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Article

Ethnoecology and socioeconomic around an artificial reef: the case of artisanal fisheries from southeastern Brazil

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Abstract: The objective of this study is to describe the ethnoecological aspects, valorization, and commercialization of target species caught by artisanal fishers on the northern coast of Rio de Janeiro, southeastern Brazil. The data were obtained through semi-structured interviews conducted with 60 fishers from the fishing community of Guaxindiba (21°29'S, 41°00'W), which is associated with the Z-1 fishers' colony. Eighty-nine species were cited by the fishers and 44.1% are important commercial fish in the region. The fishers cited five distinct zones used to fish: border zone (68 species), estuary (41 spp.), artificial reef (27 spp.), "malacacheta" (24 spp.), and open ocean (10 spp.). The fishery resources were classified according to their gastronomic and economic characteristics: primary fish (35 spp.), secondary fish (32 spp.), mixed fish (10 spp.), discarded fish (7 spp.), and fish used as bait (5 spp.). The price of the target species increases along the production chain due to the greater number of people involved, processing costs, and improvement of the product. The data from this study can contribute to local fisheries management and point out to the use of artificial reefs in the maintenance of fishery resources in northern Rio de Janeiro.
Keywords: *artisanal fishing, traditional knowledge, fishery management.*

Etnoecologia e socioeconomia em torno de um recife artificial: o caso da pesca artesanal do sudeste do Brasil

Resumo: O objetivo desse estudo é descrever os aspectos etnoecológicos, a valoração e a forma de comercialização das espécies-alvo capturadas na pesca artesanal praticada na costa norte do Rio de Janeiro, sudeste do Brasil. Os dados foram obtidos a partir de entrevistas semiestruturadas realizadas com 60 pescadores da comunidade pesqueira Guaxindiba (21°29'S, 41°00'O), vinculados à colônia de pescadores Z-1. Oitenta e nove espécies foram citadas pelos pescadores e 44,1% desse total são importantes para o comércio da região. Os pescadores citaram cinco zonas distintas que são utilizadas para a pesca: zona da "borda" (68 espécies), estuário (41 spp.), recife artificial (27 spp.), "malacacheta" (24 spp.) e mar aberto (10 spp,). Os recursos pesqueiros foram classificados de acordo com suas características gastronômicas e econômicas: pescado-de-primeira (35 spp.), pescado-de-segunda (32 spp.), pescado-mistura (10 spp.), pescado-de-descarte (7 spp.) e pescado-isca (5 spp.). O preço das espécies-alvo aumenta ao longo da cadeia produtiva em decorrência do maior número de pessoas envolvidas, dos gastos com insumos e do processo de beneficiamento do pescado. Os dados desse estudo podem contribuir para o manejo da pesca local e apontam para o uso de recifes artificiais na manutenção dos recursos pesqueiros no norte do Rio de Janeiro.
Palavras-chave: *pesca artesanal, conhecimento tradicional, manejo pesqueiro.*

Introduction

Artisanal fishing is important to the economy in many fishing communities, since it provides food security, employment and income, and is part of the cultural identity of various social groups (FAO 2016). In these practices, the fishermen explore the coastline with small equipment that have low autonomy and capture species for subsistence or small-scale commercialization (Clauzet et al. 2005, Oliveira et al. 2016). Artisanal fishermen usually are organized in fishing colony or association with a local leader as representative (Brasil 2009, Brasil 2011). However, factors such as the use of active gears (*e.g.* trawls, dredges and seine nets), overexploitation of fisheries resources, degradation of coastal environments, and climate change have affected local fishing communities and intensified the economic crisis in this sector (Silvano & Valbo-Jorgensen 2008, Vasconcellos et al. 2011, Santos & Alves 2016). In this context, ethnoecological studies have provided relevant information about the environment and exploited species, because they consider the knowledge of subjects that are in direct and regular contact with natural resources (Johannes 2002, Silvano et al. 2009). Based on local ecological knowledge (LEK) it is possible to better understand, for example, aspects related to the behavior and occurrence of species, as well as environmental impacts that affect them, which often go unnoticed by researchers (Begossi et al. 2000, Silvano 2004, Hanazaki et al. 2013).

The LEK of artisanal fishers provides knowledge about ecological, taxonomic, and ethological aspects of aquatic communities that are important for inventories, especially in places where scientific studies are scarce (Mourão & Montenegro 2006, Silvano & Begossi 2012, Pinto et al. 2015, Pitcher & Lam 2015). Analyzing the interactions between fishers and fishery resources is important to understand distinct forms of use, capture, categorization, and commercialization of target species (Begossi 2006, Souza et al. 2007, Gerhardinger et al. 2009). Studies on fishing dynamics through LEK are related to developing management measures for the conservation of species that are the most vulnerable or threatened with extinction.

Rio de Janeiro State is ranked as seventh fish producer in Brazil, and the northern coast has six important artisanal fishing ports (Vianna 2009, ICMBIO 2011). Despite management strategies for fishing in Brazil (*e.g.*, regulation of fisheries and closed season, public benefits for fishers and input subsidies), public policies for artisanal fishing in northern Rio de Janeiro are still inefficient, due the impossibility of the State to ensure legal presuppositions (Pérez et al. 2001, Castello, 2007, Brasil, 2009, FIPERJ 2013, 2015). Co-shared management of fishing activities include information about fisheries resources and how they are exploited, besides the participation of fishers in the political and economic decision-making process (Berkes et al. 2006, Pomeroy et al. 2007).

Several studies have contributed on this subject, through daily observations of fishing activities, regular monitoring, and interviews with fishers (Ota & Just, 2008, Silvano & Begossi 2012, Pinto et al. 2015, Pitcher & Lam 2015). Studies along the coast of Rio de Janeiro (*e.g.*, Di Beneditto et al. 1998, Di Beneditto 2001, Fernandes et al. 2014, Oliveira et al. 2016, Zappes et al., 2016) have been conducted to analyze the activities of fishers and the management of fishery resources. These studies aimed to describe the main boats, fishing gear and target species. However, little is known about the catching process of target species in different fishing areas ("pesqueiros"), and the socioeconomics of fishing resources in the north coast of Rio de Janeiro.

