Reef Fisheries and Underwater Surveys Indicate Overfishing of a Brazilian Coastal Island

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Abstract

The preoccupation about fishing effects on marine ecosystems has increased sharply over the last three decades. However, little is known about the impact of multi-gear artisanal and recreational fisheries on the structure of local reef fish communities in Brazil. Fishing activities around a Brazilian coastal island were monitored while reef fish density was censused during underwater surveys (UVC). The links between frequency of capture, intensity at which species are wished and UVC density were explored. Species were classified according to their frequency of capture as regular, occasional and rare, and classified according to the intensity at which they are wished (based on size and price), as highly targeted, average and non-targeted species. Ninety-seven species were caught by fishing, the majority of them being either rarely caught or non-targeted. Nineteen species were highly targeted but rarely caught. The highly targeted species showed extremely low density in the UVC. These results put in question the sustainability of the local fishing activities. The predominance of non-targeted species in the catches and in the reefs environment studied supports the expectation that these species will be more and more captured, thus collaborating to further change the structure of the reef community.

Key words: Rocky Reefs, Fishery, Catch, Discards, Tourism, Sustainable Use.

Introduction

The effects of human activities on reef and island environments are a wide-world preoccupation (Roberts *et al.* 2002). Fishing has been recognized as the principal activity able to alter the structure of fish communities (Jennings & Blanchard 2004) because it is widespread, typically multi-specific and practiced with a variety of methods (Roberts 1995). Recent analysis suggest that the majority of fish stocks are decreasing (Myers & Worm 2003), principally those of predators (Dulvy *et al.* 2004). This removal often induces a cascade effect of extinctions, thus reducing the stability of the environment and turning it more vulnerable to natural and anthropic disturbances (Friedlander & DeMartini 2002).

Although the information about Brazilian reef fish communities is rising in the last years, the conservation status of reef fish communities in Brazil remains largely unknown. Even with the proven effectiveness of some Brazilian MPAs (Floeter *et al.* 2006, Francini-Filho & Moura 2008), the number of commercially-relevant reef species

overexploited is still growing (*e.g.*, Klippel *et al.* 2005, Araujo & Martins 2009). In the other hand, the official Brazilian red list shows only 19 marine species threatened of extinction. This low number of included species probably reflects an important lack of studies (Rosa & Lima 2008).

In this context, artisanal and recreational fisheries were monitored at Franceses Island (central coast of Brazil) between 2005 and 2006. In parallel, underwater visual census were realized in the same area to determine the community structure and establish the conservation status of the studied reefs. The relationships among frequency of capture, intensity at which species are wished and UVC density are explored and sustainability of resources and alternatives for coastal reefs management are discussed.

Materials and Methods

Study site

The study was carried out in the state of Espírito Santo, central coast of Brazil (Figure 1). The state is located in a transition area between tropical and sub-tropical zones, influenced by the warm southward-flowing oligotrophic Brazilian current and strong seasonal upwellings in the south of the state (Schmid *et al.* 1995). Franceses Island

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Figure 1. Location of the study area, Franceses Island, Espírito Santo, Brazil.

and associated rocky reefs (20° 55' S and 40° 45' W) are granitic formations 4 km off the coast. The region, overall, shelters a rich reef fish fauna (Floeter & Gasparini 2000) and the presence of 181 fish species has been recorded at the site (Pinheiro *et al.* unpublished data). Like the majority of coastal environments in Brazil, the local is not under any special management rules. Activities practiced are diverse and include professional-scale artisanal fishing (using gill nets, seine nets and trolling) and invertebrate exploitation (sea stars, mussels and gorgonians) along recreational activities such as hook-and-line fishing, spear-fishing and mussel extraction.

Fishing activities monitoring

Ten expeditions to Franceses Island were done (March, April, June, August, September, October and December 2005, January and 2 in February 2006) totaling 51 field days. Observations were realized in the Island, during both day and night, each time that professional or recreational extractive activities were sighted. Target, by-catch and discard species were censused through direct observation and by questions (about number and species caught; wished species to capture and discard species). Whenever possible (e.g., small specimens, discard species), vouchers were preserved to confirm field identification. The main characteristics of the anthropic activities (extractive or not) monitored at Franceses Island during the ten expeditions are shown in Table 1.

