Reef fishes captured by recreational spearfishing on reefs of Bahia State, northeast Brazil

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Abstract: Although recreational spearfishing is a growing activity, its impacts are poorly understood. This paper aims to present data on reef fishes captured by recreational spearfishing in the Bahia State, Northeastern Brazil. We analyzed 168 photos of spearfishing conducted in the reefs of this region between 2006 and 2008. A total of 1.121 fish belonging to 48 species were captured in three sub-regions of the Bahia coastline: Litoral Norte (LN), Salvador (SSA) and Baixo Sul (BS). The main species caught were: *Scomberomorus brasiliensis* (n = 191), *Sphyraena barracuda* (n = 153), *Lutjanus jocu* (n = 150) and *Caranx bartholomaei* (n = 141); these four species represented 56.5% of total captures. Over the sampling period, the highest values of catch rates per day were observed at BS, followed by SSA and LN. There were significant between-sites differences in the number of fish in the number of species caught. However, there were no significant between-years differences in the number of fish and numbers of species caught. The trophic classification of fish showed that carnivores (n = 623) were more frequently captured, followed by piscivores (n = 371), herbivores (n = 101) and invertivores (n = 26). The results showed that high sized, top predatory fishes, were the main targets, although other trophic levels were also captured.
Keywords: *overfishing, coral reefs, Salvador, Litoral Norte, Baixo Sul.*

COSTA NUNES, J.A.C., MEDEIROS, D.V., REIS-FILHO, J.A., SAMPAIO, C.L.S., & BARROS, F. **Peixes recifais capturados pela pesca submarina recreativa nos recifes do Estado da Bahia, nordeste do Brasil**. Biota Neotrop. 12(1): http://www.biotaneotropica.org.br/v12n1/pt/abstract?article+bn02012012012

Resumo: Apesar da caça submarina recreativa ser uma atividade crescente, seus impactos ainda são mal compreendidos. Este trabalho tem como objetivo apresentar dados sobre peixes recifais capturados pela pesca submarina recreativa no Estado da Bahia, região Nordeste do litoral brasileiro. Foram analisados 168 fotos de caça submarina realizada entre 2006 e 2008. Foram registrados 1.121 peixes pertencentes a 48 espécies em três sub-regiões do litoral baiano: Litoral Norte (LN), Salvador (SSA) e Baixo Sul (BS). As principais espécies capturadas foram: *Scomberomorus brasiliensis* (n = 191), *Sphyraena barracuda* (n = 153), *Lutjanus jocu* (n = 150) e *Caranx bartholomaei* (n = 141); estas quatro espécies representaram 56,5% do total de peixes capturados. Ao longo dos anos amostrados, foram registradas taxas mais elevadas de captura por dia em BS, seguido pelo SSA e LN. Foram encontradas diferenças significativas entre os locais estudados para a quantidade de peixes e o número de espécies capturadas. Entretanto, não foram encontradas diferenças significativas entre os anos para a quantidade de peixes e número de espécies capturadas. A classificação trófica de peixes mostrou que os carnívoros (n = 623) foram mais frequentemente capturados, seguidos de piscívoros (n = 371), herbívoros (n = 101) e invertívoros (n = 26). Os dados apresentados demonstram que grandes peixes predadores de topo são o alvo principal, no entanto outros níveis tróficos também são capturados.
Palavras-chave: *sobrepesca, recifes de coral, Salvador, Litoral Norte, Baixo Sul.*

Introduction

Fishing activities are regarded as one of the major sources of anthropogenic disturbance in the marine realm and consequently several stocks of fishes were reported as overexploited worldwide due to overfishing (Food... 2009). Collapse of important fish stocks and extreme habitat degradation have been widely described as examples of the impacts caused by fishing (Hawkins & Roberts 2004). The removal of organisms by fishing can trigger a variety of direct and indirect impacts on the structure of marine communities and are often responsible for the reduction or loss of functionality in coral reefs (Dayton et al. 1995, Jennings & Kaiser 1998, Pauly et al. 2002). For example, the removal of only 5% of fish biomass may significantly alter the community structure of reef fish, especially where predator fish species are the main target (Jennings & Polunin 1996). Fishing intensity might influence community composition and lead to local or global extinctions of particularly vulnerable species (Russ & Acala 1989, Roberts & Hawkins1999).