In 1996, an artificial reef complex (ARs) composed of reef balls was installed on the north coast of Rio de Janeiro near the fishing community of Guaxindiba. These modules were installed to increase the abundance, biomass of fishing resources and improve the artisanal fishing rates (Santos et al. 2010, Santos & Zalmon 2015). Over the years, the local fishermen have used the area where the ARs were deployed as an ancillary fishing area to capture some target species (Lima et al. 2018). However, there is little information about the species caught in these artificial structures or in other fishing areas used for artisanal fishermen in the northern Rio de Janeiro.

Thus, the objective of this work is to describe the ethnoecological aspects and commercialization of target species caught by artisanal fishers in different fishing areas on the northern coast of Rio de Janeiro (especially in the ARs). The results will contribute to local fisheries management, besides the evaluation of ARs usage to co-management of species that are vulnerable and threatened.

Material and Methods

1. Study area

The northern coast of Rio de Janeiro is located in a transition zone between hot, oligotrophic waters and the cold, resurgent, nutrient-rich current from the South Atlantic (Valentin & Monteiro-Ribas 1993) (Figure 1). The continental platform in this region has a seabed that is composed of sand, mud, and biogenic sediment from Paraíba do Sul River (PSR) (Murilo et al. 2009). During rainy season (January to March), the estuarine plume of PSR reach up to 20 km offshore, which affects the ecological processes of marine and local fish communities (Ovalle et al. 2014).

Fishing community of Guaxindiba (21°29'S, 41°00'W) is characterized by capture of shrimp, weakfish, croakers, catfish and shark (Di Beneditto 2001, Vianna 2009). Fishing in this region is predominantly artisanal and the fishers are represented by the Z-1 Fishers' Colony, which has 328 associates (FIPERJ 2015). Most of these operate in coastal marine areas of Campos Basin between the municipalities of São Francisco de Itabapoana (21º18'S, 40º57'W) and Macaé (22º22'S, 41º47'W), from areas near the coast to 120 km offshore.

In 1996, ARs were installed 5 km from the community of Guaxindiba to increase coastal resources and improve artisanal fishing. These ARs are composed of 36 reef balls (1 m^3) covering an area of 60.000 m^2, each module weight 500 kg with holes 20 cm diameter. The reef balls are ideal for creating habitats for several marine species (fish, lobsters, oysters) and also to prevent industrial fishing (Sherman et al. 2002, Young et al. 2012). Lima et al. (2018) showed that fishermen on the northern coast of Rio de Janeiro have used the area where the ARs were deployed as an ancillary fishing area to capture some target species, using fishing gears that best suit the characteristics of that area as bottom lines and hook, longlines and surface gillnets.

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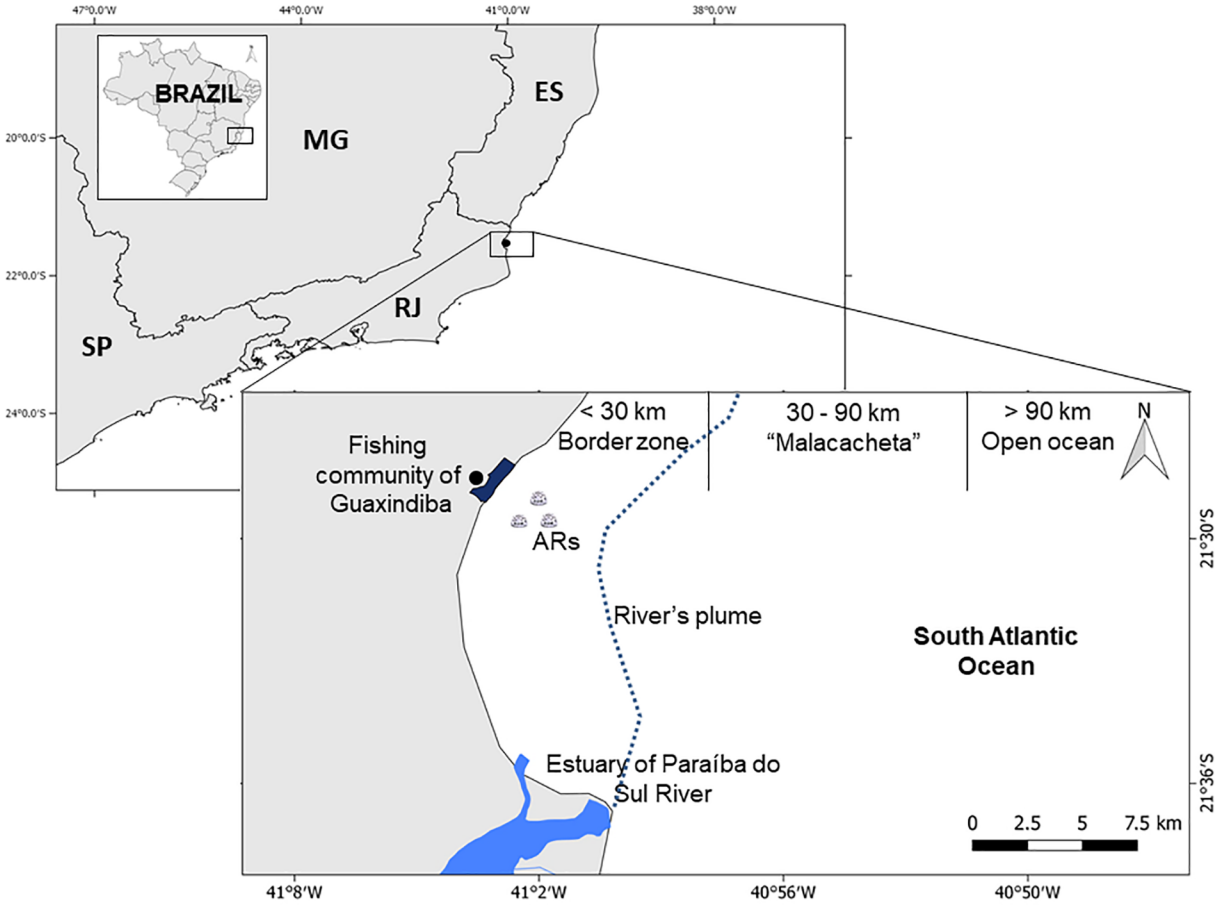

Figure 1. Location of the community of Guaxindiba and delineation of fishing zones according to the local fishermen. Southwestern states: MG - Minas Gerais, ES - Espírito Santo, SP - São Paulo and RJ - Rio de Janeiro.

