Ambio 2017, 46:907–914
DOI 10.1007/s13280-017-0931-9

KUNGL. VETENSKAPS-AKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES

REPORT

Threatened fish and fishers along the Brazilian Atlantic Forest Coast

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Received: 10 October 2016 / Revised: 3 March 2017 / Accepted: 10 June 2017 / Published online: 14 July 2017

Abstract Small-scale fisheries of the Brazilian Atlantic Forest Coast (BAFC) depend on fish resources for food and income. Thus, if the catch diminishes or if fish species that are a target for fishers are overexploited or impacted, this could affect fishers' livelihoods. The exclusion of threatened fish species from the catch is believed to be a threat to small-scale fisheries, which is likely to be the case along the BAFC. Many fish species are currently listed as threatened or vulnerable, whereas there is not enough biological information available to determine the status of the majority of the other species. Failure to protect the BAFC biodiversity might negatively impact fishers' income and the regional economy of local small-scale fisheries. We collected data from 1986 to 2009 through 347 interviews and 24-h food recall surveys at seven southeastern coastal sites of the Atlantic Forest. We show that important species of consumed fish are currently threatened: of the 65 species mentioned by fishers as the most consumed fishes, 33% are decreasing and 54% have an unknown status. Thus, biological and ecological data for BAFC marine species are urgently needed, along with co-management, to promote fish conservation.

Keywords Biodiversity · Coastal · Conservation evaluation · Fish · Fishing · Littoral · Ocean

INTRODUCTION

Overfishing has impacted the biodiversity of aquatic ecosystems (Jackson et al. 2001; Pauly et al. 2002; Myers and Worm 2003; Worm et al. 2006), whereas other factors, such as pollution, have likely caused habitat destruction and decreases in fish populations. In Brazil, areas affected by overfishing and pollution include Sepetiba Bay, which lies along the Coast of Rio de Janeiro (Lacerda and Molisani 2006), and coastline regions near the nuclear power plants in Rio de Janeiro and São Paulo. Small-scale fisheries can also impact fish species (Pinnegar and Engelhard 2007): at some sites, such as in the Philippines, the Seychelles and the Fijian reefs, artisanal fisheries have impacted target fish species. Pollution and/or overfishing, depending on the site and the species of fish, can also affect the fishers that depend upon the target species, which might be the same ones that have already been impacted.

Despite the long history of the importance of fish to the food security of human populations (McClanahan et al. 2015; Béné et al. 2015, 2016), few studies have shown a direct association between the consumption of fish species and food security. Small-scale fisheries ensure incomes for millions of people worldwide, especially in developing countries (Andrew et al. 2007; De Graaf et al. 2011). In such countries, fishing does not guarantee high earnings, but it can prevent food deprivation and poverty (Béné 2006). Due to the high species diversity in available fish catches along the Brazilian Atlantic Forest Coast (BAFC), fish diversity is particularly important for the livelihoods of the residents of this region; for example, at Búzios Island and in Sepetiba Bay in SE Brazil, approximately 70–110 species are used for food and are important in local culture and for commercial purposes (Begossi and de Figueiredo

Electronic supplementary material The online version of this article (doi:10.1007/s13280-017-0931-9) contains supplementary material, which is available to authorized users.

1995). Fish, in particular, is very important in the BAFC region.

Fishing is a traditional activity that has ecological and cultural importance and helps maintain economic livelihoods along the Atlantic Forest coast and in the Amazonian rivers (Begossi 1992, 2014; Begossi et al. 2004, 2012a; Hallwass et al. 2011; Hallwass and Silvano 2016). Local fishes are important as food and some are also culturally important, being used for example in local medical practice to treat illnesses or consumed during such periods (Begossi et al. 2004). Among the riverine inhabitants of the Amazon and the small-scale fisheries of the Atlantic Forest coast, fishers and their families have depended on fish since the 1950s for sale in regional markets and for consumption; before the 1950s, especially in the BAFC, manioc flour was one of the main products sold (Begossi 2014). Along the BAFC, small-scale fisheries, mostly of the Caiçara culture, rely heavily on fish, and they supply fish to regional markets (Diegues 1983; Begossi and Richerson 1993; Hanazaki et al. 2013). Therefore, the small-scale fisheries of the BAFC affect and are affected by the availability of aquatic resources and by fish diversity. Considering that "fisheries" include both the fish and the fishers, any impact on the fish would affect the fishers, since they depend on the fish to sustain their livelihoods.