Spearfishing is a very old human activity. Even before written history, indigenous people in various parts of the world were probably already fishing with spears underwater. Nowadays, spearfishing generally involves the use of a rubber propelled or airgun spear, as well as associated diving gear such as mask, snorkel and fins (Frisch et al. 2008). In South Africa the recreative spearfishing has grown at an annual rate of 6.14% (Mann et al. 1997). Spear fishing is an activity that frequently overlaps with fishing areas of the commercial and artisanal fleets (Coll et al. 2004). Since 1975 there is a monitoring of catches of spear fishing in the Balearic Islands and it was observed that before 1987 capture of fish more than 4 kg diminished drastically, indicating overfishing (Coll et al. 2004). The improvement of equipment and especially the increasing number of spearfishers are responsible for the decline of several species in the Mediterranean (Norton 2001, Coll et al. 2004), as well as in other parts of the world (e.g. Aiken & Haughton 1987). Nevertheless, for most countries there is no information on spearfishing activities and its potential impacts.

In Brazil, the first records of recreational spearfishing date to the late 40's, when Brazilian war pilots brought equipments that, at that time, did not exist in Brazil. The Brazilian Association of Spearfishing (Associação Brasileira de Caça Submarina-ABCS), founded in 1951 in Rio de Janeiro, held several championships and afterwards the sport started to spread in the country. In the early 60's, Americo Santarelli created a company of diving equipment, and since then spear equipments became more accessible to divers, thus popularizing the sport (Santarelli 1983, Colassanti 2009). Nowadays, spearfishing is practiced throughout the entire Brazilian coast, and there is critical lack of landings records.

This paper aims to quantitatively describe catches (i.e. fish abundance, composition and temporal patterns) from recreational spearfishing in three different regions within the Bahia State through the analyses of photographs of fish landings conducted between 2006 and 2008. The approach of using photographs is considered useful for evaluating quantitative changes in average sizes and composition of fish species caught by sport fishing (McClenachan 2009), and may be the only way the recover baseline information from 60'onwards.

Metodology

We analyzed a series of photographs (n = 168) from a spearfishing club from the Bahia State, Brazil. Each photograph was taken in a different fishing day from 2006 to 2008. We only include in the analyses photos for which information on the specific region and year of capture were available. Three main fishing areas were established: Litoral Norte (LN) - between the northern portion of Salvador city to the border of the Sergipe State; Salvador (SSA) - coastal region of Salvador city and Baía de Todos os Santos; and Baixo Sul (BS) - located between Tinharé Island and Baía de Camamu (Figure 1). We identified and counted the number of fish in each photo. Species identification was performed with literature data (Carvalho-Filho 1999, Humann & Deloach 2002, Hostim et al. 2006, and Sampaio & Nottingham 2008). Fish trophic categories were assigned following the classification of Ferreira et al. (2004), Floeter et al. (2004).

Data Analysis

Each photograph corresponded to one fishery, and was considered as an independent sample. Spatial and temporal variations in total capture and richness (total number of species) were evaluated with nonparametric analysis of variance (Kruskall-Wallis test). Whenever differences were detected in the parameters, the Dunn's test was applied to the data in order to quantify and establish those differences.