Fish census

During the five expeditions between October and February we carried out 208 underwater visual censuses (UVC) to determine the numerical density of fish species in the area directly used by fishers. The fishes were identified and enumerated in replicate belt transects of 20 × 2 m (40 m²), and the density calculated is therefore the number of fish per 40 m². This small-width transect method is much used by Brazilian researchers due to the low water transparency of coastal waters (about 5 m in summer) (see Floeter *et al.* 2006, 2007).

Data analysis

Species were classified according to their frequency of capture as regular (species registered in more than 50% of the expeditions), occasional (30-40% of the expeditions), and rare (up to 20% of the expeditions). The species were also classified according to the intensity at which they are wished, based on size and price. The categories established were highly targeted (larger species [TL > 40 cm] or species with commercial value above R\$ 4.00 kg⁻¹ [selling price in 2006; about US\$ 2.00 kg⁻¹]), average (medium size [10 cm < TL < 40 cm] or low commercial values [below R\$ 4.00]) and non-targeted species (small-sized fishes [TL < 10 cm] and species without commercial value).

Table 1. Human activities realized at Franceses Island, Brazil, between March 2005 and February 2006. The frequency of occurrence (percentage of expeditions in which the activity was recorded), the number of operations monitored for the present study, the type of interaction the activity has with the local ichthyofauna, the number of fish species directly involved (*i.e.*, caught) and a summary of the characteristics of these activities are given.

Activities	Occurrence (%)	Number	Interaction	Species	Characteristics
Spear-fishing	80	8	direct	54	Practiced by visitors transported to the island by local boats for leisure, subsistence or small commerce. It is carried out in all the island surroundings but beginners are mainly found in the shallow sheltered zone and more advanced fishermen in the deeper exposed zone.
Hook-and-line	70	13	direct	44	Practiced by tourists and visitors, rarely by professional fishers. It is done from all rocky shores that surround the island, mainly during the day but also at night by campers. The bait is shrimp and small fish purchased on the continent or fishes and small crabs caught at the island.
Tourism on island	70	-	indirect	-	Done by all the stakeholders of the island. Occurs throughout the year, mainly on weekends but on a daily basis during the summer. It is most practiced by tourists that spend the day in the island. Normally, the same boat carries the tourists both on the island and on a boat tour. On the island, the visitants look for leisure (barbecues, picnic, sun-bathing and sea swimming) and sports (fishing, swimming and walking).
Gill netting	60	3	direct	2	Practiced a few meters off the island shoreline. It is often an alternative extra-income for some fishermen that set their nets when they go out to sea to practice other fishing activities and pick up the net at their return.
Seining	50	6	direct	57	Practiced in the sheltered zone, daily during the summer and sporadically during the rest of the year. A large number of fishermen (at least 6) are needed. Few, however, are professionals. The nets reach over 800m of length. Two boats are used, a smaller one (moved by paddle) to surround the school and a larger motorized boat to transport the crew and the catch. If the lance fails, another haul is carried out at the same locale.
Boat tour	50	-	indirect	-	Practiced by local fishers that carry groups of tourists (up to 20 persons) for a tour around the island.
Invertebrate extraction	50	9	indirect	-	The fishermen and the local community use boats, compressors (for diving) and scrapers to collect sea stars, mussels and gorgonians. Other visitants, such as tourists, also collect mussels and sea stars but in lesser quantities.
Trolling	40	2	direct	8	Trolling is carried out around the entire island, especially in the exposed zone. It is practiced by local fishermen and a few tourists in their own motorized boats. It occurs during the whole year, but is most commonly practiced during summer afternoons.
Trap setting	10	0	direct	-	It is practiced by a few motorized boats that set fishing traps in exposed reefs. It targets small fish that are commercialized as bait and ornamentals. Lobster and octopus are also caught.