2. *Data collection*

This study was approved by the Human Research Ethics Committee of the Federal Institute of Sergipe, Brazil (CAAE 64939116.1.0000.8042). The permission to perform this study was granted by the president of the Fishing Colony Z-1, an autocracy that represents the professional category studied. The data were collected from November 2016 to May 2017 through 60 semi-structured interviews with artisanal fishers from the fishing community of Guaxindiba. In the first phase of the study, the participant observation method was used through observations of the fishers routine (Malinowski 1984, Sieber et al. 2014).

The observations were recorded in a field diary to obtain data about the structural and cultural characteristics of the community (Clifford 1998). The interviews were conducted using a semi-structured questionnaire (Kendall 2008) with open and closed questions characterizing the local interviewees, description of artisanal fishing and commercialization of fish (Box 1).

The interviewee selection was based on the following mandatory aspects: i) to be an artisanal fisher based in northern Rio de Janeiro, and ii) having fishing as the main professional activity. The first interviewee involved the collaboration of a local guide (president of the Z-1 Fishers' Colony), and a snowball sampling was used with the second interview, where the interviewee indicate the next one (Lyra-Neves et al. 2015). At times the snowball sampling was interrupted, a fisherman was randomly chosen in order to minimize the possible personal tendencies of indicating someone (Silva et al. 2014).

To taxonomically identify the fishery resources mentioned by the interviewees, fish were caught with gill nets or obtained from local markets after verifying where they came from. Lobsters, oysters and shrimps were sampled at local markets, upon confirmation with the fisherman about the place of capture. The samples were preserved in a solution of 10% formaldehyde. Fish were identified using taxonomic keys (Figueiredo & Menezes 1977, 1978, 1980a, 1980b, 1985 and 2000, Carvalho Filho 1994, Eschmeyer & Fong 2018, Froese & Pauly 2018), and for mollusks and crustaceans, information was compared with literature (Costa et al. 2003, Jereb & Roper 2010, Tudesco et al. 2012, Amaral & Simone 2014, Giraldes & Smyth 2016). After the scientific names identification, the species common names were confirmed with the contribution of seven 'local knowledge experts'. These 'experts' were defined as major holders of fishing knowledge.

3. *Data analysis*

The responses were organized into categories according to the questionnaire (Ryan & Bernard 2000). This allowed the local knowledge of the artisanal fishers to be described and compared, as well as the ecological and economic characterization of the fishery resources in the

Box 1. Topics addressed in the semi-structured questionnaire addressed to fishers from the community of Guaxindiba, Brazil.

Topics	Questions
1. Characterization of the interviewees	Gender
	Age
	Education
2. Description of artisanal fishing	Boats
	Fishing gear
	Fishing areas
	Environmental interferences that influence fishing
3. Characterization of fishing	Marine species that occur in the region
	Habitat of target species
	Categorization of target species
4. Commercialization of fish	Main commercialized target species
	Fishing season of the target species
	Value of target species
	Production chain of target species

region. The comparisons were made based on the percentage frequencies of the responses to the questionnaire (Sieber et al. 2014). Topics that fishermen responded more than one option included the percentage frequency calculated by the number of total responses and not by the number of interviewed.

Based on the interviews and *in situ* observations, a fishing calendar was created including the months with the highest catch, average prices of the main commercial species, and conservation status of the target species according to the International Union for Conservation of Nature (IUCN 2017) and the Ministry of the Environment of Brazil (MMA 2014). Subsequently, the calendar was shown to the artisanal fishers to confirm the results. The LEK was analyzed through the triangulation method, which consists of crossing information collected through field diary, participant observation, and interview-questionnaire to compare similarities and discrepancies in the data (Yeasmin & Rahman 2012, Albuquerque et al. 2014).

Results

1. *Description of artisanal fishing and environmental interferences*

The interviewed fishers were mostly male (n = 59); only one professional fisher was female. Age varied from 40 to 78 years and the amount of time fishing ranged from 22 to 60 years. Considering the formal education, 61.7% (n = 37) of the fishers did not finish elementary school, 23.3% (n = 14) finished elementary school, and 15% (n = 9) never went to school.

The most common boats in are trawlers and canoes (paddled or motorized). Trawlers are used for short (up to 8 h) and long (up to 10 days) fishing trips. Motorized canoe is used for short fishing trips (up to 6 hours), and paddled canoe is used to transport cargo to trawlers, since there are no docks in the fishing community.

The most used fishing gear is the bottom trawl net (n = 41, 32.5%), followed by bottom line and hook (n = 21, 16.7%), longline (n = 19, 15.1%), bottom gillnet (n = 17, 13.5%), purse seine net (n = 12, 9.5%), trammel net (n= 9, 7.1%), and surface gillnet (n = 7, 5.6%). The same fisher sometimes uses more than one fishing gear, and consequently the number of responses is greater than the number of interviewees.

The fishers mentioned five distinct zones that are used for artisanal fishing in the region: border zone (0 to 30 km from the coast zone), ARs (zone with reef balls), estuary zone (PSR mouth), "malacacheta" (30 to 90 km), and open ocean (over 90 km) (Figure 1). According to the interviewees, the border zone has the greatest number of species that are caught (68 spp., 40%), followed by the PSR estuary (41 spp., 24.1%), ARs (27 spp., 15.9%), "malacacheta" (24 spp., 14.1%), and open ocean (10 spp., 5.9%). The same target species can be caught in more than one zone, and consequently the number of responses is greater than the species cited.