Results

In the three years encompassed by this study it was recorded 1.121 captured fish belonging to 48 species (Table 1). The main species caught were: *Scomberomorus brasiliensis* (n = 191 fish), *Sphyraena barracuda* (n = 153), *Lutjanus jocu* (n = 150) and

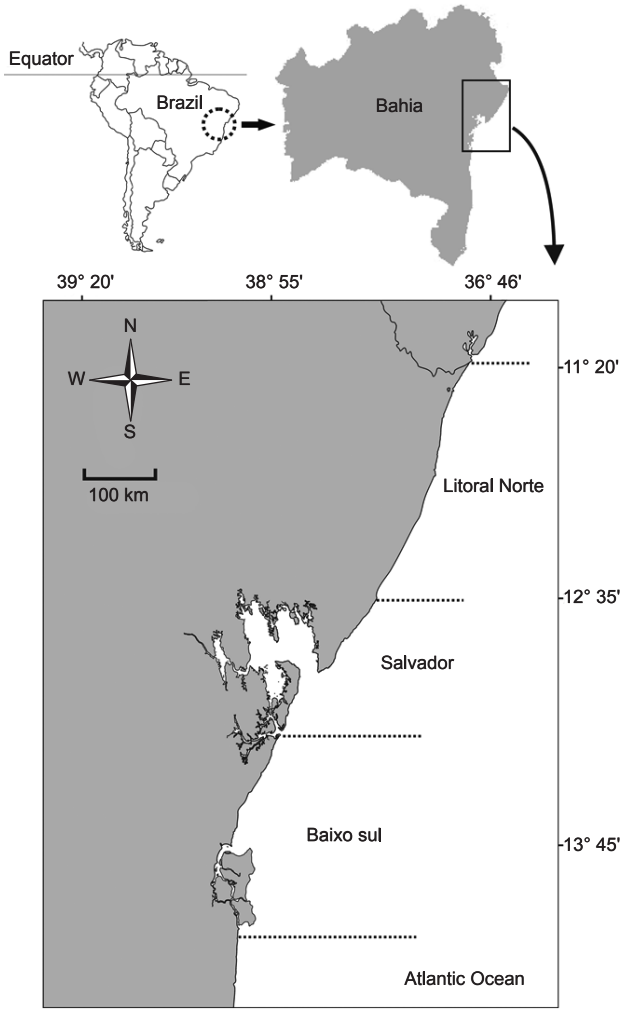

Figure 1. Map showing the fishing regions.

Figura 1. Mapa mostrando as regiões de pesca.

Table 1 Species captured by spearfishers, trophic guild (CAR: carnivores, PIS: piscivores, MOB INV: mobile invertivores, HERB: herbivores and SES INV: sessile Invertivores), total number of individuals (N Total) and % of the total number of individuals at each sites (LN: Litoral Norte, SSA: Salvador and BS: Baixo Sul).
Tabela 1. Espécies capturadas pelos caçadores submarinos, guildas tróficas (CAR: carnivoros, PIS: piscivoros, MOB INV: invertívoros móveis, HERB: herbívoros and SES INV: invertívoros sésseis), número total de indivíduos (N Total) e % do número de indivíduos em cada região (LN: Litoral Norte, SSA: Salvador e BS: Baixo Sul).