The decline of fishery resources increases food insecurity, with many examples available from African countries (McClanahan et al. 2015). In the present study, our main goal was to conduct a meta-analysis of data collected over more than 20 years on fish that were consumed in seven communities with small-scale fisheries along the BAFC to investigate the potential relationship between fish consumption and their conservation status.

MATERIALS AND METHODS

We accessed data that were collected during different periods from 1986 to 2009 from BAFC small-scale fisheries (Fig. 1). The included studies were all conducted on small-scale fisheries run by people who depended upon aquatic resources for a living. We collected data from seven different communities from the Rio de Janeiro and São Paulo coasts: four located on the Islands of Búzios, Vitória, Jaguanum and Itacuruçá and three located along the coast (Puruba, Picinguaba and Praia Grande/Paraty) (Fig. 1 and Appendix S1). These studies were conducted as part of earlier projects coordinated by one of the authors (AB) and were supported especially by Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP) but also by Fundação de Amparo a Pesquisa do Estado do Rio de Janeiro (FAPERJ). The data were deposited in the archives of the Fisheries and Food Institute (www.fisheriesandfood.org). Some of the data analysed here were published in Begossi and de Figueiredo (1995) and Begossi et al. (2012b, 2013).

In this study, we used two different methods: interviews and direct sampling of the fish species included in their

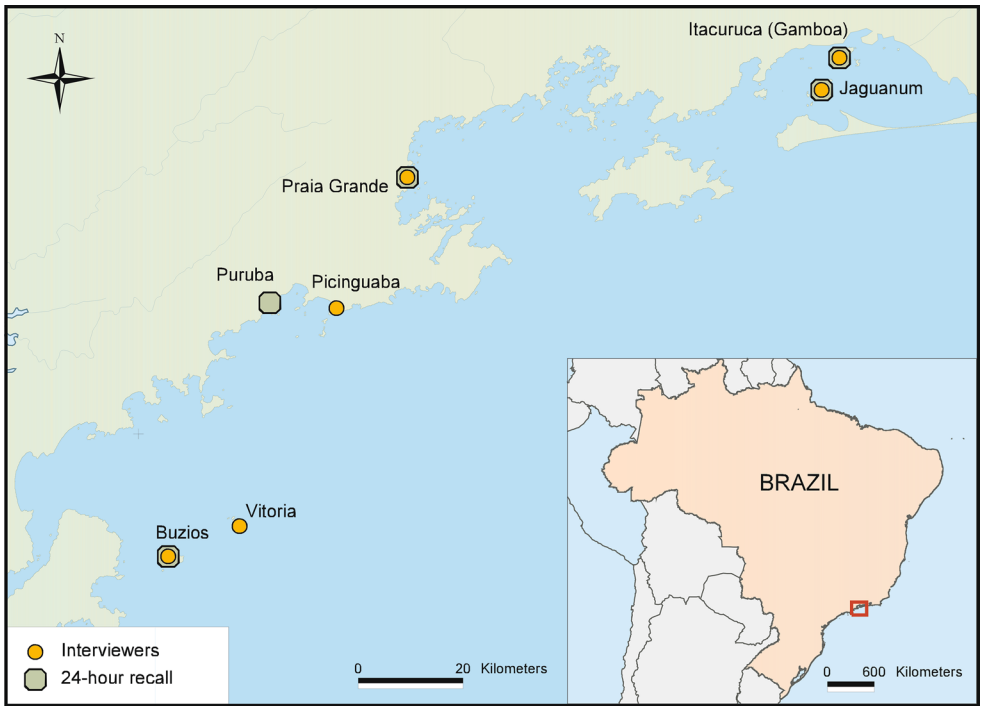

Fig. 1 Map of the study area including communities of the BAFC

Table 1 Results from interviews (20% or more citations) and 24-h recall diet (20% or more citations in interviews)

Atlantic Forest/fish	*Pomatomus saltatrix* (bluefish-enchova)	*Cynoscion* spp. (weakfish-pescada)	*Micropogonias furnieri* (sand drum-corvina)	*Trichiurus lepturus* (cutlass fish-espada)	*Epinephelus marginatus* (dusky grouper-garoupa)	*Caranx* spp. (bluerunner-xarelete)	*Mugil curema* parati	*Menticirrhus americanus* imbetara
Búzios Island	F1 (27) F2 (25) D1 (33)				F1 (18)	F1 (24)		
Vitória Island	F1 (46)				F1 (27)			
Itacuruçá Island (Gamboa)		F1 (27)	F1 (22) F2 (31)					D2 (24)
Paraty		F1 (25)						
Jaguanum Island			F1 (46) F2 (24)					
Picinguaba				F1 (26)	F1 (20) F2 (55)			
Puruba							D1 (40) D2 (26)	

diets: diet recall within 24 h of a meal, which means a diet survey based on a 24-h food recall of the protein consumed at lunch and dinner.

