View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Elsevier - Publisher Connector

NAT CONSERVACAO. 2014; **12(1):**11-18

Natureza & Conservação
Brazilian Journal of Nature Conservation
Supported by O Boticário Foundation for Nature Protection

Essays and Perspectives

Threats to sharks in a developing country: The need for effective and simple conservation measures

Hugo Bornatowski[a,*], *Raul Rennó Braga*[a], *Jean Ricardo Simões Vitule*[b]

[a] *Universidade Federal do Paraná – UFPR, Curitiba, PR, Brazil*
[b] *Laboratório de Ecologia e Conservação, Universidade Federal do Paraná – UFPR, Curitiba, PR, Brazil*

ARTICLE INFO

Article history:
Received November 2013
Accepted January 2014

Keywords:
Conservation
Elasmobranchs
Fisheries
Management
Mislabeling
Shark attack

ABSTRACT

Reductions of shark populations produce negative ecological and economic consequences. Overfishing is the primary threat to these reductions; however, two other indirect problems can be mentioned as threats to sharks populations: shark meat mislabeling, and shark attacks. In this study, we use Brazil as an example to focus on these three critical problems related to shark conservation: the lack of proper, specific identification of landed species in the industrial and artisanal fisheries; shark attacks; and mislabeling in markets. We discuss these situations, highlighting brief examples and conservation barriers. The main goal is to present these problems and provide simple, effective solutions. On the fisheries side, the solution lies in having trained personnel at specific landing ports. Implementation of this practice would also aid in the solution to the mislabeling of shark meat. However, whenever this does not occur, supermarkets or any other final seller should be held legally responsible for the identification. At this stage, genetic techniques such as DNA barcoding must be used. Regarding the shark attack problem, the only truly efficient solution with no indirect effects is education and taking the matter to society, rather than waiting until there is a shark attack incident. The government needs to invest more funds on educational awareness programs and research to avoid encounters with sharks. We must ensure that the society does not see sharks as villains, but instead as key elements in maintaining the ecosystem services that are so valuable to human well-being.

© 2014 Associação Brasileira de Ciência Ecológica e Conservação.
Published by Elsevier Editora Ltda.

Introduction

Human populations worldwide rely on sharks both directly and indirectly; however, they are generally unaware of this dependence. First, sharks, as apex predators, exert top-down effects by controlling prey populations; therefore, declines in shark populations can lead to cascading effects in ecosystems (e.g., reduction of commercial scallops in northeast Atlantic,

*Corresponding author at: Rua Benedito Conceição, 407, 82810-080, Curitiba, PR, Brazil.
E-mail address: anequim.bio@gmail.com (H. Bornatowski).
1679-0073/$ - see front matter. © Associação Brasileira de Ciência Ecológica e Conservação. Published by Elsevier Editora Ltda.
DOI: 10.4322/natcon.2014.003

see Myers *et al.* 2007). Second, shark meat provides much of the protein requirement for poorer communities (WildAid 2007), and many communities depend on small-scale fisheries for subsistence. Third, in some regions shark tourism generates thousands of dollars per year (Vianna *et al.* 2012). In summary, reductions of shark populations can lead to negative consequences in both an ecological and an economic sense.

Biological characteristics of Chondrichthyes, such as long generation times and low growth and reproductive rates (Cahmi *et al.* 1998), make them especially susceptible to overexploitation and extinction. Due to their low resilience, the majority of elasmobranch populations, particularly large sharks, decline more rapidly and are not able to respond as quickly as other fish to reductions in their populations caused by fisheries (Musick *et al.* 2000). Estimates of fishing mortality demonstrate that, in the current intensity of fishing pressure, large sharks and other sensitive species will become extinct in the near future (Myers & Worm 2005).

Recent worldwide attempts to organize the commercial capture of sharks, prompted by stock assessments, overfishing, or conservation needs have encountered numerous difficulties related to the establishment of fishing limits and controls (Pauly *et al.* 2013). Unfortunately, many sharks are frequently not recorded in fisheries statistics, and only 15% are identified and reported at the species level, according to the United Nations Food and Agriculture Organization (FAO; see Dulvy *et al.* 2008). The lack of species identification appears to be a chronic problem for industrial and artisanal fisheries, making the suitable management of fisheries, as well as the supervision of species protected by law, very difficult or even impossible to implement.

Although fisheries appear to be the main direct threat to sharks and rays, elasmobranch populations face a variety of additional threats, including habitat degradation, pollution, and climate change (Simpfendorfer *et al.* 2011). Two other problems, often neglected and underestimated, are mislabeling of shark meat by final sellers and shark attacks.