Family	Species	Trophic Guild	N Total	LN	SSA	BS
DASYATIDAE	*Dasyatis americana* Hildebrand and Schroeder, 1928	CAR	8	25	75	-
	Dasyatis sp.	CAR	1	-	-	100
MYLIOBATIDAE	*Aetobatus narinari* (Euphrasen, 1790)	CAR	1	-	100	-
MEGALOPIDAE	*Megalops atlanticus* (Valenciennes, 1846)	PIS	2	50	50	-
MURAENIDAE	*Gymnothorax funebris* Ranzani, 1840	CAR	1	-	100	-
CENTROPOMIDAE	*Centropomus undecimalis* (Bloch, 1792)	CAR	54	7.4	92.6	-
EPINEPHELIDAE	*Epinephelus adscensionis* (Osbeck, 1765)	CAR	15	73.3	20	6.6
	Mycteroperca bonaci (Poey, 1861)	CAR	77	16.8	71.4	11.6
PRIACANTHIDAE	*Priacanthus arenatus* Cuvier, 1829	MOB INV	3	100	-	-
CORYPHAENIDAE	*Coryphaena hippurus* Linnaeus, 1758	CAR	2	100	-	-
RACHYCENTRIDAE	*Rachycentrun canadum* (Linnaeus, 1766)	CAR	6	16.6	83.3	-
CARANGIDAE	*Alectis ciliaris* (Bloch, 1787)	CAR	8	25	50	25
	Elegatis bipinnulatus (Quoy & Gaimard, 1824)	CAR	11	100	-	-
	Caranx bartholomaei (Cuvier, 1833)	PIS	141	32.6	67.3	-
	Caranx crysos (Mitchill, 1815)	CAR	20	60	35	5
	Caranx hippos (Linnaeus, 1766)	CAR	1	-	100	-
	Caranx latus Agassiz, 1831	CAR	14	21.4	78.6	-
	Caranx sp.	CAR	1	-	-	100
	Selene vomer (Linnaeus, 1758)	CAR	7	42.8	57.1	-
	Selene sp.	CAR	1	100	-	-
	Seriola dumerili (Risso, 1810)	CAR	4	75	25	-
	Seriola rivoliana Valenciennes, 1833	CAR	15	53.3	46.6	-
	Trachinotus falcatus (Linnaeus, 1758)	MOB INV	2	-	100	-
LUTJANIDAE	*Lutjanus analis* (Cuvier, 1828)	CAR	14	28.6	71.4	-
	Lutjanus alexandrei Moura e Lindeman, 2007	CAR	2	50	50	-
	Lutjanus cyanopterus (Cuvier, 1828)	CAR	26	42.3	53.8	3.8
	Lutjanus jocu (Bloch & Schneider, 1801)	CAR	150	22.6	48.6	28.6
	Lutjanus synagris (Linnaeus, 1758)	CAR	6	100	-	-
	Lutjanus sp.	CAR	18	31.6	57.8	10.5
	Ocyurus chrysurus (Bloch, 1791)	CAR	3	66.6	33.3	-
LOBOTIDAE	*Lobotes surinamensis* (Bloch, 1790)	CAR	1	100	-	-
GERREIDAE	*Diapterus auratus* Ranzani, 1840	MOB INV	4	-	100	-
HAEMULIDAE	*Anisotremus surinamensis* (Bloch, 1791)	MOB INV	6	33.3	66.6	-
	Haemulon parra (Desmarest, 1823)	MOB INV	1	-	100	-
SPARIDAE	*Calamus* sp.	MOB INV	1	-	100	-
KYPHOSIDAE	*Kyphosus* sp.	HERB	4	-	100	-
LABRIDAE	*Scarus trispinosus* Valenciennes, 1840	HERB	68	20.5	63.2	16.1
	Sparisoma amplum (Ranzani, 1842)	HERB	17	64.7	35.2	-
	Sparisoma axillare (Steindachner, 1878)	HERB	13	-	100	-
EPHIPPIDAE	*Chaetodipterus faber* (Broussonet, 1782)	SES INV	9	44.4	55.5	-
SPHYRAENIDAE	*Sphyraena barracuda* (Walbaum, 1792)	PIS	153	92.1	4.5	3.2
SCOMBRIDAE	*Acanthocybium solandri* (Cuvier, 1831)	CAR	11	81.8	18.1	-
	Scomberomorus brasiliensis Collette, Russo & Zavala-Camin, 1978	CAR	191	40.8	59.1	-
	Scomberomorus cavalla (Cuvier, 1829)	PIS	19	47.3	52.6	-
	Scomberomorus regalis (Bloch, 1793)	PIS	6	33.3	50	16.6
	Thunnus albacares (Bonnaterre, 1788)	CAR	1	-	100	-
	Thunnus atlanticus (Lesson, 1830)	CAR	1	-	100	-
BALISTIDAE	*Balistes vetula* Linnaeus, 1758	MOB INV	1	100	-	-