The fishers highlighted some environmental conditions (wind, tides, and moon phases) as determining factors in planning fishing trips. Wind direction is the main predictor used to conduct these activities in the region. Winds from the north (n = 26, 43.3%), northeast (n = 22, 36.7%), and southeast (n = 12, 20.0%) are considered the best for fishing. Winds from the north lead several target species to the coast and those from the northeast increase the turbidity of the water making it possible to catch shrimp and sharks. Winds from the southeast are less intense, which is good for fishing in areas farther from the coast.

However, southern (n = 31, 51.7%), southeastern (n = 18, 30.0%), and continental (n= 11, 18.3%) winds cause the worst fishing conditions. According to the fishers, wind from the south ("vento de viração") is very intense so they do not fish during this time (August and September). Wind from the southeast is related to an increase in the availability of target species; however, strong bottom currents hamper to handle the fishing gear. Continental winds are considered calm, but they direct the target species away from the coast, which increases the time and cost of fishing.

The interviewers considered high ("alive" or syzygy) tide (n = 32, 53.3%) as the best condition to fish compared to low ("dead" or quadrature) tide (n = 19, 31.6%). Full moon with a spring tide (n = 24,

40.0%) was reported as a favorable condition to fish for shrimp and when fish species move to regions closest to the coast. Neap tide is suitable for catching species such as mullet, snook, and sharks because the moonlight is less intense on the water's surface. Waxing moon (n = 14, 23.3%) is characterized by fishing in regions further than 30 km from the coast due to weaker sea currents. Fishers commonly associated waning moon (n = 13, 21.6%) with the fish spawning period in PSR estuary region.

2. *Characterization and commercialization of the fish*

Eighty-nine species belonging to four classes and 44 families were reported by the interviewees: Osteichthyes (69 species), Chondrichthyes (11), Malacostraca (7), Cephalopoda (1) and Bivalvia (1). The most representative families were Sciaenidae (14 species), Carangidae (7), Ariidae (6), Haemulidae (6) and Carcharhinidae (5).

The fishers differentiated the fish habit by their vertical distribution in the water column. The "peixes-boieiros" (surface fish) (12 spp., 13.5%) are represented by species that feed on the water surface, "peixes-meio-d'água" (midwater fish) (39 spp., 43.8%) include species that move a lot in the water column based on climatic conditions or to feed, and "peixes-de-fundo" (bottom fish) are divided into "peixes-de-lama" (mudfish) (23 spp., 25.8%) and "peixes-de-pedra" (rockfish) (15 spp., 16.9%), which inhabit and feed within soft and hard substrates, respectively.

The fishing resources in the region were classified into five categories by the interviewees: 1) Primary fish (35 spp., 39.3%), which are the most preferred species by the fishers due to their better flavor and high commercial value. These resources are exclusively for commercialization and are only eaten by the fishers and their families on special occasions. The sale price varies between US$ 2.90/kg and US$ 8.60/kg (Table 1). Secondary fish (32 spp., 36.0%), which are less preferred by the consumer market due the presence of many small bones ("espinhas"). In general, these fish are consumed by fishermen and their families. The sale price varies between US$ 0.60/kg and US$ 2.30/kg (Table 2).

Mixed fish (10 spp., 11.2%), which are less preferred by the consumer market due to their rancid flavor and/or presence of many small spines. The "mixed" category was designated by the fishers for by-catch from shrimping. The fish are sold together for a single price, which is US$ 0.20/kg. These species are also given to friends and family (Table 3). Discarded fish (7 spp., 7.9%) include species that lack commercial value and are discarded during fishing as the spotted moray (*Gymnothorax moringa* Cuvier 1829) and ocellated moray (*Gymnothorax ocellatus* Agassiz 1831), which the fishermen avoid due to the bite of these fishes. Some fishers (n = 6, 6.7%) wait for seabirds, such as the brown booby (*Sula leucogaster* Boddaert 1783) and seagulls (*Larus* sp.) to discard this type of fish, which keeps the birds from looking for fish on the boat that have a higher commercial value. Fish used as bait (5 spp., 5.6%), which are species of small size that are not consumed by humans in the region. This category includes some species that are used as bait in bottom line, hook and longline fisheries to catch commercially valuable fish species. The Atlantic thread herring (*Opisthonema oglinum* Lesueur 1818) is used as bait to catch the common dolphinfish (*Coryphaena hippurus* Linnaeus 1758) and the American coastal pellona (*Pellona harroweri* Fowler 1917) is used to catch the grey triggerfish (*Balistes capriscus* Gmelin 1789) and queen triggerfish (*Balistes vetula* Linnaeus 1758). Species of this category are not commercialized.

Among the 89 species mentioned by the fishers, only 39 (43.8%) are commercialized in the community of Guaxindiba (Table 4). Notable target species are shrimp (*Artemesia longinaris* Bate 1888, *Farfantepenaeus paulensis* Pérez Farfante 1967*, Litopenaeus schmitti* Burkenroad 1936 and *Xiphopenaeus kroyeri* Heller 1862), snook (*Centropomus parallelus* Poey 1860 and *Centropomus undecimalis* Bloch 1792), sharks (*Carcharhinus porosus* Ranzani 1839, *Rhizoprionodon porosus* Poey 1861 and *Rhizoprionodon lalandii* Valenciennes 1839), weakfish (*Cynoscion microlepidotus* Cuvier 1830, *Cynoscion virescens* Cuvier 1830, *Nebris microps* Cuvier 1830 and *Isopisthus parvipinnis* Cuvier 1830), mullet (*Mugil liza* Valenciennes 1836*)*, "sargos" (*Anisotremus surinamensis* Bloch 1791 and *Archosargus probatocephalus* Walbaum 1792), and lobsters *(Panulirus argus* Latreille 1804 and *Panulirus* sp.).