Consumption of shark meat has been recorded since the fourth century (Vannuccini 1999). Today, shark meat is eaten all over the world, although in some places there is a cultural barrier to its consumption (Vannuccini 1999; Bornatowski *et al.* 2013). While shark meat provides much of the protein requirement in poorer communities in developing countries, in developed countries it is viewed as a low-quality meat, and a name-change was necessary to overcome consumer resistance (Vannuccini 1999; WildAid 2007; Bornatowski *et al.* 2013). As exceptions, shortfin mako (*Isurus oxyrinchus*), thresher (*Alopias vulpinus*), and porbeagle (*Lamna nasus*) sharks have a highly palatable meat, comparable to swordfish (*Xiphias gladius*) meat in the United States and Europe (Vannuccini 1999).

Erroneous identification or intentional mislabeling of elasmobranchs is a large problem in some countries, creating a barrier to conservation (Bornatowski *et al.* 2013). The U.S. government issued rules to prevent mislabeling of shark meat. Previously, sharks were commercialized under other fish names, but now are sold under their real names (Vannuccini 1999). European Union regulations (Council Regulation 2000) require listing the species name on shark products in order to avoid fraud and to help conserve certain shark species (Blanco *et al.* 2008).

In addition to the two abovementioned problems (fisheries and meat mislabeling), the recent number of shark attacks is raising great concern among researchers. Shark attacks are a prominent problem in several countries, such as Australia, the United States, South Africa, and Brazil (International Shark Attack File [ISAF, https://www.flmnh.ufl.edu/fish/sharks/isaf/isaf.htm]). Shark attacks result in socioeconomic impacts, and some countries have worked to diminish these impacts through measures such as shark control programs (e.g., nets to avoid shark attack) in Australia and South Africa (Dudley 1997). Shark control programs aim to reduce populations of hazardous species that threaten humans, such as great white, tiger, and bull sharks. However, beyond killing large numbers of large sharks (apex predators that regulate inferior levels of food webs), these programs frequently lead to increased mortality of small elasmobranchs that are not dangerous, in addition to teleost fish, marine turtles, whales, dolphins, etc. (e.g., Dudley & Cliff 2003; 2010). Aside from the institution of shark attack control programs, public outcry after shark attack incidents frequently leads governments to take actions to kill sharks (Neff & Yang 2013). For instance, recent fatal shark attacks in Western Australia led the government to develop a plan to cull aggressive sharks (mainly great whites) in order to prevent attacks on humans (Cressey, 2013). In summary, both shark attack controls (nets or killing of sharks) and meat mislabeling amount to fishing on a large scale, further threatening the elasmobranch group.

Based on these questions, in this article we use Brazil as an example to focus on these three critical problems related to shark conservation: industrial and artisanal fisheries, shark attacks, and mislabeling in markets. We discuss these situations, highlighting brief examples and conservation barriers. The main goal is to present these problems and provide, effective solutions.

Industrial and artisanal fisheries: a case study from Brazil

Brazil is the fifth largest country in the world, with an exclusive economic zone covering ~4.5 million km^2, and a coastline of 8,500 km (Brasil 2011). Numerous artisanal fishing communities and industrial fishing harbors (e.g. Belém, Natal, Santos, and Itajaí) are found in coastal areas. However, some fisheries along the coast are poorly documented, and the broad identification levels of landed species (e.g. "sharks or rays") at nearly all sites makes species-specific regulation very difficult (Bornatowski *et al.* 2011; 2013). The Itajaí harbor, for instance, one of the main industrial harbors in southern Brazil, landed 2,353 tons of elasmobranchs in 2010, with over 85% not identified at the species level (UNIVALI/CTTMar 2011). This situation is even worse in artisanal fisheries (Sparre & Venema 1997; Costa *et al.* 2003). Approximately one million artisanal fishermen are recorded along the Brazilian coast (considering freshwater and marine areas), and small-scale fisheries are responsible for 45% of the national fishery production (Brasil 2011). The difficulty in monitoring all fishing communities along the Brazilian coast and obtaining accurate information regarding what is captured is enormous, and few measures are effective in estimating the total landed fish at multi-species and small scale fisheries (Alves *et al.* 2012). The location of the communities (far from large cities), the resistance of fishermen to provide biological or catch data, and the multiplicity of fishing gear are just some of the major obstacles to conducting an effective monitoring and management program for species caught by artisanal fisheries along the Brazilian coast (Polunin & Roberts 1996).