Caranx bartholomaei (n = 141); these species accounted for 56.5% of the total landings. At LN *S. barracuda* was the most frequently captured species, while at BS and SSA *L. jocu* and *S. brasiliensis* were the main targets, respectively (Figure 2). Pelagic species accounted for 60% of the main 10 species caught. Species of lower trophic level and endemic to the Brazilian province were also targeted, as follows: *Scarus trispinosus* (n = 68), *Sparisoma amplum* (n = 17), *Sparisoma axillare* (n = 13). Two species of elasmobranchs were also recorded: *Dasyatis americana* (n = 8) and *Aetobatus narinari* (n = 1), both of them mostly captured in the LN region.

The average number of fish caught per day was 6.7 ± 0.03 (S.E.), with a year estimate of 370 ± 1.9 (S.E.). The majority of the photographs were from LN (Table 2), with 91 records (i.e. photos) and 465 fish at this location. At SSA, 579 fish were caught in 71 fisheries, and at BS there were only 6 fisheries, in which 78 fish were captured.

There were significant differences in the number of fish caught and numbers of species between sites (H = 6.53, p = 0.03 and H = 6.50, p = 0.03, respectively). Differences between LN and BS were found for numbers of fish captured and richness, with highest values of capture in LN, which was responsible for the difference in the model (Dunn's test). There were no statistical differences between the number of fish and numbers of species between years (H = 0.95, p = 0.62 and H = 1.12, p = 0.57, respectively). During 2008, despite the low number of fisheries, there were observed the highest average catch per day (3.5 ± 0.1), followed by 2007 (2.4 ± 0.03) and 2006 (2.24 ± 0.04). In all years, BS obtained higher values of cacth rates than the two other sites and the diversity of species caught at SSA was higher than at the other two regions (Figure 3a, b).

Analyzing the five top target species over time (Figure 4), three species (*S. barracuda*, *L. jocu* and *M. bonaci*) were intensivelly captured in 2007. In 2008 *S. barracuda*, *L. jocu* and *S. brasiliensis* had the lowest catch rates. *S. brasiliensis* showed a decline of capture along the time, while *C. bartholomaei* catches increasing in 2008.

The trophic classification of fish species showed that carnivores (n = 623 fishes; 50-68% of total fishes at each region) dominated in the catchs, followed by piscivores (n = 371; 18-43%), herbivores (n = 101; 5-14%) and invertivores (n = 26; 1-2%) (Figure 5).

