 1758)	MIF	8.11	±	0.27	2.94	44.44

substrate use, changing its behavior from a camouflage strategy over complex turf algae substrates (Fig. 3e) and deceiving potential menaces close to sea urchins over less-structured habitats (Fig. 3f). A few individuals of *P. pilicornis* with the golden-orange morph were rarely observed. Single squirrelfish *Holocentrus adscensionis* were frequently recorded sheltering under rock cavities, with high densities of black sea urchins (Fig. 3g). The cornetfish *Fistularia tabacaria,* an occasional visitor of these reefs, was also photographed (Fig. 3h).

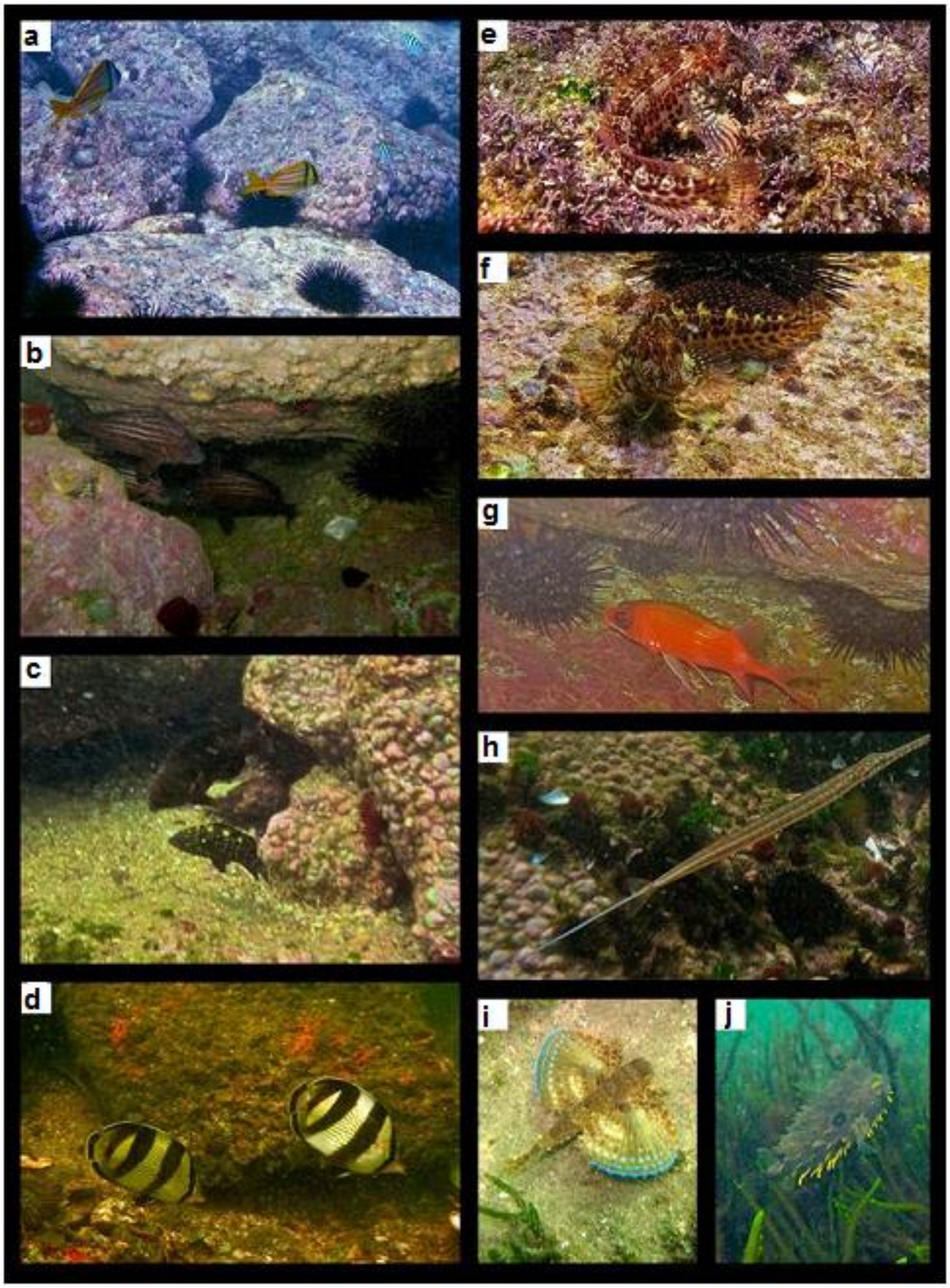

Figure 3. Fish species at Vermelha Beach, Guanabara Bay, Rio de Janeiro. Brazil showing some different habitat uses patterns and interactions between reef-associated fishes and rocky substrates. a) *Anisotremus virginicus, Abudefduf saxatilis* and *Diplodus argenteus* over rocky reef boulders, b) a small shoal of *Pareques acuminatus* using crevices, c) territorial and agonistic display of *Stegastes fuscus* against a young *Epinephelus marginatus*, d) a pair of *Chaetodon striatus* foraging over the rocky bottom, e) different behavior displayed by *Parablennius pilicornis*. changing from a camouflage strategy on complex turf algae substrate to f) interacting with sea urchin in a less-structured habitat, g) a single *Holocentrus adscensionis* sheltering among sea urchins, h) *Fistularia tabacaria*, an occasional visitor, i) *Dactylopterus volitans* displaying its pectoral fins, j) *Chilomycterus spinosus* among dense *Codium* sp. beds.

The area is also abundant in flying gurnards, *Dactylopterus volitans* that often display their pectoral fins as a warning signal for potential predators (Fig. 3i), and also isolated burrfish, *C. spinosus*, were observed among dense *Codium* sp. beds (Fig. 3j).

DISCUSSION

The trophic structure found in the present work for the fish associated to the rocky reefs of Vermelha Beach followed a similar pattern of the reef fish assemblagesrecorded for the nearshore islands at the entrance of Guanabara Bay (Chaves & Monteiro-Neto, 2009), where Mãe Island (Niterói), and Comprida Island (Rio de Janeiro) show a dominance of the groups MIF and OMN in the relative abundance. The dominance of the omnivorous guild can be explained by the high abundances of *D. argenteus*, that not only showed the highest mean density (94.6 100 m^{-2}), but accounted to more than 1/3 of the fishes observed (34.2%). This species shows a great plasticity on the use of food resources (Ferreira *et al.*, 2004).

The high prevalence of *D. argenteus* and *H. aurolineatum*, which accounted together for 48.2% of total abundance, might be also related to their gregarious behavior, in which large roving schools cross the transects (see Kulbicki *et al.*, 2010). High relative abundances and frequency of occurrence (12.5% and 71.1% respectively) were also observed for *S. hispidus*, corroborating with Ferreira *et al.* (2004), who found *S. hispidus* and *D. argenteus* among the most abundant species in the southern areas along a latitudinal gradient through the Brazilian cost, from Tamandaré (Northeast) to Arvoredo (South).