Differences among cells of contingency tables were evaluated through chi-square (X^2) tests against the null hypothesis (no difference among cells) while differences in fish density in UVC among categories for intensity of targeting and frequency of capture were tested by Kruskal-Wallis (KW) (Zar 1999) due to the lack of normality of the data.

Results

Species caught by fishing

Ninety-seven fish species were caught by fishing activities (Table 2), which represents 53.6% of the 181 species previously registered at the site. Captured species were classified heterogeneously among targeting categories (X^2 ; $p = 0.044$) with 43% not been targeted by any activity and 34% being highly target (Figure 2; Table 2). Also, the frequency of capture varied importantly among species (X^2 ; $p < 0.001$) and, while the majority of species (57%) were rarely caught, a few (13%) were regularly captured (Figure 2; Table 2). Among species that are especially interesting due to price or size, those rarely caught were much more numerous (19) than those regularly caught (5; Table 2). Many species were neither targeted nor frequently captured (26; Table 2) and only three untargeted species were regularly caught. Thirty-two species, corresponding to 17.7% of the whole community (*i.e.*, 181) or to 34% of the species captured (*i.e.*, 97), were present in discards from fishing activities. Most of this (91%) were classified as not targeted species (Table 2).

Captured species density

Underwater visual censuses registered 90 fish species, among which 51 (57%) were caught by fishing activities done at the site (these are listed in bold in Table 2). Fished species that went unrecorded during UVC (Table 2) were rare species or species that show escape behavior near divers. The highest numeric density was shown by untargeted species (KW; $p < 0.001$) and occasionally caught species (KW; $p < 0.001$) while highly targeted and regularly caught

species had the lowest recorded numeric density (Figure 3). Twenty-nine highly targeted species were rarely caught (Table 2) and were not seen during UVC (Table 3). Most of the abundant species in the community are not targeted by any fishing activities and were only occasionally or rarely caught (Table 3).

Discussion

Preservation status

Coastal islands and their reefs, due to the partial protection offered by distance from shore, show natural environments that are slightly more preserved than those found along the coastline (Floeter *et al.* 2006). These places attract recreational hook-and-line and spear fishers that come looking for fishes that have been extirpated elsewhere. However, our study shows that the reef fish community of the coastal island and reefs studied is already overexploited, with a low density of highly targeted species and a high predominance of non-target species both in natural environments and in the fishery caught. Fishermen related that many target species were more abundant in the past (Pinheiro HT & Martins AS, unpublished data). However, the majority of highly targeted species are rare nowadays, hardly being found and caught in the area.

Many species registered in the fisheries catches were not recorded during SCUBA census, being rare in the study area. Many studies have shown that pristine and protected sites have higher relative abundance of target and predators species in UVCs than in overexploited sites (Friedlander & DeMartini 2002, Floeter *et al.* 2006, Francini-Filho & Moura 2008). Others, however, contest the efficacy of UVC methods to register commercial species in exploited areas due to the behavioral features adopted by target species (Kulbicki 1998). In this context, species that are highly targeted, regularly caught and not observed under water may be underestimated by visual census. On the other hand, species that are highly targeted, rarely caught and have low density, as estimated by UVC, can already be considered

Figure 2. Number of species in function of the intensity at which they are wished (left; as determined from interviews) and their frequency of capture (right; as censused in monitored fishing operations) at Franceses Island, central coast of Brazil.

Table 2. Reef fish species caught by the various fishing activities monitored at Franceses Island, Brazil, including the intensity at which they are wished and the frequency at which they are captured. Families are ordered alphabetically within each cross-category of decreasing intensity and decreasing frequency (*i.e.*, the same family may appear in several places in the table). Species also recorded in UVC are in bold. Abbreviations for intensity are H: highly targeted; A: average; N: non-targeted. Abbreviations for frequency are Re: regularly; Oc: occasionally; Ra: rarely. Fishing activities are listed in decreasing order of frequency of capture and the frequency at which the species appears in discards is indicated.