Here, we give examples highlighting two species rated as threatened by the International Union for Conservation of Nature and Natural Resources (IUCN 2013): the scalloped hammerhead shark, *Sphyrna lewini* (Griffith and Smith, 1834) considered endangered, and the smooth hammerhead shark, *S. zygaena* (Linnaeus, 1758) considered vulnerable. Both were added in 2013 to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; Appendix II, CITES 2013). These two species have declined by more than 95% in the northwestern Atlantic (Myers *et al.* 2007). In addition, the scalloped hammerhead shark has a higher economic interest than other species due to its fins (fin trade), leading to increased fishing pressure on this species (Baum *et al.* 2013). In Brazil, while industrial fisheries capture large individuals by longlines and gillnets (~ 80 tons of "hammerhead sharks" in 2009 - UNIVALI/CTTMar 2010) (Vooren *et al.* 2005), artisanal fisheries capture large proportions of neonates and juveniles (~ 15% *S. lewini* and 2.7% *S. zygaena*) over the continental shelf using gillnets and trawl nets (Gadig *et al.* 2002; Motta *et al.* 2005). Unfortunately, statistical data grouping all hammerhead shark species into a single category do not allow for a good assessment of conservation status of *S. lewini* and *S. zygaena* separately (Vooren *et al.* 2005).

While industrial fisheries appear to exert a greater impact on shark populations (Shepherd & Myers 2005; Myers *et al.* 2007; Dulvy *et al.* 2008), it is difficult to ascertain whether small-scale fisheries, as a whole, also contribute significantly to the decline of coastal and semi-coastal sharks (Walker 1998; Bornatowski *et al.* 2011). Nevertheless, artisanal fisheries along the Brazilian coast catch large numbers of neonate and juvenile elasmobranchs, suggesting a high potential impact on the rates of recruitment (Gadig *et al.* 2002; Vooren *et al.* 2005; Yokota & Lessa 2006; Bornatowski *et al.* 2011). It is also noteworthy that the Brazilian artisanal fishery is not primarily for subsistence (MPA 2012). It has a clear commercial interest, making it something of an industrial fishery, although at a smaller scale.

It is plausible that industrial and artisanal fishing play a complementary role in the depletion of elasmobranch stocks in Brazil (Kotas *et al.* 1995; Walker 1998; Vooren & Klippel 2005). First, they are spatially complementary, since artisanal fisheries operate nearer to the coast. Second, they are acting on different life stages—industrial fisheries have a more severe impact on large and/or adult individuals and artisanal fisheries are responsible for catching huge numbers of neonates and small-sized species (Kotas *et al.* 1995; Walker 1998; Vooren & Klippel 2005).

Urgent conservation measures need to be implemented in Brazilian waters; there are already 12 threatened elasmobranch species and eight species are overexploited or under threat of overexploitation (Brasil 2004) (Table 1). In 2013, the oceanic whitetip shark *Carcharhinus longimanus* (Poey, 1861); three species of hammerhead sharks *S. lewini, S. zygaena,* and *S. mokarran* (Rüppell, 1837); the porbeagle shark *L. nasus* (Bonnaterre, 1788); and manta rays *Manta* spp. were added to CITES Appendix II. Now, international trade of these species can only take place under CITES permits that ensure a legal and sustainable origin of the meat.

In Brazil, although there are laws restricting the length of gillnets and gillnet mesh-sizes, limiting the number of fishing vessels (Brasil 2012a), and prohibiting finning (Brasil 2012b), the control of fishery has been difficult. Effective monitoring of elasmobranch fishing can be performed through the training of onboard observers, and by employing trained individuals to monitor elasmobranch landings in all main harbors. However, these individuals need to know how to identify what is caught and which species can be found in landings. A simple fish guide, with didactical taxonomic and biological information, and a wide list of species common names, can be a good resource for fish identification. As an example, a elasmobranch field guide was developed to aid in species identification on the Paraná coast of Southern Brazil. This book is available online and everyone, from researchers to laymen, are capable of using it (Bornatowski & Abilhoa, 2012). However, fish guides can also lead to misidentifications since some species are difficult to distinguish morphologically (Ward *et al.* 2008). However, we do not think this is a major problem. Failing to distinguish a few, often rare, species will not strongly compromise rough estimates of catch data. In the first instance, the crucial point is to gather information on those species that are under intense fishing pressure, and thus, are present in the majority of landings. In this case, trained personnel will be used to identify the most common species.

Another option for artisanal monitoring are estimations based on yields recorded by fishermen, the focus of the participatory fisheries monitoring program proposed by Alves *et al.* (2012). Although this estimate is biased and should not be used to support increases in fishing, the methodology can help in the design of conservation strategies (Alves *et al.* 2012).

It is urgent and necessary to create a national program of fishery statistics with wide spatial and temporal coverage, with extensive species-catch monitoring throughout the Brazilian coast. However, the reliability of data follows a correct identification of elasmobranchs species, as cited above. Without an overview on fishery catches and correct species-specific information, any monitoring will fail.

