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Why implement measures to conserve the diversity of Elasmobranchs? The case of the northern coast of Brazil

Conservation of Elasmobranchs off the northern coast of Brazil

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Abstract. The subclass Elasmobranchii, is a group of fish that has raised increasing concerns from a conservation perspective in recent years. The complex biology and reproductive modes of the elasmobranchs contribute to their vulnerability to overfishing. The fisheries that target elasmobranchs have intensified their activities in recent years, impacting their populations on a global scale. In this context, studies in Brazil have led to the inclusion of many elasmobranchs in the list of endangered species, in particular the endemic species in the northern region of the country. The review of the available data aims to analyze the conservation status of the elasmobranch species found in Brazil and the importance of the research techniques that may contribute to the conservation of their stocks.
Keywords. *Elasmobranchii; conservation; threatened species; fishery; stocks*

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Introdução

The biodiversity and commercial exploitation of sharks and rays

Sharks and rays are members of the subclass Elasmobranchii Bonaparte, 1838, and are found in the tropical, subtropical, temperate and cold waters of all entire world's seas and oceans, inhabiting both offshore and coastal areas in pelagic, demersal, reef and estuarine environments, and even in freshwater habitats (Compagno, 1984). However, data on the biology of the elasmobranchs are scant for some regions, such as the Southwestern Atlantic, where the populations of even critically endangered species are still captured by commercial fisheries, as well as being sold in local fish markets (Tavares et al., 2013; Palmeira et al., 2013).

The verification lists of the diversity of species of the class Chondrichthyes (Huxley, 1880), which includes the Elasmobranchii, vary considerably around the world, and are based on the available data, which often leads to misinterpretations and inconsistencies in the listings of valid species (Last and Séret, 2016; Last et al., 2016a; Last et al., 2016b). Given these considerations, a scientific review of the group was conducted, based on recent data on the taxonomic diversity, geographic distribution, and the depth of the waters inhabited by these species. By November 7th 2015, a total of 1139 species of elasmobranch had been catalogued (Figure 1A), representing 15 orders, 58 families, and 193 genera. This new listing includes nine orders, 34 families, 105 genera and 509 species of shark, and six orders, 24 families, 88 genera and 630 species of ray. The species that are currently being described were not considered valid for this inventory (Weigmann, 2016).

Recently, data on the diversity of the marine chondrichthians that occur in Brazil has been updated (Rosa and Gadig, 2014) (Figure 1B), and concluded that the subclass Elasmobranchii is represented by 11 orders, 33 families, 75 genera and 159 species, six orders, 22 families, 43 genera, and 89 species represented by Sharks, while the rays are classified in five orders, 11 families, 32 genera, and 70 species. Overall, 49 of these 159 elasmobranch species are included in one of the three principal threatened categories of the IUCN, i.e., Critically Endangered, Endangered and Vulnerable (Figure 2A: Supplementary Table 1). The Brazilian Environment Ministry (IBAMA ordinance number 445 of December 17, 2014) classifies 53 of these species in one of the threatened categories. In addition to this large number of threatened species, there are a relatively large number of species (50 according to the IUCN

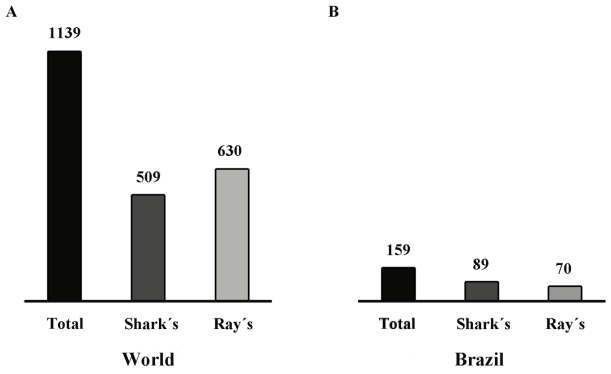

Figure 1. Diversity of the Elasmobranchii in the world (A) and in Brazil (B), based on Rosa and Gadig (2014) and Weigmann (2016).

and 48 in the IBAMA classification) in the Data Deficient category, that is, almost a third of all the species occurring the coast of Brazil (Figure 2; Supplementary Table 1).