Family	Species	Intensity	Capture	Fishing activity / discards
Clupeidae	<i>Opisthonema oglinum</i>	H	Re	seine
Carangidae	<i>Caranx crysos</i>	H	Re	seine, spear, hook, trolling, gill net
	<i>Caranx latus</i>	H	Re	seine, discard, spear, hook, trolling, gill net
Haemulidae	<i>Anisotremus surinamensis</i>	H	Re	spear, hook
Scombridae	<i>Scomberomorus brasiliensis</i>	H	Re	seine, spear, trolling, gill net
Pomatomidae	<i>Pomatomus saltator</i>	H	Oc	spear, seine, trolling
Carangidae	<i>Carangoides bartholomaei</i>	H	Oc	seine, spear, hook, trolling
	<i>Trachinotus goodei</i>	H	Oc	spear, trolling, hook
Lutjanidae	<i>Lutjanus jocu</i>	H	Oc	spear, hook
	<i>Lutjanus synagris</i>	H	Oc	seine, hook
	<i>Ocyurus chrysurus</i>	H	Oc	seine
Sparidae	<i>Diplodus argenteus</i>	H	Oc	spear, seine, hook
Ephippididae	<i>Chaetodipterus faber</i>	H	Oc	spear, seine
Trichiuridae	<i>Trichiurus lepturus</i>	H	Oc	seine
Ginglymostomatidae	<i>Ginglymostoma cirratum</i>	H	Ra	spear
Rhinobatidae	<i>Rhinobatos horkelii</i>	H	Ra	spear, hook, seine
	<i>Rhinobatos percellens</i>	H	Ra	spear, hook, seine
Centropomidae	<i>Centropomus undecimalis</i>	H	Ra	spear, gill net
Serranidae	<i>Epinephelus itajara</i>	H	Ra	Spear
	<i>Mycteroperca marginata</i>	H	Ra	spear, hook
	<i>Mycteroperca acutirostris</i>	H	Ra	Spear
	<i>Mycteroperca bonaci</i>	H	Ra	spear, seine
Carangidae	<i>Caranx hippos</i>	H	Ra	seine, spear, trolling, gill net
	<i>Trachinotus carolinus</i>	H	Ra	spear
	<i>Trachinotus marginatus</i>	H	Ra	spear, hook
Lutjanidae	<i>Lutjanus analis</i>	H	Ra	seine, hook
	<i>Lutjanus cyanopterus</i>	H	Ra	spear
Sparidae	<i>Archosargus probatocephalus</i>	H	Ra	spear
Sciaenidae	<i>Micropogonias furnieri</i>	H	Ra	gill net, seine
Scaridae	<i>Scarus trispinosus</i>	H	Ra	spear
Scombridae	<i>Euthynnus alletteratus</i>	H	Ra	seine, spear, trolling, gill net
	<i>Scomberomorus cavalla</i>	H	Ra	seine, spear, trolling, gill net
Tetraodontidae	<i>Lagocephalus laevigatus</i>	H	Ra	seine, hook
Holocentridae	<i>Holocentrus adscensionis</i>	A	Re	hook, spear
Carangidae	<i>Oligoplites saliens</i>	A	Re	seine, spear, gill net
Haemulidae	<i>Anisotremus virginicus</i>	A	Re	spear, hook, seine, discard
Kyphosidae	<i>Kyphosus sectator</i>	A	Re	spear, hook, seine
Scaridae	<i>Sparisoma axillare</i>	A	Re	spear, seine, hook
Clupeidae	<i>Sardinella brasiliensis</i>	A	Oc	seine
Haemulidae	<i>Anisotremus moricandi</i>	A	Oc	hook
	<i>Haemulon plumieri</i>	A	Oc	spear, hook, seine
	<i>Haemulon parra</i>	A	Oc	hook, spear, seine
	<i>Orthopristis ruber</i>	A	Oc	hook, seine, discard