The data indicate that ARs are important in the context of local fishing due to the ability to attract commercial fish to the fishing zone closer to the port of Guaxindiba. According to the fishermen bluefish (*Pomatomus saltatrix* Linnaeus 1766), lobsters (*Panulirus* sp. and *P. argus*), atlantic spanish mackerel (*Scomberomorus maculatus* Mitchill 1815*)* and "sargos" (*A. surinamensis* and *A. probatocephalus*) are captured in the coastal zone after the implantation of ARs in the north coast of Rio de Janeiro.

Based on the information provided by the interviewees about fishing periods, an ecological-economic calendar was created for the main target species caught along the northern coast of Rio de Janeiro (Table 4). The fishing season of commercialized target species is related to the rainy period and variation in the flow of PSR: rainy period and greatest flow (December to February); dry period and least flow (June to August). The rainy period is the best time to fish for lobsters, weakfish, "sargos" and mullet (except when the season is closed for fishing), and the dry period is the best time to fish for shark and snook. Shrimp are caught throughout year, except when the season is closed (March to May).

The market price for shrimp varies based on the time of year (season vs. off season). During the fishing seasons (June and July; October to January) shrimp are usually cheaper (-30%) compared to off seasons (February, August, and September). For the fish species, there was a relation between the average prices per kilo and the length of fishing season; the target species with the highest added value are those whose fishing season is the shortest.

Despite the lack of information on the conservation status of many target species that are commercially fished on the northern coast of Rio de Janeiro, some species are at risk (14 species) by the IUCN (2017) and the National List of Threatened (MMA 2014). The sharks are target species whose decrease in numbers have been most noticed by the fishers (n = 41). Replacing shark fillet with catfish fillet (*Bagre bagre* Linnaeus 1766 and *Bagre marinus* Mitchill 1815) is an example of a utilitarian substitution due to a stock decrease of sharks in the region. The similar flavor of these species favored an increase in the catfish fishery and a higher market value, resulting on a decrease on their stock population.

The production chain is a matrix of artisanal fishers that can comprise up to six steps (n = 47, 78.4%): 1) investment of goods and inputs, 2) catching target species, 3) bringing the catch to shore, 4) selling the species of commercial value (primary and secondary fish)

Table 1. Species related as primary fish by artisanal fishermen from the community of Guaxindiba, Brazil.

Common name	N	Scientific name	Fishery gear	Fishing zone
“Anchova”	15	*Pomatomus saltatrix*	L, SG	AR, M, OS
“Badejo”	9	*Mycteroperca microlepis*	B, SG	M, OS
“Bicuda”	7	*Sphyraena guachancho*	B, L	B, M, OS
“Bijupirá”	6	*Rachycentron canadum*	B, L	B, M
“Bonito”	8	*Euthynnus alletteratus*	B, SG	B, M
“Cação-anequim”	6	*Isurus oxyrinchus*	L, BL	B, M, OS
“Cação-areia”	12	*Carcharias taurus*	L, BL	B, M
“Cação-barriga-d'água”	6	*Carcharhinus* sp.	L, BL, SG	B, M, OS
“Cação-galha-preta”	27	*Carcharhinus porosus*	L, BL, SG	B, M
“Cação-olho-verde”	35	*Rhizoprionodon porosus*	L, BL, SG	AR, B
“Cação-panan”	6	*Sphyrna* sp.	BL, BT, BG	B
“Cação-tintureiro”	18	*Prionace glauca*	L, BL, SG	B, M
“Cação-torce-torce”	32	*Rhizoprionodon lalandii*	L, BL, SG	AR, B
“Cação-viola”	15	*Rhinobatos percellens*	BL, BT, BG	B
“Camarão-barba-russa”	37	*Artemesia longinaris*	BT	B, E
“Camarão-branco”	31	*Litopenaeus schmitti*	BT	B, E, M
“Camarão-rosa”	35	*Farfantepenaeus paulensis*	BT	B, M
“Camarão-sete-barbas”	52	*Xiphopenaeus kroyeri*	BT	B, E
“Cherne”	6	*Epinephelus niveatus*	B, SG	OS
“Dourado”	15	*Coryphaena hippurus*	B, L	OS
“Garoupa”	6	*Epinephelus marginatus*	B, SG	M, OS
“Lagosta-marrom”	20	*Panulirus* sp.	BT, BG	AR
“Lagosta-rainha”	20	*Panulirus argus*	BT, BG	AR
“Lula”	9	*Loligo* sp.	BT, PS	B, M
“Namorado”	14	*Pseudopercis numida*	BL, L	OS
“Pescada-banana”	16	*Nebris microps*	BL, BG, BT	B, E
“Pescada-branca”	25	*Cynoscion microlepidotus*	BL, BG, BT	B, E
“Pescada-selvagem”	45	*Cynoscion virescens*	BL, BG, BT	AR, B, E
“Prejereba”	10	*Lobotes surinamensis*	L, SG	B, M
“Robalo-fincudo”	42	*Centropomus undecimalis*	BL, BG	AR, E
“Robalo-peva”	48	*Centropomus parallelus*	BL, BG	AR, E
“Sarda”	21	*Scomberomorus maculatus*	L, SG	AR, M, OS
“Sargo-de-beiço”	32	*Anisotremus surinamensis*	BL, BG	AR
“Sargo-de-dente”	26	*Archosargus probatocephalus*	BL, BG	AR
“Tainha”	42	*Mugil liza*	RF, SG	B, E

N - Number of citations. Fishery gear: L - longline, BL - bottom line and hook, BT - bottom trawl net, TN - trammel net, SG - surface gillnet, BG - bottom gillnet and PS - purse seine net. Fishing zone: B - border area, E - estuary, AR - artificial reef, M - “Malacacheta” and OS - Open Sea.

to intermediaries or owners of local markets, 5) selling or donating mixed fish to family and friends, and 6) commercialization of fish in local markets. However, some fishers have tried to change the local production chain by selling fish they catch out of their home. In this new production chain model (n = 13, 21.6%) the fish is refrigerated, processed and sold directly to consumers, avoiding the intermediaries and owners of local markets.