Shark mislabeling in Brazilian markets

Different popular names are often used for elasmobranch meat, so that the general population does not associate the wild animal with the meat they are consuming, avoiding the previously mentioned consumer's prejudice to these meats (Bornatowski *et al.* 2013). This practice imposes a serious barrier to conservation measures on shark meat consumption, as it becomes very difficult, for example, to promote the consumption of non-threatened species. In addition, shark meat mislabeling is of great concern to human health as well.

Table 1 - Threatened species of Brazil mentioned in the Normative Instruction – NI-05/2004 (Brasil 2004) in comparison with the International Union for Conservation of Nature Red List (IUCN 2013) and Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2013) status.

Species	NI - 05	IUCN	CITES
Sharks			
Squatinidae			
Squatina guggenheim Marini, 1936	Threatened	Endangered	
S. occulta Vooren & Silva, 1991	Threatened		
Ginglymostomatidae			
Ginglymostoma cirratum (Bonnaterre, 1788)	Threatened	Data deficient	
Rhincodontidae			
Rhincodon typus Smith, 1828	Threatened	Vulnerable	
Odontaspididae			
Carcharias taurus Rafinesque, 1810	Species overexploited or threatened with exploitation.	Vulnerable	
Cetorhinidae			
Cetorhinus maximus (Gunnereus, 1765)	Threatened	Vulnerable	
Lamnidae			
Lamna nasus (Bonnaterre, 1788)[a]	Excluded of NI 05/04 according to Normative Instruction - NI 52/2005	Vulnerable	Appendix II - 2013
Triakidae			
Mustelus schmitti Springer, 1939	Threatened	Endangered	
Galeorhinus galeus (Linnaeus, 1758)	Threatened	Vulnerable	
Carcharhinidae			
Carcharhinus longimanus (Poey, 1861)[b]	Species overexploited or threatened with exploitation	Vulnerable	Appendix II – 2013
C. porosus (Ranzani, 1839)[b]	Species overexploited or threatened with exploitation	Data deficient	
C. signatus (Poey, 1868)[b]	Species overexploited or threatened with exploitation	Vulnerable	
Isogomphodon oxyrhynchus (Müeller & Henle, 1839)	Threatened	Critically endangered	
Negaprion brevirostris (Poey, 1968)	Threatened	Near threatened	
Prionace glauca (Linnaeus, 1758)	Species overexploited or threatened with exploitation.	Near threatened	
Sphyrnidae			
Sphyrna lewini (Griffith and Smith, 1834)	Species overexploited or threatened with exploitation.	Endangered	Appendix II – 2013
S. zygaena (Linnaeus, 1758)	Species overexploited or threatened with exploitation.	Vulnerable	Appendix II – 2013
S. tiburo (Linnaeus, 1758)	Species overexploited or threatened of exploitation.	Least concern	
Rays			
Pristidae			
Pristis perotteti Müeller & Henle, 1841	Threatened		Appendix I – 2007
P. pectinata Lathan, 1794	Threatened	Critically endangered	Appendix I – 2007
Rhinobatidae			
Rhinobatos horkelii Müeller & Henle, 1841	Threatened	Critically endangered	

[a] Excluded from NI 05/04 according to Normative Instruction - NI 52/05.
[b] Moved from Annex I to Annex II according to Normative Instruction - NI 52/05.

Shark meat is known to contain high levels of heavy metals, such as lead and mercury, due to biomagnification (Pethybridge *et al.* 2000; Escobar-Sánchez *et al.* 2011; Lopez *et al.* 2013). It is very difficult to alert the general population to these facts if they do not know that they are consuming shark meat.

We believe that with proper labeling provided by the fishery industry and markets, coupled with environmental education and advertisement, consumers will be able to make informed decisions about shark meat consumption and conservation while maintaining consumer confidence in seafood. A simple method would be to provide pamphlets on the fish consumed, saying that "cação" (a popular name for small sharks or pups in Brazil) is in fact a shark. The use of genetic techniques such as DNA barcoding to identify elasmobranchs to the species level should be readily implemented. This technique has been shown to be accurate for elasmobranchs (Ward *et al*. 2008). In addition, it allows for the identification of the species from just a small sample of tissue, eliminating the need to integrate whole body morphological identification (Ward *et al*. 2008). To implement this measure, it is important to create a legal demand, so that supermarkets are obliged to sell properly identified meats. As mentioned above, ideally the species-level identification should be conducted in fishery landings, but whenever this does not occur, sellers should be held responsible.