In general, the elasmobranchs have complex biological and reproductive characteristics that make them vulnerable to overfishing, such as a long life cycle, late sexual maturation, and low fecundity (production of few offspring), which combine to produce relatively low rates of population growth (Musick, 1998; Camhi et al., 1998). This limits population growth and the recovery of stocks (Vooren and Klippel, 2005).

The fishing of sharks and rays has always been a common practice of coastal populations throughout most of the world (Figure 3). In addition to the meat, certain sub-products of the animal are also used, primarily as a source of nutrients. Over the past few decades, however, the demand for shark meat and its sub-products (principally, fins) has become a global phenomenon, and the fishing of elasmobranchs, which was once largely accidental or opportunistic, has become the primary objective of many fisheries (Séret, 2006).

According to the United Nations' Food and Agriculture Organization (FAO), catches of chondrichthians peaked globally in 2003, but declined approximately 20% over the subsequent decade (Davidson et al., 2015). This decline in stocks was linked directly to increasing pressure from fisheries. The countries that experienced the greatest reduction in catches, such as Pakistan, Sri Lanka, and Thailand, export large quantities of ray and shark meat, due to the relatively large populations of their coastal cities (Davidson, et al., 2015).

A large international market now exists for shark fins, which stimulates the practice of finning, in which the sharks are mutilated at sea and thrown back into the water with no chance of survival (Szpilman, 2004; Kotas et al., 2005). Shark fins are now a major global commodity, destined for markets in Asian countries, stimulating the establishment of specialized fisheries (Lessa et al., 2005; Clarke et al., 2006). In Brazil, however, elasmobranchs are still mostly captured as bycatch (non-intentionally) by industrial fisheries and are targeted specifically only by some traditional fishing communities (Lessa et al., 2005; Rodrigues-Filho, 2012).

Shark fin soup is a common dish in many Asian countries, where it is widely believed to have aphrodisiac powers (Séret, 2006). It is important to note that, whatever the ultimate application of the shark fins, the trade in this item generates billions of dollars in worldwide trade (Séret, 2006). While "dogfish" (shark) costs US$10 per kilogram, on average, on the international market, a kilogram of shark fin may reach US$ 500. These prices have stimulated an increase in shark fishing throughout the world, resulting in a drastic decline in the stocks of some species, which have been brought to the brink of extinction (Serét, 2006). Following the deliberate and unregulated exploitation of these fish on a global scale, the stocks of a number of species have declined by up to 97% in some regions (Séret, 2006).

The commercial exploitation of elasmobranchs is not restricted solely to the marine species, however. The elasmobranch that inhabit exclusively freshwater environments such as Potamotrygonidae family, are also commonly marketed (Compagno and Cook, 1995; Charvet-Almeida, 2001; Lasso et al, 2014; Almeida et al., 2009). The members of this family are taxonomically complex, and are currently classified in four genera – the monotypic *Paratrygon* Duméril, 1865, two genera (*Plesiotrygon* Rosa, Castello and Thorson, 1987 and *Heliotrygon*