Discussion

1. *Description of artisanal fishing and environmental interferences*

The artisanal fishers of Guaxindiba are mostly male, which is common in many Brazilian fishing communities (Alencar & Maia 2011, Côrtes et al. 2014, Fonseca et al. 2016). In general, fishers have a low

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Table 2. Species related as secondary fish by artisanal fishermen from the community of Guaxindiba, Brazil.

Common name	N	Scientific name	Fishery gear	Fishing zone
"Bagre-amarelo"	39	*Aspistor luniscutis*	BT, BG	B, E
"Bagre-bandeira"	47	*Bagre bagre*	BL, BT, BG	B, E
		Bagre marinus	BL, BT, BG	B, E
"Bagre-branco"	45	*Genidens barbus*	BL, BT, BG	B, E
"Bagre-calafate"	21	*Notarius grandicassis*	BT, BG	B, E
"Bagre-urutu"	39	*Genidens genidens*	BT, BG	B, E
"Baiacú-ará"	24	*Lagocephalus laevigatus*	BL, L, BG	B, AR
"Barana"	9	*Elops saurus*	L, SG	B
"Carapeba"	15	*Diapterus rhombeus*	BL, L, BG	B
"Castanha"	6	*Umbrina canosai*	BT, BG, PS	B, E
"Cororoca"	7	*Orthopristis ruber*	BL, BG	B
"Corvina"	21	*Micropogonias furnieri*	BL,L,BT, BG	B, E
"Espada"	6	*Trichiurus lepturus*	BL, BG	B
"Goete"	34	*Cynoscion jamaicensis*	BL, BG, BT	B, E
"Goibira"	15	*Oligoplites saliens*	BL, BG	B, M
"Linguado"	7	*Syacium papillosum*	BT, BG	B, E
"Olhete"	8	*Seriola* sp.	L, SG	B, M
"Olho-de-cão"	6	*Priacanthus arenatus*	BL, L, BG	B
"Papa-terra"	16	*Menticirrhus americanus*	BT, BG, PS	B, E
"Pargo"	22	*Lutjanus analis*	BL, L	AR, M
"Parú"	15	*Chaetodipterus faber*	BL, BG, RF	AR
"Peroá-leste"	32	*Balistes vetula*	L, BL	M
"Peroá-preto"	45	*Balistes capriscus*	L, BL	M
"Pescadinha"	56	*Isopisthus parvipinnis*	BT, BG, PS	AR, B, E
		Macrodon ancylodon	BT, BG, PS	AR, B, E
"Raia-marrom"	15	*Hypanus americanus*	L, BT, BG	AR
"Raia-pintada"	9	*Aetobatus narinari*	L, BT, BG	B
"Sabãozinho"	11	*Peprilus paru*	BT, PS, BG	B, E
"Salema"	7	*Anisotremus virginicus*	BT, BG	B
"Xarelete"	11	*Caranx crysos*	L, SG	AR, B, M
"Xaréu"	11	*Caranx latus*	L, SG	AR, B, M
"Xixarro"	8	*Trachurus lathami*	L, SG	B, M

N - Number of citations. Fishery gear: L - longline, BL - bottom line and hook, BT - bottom trawl net, TN - trammel net, SG - surface gillnet, BG - bottom gillnet and PS - purse seine net. Fishing zone: B - border area, E - estuary, AR - artificial reef and M - "Malacacheta".

level of education and are highly dependent on fishing. Low education level affects the fishers socioeconomic situation and can interfere in the process of changing professions (Oliveira et al. 2016, Zappes et al. 2016). Artisanal fisheries involve fishers and their families as the main labor force related to catching and processing the fish. Socioeconomic data related to these fishers are similar to those recorded in other coastal areas of Brazil (Diegues 2008, Cunha 2009, Colaço 2012).

Fishing out of Guaxindiba port involves different gear related to the target species. Surface gillnets, bottom gillnets, and trammel nets are important to local fishing and are used to catch most of the commercially important species. Bottom trawl net is the most used fishing gear in the region to catch shrimp (*X. kroyeri* and *A. longinaris)* (Semensato & Di Beneditto 2008, Fernandes et al. 2014). The boats have low or medium autonomy, which limits the fishers to a few hours or days of consecutive fishing. In addition, fishing gear is limited to the type of boat. Trawling and purse seine nets, for example, are associated with larger boats with more powerful engines due to the mechanical traction associated with launching and pulling in the fishing nets. Many authors have noted that use and type of fishing gear are associated with the boats used by the fishing community (Diegues 2004, Begossi 2006, Oliveira et al. 2016).

Fishing effort in the region is concentrated along the coastal zone (border, ARs and PSR estuary). Only the larger boats can reach the farthest fishing grounds ("malacacheta" and open water) due to their greater autonomy (high speed, capacity of displacement and space to

Table 3. Species related as mixed, discarded and bait by artisanal fishermen from the community of Guaxindiba, Brazil.

Common name	N	Scientific name	Fishery gear	Fishing zone	C
"Boca-de-velho"	6	*Anchovia* sp.	BT, SG	AR, B, E	B
"Cabeça-dura"	10	*Stellifer brasiliensis*	BT, BG, PS	AR, B, E	M
		Stellifer rastrifer	BT, BG, PS	AR, B, E	M
		Stellifer stellifer	BT, BG, PS	AR, B, E	M
"Cangoá-relógio"	16	*Larimus breviceps*	BT, BG, PS	B, E	M
"Cobra-caramuru"	3	*Gymnothorax ocellatus*	BT, PS, BG	B, E	D
"Cobra-preta"	3	*Gymnothorax moringa*	BT, PS, BG	B, E	D
"Folha-de-mangue"	6	*Chloroscombrus chrysurus*	BT, OS	B, E	D
"Gurundeia"	5	*Haemulon aurolineatum*	BT, BG	B	M
"Língua-de-mulata"	5	*Trinectes paulistanus*	BT, BG, PS	B, E	D
"Manjuba"	5	*Anchoviella* sp.	BT, SG	B, E	B
"Maria-luiza"	12	*Paralonchurus brasiliensis*	BT, BG, PS	AR, E	M
"Maria-sapeba"	5	*Symphurus plagusia*	BT, BG, PS	B, E	D
"Ostra"	3	*Crassostrea* sp.	BG	AR	D
"Pargo-vermelho"	6	*Haemulon steindachneri*	BT, BG	B	M
"Peixe-galo"	6	*Selene setapinnis*	BT, BG	AR, E	M
"Peixe-voador"	6	*Dactylopterus volitans*	BT, PS, BG	B	M
"Piaba-olhuda"	5	*Pellona harroweri*	BT, PS	B, E	B
"Roncador"	6	*Conodon nobilis*	BT, BG	AR, B, E	M
"Sardinha-de-vidro"	5	*Odontognathus mucronatus*	BT, BG, PS	B, E	B
"Sardinha-laje"	8	*Opisthonema oglinum*	BT, OS	B, E	B
"Siri"	9	*Callinectes* sp.	BT	B, E	D