In the interviews, we asked fishers to answer the question "What fish species do you consume the most?", and we compiled the first and second answers, referred to here as "FISH1" and "FISH2" (F1 and F2, respectively), provided by the person being interviewed. Diet recall (diet survey based on a 24-h food recall of the protein consumed at lunch and dinner) data collection was conducted at some communities (Búzios Island, Puruba, and Jaguanum and Itacuruçá Islands). We also compiled the first and second answers from the diet recall surveys (LUNCH 1 and LUNCH 2 and DINNER 1 and DINNER 2) (referred to as Diet, D1 and D2, respectively).

We analysed the responses from a total of 347 interviews and 1904 results from meals at the seven sites (Table 1; Fig. 1). Fish is a very important food source for coastal fishers, representing approximately half of the animal protein they consumed. Hanazaki and Begossi (2003) showed that, at some sites, approximately 32% of interviewed people depended upon fish as the main animal protein consumed, while at others, this proportion was 68% (Hanazaki and Begossi 2003).

RESULTS

In this study, we show that the exhaustion of coastal and riverine resources is likely to affect the food security and livelihood of small-scale fishers. We investigated several examples of fish species obtained and consumed by fishers in small-scale fisheries and their current conservation status according to the The International Union for the Conservation of Nature (IUCN) Red List of Endangered Species and the most recent Brazilian Red List, which was published in November 2014. Information from fishers is important for data-poor fisheries, such as small-scale fisheries from Brazil, since there is no systematic collection of data on fish catches in these fisheries (Begossi 2010; Lopes et al. 2013). The available information is usually found in the data base www.fishbase.org (Froese and Pauly 2016), but it does not provide sufficient details for specific sites.

The most consumed fish

The most consumed fish species reported in the interviews and the diet surveys along the BAFC varied among the sites and included mullet (*Mugil* spp.), sand drum (*Micropogonias furnieri*), bluefish (*Pomatomus saltatrix*), and weakfish (*Cynoscion* spp.). In some areas (islands), reef fishes, such as the dusky grouper (*Epinephelus marginatus*), were very important, and in other areas, such as along bays, weakfish and sand drum (whitemouth croaker) were more important (Table 1).

Table 1 shows the relative importance of the different fishes. For example, bluefish is a very important species for local consumption by the fishers from Búzios Island. Its importance to their livelihoods was also published elsewhere, where it was shown that this species is also relevant in the local and regional markets (Begossi 1996a, b). The

Spearman correlation coefficient between the interview results and the diet recall data was 0.55 ($df = 80$, $p < 0.001$), reinforcing the association between these datasets. In many cases, especially for the target and most important species, the results of the general interviews and diet recall interviews were positively correlated.

The conservation status of fishes

This study did not intend to detail the fish making up the diets of BAFC fishers since this has already been extensively published in the aforementioned studies. The main goal of this study was to determine the main target fish used for food and their current conservation status.

Information on the conservation status of the fishes is shown in Table 2. As not all species are included in each source list, the total sample differs when we use different lists of threatened species. The restrictions of the latest Brazilian Red List were suspended by the Brazilian government (Pinheiro et al. 2015). In the Atlantic Forest, among the 65 fish species cited by the fishers, the population trends of 33% are decreasing and 54% have an unknown status ($n = 54$, IUCN List, Table 2). Thirty-eight percent of the species are critically endangered, vulnerable or near-threatened, and 21% have insufficient data or have not been assessed ($n = 59$).

DISCUSSION

Our results identify those fish species that are important in supplying protein to small-scale fishers along the BAFC. Captures from fisheries improve nutrition and food security and help prevent or reduce poverty in developing tropical countries (Béné et al. 2016). We show that fish considered as endangered or threatened, such as the dusky grouper (*E. marginatus*) (Begossi and Silvano 2008; Begossi et al. 2016), are valuable food sources for local fishers. This species, in particular, is highly prized in regional and world markets (Trotta et al. 2005; Begossi et al. 2016). Our results support the view that threats to coastal tropical fish can directly affect small-scale fishers and their livelihoods.

A decrease in the supply of fish as a food source may have indirect consequences on these populations, their livelihoods and the local biodiversity-rich ecosystems. Also, a decrease in fish populations can lead to the classical 'fishing down the food web' scenario (Pauly 1995), increase the use of land for agriculture and deforestation rates (Orr et al. 2012), and exacerbate current conflicts between the fishers and government managers of protected areas (Begossi et al. 2011; Lopes et al. 2013).