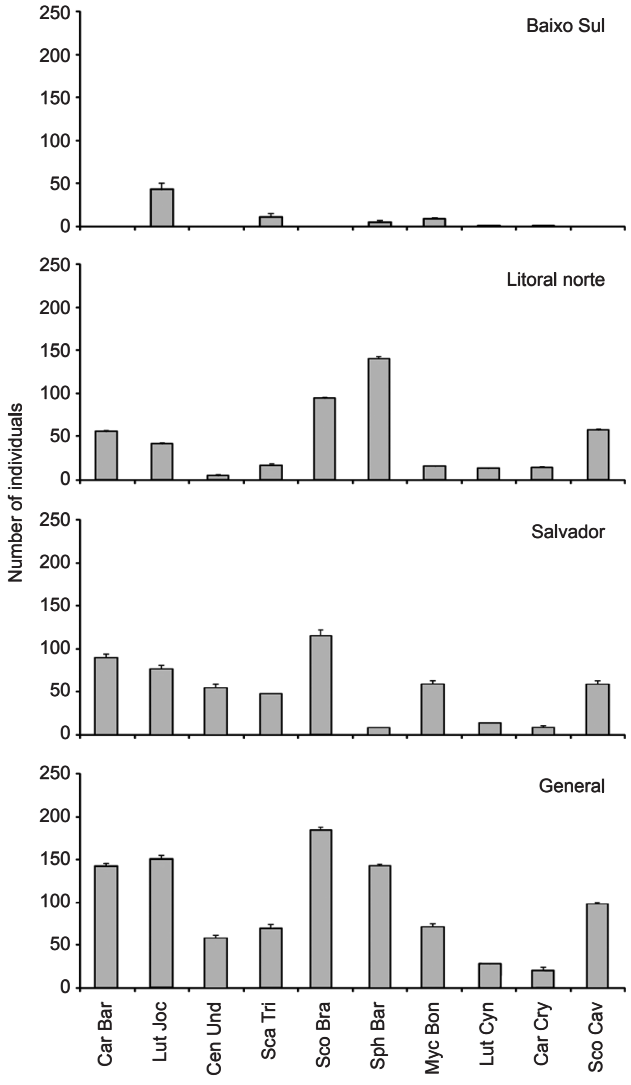

Figure 2. Number of individuals with standard error of the main species presents in the captures between 2006 and 2008.

Figura 2. Número de indivíduos com erro padrão das principais espécies presentes nas capturas entre 2006 e 2008.

Table 2. Number of fishing days (% of total) for each region.
Tabela 2. Número de dias de pesca (% do total) para cada região.

	LN	SSA	BS
2006	37 (58.7)	22 (34.9)	4 (6.4)
2007	35 (56.5)	27 (43.5)	-
2008	19 (44.2)	22 (51.1)	2 (4.7)
Total	91 (54.2)	71 (42.3)	6 (3.5)

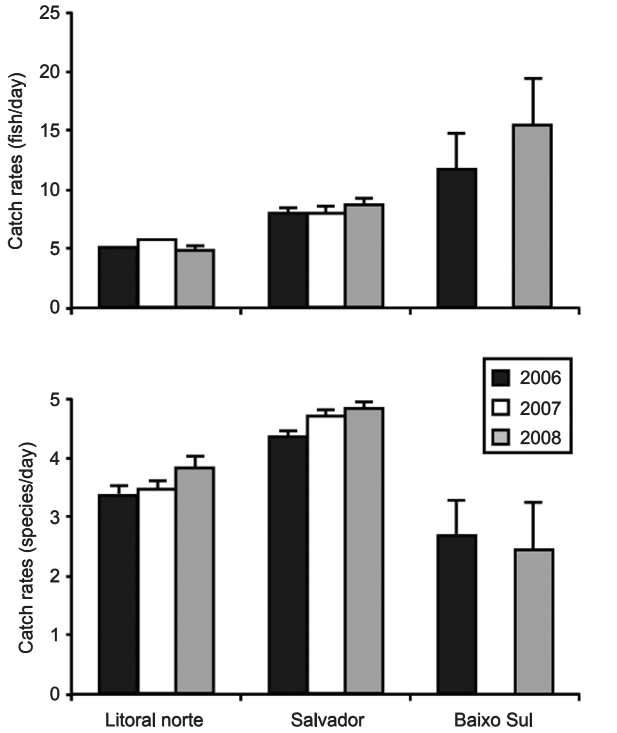

Figure 3. Catch rates values with standard error of fish/day and species/day between regions and years.

Figura 3. Valores da taxa de captura com erro padrão de peixes/dia e espécie/dia entre regiões e anos.

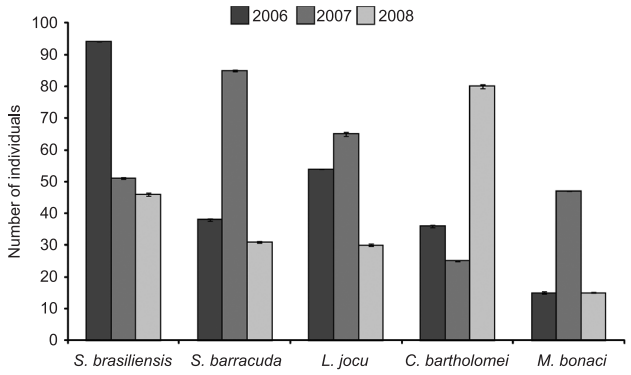

Figure 4. Target species captured with standard error in the three years of photograph sampled.