Shark attack: An eminent problem in Brazil

The beaches in Recife and metropolitan region, northeastern Brazil, have been the site of shark attacks from 1992 to 2013, in which 59 cases were officially recorded (Comitê Estadual de Monitoramento de Incidentes com Tubarões (CEMIT, 2013). Researchers believe that the high number of attacks in Recife over the past two decades may be caused by pollution in the Jaboatão River estuary, primarily a result from the construction of the Suape Port, which resulted in considerable environmental degradation (Hazin *et al*. 2008, 2013). Bull sharks, *Carcharhinus leucas* (Müller & Henle, 1839), and tiger sharks, *Galeocerdo cuvier* (Péron & Lesueur, 1822), are indicated as main candidates responsible for the attacks (Hazin *et al*. 2008; 2013).

Shark attack cases have become a chronic problem for those concerned with conservation and raising the awareness of society. An organization of fisherman, shark attack victims, doctors, and engineers are acting to capture sharks (mainly bull and tiger sharks), in an attempt to end instances of shark attack on Recife beaches ("Manifesto P5 - Movimento Praia é Nossa" and "ProPesca"). However, two endangered species (nurse shark *Ginglymostoma cirratum* [Bonnaterre, 1788] and lemon shark *Negaprion brevirostris* [Poey, 1868]) were also captured and shown as "potential shark attack species". Although these two endangered species are known to the scientific community as not responsible for the attacks, they are being displayed as "trophies" to the population in an erroneous and irrational sense of revenge. These attitudes gain strength shortly after a shark attack. For instance, a recent shark attack (22 July, 2013) upon a 18-year-old teenager on Boa Viagem Beach, Recife, shocked the Brazilian population. In this case, the swimmer was fatally bitten by a shark. Less than a week later, the abovementioned group of shark attack victims and colleagues, which had been inactive in their fishing activities, was re-invigorated by the general public opinion and started to indiscriminately "hunt" for sharks.

It might also be worth mentioning that the State Committee for the Prevention of Shark Attacks developed a method of catching sharks approaching beaches using drumlines and longlines, transporting the sharks to the continental slope, tagging them with acoustic and satellite tags, and then releasing them (Hazin *et al*. 2013). The results have shown that once released, the sharks tend to continue their migration northward following the prevailing currents, and do not return to the risk area. This system, when operational, succeeded in reducing the rate of shark attacks by 97%, with a mortality rate for the tagged sharks, (mainly tigers), of 15% (Hazin & Afonso, 2013). No mortality has been recorded for tagged nurse or lemon sharks so far.

Other possible solutions are shark-control programs (gillnets) to reduce the number of shark attacks, as cited in introduction of this article. This method has been applied in Australia and South Africa, and has proved effective in reducing attacks on protected beaches (Dudley 1997). However, these programs can lead to the deaths of turtles, dolphins, fishes, whales, and mainly, several shark species (e.g. Atkins *et al*. 2013). In addition, shark-control programs killed thousands of elasmobranchs every year (Dudley *et al*. 2010), further depleting populations, and some authors have pointed to a poor performance of these gillnets in selectivity of species (Sumpton *et al*. 2011). Recently, a humpback whale was trapped in a shark net off the Gold Coast, Australia (http://www.bbc.co.uk/news/world-asia-pacific-23700446). Moreover, a hypothesis is that in turbid waters such as those found in Recife, if a shark becomes stuck inside the protected area, the results can be even worse.

The risk of shark attacks exists on Recife beaches because of the impacts of human intervention on natural ecosystem functioning (Hazin *et al*. 2008); thus, the population of the state of Pernambuco needs to help overcome this problem. Warnings are posted all around the waterfront of Recife beaches (Fig. 1). If swimmers know that the chances of a shark attack occurring are high, they either do not enter the water or enter at their own risk. The lack of environmental education is no longer an acceptable excuse, at least for the Recife and metropolitan region. In the abovementioned recent case of fatal attack, friends and relatives confirmed that the victim saw the signs and chose to enter the water anyway.

Interesting approaches are being developed that can influence the public opinion of sharks and turn the general population into allies in conservation matters. The economic benefit that can be obtained from ecotourism is a good example. A single live shark generates US$ 178,000 per year from diving tourism, while each landed shark is worth only around US$ 200 (Vianna *et al*. 2012). In the Bahamas, it is estimated that shark ecotourism renders nearly US$ 80 million every year to the local economy (Gallagher & Hammerschlag 2011). Unfortunately, this tourism industry is being negatively affected by fishery activities, since 83% of the targeted species for diving tourism are listed in the IUCN Red List (Topelko & Dearden 2009). In Fernando de Noronha archipelago, Northeastern Brazil, everyone is able to dive with sharks (e.g. nurse and lemon sharks) with snorkelling or scuba gear, and so far there has never been an official report of shark attack.