We do not know how a decrease in the fish supply along the BAFC could affect local livelihoods in terms of a shift towards agriculture. Historically, until the 1950s, inhabitants along the BAFC relied on agriculture; low prices for agricultural products probably made them turn to fishing. If returns from fishing start to be difficult to sustain, local inhabitants could probably concentrate on tourism (Begossi 2006). However, an impact on their subsistence could still occur as species start to be difficult to catch since marine protein is an important part of their diet, especially because hunting has been forbidden for many years in the BAFC region (Hanazaki et al. 2009).

In Brazil, management often assumes a top-down approach, and both protected areas and industrial fisheries are often in conflict with small-scale fisheries (Begossi 2010; Begossi et al. 2011; Lopes et al. 2013). Unfortunately, the Brazilian government has suspended the restrictions of the Brazilian Red List along with the spawning closures (Table 1 and Pinheiro et al. 2015), which might affect fish species (Table 2). Although there are ongoing conservation efforts to protect large, commercially valuable and threatened flagship fish species (Gerhardinger et al. 2009), most of the threatened or poorly known fish species that are consumed by small-scale fishers, as reported in this study, have not been the focus of conservation efforts. For example, groupers and snappers (*Lutjanus* spp.) are important food fishes that have been heavily fished in some regions along the Brazilian coast (Begossi and Silvano 2008; Begossi et al. 2012c).

Even though fishers could be badly affected if catches of their target fish species become diminished, it will be difficult for them to support the many governmental initiatives directed towards protected areas. The reasons are manifold, but one is certainly the top-down approach, as well as the blind eye shown towards the actions of politically influential industrial fisheries and tourism companies (Begossi et al. 2011; Lopes et al. 2015). Therefore, approaches that could induce fishers to support the local management of species would be welcome. Such approaches might include economic tools, such as payment for environmental services (Begossi et al. 2011), which could provide a balance and integrative process of conservation, management and the maintenance of local fishing and local fish protein consumption.

CONCLUSION

Fishes such as rays (raia/arraia) (*Atlantoraja cyclophora*), mullets (tainha) (*Mugil platanus*), bluefish (enchova) (*P. saltatrix*), sand drums (corvina) (*M. furnieri*), and dusky groupers (garoupa) (*E. marginatus*) are examples of

Table 2 Conservation status of fish consumed in coastal (Atlantic Forest)

Popular names	Scientific names[a]	Species "spp."	IUCN	Population trend (IUCN)	Brazilian Red List[b]	Ordinance N° 445/2014 (**Suspended**)[c]
Arraia	*Atlantoraja cyclophora*		VU	Decreasing	NA	NA
	Dasyatis guttata		DD	Unknown	NA	NA
	Dasyatis spp.	*D. americana*	DD	Unknown		
		D. centroura	LC	Unknown		CR
		D. hypostigma	DD	Unknown		
		D. colarensis				VU
	Myliobatis spp.	*M. freminvillii*	DD	Unknown		EN
		M. goodei	DD	Unknown		CR
		M. ridens				CR
	Raja cyclophora		NA		NA	NA
	Rhinoptera bonasus		NT	Unknown	NA	NA
Barana	*Elops saurus*		LC	Stable	NA	NA
Cação	*Carcharhinus* spp.					
		C. acronotus	NT	Decreasing		
		C. brevipinna	NT	Unknown		
		C. falciformis	NT	Decreasing		
		C. isodon	LC	Unknown		
		C. leucas	NT	Unknown		
		C. limbatus	NT	Unknown		
		C. longimanus	VU	Decreasing	Overexploited or threatened overexploitation	VU
		C. obscurus	VU	Decreasing		EN
		C. perezi	NT	Decreasing		VU
		C. plumbeus	VU	Decreasing		CR
		C. porosus	DD	Unknown	Overexploited or threatened overexploitation	CR
		C. signatus			Overexploited or threatened overexploitation	VU
		C. galapagensis				CR
	Rhinobatos horkelii (cação viola)		CR	Decreasing	EN	NC
	Rhinobatos percellens (cação viola)		NT	Unknown	NA	NA
	Rhizoprionodon porosus		LC	Stable	NA	NA
	Rhizoprionodon lalandii		NA		NA	NA
	Sphyrna spp.	*S. media*	DD	Unknown		CR
		S. mokarran	EN	Decreasing		EN
		S. tiburo	LC	Unknown	Overexploited or threatened overexploitation	CR
		S. tudes	VU	Decreasing		CR
		S. zygaena			Overexploited or threatened overexploitation	CR
	Sphyrna lewini		EN	Unknown	VU	CR
	Squatina sp. (cação anjo)	*S. argentina*	EN	Decreasing		CR
		S. guggenheim	EN	Decreasing	CR	CR
		S. occulta			CR	CR
		S. punctata	EN	Decreasing		