The species registered in UVC not captured by the fisheries are: *Acanthostracyon polygonius*, *A. quadricornis*, *Canthigaster figueiredoi*, *Cantherhines pullus*, *Chaetodon sedentarius*, *C. striatus*, *Coryphopterus* spp., *Chromis multilineata*, *Cryptotomus roseus*, *Ctenogobius saepepallens*, *Diodon hystrix*, *Diplectrum radiale*, *Doratonotus megalepis*, *Elacatinus figaro*, *Gramma brasiliensis*, *Halichoeres penrosei*, *Hippocampus reidi*, *Holacanthus ciliaris*, *H. tricolor*, *Labrisomus cricota*, *Malacoctenus delalandii*, *Malacoctenus* aff. *triangulatus*, *Myripristis jacobus*, *Odontoscion dentex*, *Pareques acuminatus*, *Parablennius marmoreus*, *P. pilicornis*, *Pempheris schomburgkii*, *Pseudocaranx dentex*, *Scorpaena brasiliensis*, *S. plumieri*, *Serranus baldwini*, *S. flaviventris*, *Sparisoma amplum*, *S. tuiupiranga*, *S. radians*, *Stegastes fuscus*, *S. variabilis*, *Synodus intermedius*, *S. synodus*.

Table 2. Continued ...

Family	Species	Intensity	Capture	Fishing activity / discards
Mugilidae	<i>Mugil incilis</i>	A	Oc	seine, spear
	<i>Mugil liza</i>	A	Oc	seine, spear
Sphyraenidae	<i>Sphyraena tome</i>	A	Oc	seine, hook
Rhinobatidae	<i>Zapteryx brevirostris</i>	A	Ra	spear, hook, seine
Dasyatidae	<i>Dasyatis guttata</i>	A	Ra	spear, hook
Myliobatidae	<i>Aetobatus narinari</i>	A	Ra	seine
Carangidae	<i>Carangoides ruber</i>	A	Ra	seine
Gerreidae	<i>Eugerres brasiliensis</i>	A	Ra	spear
Sparidae	<i>Archosargus rhomboidalis</i>	A	Ra	seine
	<i>Calamus penna</i>	A	Ra	seine, spear, hook
Scaridae	<i>Sparisoma frondosum</i>	A	Ra	spear
Balistidae	<i>Balistes capriscus</i>	A	Ra	hook,
	<i>Balistes vetula</i>	A	Ra	hook, spear
Clupeidae	<i>Harengula clupeola</i>	N	Re	seine, discard
Carangidae	<i>Chloroscombrus chrysurus</i>	N	Re	seine, hook, discard
Labrisomidae	<i>Labrisomus nuchipinnis</i>	N	Re	hook, discard
Elopidae	<i>Elops saurus</i>	N	Oc	seine, spear, discard
Muraenidae	<i>Gymnothorax moringa</i>	N	Oc	hook, spear, discard
Engraulidae	<i>Anchoviella lepidentostole</i>	N	Oc	seine, discard
	<i>Anchoa spinifer</i>	N	Oc	seine, discard
Belonidae	<i>Tylosurus acus</i>	N	Oc	Seine
Dactylopteridae	<i>Dactylopterus volitans</i>	N	Oc	seine, hook, discard
Haemulidae	<i>Haemulon aurolineatum</i>	N	Oc	seine, discard
	<i>Haemulon steindachneri</i>	N	Oc	seine, hook, discard
Mullidae	<i>Pseudopeneus maculatus</i>	N	Oc	seine, discard
Pomacentridae	<i>Abudefduf saxatilis</i>	N	Oc	Hook
Labridae	<i>Halichoeres brasiliensis</i>	N	Oc	hook, spear, discard
	<i>Halichoeres poeyi</i>	N	Oc	hook, discard
Diodontidae	<i>Chilomycterus spinosus</i>	N	Oc	seine, discard
Narcinidae	<i>Narcine brasiliensis</i>	N	Ra	Spear
Muraenidae	<i>Gymnothorax funebris</i>	N	Ra	hook, spear, discard
	<i>Gymnothorax ocellatus</i>	N	Ra	hook, discard
	<i>Gymnothorax vicinus</i>	N	Ra	hook, discard
Ophichthidae	<i>Ophichthus ophis</i>	N	Ra	Spear
Engraulidae	<i>Anchoa filifera</i>	N	Ra	seine, discard
	<i>Cetengraulis edentulus</i>	N	Ra	seine, discard
Hemiramphidae	<i>Hemiramphus brasiliensis</i>	N	Ra	seine, discard
Aulostomidae	<i>Aulostomus strigosus</i>	N	Ra	Spear
Serranidae	<i>Diplectrum formosum</i>	N	Ra	hook, discard
	<i>Rypticus saponaceus</i>	N	Ra	Spear
Echeneidae	<i>Echeneis naucrates</i>	N	Ra	seine, discard
Carangidae	<i>Decapterus punctatus</i>	N	Ra	seine, discard
	<i>Selene browni</i>	N	Ra	Seine
	<i>Selene vomer</i>	N	Ra	Seine
Gerreidae	<i>Eucinostomus spp.</i>	N	Ra	seine, discard
Pomacanthidae	<i>Pomacanthus paru</i>	N	Ra	Spear
Labridae	<i>Bodianus rufus</i>	N	Ra	spear, hook
Labrisomidae	<i>Labrisomus kalisherae</i>	N	Ra	hook, discard