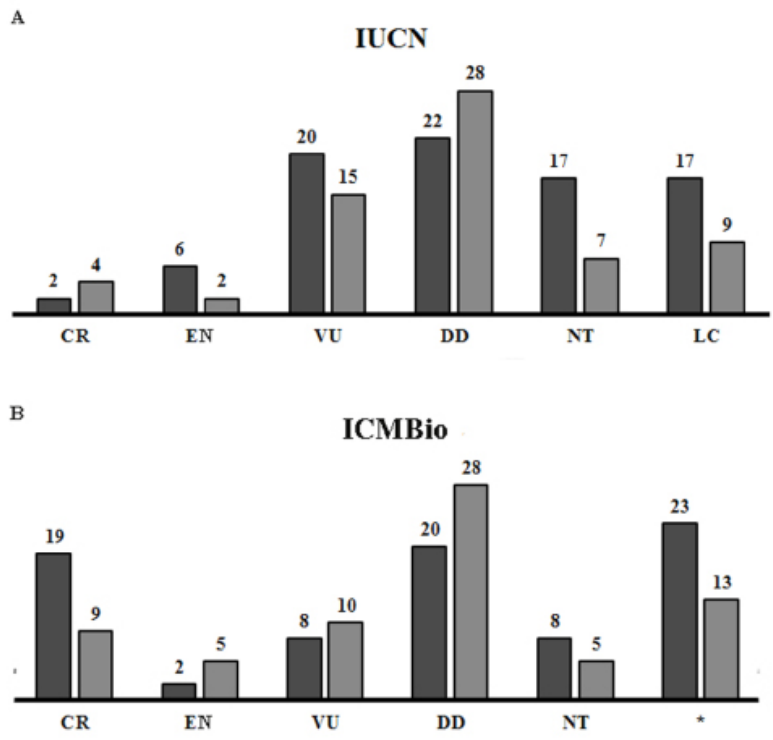

Figure 2. Conservation status of the Brazilian elasmobranch species (Rosa and Gadig, 2014) according to (A) IUCN and (B) ICMBio (ordinance number 445 of December 17 2014). The following categories are used: Not Evaluated (NE), Data Deficient (DD), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CR), Extinct in the Wild (EW), Extinct (EX) and (*) Species with no information.

Carvalho and Lovejoy, 2011) that each have two species, and the polyspecific *Potamotrygon* Garman,1877 (Rosa et al., 2010; Lasso et al., 2014). The most diverse group of potamotrygonids is found in the Amazon region, where these stingrays have long been considered, in particular by riverside populations, as an important source of food (Charvet-Almeida, 2001; Almeida et al., 2009), although the larger species, such as *Paratrygon aiereba* and *Potamotrygon motoro*, are fished in the Negro and Amazon basins for export to markets in southeastern Brazil (Araújo et al., 2005). In the estuarine zone of the Amazon River, on Marajó Island, for example, and in the municipal market at Colares, in Pará, species such as *Potamotrygon orbignyi* and *Potamotrygon scobina* are sold cheaply, with an estimated annual catch of up to 100 tons (Ferreira et al., 1998: Charvet-Almeida, 2001; Charvet-Almeida et al., 2002) (Figure 3). The potamotrygonids are considered to be K strategists (development of young with low levels of competition for nutrients), and the juveniles have low survival rates in environments where there are high levels of competition for nutrients. Given this, if these species become one of the principal targets of fisheries in the near future, they are likely to be increasingly vulnerable, and may soon be added to the listings of endangered taxa (Duncan et al., 2010).

The potamotrigonids face threats similar to the other elasmobranch species, then, including their capture as bycatch, and the destruction of habitats (Araujo et al., 1998; Toffoli, 2006), although they suffer pressures from two other sources. One is the capture of ornamental species for sale to aquarium enthusiasts, and the other is that, due to their venomous stings, which can cause extremely painful injuries when the animals are accidentally trodden on by people when wading, stingrays are often killed on sight or have their tails cut off (Toffoli, 2006). In one extreme case, the Manaus city council, responding to appeals from the local tourism industry, ordered the elimination of approximately 21,000 stingrays to keep the city's beaches free of accidents between 2001 and 2004 (Charvet--Almeida et al., 2002; Toffoli, 2006).

Conservation status of elasmobranchs

Worldwide, predatory fisheries have had a fundamental influence on the inclusion of a large number of fish species on the Red List of the International Union for Conservation of Nature and Natural Resources, the IUCN (Camhi et al., 1998). In this context, research in Brazil has resulted in the inclusion on the list of a number of endangered species, including some that are present in Brazilian waters, such as the Brazilian guitarfish (*Rhinobatos horkelii*), daggernose shark (*Isogomphodon oxyrhynchus*), striped smooth-hound (*Mustelus fasciatus*), sawfish (*Pristis* spp.), sand tiger shark (*Carcharias taurus*), school shark (*Galeorhinus galeus*), and angel sharks, *Squatina* spp. (Les-

Figure 3. Sharks and rays processed for marketing in northern Brazil. (A) gutted and finned shark carcasses (known as "cigars"); (B and C) rays of the genus *Dasyatis* ready for sale; (D, E, and F) rays of the genus *Potamotrygon* ready for sale. Fotos: A and B of Monteiro (2016); C and D of Freitas (2016); E and F of Gonçalves (2016).

sa et al., 1999b).