N - Number of citations. Fishery gear: BT - bottom trawl net, SG - surface gillnet, BG - bottom gillnet and PS - purse seine net Fishing zone: B - border area, E - estuary and AR - artificial reef. C - Category: M - mixed fish, D - discarded and B - bait.

store the fish). By living in this marine environment, the fishers can recognize and identify the best fishing grounds and environmental conditions to catch various target species. The empirical knowledge about the dynamics of environmental factors (winds, tides, currents and moon phases) and the ethology of the target species allow the fishers to understand the marine environment and consequently, increase their chances of catching the fishery resources (Diegues 2004, Begossi 2006, Berkes & Turner 2006).

2. *Characterization and commercialization of fish*

The fishers of Guaxindiba have vast LEK about fishing resources on the northern coast of Rio de Janeiro, which is demonstrated by their recognition of target species and their occurrence characteristics. In this study, 39 species were recorded as having commercial value in the region. This number is slightly greater than those recorded in previous studies conducted for fishing ports near our local study (Di Beneditto 2001: 23 species of commercial importance, Oliveira et al. 2016: 17 species, Zappes et al. 2016: 29 species).

The spatial distribution of the fish in the water column allowed some habitat categories to be assigned by the artisanal fishers. Studies indicate that spatial location of fish in a marine environment influences the definition of fishing strategies and fishing gear used by Brazilian fishers (*e.g*., Diegues 1998, Silvano et al. 2006, Silvano & Begossi 2010, Bezerra et al. 2012). Most of the target species caught is concentrated near the coast (border, ARs and estuary). Some species are caught 30 km from the coast and have a high commercial value (some primary fish) due to their quality and size, besides the higher fishing cost in remote regions. In this context, the implementation of the ARs resulted in benefit to the fishers and these structures emerge as an ancillary fishing area to capture some commercial species as *C. parallelus*, *C. undecimalis, R. porosus* and *R. lalandii* (Lima et al. 2018). After the implantation of ARs the local fishermen captured some target species closer the coastal zone with fewer inputs. The role of ARs in the enrichment of fish stocks is demonstrated in others regions of the world (e.g., Portugal: Ramos et al. 2011, India: Kassim et al. 2013; France: Tessier et al. 2015, Philippines: Macusi et al. 2017, Scotland: Rouse et al. 2018).

Another important question to consider is that categorizing the target species is mainly based on their economic value, which is influenced by gastronomic characteristics and the amount of each available species. In Brazil, artisanal fishers use various emic systems to classify target species, which is dependent on use and cultural significance; however the fishermen preference may increase the pressure on certain target species (Berry 1999, Berkes et al. 2006, Silvano & Begossi 2012, Santos & Alves 2016).

Shrimp, especially the species *X. kroyeri*, is the main fishing resource in Guaxindiba. However, shrimp fishing with bottom trawl net capture a large number of young fish species and also some of lower commercial value (Eayrs 2007). It is estimated that for each kilo

Table 4. Annual calendar of the fish marketed by fishermen from the community of Guaxindiba, Brazil. Gray-light frames represent the months of capture of a target species and dark-gray frames represent the closed seasons established by Brazilian legislation (IBAMA 189/2008[1] and MPA/MMA 04/2015[2]).

Common name	Scientific name	J	F	M	A	M	J	J	A	S	O	N	D	US$	RS
"Anchova"	*Pomatomus saltatrix*													2.9	VU
"Bagre-amarelo"	*Aspistor luniscutis*													0.8	ND
"Bagre-bandeira"	*Bagre bagre*													2.0	NT
	Bagre marinus														
"Bagre-branco"	*Genidens barbus*													1.7	EN
"Bagre-calafate"	*Notarius grandicassis*													1.4	LC
"Bagre-urutu"	*Genidens genidens*													1.4	LC
"Baiacu-ará"	*Lagocephalus laevigatus*													2.3	LC
"Cação-galha-preta"	*Carcharhinus porosus*													4.2	CR
"Cação-olho-verde"	*Rhizoprionodon porosus*													4.2	VU
"Cação-torce-torce"	*Rhizoprionodon lalandii*													3.7	NT
"Cação-viola"	*Rhinobatos percellens*													2.9	NT
"Camarão-barba-russa"	*Artemesia longinaris*[1]													3.0	ND
"Camarão-rosa"	*Farfantepenaeus paulensis*[1]													4.2	ND
"Camarão-sete-barbas"	*Xiphopenaeus kroyeri*[1]													3.4	ND
"Camarão-branco"	*Litopenaeus schmitti*[1]													8.6	ND
"Corvina"	*Micropogonias furnieri*													2.3	LC
"Goete"	*Cynoscion jamaicensis*													1.7	LC
"Goibira"	*Oligoplites saliens*													4.0	LC
"Lagosta-comum"	*Panulirus* spp													8.6	ND
"Lagosta-rainha"	*Panulirus argus*													8.6	ND
"Papa-terra"	*Menticirrhus americanus*													1.7	LC
"Pargo"	*Lutjanus analis*													1.4	NT
"Parú"	*Chaetodipterus faber*													1.7	LC
"Pescada-banana"	*Nebris micros*													2.9	LC
"Pescada-branca"	*Cynoscion microlepidotus*													2.9	NT
"Pescada-selvagem"	*Cynoscion virescens*													5.2	NT
"Pescadinha"	*Isopisthus parvipinnis*													1.2	LC
	Macrodon ancylodon														
"Raia-marrom"	*Hypanus americanus*													0.6	VU
"Robalo-fincudo"	*Centropomus undecimalis*													5.7	NT
"Robalo-peva"	*Centropomus parallelus*													5.7	NT
"Sabãozinho"	*Peprilus paru*													0.6	LC
"Sarda"	*Scomberomorus maculatus*													2.9	LC
"Sargo-de-beiço"	*Anisotremus surinamensis*													2.9	NT
"Sargo-de-dente"	*Archosargus probatocephalus*													2.9	LC
"Tainha"	*Mugil liza*[2]													2.9	LC
"Xarelete"	*Caranx crysos*													1.7	LC
"Xaréu"	*Caranx latus*													1.7	LC