The species registered in UVC not captured by the fisheries are: *Acanthostracyon polygonius*, *A. quadricornis*, *Canthigaster figueiredoi*, *Cantherhines pullus*, *Chaetodon sedentarius*, *C. striatus*, *Coryphopterus spp.*, *Chromis multilineata*, *Cryptotomus roseus*, *Ctenogobius saepepallens*, *Diodon hystrix*, *Diplectrum radiale*, *Doratonotus megalepis*, *Elacatinus figaro*, *Gramma brasiliensis*, *Halichoeres penrosei*, *Hippocampus reidi*, *Holacanthus ciliaris*, *H. tricolor*, *Labrisomus cricota*, *Malacotenus delalandii*, *Malacotenus aff. triangulatus*, *Myripristis jacobus*, *Odontoscion dentex*, *Pareques acuminatus*, *Parablennius marmoreus*, *P. pilicornis*, *Pempheris schomburgkii*, *Pseudocaranx dentex*, *Scorpaena brasiliensis*, *S. plumieri*, *Serranus baldwini*, *S. flaviventris*, *Sparisoma amplum*, *S. tuiupiranga*, *S. radians*, *Stegastes fuscus*, *S. variabilis*, *Synodus intermedius*, *S. synodus*.

Table 2. Continued ...

Family	Species	Intensity	Capture	Fishing activity / discards
Acanthuridae	<i>Acanthurus chirurgus</i>	N	Ra	spear, seine, discard
	<i>Acanthurus bahianus</i>	N	Ra	spear, seine, discard
	<i>Acanthurus coeruleus</i>	N	Ra	Spear
Bothidae	<i>Bothus ocellatus</i>	N	Ra	seine, discard
Monacanthidae	<i>Stephanolepis hispidus</i>	N	Ra	Seine
Tetraodontidae	<i>Sphoeroides testudineus</i>	N	Ra	hook, discard
	<i>Sphoeroides spengleri</i>	N	Ra	hook, discard

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Figure 3. Mean fish density (Number 40 m⁻² ± 1 standard error) in UVC in function of the intensity at which they are targeted (left) and their frequency of capture (right) at Franceses Island, central coast of Brazil.

Table 3. Mean density (Number 40 m⁻² ± 1 standard error) in UVC by cross-category for intensity at which fish are wished and their frequency of capture at Franceses Island.