Except for *Atherinella brasiliensis*, all other species are associated with rocky reefs or hard substrates, showing the influence of the Guanabara Bay in the study area, once this species is common and numerically dominant, as young-of-the-year, in inner beaches of bays (see Pessanha & Araújo, 2003).

Size classes revealed a community of small sized fish, with very few specimens over 20 cm TL. Although the area has an intense fishing activity (line and pole, spearfishing), its effects over the reef fish community are still unknown.

Cryptic-small-sized labrisomids and blenniids, display camouflage behavior and strong association with the benthic community. Consequently, the abundances of these cryptic species tend to be underestimated in visual censuses (*i.e.*, up to 90% according to Willis, 2001; Depczynski & Bellwood, 2004). Despite this inherent problem, *L. nuchipinnis* and *P. pilicornis* ranked amongst the ten most abundant species with frequencies of occurrence superior to 20% which could be related to the previous divers' experience from training surveys.

In general, our results reflected the high selectivity of the visual censuses, showing a higher efficiency toward species with curious and gregarious behavior, and closely associated to hard substrates (see Jennings & Polunin, 1995; Kulbicki, 1998; Colvocoresses & Acosta, 2007; Kulbicki *et al.*, 2010).

Even though the Vermelha Beach is under influences of both inner-estuarine and outer-oceanic waters, our results provided a high fish richness with dominances of marine species, mostly reef associated. However, our results also show the effects of this transitional estuarine-marine environment on fish, since other studies support the trend in the increase of species richness for fish assemblages associated with islands along the land-ocean gradient for the coastal islands adjacent to Guanabara Bay entrance. This hypothesis can be confirmed analyzing Mendonça-Neto *et al.* (2008), in which 42 species were recorded at three islands north the entrance of Guanabara Bay, and Rangel *et al.* (2007) who provided a list of 99 fish species for the Cagarras Archipelago, complemented by Bertoncini *et al.* (2013) and Monteiro-Neto *et al.* (2013), that reported 193 and 197 species respectively, for the whole Cagarras Archipelago.

Our findings highlight the importance of future studies in this transitional area (bay-ocean), which shelters important rocky reef fish species. Future efforts shall investigate the relationships of periodic influences of estuarine and oceanic waters and other variables such as tides, benthic macrofauna and rugosity, as structuring factors of the fish assemblages associated with rocky reefs at Vermelha Beach.

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