US$ - Average value of the species (one pound) in dollars. RS - Risk situation of target species established by IUCN (2017) and (MMA, 2014): LC - least concern, NT - near threatened, VU - vulnerable, EN - endangered, CR - criticaly endangered and ND - no data.

of shrimp there is about four to six kilos of by-catch (Beckman 2013, Fernandes et al. 2014). In Guaxindiba, part of the by-catch (mixed fish) is sold at a low price and the other part (bait fish) is used to fish for species of higher commercial value. The shark species of the family Carcharhinidae, for example, deserve the greatest attention because they are particularly vulnerable to the effects of overfishing and also to bottom gears (Lack & Sant 2011). Studies conducted in the Southeast Region of Brazil have demonstrated that low-selectivity fishing gear is considered one of the factors responsible for the decrease in fishing stocks and degradation of the seabed (São Paulo: Souza et al. 2007, Rio de Janeiro: Vianna 2009, Fernandes et al. 2014, and Espírito Santo: Musiello-Fernandes et al. 2017).

Despite the frequent use of bottom trawling, this equipment is not used in the vicinity of the ARs. The ARs have provide refuge and feeding areas for local species, since these artificial structures prevent the use of bottom gears and their negative impact on seabed health (Seaman & Jensen 2000, Conceição & Nascimento 2009). Practices that control the use of active gears should be encouraged for the Guaxindiba coast. Thus, this study and several researches along 20 years suggest that the deployment of ARs can contribute to the sustainable management of fishery resources in northern Rio de Janeiro (Zalmon et al. 2002, Brotto et al. 2006, Santos et al. 2008, Santos et al. 2010, Rocha et al. 2014, Santos & Zalmon, 2015).

Defining fishing seasons is one of the rules adopted to limit the exploitation of fishery resources. In northern Rio de Janeiro, the Normative Instruction nº 195/2008 by IBAMA defines the fishing seasons and protection of reproductive periods of the ichthyofauna (IBAMA 195/2008). Some species, such as mullet (MPA/MMA 04/2015) and shrimp (IBAMA 189/2008) have their own rules that define off seasons when commercial fishing is prohibited. However, most species caught in northern Rio de Janeiro do not have fishing seasons defined and the seasons are determined by the fishers. In Guaxindiba, fishing season of target species is defined according to rainfall and outflow rates of Paraiba do Sul River. However, local fishers recognize that fishing period can change due to environmental variations that influence the life cycle (reproduction period) and ontogenetic cycle (differences in habitat between juveniles and adults) of some target species. Previous studies have also found an association between fishing period and greater precipitation or drought period in many communities along the Brazilian coast (*e.g.*, southeastern Brazil: Begossi 1996 and Silvano et al. 2010, northeastern Brazil: Costa-Neto 2001 and Pinto et al. 2015).

In general, the fish price in Guaxindiba has been influenced by the availability of target species and also by the marketing chain of fish. Intermediaries and owners of local markets that make up the end of the production chain of fish in the region are responsible for increasing the prices of target species caught by the artisanal fishers, which reduces the profit made by the fishers (producer). Vianna (2009), through diagnosing the production chain of fish in Rio de Janeiro, found that seasonality of target species supply is one of the factors that influence the final price of a fishing resource. In addition, the costs related to fishing include inputs (fuel, fishing gear, ice, meals on the boat) and fish processing (salting, filleting, deboning), which also influence the final price. Other studies in Brazil point that the length of the production chain is included in the final cost of the fish; the longer the production chain, the higher the final consumer price (Santos 2005, Rapozo 2011, Musiello-Fernandes et al. 2017). These studies demonstrated that higher price of commercialized fish species is due to intermediaries and owners of local markets, as occurs in Guaxindiba. Despite this usual way of commercializing fish, there have been initiatives to shorten the production chain and increase the profits of the producer (fisher). Thus, the creation of local cooperatives should be encouraged in order to make artisanal fishing socially just and environmentally less destructive. Long-term actions that consider such recommendations could contribute to co-managing fishery resources and maintaining artisanal fishing in northern Rio de Janeiro.

Our results provide different contributions to the fishery management on the northern coast of Rio de Janeiro related to the main target species. In addition, we show some data about the vulnerability of several local species. The use of these information's and the annual calendar of commercial species provide important data that can support new proposals for fishing regulations, especially fishing species not yet regulated by law. Our findings also provide new data about species associated to artificial structures, mainly of commercial interest. These results are important because it complements past data related to fish assemblages associated with ARs on the northern coast of Rio de Janeiro and reinforces the importance of these structures to local fishing.

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Author Contributions

Juliano Silva Lima: Substantial contribution in the concept and design of the study; Contribution to data collection; Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intelectual content.

Camilah Antunes Zappes: Contribution to data analysis and interpretation; Contribution to critical revision, adding intelectual content.

Ana Paula Madeira Di Beneditto: Contribution to data analysis and interpretation; Contribution to critical revision, adding intelectual content.

Ilana Rosental Zalmon: Contribution in the concept and design of the study; Contribution to manuscript preparation; Contribution to critical revision, adding intelectual content.

Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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