Lessa et al. (1999b) notes that fisheries have a significant impact on the coastal resources found off Pará and Maranhão. For most northern Brazilian fisheries, rays and sharks represent bycatch, principally during the bottom trawling of the continental shelf, when the primary targets are shrimp and other commercially-valuable fish species. In Pará and Maranhão, some shark populations are already in decline, and have all the characteristics of overfished species (Lessa et al., 1999; Tavarez et al., 2013).

The Brazilian Society for the Study of Elasmobranchs (SBEEL.) recorded the capture of 47 species in northern Brazil, of which 41% % were classified as "no data" (IUCN; ICMBio), reinforcing the need for research into the biology and population ecology of the elasmobranchs exploited by the region's fisheries (Lessa et al., 2005). Prior to the present study, some data were available on the exploitation, feeding ecology, and reproductive biology of only 12 species – *Ginglymostoma cirratum* Bonnaterre, 1788, *Galeocerdo cuvieri* Peron and Lesueur, 1822, *Carcharhinus acronotus* Poey, 1860, *Carcharhinus leucas* Müller and Henle, 1839, *C. porosus* Ranzani, 1839, *Rhizoprionodon porosus* Poey, 1861, *Isogomphodon oxyrhynchus* Müller and Henle, 1839, *Sphyrna tiburo* Linnaeus, 1758, *Sphyrna lewini* Griffith and Smith, 1834, *Dasyatis guttata* Bloch and Schneider, 1801, *Dasyatis colarensis* Santos, Gomes and Charvet-Almeida, 2004, and *Pristis perotteti* Müller and Henle, 1841. No data are available on the exploitation of the stocks of the remaining species, which may be due in part to the difficulties of access to the region's fishing ports, and the infrequent monitoring of catches (Lessa et al., 2005).

The large-bodied Colares stingray (*Dasyatis colarensis* Santos, Gomes and Charvet-Almeida, 2004), known locally as the "white stingray" or "beaked stingray", is a commercially-valuable species endemic to the northern coast of Brazil. As the local population applies the same common name to a second species of this genus, *Dasyatis guttata*, it is often unclear which species is being sold in markets (Lessa et al., 2005).

A recent analysis of the intrinsic and extrinsic vulnerabilities of the daggernose shark (*Isogomphodon oxyrhynchus* Müller and Henle, 1839), an endemic species that occurs on the northern coast of South America, between Trindad and Tobago, Venezuela and Maranhão (Brazil), indicate that the stocks continue to be affected (Lessa et al., 2016). The data on the biological characteristics of the species indicate that it is particularly vulnerable to the intense gillnetting for other fish species and trawling for shrimp, which lead to the capture of immature male and adult female sharks, contributing to the overfishing of this species. After analysis of these data, the species' conservation status was updated from critically endangered to almost extinct (Lessa et al., 2016).

Conservation and management

A preliminary list of the conservational status of Brazilian fish species, based on extensive consultations with specialists included 12 species of elasmobranchs, of which, 10 are marine (*Rhincodon typus, Cetorhinus maximus, Carcharodon carcharias, Megachasma pelagios, Galeorhinus galeus, Mustelus fasciatus, Squatina guggenheim, Pristis pectinata, Pristis perotteti, Rhinobatos horkelii*), and two, freshwater (*Potamotrygon henlei* and *Potamotrygon leopoldi*) (Rosa and Menezes, 1996).