In response to the attacks on beaches of Recife and metropolitan region, in contrast, measures to avoid shark attacks and studies to understand these incidents were implemented by researchers and government (mentioned above). Unfortunately, people have the power in nitpicking, so a simple way to avoid shark attacks is to respect the warnings posted along waterfront beaches and find safe areas to swim.

Fig. 1 – Warning signs are dispersed in all waterfront areas of Recife beaches, Northeastern Brazil.

Conclusions and recommendations

Solutions for many of the conservation issues regarding elasmobranchs already exist. Part of the solution lies in propagating science-based ideas to the lay society, that is, the information cannot be restricted to the scientific community. With the support of the whole society and, therefore, increased pressure on decision makers, it will become easier to implement conservation measures such as those proposed here.

The first problem is related to species identification. On the fisheries side, the solution lies in having trained personnel at specific landing ports. Implementation of this practice would aid in the solution to the mislabeling of shark meat. However, whenever this does not occur, supermarkets or any other final seller should be held legally responsible for the identification. At this stage, since the source of the meat cannot be identified by its whole body morphological characteristics, genetic techniques such as DNA barcoding must be used.

It is urgent and necessary to create a national program of fishery statistics with wide spatial and temporal coverage, with extensive species-catch monitoring throughout the Brazilian coast.

Regarding the shark attack problem, the only truly efficient solution with no indirect effects is education and taking the matter to the society, rather than waiting until there is a shark attack incident. The government needs to invest in educational awareness programs and research to avoid encounters with sharks.

We must ensure that the society does not see sharks as villains, but, on the contrary, as key elements in maintaining ecosystem services that are so valuable to human well-being. In cases where attacks occur within areas with intensive warning of the risk of shark attack, the victim should be held responsible for the consequences of ignoring the signs.

If we continue to ignore these issues, we run the risk of losing a valuable component of marine ecosystems in the near future, and as we know so far, the consequences can be catastrophic.

Acknowledgments

We thank Dr. Fábio H. V. Hazin for valuable information on shark attacks, MSc. Natascha Wosnick for reviewing and suggestions, and Dr. James Nienow and Jeffrey Muehlbauer for reviewing our English. We thank two reviewers for their valuable comments. This work was supported by a CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) scholarship to R.R.B and CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) to H.B. J.R.S.V. is supported by grants from CNPq.

R E F E R E N C E S

Alves DC, Moura RL & Minte-Vera CV, 2012. Estimativa da captura total: desenhos amostrais para pesca artesanal. *Interciencia*, 37:899-905.

Atkins S, Cliff G & Pillay N, 2013. Humpback dolphin bycatch in the shark nets in KwaZulu-Natal, South Africa. *Biological Conservation,* 159:442–449.

Baum J *et al*., 2013. *Sphyrna lewini*. *In* IUCN 2013. IUCN Red List of Threatened Species. Version 2013.1. <www.iucnredlist.org>.

Blanco M, Pérez-Martín RI & Sotelo CG, 2008. Identification of shark species in seafood products by forensically informative nucleotide sequencing (FINS). *Journal of Agricultural and Food Chemistry,* 56(21):9868-9874.

Bornatowski H *et al.*, 2011. Unconventional fishing for large sharks in the state of Paraná southern Brazil: a note of concern. *Journal of Applied Ichthyology,* 27:1108– 1111.

Bornatowski H & Abilhoa V, 2012. Tubarões e raias capturados pela pesca artesanal no Paraná: guia de identificação. Curitiba, Paraná: Hori Consultoria Ambiental. Available from: http://www.hori.bio.br/cadernos/23-HCT4.pdf.

Bornatowski H, Braga RR & Vitule JRS, 2013. Shark mislabeling threatens biodiversity. *Science,* 340:923.

Brasil, 2004. Instrução Normativa n° 05, Dispõe sobre o reconhecimento como espécies ameaçadas de extinção e espécies sobreexplotadas ou ameaçadas de sobreexplotação, os invertebrados aquáticos e peixes. *Diário Oficial da União*, n. 102, 28 de maio de 2004, Seção 1, p. 136-142.

Brasil, 2005. Instrução Normativa n° 52, Dispõe alterar os Anexos I e II da Instrução Normativa n° 5 do Ministério do Meio Ambiente. Diário Oficial da União, 21 de novembro de 2005.

Brasil, 2011. Ministério da Pesca e Aquicultura (MPA). Available from: http://www.mpa.gov.br. Accessed 23 August 2013.