Figura 4. Espécies alvo capturadas com erro padrão nos três anos de fotografias amostradas.

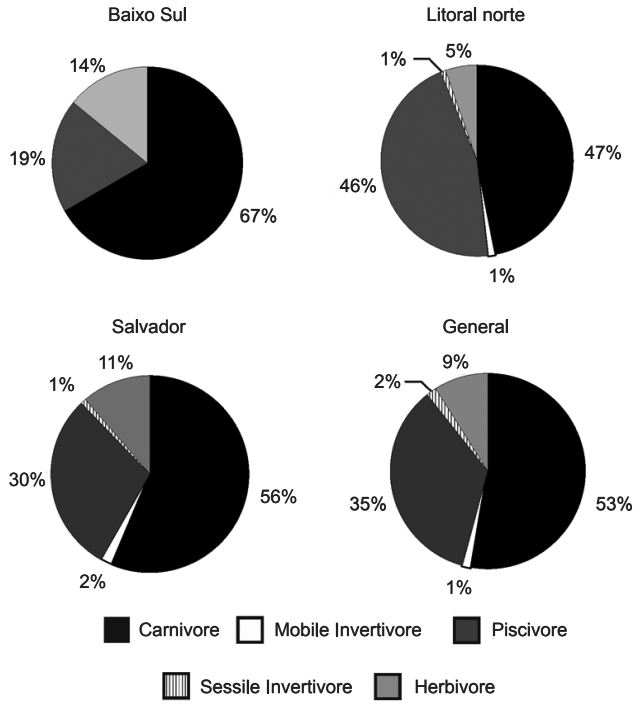

Figure 5. Trophic guilds of the fishes captured for spearfishers.

Figura 5. Guildas tróficas dos peixes capturados pelos caçadores submarinos.

Discussion

Considering all sampling years, more fishing days were recorded in the LN than the other locations. Nevertheless, fish catch rates were higher in BS and numbers of species were higher in SSA. It is possible that these results are related to differences in fishing time and in the number of fisheries in each region. The results might be indicating that each region has different target species, however this may be also due to natural local differences in abundances of different target species. Spearfishers visited few times the BS, probably due to the difficult in access to the region.

In the Bahia state all species observed in the photos are already suffering fishing pressure in other forms of fishing such as linefishing and ornamental purposes (Costa et al. 2003, Costa et al. 2005, Sampaio & Nottingham 2008). Frisch et al. (2008) compared line fishing and spearfishing on the Great Barrier Reef (Australia) and concluded that both have impacts that are broadly equivalent, but spearfishers retained 43% more biomass of target species than line fishing. This type of comparison should be made in Brazilian reefs allowing to a better understanding of the potential effects of different fishing techniques.

The main species caught were identified as sportive species; they have those characteristics that fishermen seek (e.g size, strenght during fishing, good taste). However, these species have relatively low power of resilience and high vulnerability (Froese & Pauly 2010). Individuals of *Lutjanus jocu* observed in the photos were possibly captured in reproductive aggregations, since peaks of capture can be interpreted as indirect signs of this type of aggregation (Colin et al. 2003). Considering the vast coast of Brazil, very few studies related reef fisheries to fish forming spawning aggregations (Gerhardinger et al. 2006, Gerhardinger et al. 2007). Knowledge on where reef fish aggregations occur is very important for the conservation of the target species, even more for those fishes commercially exploited.