Table 2 continued

Popular names	Scientific names[a]	Species "spp."	IUCN	Population trend (IUCN)	Brazilian Red List[b]	Ordinance N° 445/2014 (**Suspended**)[c]
	Eugomphodus taurus		NA		NA	NA
Corvina	*Micropogonias furnieri*		LC	Decreasing	NA/overexploited or threatened overexploitation	NA
	Umbrina coroides		LC	Unknown	NA	NA
	Conodon nobilis		LC	Unknown	NA	NA
Enchova	*Pomatomus saltatrix*		VU	Decreasing	NA/overexploited or threatened overexploitation	NA
Espada	*Trichiurus lepturus*		LC	Stable	NA	NA
Garoupa	*Epinephelus marginatus*		EN	Decreasing	NA/overexploited or threatened overexploitation	VU
	Epinephelus morio		NT	Decreasing	NA/overexploited or threatened overexploitation	VU
Imbetara	*Menticirrhus americanus*		LC	Unknown	NA	NA
Palombeta	*Chloroscombrus chrysurus*		LC	Stable	NA	NA
Panaguaiú	*Hemiramphus balao*		LC	Unknown	NA	NA
Parati	*Mugil curema*		LC	Unknown	NA	NA
Pescada	*Cynoscion guatucupa*		NA		NA/overexploited or threatened overexploitation	NA
	Cynoscion jamaicensis		LC	Stable	NA	NA
	Cynoscion leiarchus		LC	Stable	NA	NA
	Cynoscion spp.	*C. microlepidotus*	LC	Unknown	NA	NA
	Cynoscion virescens		LC	Unknown	NA	NA
	Cynoscion acoupa		LC	Unknown	NA	NA
	Isopisthus parvipinnis		LC	Unknown	NA	NA
	Macrodon ancylodon		LC	Decreasing	NA/overexploited or threatened overexploitation	NA
	Nebris microps		LC	Unknown	NA	NA
Robalo	*Centropomus parallelus*		LC	Unknown	NA	NA
	Centropomus undecimalis		LC	Unknown	NA	NA
Tainha	*Mugil platanus*		NA		NA/overexploited or threatened overexploitation	NA
Xarelete	*Caranx crysos*		LC	Unknown	NA	NA
	Caranx hippos		LC	Stable	NA	NA
Total number	65		59	54	43	56

Data from 1986 to 2009 from interviews ($n = 347$) and on most consumed fish (first two mentioned species) as well as 24 h food recall, at seven Atlantic Forest coast communities (Búzios, Vitória, Jaguanum and Itacuruçá Islands, and the coastal communities of Puruba, Picinguaba and Paraty) on the Coast of São Paulo and Rio de Janeiro

NA not assessed, *DD* data deficient, *LC* least concern, *NT* near threatened, *VU* vulnerable, *EN* endangered, *CR* critically endangered, *EW* extinct in the wild, *EX* extinct

[a] Fish was identified based on Begossi and de Figueiredo (1995) and Begossi et al. (2013)

[b] Based on Normative Instruction N° 5, 21th May 2005

[c] Ordinance of Ministry of the Environment N° 445, 17th December 2014—Suspended. This list (Portaria 445/2014) was made official in 2014, suspended in 2015 and turned to be official again after June 26, 2016

threatened species along the BAFC. These aquatic resources are important for fishers' livelihoods. From the 65 fish species mentioned by fishers in interviews as the most consumed, 33% of them ($n = 54$) are decreasing and 54% have an unknown biological status due to a lack of data. In particular, *E. marginatus*, the dusky grouper, a

sedentary and slow-growing reef fish, is very important as a source of food and income, and this species is currently endangered. Attention should be given to fish and to the food security of fishers from the BAFC through research and co-management. It is important to identify those fishes that are the most important for sustaining livelihoods and providing food security, particularly those that are the most endangered. Policies to conserve these fish species, including efforts towards the collection of biological data regarding these species, should be established before they disappear. Moreover, policies that can engage fishers in conservation plans might have greater possibilities of success if they are based on the importance of fish to local livelihoods, among other factors.

Acknowledgements We are very grateful for FAPESP Grants from 1996 to 2014 (#14/24994-8), FAPERJ (1989), CNPq (1990), and Productivity Scholarships CNPq to AB, NH, PFL and RAMS.

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