Brasil, 2012a. Instrução Normativa n° 12, Dispõe sobre critérios e padrões para o ordenamento da pesca praticada com o emprego de redes de emalhe nas águas jurisdicionais brasileiras das regiões Sudeste e Sul. *Diário Oficial da União*, n. 165, 24 de agosto de 2012, Seção 1, p. 39-40.

Brasil, 2012b. Instrução Normativa n° 14, Dispõe sobre normas e procedimentos para o desembarque, o transporte, o armazenamento e a comercialização de tubarões e raias. *Diário Oficial da União*, n. 229, 29 de novembro de 2012, Seção 1, p. 34.

Camhi M *et al.*, 1998. *Sharks and their relatives: ecology and conservation. Occasional Paper IUCN Species Survival Commision*, Switzerland: World Conservation Union.

CEMIT, 2013. Comitê Estadual de Monitoramento de Incidentes com Tubarões. Available from: http://www.portaisgoverno.pe.gov.br/web/sds/cemit1

CITES, 2013. Convention on International Trade in Endangered Species of Wild Fauna and Flora – CITES. Available from: http://www.cites.org/eng/app/appendices.php

Costa PAS, Braga AC & Rocha LOF, 2003. Reef fisheries in Porto Seguro, eastern Brazilian coast. *Fisheries Research,* 60:577–583.

Council Regulation (EC), 2000. EC No. 104/2000 of December 17, 1999 on the common organization of the markets in fishery and aquaculture products. Available from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000R0104:en:NOT.

Cressey D, 2013. Australian shark-cull plan draws scientists' ire. *Nature News*. Available from: http://www.nature.com/news/australian-shark-cull-plan-draws-scientists-ire-1.14373. doi:10.1038/nature.2013.14373.

Dudley SFJ, 1997. A comparison of the shark control programmes of New South Wales and Queensland (Australia) and KwaZulu-Natal (South Africa). *Ocean & Coastal Management,* 34(1):1–27.

Dudley SFJ & Cliff G, 1993. Some effects of shark nets in the Natal nearshore environment. *Environmental Biology of Fishes,* 36:243–255.

Dudley SFJ & Cliff G, 2010. Shark control: methods, efficacy, and ecological impact. *In* Carrier JC, Musick JA, Heithaus MR (eds.) *Sharks and their relatives II: biodiversity, adaptive physiology, and conservation*, Boca Raton: CRC Press. p. 567–592.

Dulvy NK *et al.*, 2008. You can swim but you can't hide: the global status and conservation of oceanic pelagic sharks and rays. *Aquatic Conservation,* 18:459–482.

Escobar-Sánchez O, Galván-Magaña F & Rosíles-Martínez R, 2011. Biomagnification of mercury and selenium in blue shark *Prionace glauca* from the pacific ocean off Mexico. *Biological Trace Element Research,* 144:550-559.

Ferretti F *et al.*, 2010. Patterns and ecosystem consequences of shark declines in the ocean. *Ecology Letters,* 13:1055–1071.

Gadig OBF, Motta FS & Namora RC, 2002. Projeto Cação: a study on small coastal sharks in São Paulo, Southeast Brazil. *In* Duarte P (eds.). *Proceedings of the International Conference on Sustainable Management of Coastal Ecosystem*, Porto: Universidade Fernando Pessoa. p. 239–246.

Gallagher AJ& Hammerschlag N, 2011. Global shark currency: the distribution, frequency, and economic value of shark ecotourism. *Current Issues of Tourism*, 14:797-812.

Hazin FHV, Burgess GH & Carvalho FC, 2008. A shark attack outbreak off Recife, Pernambuco, Brasil: 1992-2006. *Bulletin of Marine Science,* 82:199-212.

Hazin FHV *et al.*, 2013. Regional movements of the tiger shark, *Galeocerdo cuvier*, off northeastern Brazil: inferences regarding shark attack hazard. *Anais da Academia Brasileira de Ciências,* 85(3):1053-1062.

Hazin FHV & Afonso AS, 2013. A *green* strategy for shark attack mitigation off Recife, Brazil. *Animal Conservation,* doi:10.1111/acv.12096.

IUCN Red List, 2013. International Union for Conservation of Nature and Natural Resources – IUCN Red List of Threatened Species. Available from: http://www.iucnredlist.org/.

Kotas JE *et al.*, 1995. *Gillnet activities in Southern Brazil*. Itajaí: Centro de Pesquisa e Extensão Pesqueira do Sudeste, Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis.

Lopez SA, Abarca NL & Meléndez R, 2013. Heavy metal concentrations of two highly migratory sharks (*Prionace glauca* and *Isurus oxyrinchus*) in the southeastern Pacific waters: comments on public health and conservation. *Tropical Conservation Science,* 6:126-137.