Intensity	Frequency of capture		
	Regularly	Occasionally	Rarely
Highly targeted	1.4 ± 0.3	0.8 ± 0.2	0
Average	9.9 ± 0.9	7.9 ± 1.8	0
Not targeted	1.1 ± 0.1*	19.1 ± 1.9	18.1 ± 1.7

*Shows the density of *L. nuchipinnis* since the other 2 species (*H. clupeiola* and *C. chrysurus*) aggregate in schools and were, therefore, excluded from the analysis.

threatened in the reefs we studied and nearby shores. The low density or absence of targeted species in the majority of coastal areas, and the high number (and quantity; not shown) of discard species are, most probably, consequences of inappropriate and excessive capture by artisanal and recreational activities.

Elasmobranchii, serranids, lutjanids and scarids are particularly susceptible to overexploitation due to their remarkable life history and characteristics, such as slow growth, late maturity, high site fidelity, complex social

structure, sex reversal, group spawning at predictable sites, etc. (Coleman *et al.* 2000, Hawkins & Roberts 2003). Many works show that these groups are among the first to disappear under overexploitation (Roberts 1995, Oliveira *et al.* 1997, Coleman *et al.* 2000). The capture of juvenile specimens by fisheries and the apparent absence of reproductive adults of groupers, snappers and parrotfishes, as is locally observed at the studied site and other coastal areas (Pinheiro, HT personal observation), can reduce the reproductive potential of their population (Friedlander & DeMartini 2002), promoting the total local extirpation of the species.

Albeit tropical Brazilian islands and reefs have low diversity compared to many other tropical regions of the world (Rangel *et al.* 2007, Souza *et al.* 2007), a high number of fish species was caught at Franceses Island. However, the rareness of species that are regularly captured and are highly targeted puts in question the sustainability of fishing activities. The predominance of species non-targeted in the catches and *in situ* suggest that, due to the constant increase of anthropic pressure onto explored resources, these species will be more and more heavily captured, thus collaborating to further alter the structure of the reef community.

Perspectives of sustainability

The coastal islands and reefs attract many non-professional fishermen. On the other hand, these areas are not able to economically sustain some professional fishing activities, mainly the most selective ones, due to the low abundance of remaining commercially-sized and -priced fish. Professional fishermen have been compelled to look for other fishing grounds more distant and deeper to sustain their catch rates (Martins *et al.* 2005), or to get extra alternatives to their income (Pinheiro *et al.* 2009).

However, artisanal fishermen continue to fish in coastal zones, frequently using low-selectivity artisanal gears that are able to catch a great amount of non-target species (Erzini *et al.* 2002), thus contributing to alter the structure of local fish community. Those fishermen that do not sustain their catches are exploring tourism directed to the islands and reefs, earning direct and indirect additional income (Pinheiro *et al.* 2009). Much of this tourism is also directly related to recreational fishing because of the fact, both cause and consequence, that visitors transport to the islands and reefs is exclusively provided by local fishermen. Due to the importance of fishing and tourism for coastal communities, educational programs that foment the transformation of uncontrolled and predatory activities into sustainable practices are an alternative way of valorization of the environment and sustainability of the exploited resources.

The creation of a protected area with a mosaic of usages would also collaborate to an adequate management of the area and reduce possible conflicts of social, economic and cultural orders (Pinheiro *et al.* 2009). However, the benefits for the fishing activities and tourism (see in Hall 2001, Friedlander *et al.* 2003) would be secondary close to the rehabilitation of insular and reef environments. The rocky shores and reefs, which cover small areas and are relatively shallow, would be least-difficult environments to protect and manage (compare to large and deep areas such as trawling grounds for example) and easiest to check for resulting effects of managements practices. Finally, rare species deserve a special attention about their individual size and level of capture. Brazilian laws need to incorporate maximum length to the catch of some reef fishes, once the bigger individuals are disproportionately more fecund than the smaller ones and therefore management strategies should be directed to protect the bigger and not only the smaller specimens against fishing (Palumbi 2004). However, regulation applied to fisheries, such as length limits, limited catches or area closure, has to be applied with caution because, if it offers positives prospects for species recuperation (Beets & Friedlander 1998, Coleman *et al.* 1999), it also often conflicts with resource users (Kirchner *et al.* 2001).

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