In the present study few trophic groups were intensively caught in fisheries, in general carnivores and piscivores. Saenger (1975) found that spearfishing catches from southern Queensland (Australia) were made up of carnivores, herbivores and omnivores in roughly equal proportions. The lack of some trophic groups on reefs can lead to severe negative consequences on functional roles and energy flux and the predator-prey relationship is very important to the ecological balance of these communities and the removal of predatory fish can affect the entire reef community structure (Floeter et al. 2007). The removal of herbivores by fishing is partly responsible for the phase change of many Caribbean reefs from coral dominated to algal dominated (Hughes 1994). For instance, Francini-Filho & Moura (2008) suggested that due to collapse of traditional resources such as serranids and lutjanids, fishing of parrotfish (Labridae- Scarinae and Sparisomatinae) has increased significantly in the largest reef complex of the South Atlantic Ocean, Abrolhos Bank (Leão & Kikuchi 2001, Leão et al. 2003). Lowry & Suthers (2004) showed clearly that spearfishing may have a significant impact on resident populations of long-lived fish species. There is evidence that spearing is responsible for the localised depletion of cheilodactylid populations in New Zealand (Cole et al. 1990). Spearing selectively removes the larger size class and has the potential of removing a large proportion of the males.

Along the Brazilian coast it has been documented that spearfishing has an impact on populations of endemic species (Ferreira & Gonçalves 1999, Ferreira 2005, Floeter et al. 2006, Floeter et al. 2007). Our study shows that recreational spearfishing captures the endemic and also the biggest herbivorous species in Brazil, *Scarus trispinosus* (Labridae). This species is considered to be functionally extinct in Arraial do Cabo (Rio de Janeiro State) due to spearfishing (Floeter et al. 2007) and it has become of the most important fishery resources in Abrolhos Bank in the last five years (Francini-Filho & Moura 2008).

Although carnivorous and piscivorous fish were more abundant in spearfishers catches, it is noteworthy that recreational fishing is practiced largely by people who invest in sophisticated equipment and explore distant places and deep sites (between 15 and 35 m depth). In shallow coast of the Bahia state (<18 m), some of the more abundant species captured are already functionally extinct (Nunes, J.A.C.C, pers. obs.).

McClenachan (2009) analyzed a series of photographs of fisheries held in Key West, Florida (USA), between 1956-2007, and observed that the mean fish weight declined from an estimated 19.9 to 2.3 kg. She also described a major shift in species composition where landings from 1956 to 1960 were dominated by large groupers

(*Epinephelus spp.*), and other large predatory fish, while in 2007 they were composed mostly of small snappers (*Lutjanus* spp. and *Ocyurus chrysurus*).

The Brazilian legislation (Portaria IBAMA Nº 30/2003) allows activities of recreative fishermen registered in the Brazilian Environmental Institute (IBAMA), with cottas established at 15 kg of fish and more one fish of any size per day. However, these data are not sufficient for monitoring the populations of target species.

As a consequence of the multifactorial nature of the impacts that affect the litoral zone and the lack of data concerning the specific impact each activity on resources, isolating the effect of a single factor from the rest is not an easy task (Coll et al. 2004). Although the existing literature indicates that spearfishing is an important factor that can affect the composition of fish communities (Moranta et al. 1997, Reñones et al. 1997) and structure of certain fish populations (Harmelin & Marinopoulos 1993, Harmelin & Harmelin-Vivien 1999, Jouvenel & Pollard 2001, Tuya et al. 2006) monitoring of the effects of spearfishing on stocks becomes a difficult task because, in most cases, the only alternative is the database of the fishermen's associations.

This study shows that the recreational spearfishing can be a problem to reef fishes communities of the Bahia state. The rescue of older photos, decades before those used in the present analysis, and the comparison with recent photos, can help to better assess the impact of recreational spearfishing. We suggest also that in situ monitoring activities for target species should be conducted immediately. Additionally, there is currently no regulation for spearfishing arms trade; we believe that the adjustment of arms trade and increased surveillance can reduce the impacts.

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