Motta FS *et al.*, 2005. Size and sex compositions, length–weight relationship, and occurrence of the Brazilian sharpnose shark, *Rhizoprionodon lalandii*, caught by artisanal fishery from southeastern Brazil. *Fisheries Research,* 74:116-126.

MPA, 2012. Ministério da Pesca e Aquicultura. Boletim Estatístico da Pesca e Aquicultura, Brasil 2010. Brasília, Ministério da Pesca e Aquicultura. Available from: http://www.mpa.gov.br/images/Docs/Informacoes_e_Estatisticas/Boletim%20Estat%C3%ADstico%20MPA%202010.pdf. Accessed 23 August 2013.

Musick JA *et al.*, 2000. Management of sharks and their relatives (Elasmobranchii). *Fisheries,* 25:9-13.

Myers RA & Worm B, 2005. Extinction, survival, or recovery of large predatory fishes. *Proceedings of the Royal Society B*, 360:13–20.

Myers RA *et al.*, 2007. Cascading effects of the loss of apex predatory sharks from a coastal ocean. *Science,* 315:1846-1850.

Neff C & Yang J, 2013. Shark bites and public attitudes: policy implications from the first before and after shark bite survey. *Marine Policy,* 38:545–547.

Pauly D, Hilborn R & Branch TA, 2013. Fisheries: Does catch reflect abundance? *Nature,* 494 (7437):303-306.

Pethybridge H, Cossa D & Butler CV, 2009. Mercury in 16 demersal sharks from southeast Australia: Biotic and abiotic sources of variation and consumer health implications. *Marine and Freshwater Research,* 68:18-26.

Polunin NVC & Roberts CM, 1996. *Reef fisheries*. London: Chapman and Hall.

Shepherd TD & Myers RA. 2005. Direct and indirect fishery effects on small coastal elasmobranchs in the northern Gulf of Mexico. *Ecology Letters,* 8:1095-1104.

Simpfendorfer CA *et al.*, 2011. The importance of research and public opinion to conservation management of sharks and rays: a synthesis. *Marine and Freshwater Research,* 62:518–527.

Sparre P, Venema SC, 1997. Introduction to tropical fish stock assessment. Part 1. Manual. *FAO Fisheries Technical Paper* 306:1(2).

Sumpton W *et al.*, 2011. Gear selectivity of large-mesh nets and drumlines used to catch sharks in the Queensland Shark Control Program. *African Journal of Marine Science,* 33:37–43.

Topelko KN & Dearden P, 2009. The shark watching industry and its potential contribution to shark conservation. *Journal of Ecotourism,* 2:108-128.

UNIVALI/CTTMAR, 2010. *Boletim estatístico da pesca industrial de Santa Catarina – Ano 2009 e panorama 2000 - 2009*. Itajaí: Universidade do Vale do Itajaí, Centro de Ciências Tecnológicas da Terra e do Mar.

UNIVALI/CTTMar, 2011. *Boletim estatístico da pesca industrial de Santa Catarina – Ano 2010*. Itajaí: Universidade do Vale do Itajaí, Centro de Ciências Tecnológicas da Terra e do Mar.

Vannuccini S, 1999. *Shark utilization and trade*. Rome:Food and Agriculture Organization technical paper n.389.

Vianna GMS *et al.*, 2012. Socio-economic value and community benefits from shark-diving tourism in Palau: A sustainable use of reef shark populations. *Biological Conservation,* 145:267–277.

Vooren CM & Klippel S, 2005. *Ações para a conservação de tubarões e raias no sul do Brasil*. Porto Alegre: Igaré.

Vooren CM, Klippel S & Galina AB, 2005. Biologia e status de conservação dos tubarões-martelo *Sphyrna lewini* e *Sphyrna zygaena*. *In* Vooren CM, Klippel S (eds.). *Ações para a conservação de tubarões e raias no sul do Brasil*. Porto Alegre: Igaré. p. 98-112.

WildAid, 2007. The end of the line? Global threats to sharks. Available from: www.wildaid.org. Accessed 10 August 2013.

Walker TI, 1998. Can shark resources be harvested sustainably? A question revisited with a review of shark fisheries. *Marine and Freshwater Research,* 49:553–572.

Ward RD *et al.*, 2008. DNA barcoding Australasian chondrichthyans: results and potential uses in conservation. *Marine and Freshwater Research,* 59:57–71.

Worm B *et al.*, 2013. Global catches, exploitation rates, and rebuilding options for sharks. *Marine Policy,* 40:194-204.

Yokota L & Lessa RTP, 2006. A nursery area for sharks and rays in Northeastern Brazil. *Environmental Biology of Fishes,* 75:349-360.