The Brazilian Environment Ministry (MMA), through its secretary for biodiversity and forests, promoted the updating of the official Brazilian list of endangered fauna in 1999, a process completed by December 2003. These data were used to compile an official list of endangered fish in two normative instructions published by the MMA, in 2004 and 2005, which included 15 elasmobranch species, *Carcharhinus longimanus, Carcharhinus porosus, Carcharhinus signatus, Isogomphodon oxyrhychus, Negaprion brevirostris, Galeorhinus galeus, Mustelus schmitti, Cetorhinus maximus, Ginglymostoma cirratum, Rhincodon typus, Pristis perotteti, Pristis pectinata, Rhinobatus horkelii, Squatina guggenheim,* and *Squatina occulta*. Six species were also included on the list of overfished species or species threatened with overfishing – *Prionace glauca, Sphyna lewini, Sphyrna tiburo, Sphyrna zygaena, Lamna nasus* and *Carcharias taurus*. In 2009, the MMA, together with the Chico Mendes Institute for the Conservation of Biodiversity (ICMBio), initiated a new updating process for the list, for which, the ICMBio indicated the need for a new evaluation and re-evaluation of all the elasmobranch species found in Brazil. These data were published recently (ordinance number 445 of December 17 2014) in an attempt to reinforce the regulation of the fishery industry. The endangered species are listed in Supplementary Table 1 (Diaz-Neto, 2011; Rosa and Gadig, 2014)

Molecular methods as a tool for the conservation of the elasmobranchs

Molecular methods as a tool for the conservation of the elasmobranchs

In most cases, elasmobranchs are disembarked in fishing ports in the form of processed carcasses (Abercrombie et al., 2005; Ferreira 2006; Hopkins 2011). While sharks are gutted and typically lack the head, tail, and fins, the only parts of the rays that are landed are the wings, attached to the pectoral girdle. This processing usually impedes the morphological identification of the specimens (Vooren and Klippel, 2005). An important step toward the more reliable identification of species was taken with the adoption of molecular tools, based on the sequencing of DNA (Holmes et al., 2009; Feldhein et al., 2010; Cerutti-Pereyra et al., 2012)

The DNA barcode is one of the widely-used tools for the identification of plant and animal species (Herbert et al., 2003). It is a simple and rapid means of determining the lowest taxonomic level. It is based on a segment of approximately 650 base pairs of the mitochondrial cytochrome oxidase subunit I (COI) gene, which is used as a universal marker. This sequence, amplified by PCR, is characterized by low intraspecific variability, but high levels of interspecific variation. Ward et al. (2005) standardized the DNA barcode for the identification of elasmobranchs,

sequencing the COI gene in 61 species, with the efficacy of the technique for this group being confirmed by subsequent studies (Kekkonen and Herbert, 2014; Packer et al., 2009).

Molecular techniques based on sequences of mitochondrial (mtDNA) or nuclear DNA have been widely used in studies of population genetics (Cruz, 2013; Pinhal, 2010; Tavares et al., 2013; Veríssimo et al., 2012; Rodrigues-Filho, et al., 2009; Dudgeon et al., 2012; Palmeira et al., 2013). The regions of the mitochondrial genome most used for these studies include the cytochrome b (Cyt b) gene and the Control Region (CR), which has been used in a large number of population genetics studies of sharks (Sodré et al., 2012; Tavares et al., 2013). Given its relatively high mutation rates, the CR is more adequate for the analysis of the recent evolutionary history of a population, providing useful evidence for effective conservation and management practices. These practices depend fundamentally on the understanding of the genetic diversity of the species at the population level, for the definition of the basic characteristics of its evolutionary history and the evaluation of current stocks (Tavares et al., 2013).

The molecular approach provides a useful tool for the understanding population dynamics. A recent study analyzed the genetic variability of four shark species, *Carcharhinus porosus* and *Rhizoprionodon porosus* (captured by the fishing fleet of Bragança, Pará, Brazil), and *Sphyrna tudes* and *Carcharhinus limbatus* (caught off Amapá and Pará), and found evidence of low levels of variability in *S. tudes*, indicating a critical decline of its populations (Tavares et al., 2013).

Another problem for species identification is the indiscriminate application of the same common name to a number of different species. Rodrigues-Filho et al. (2009) and Palmeira et al. (2013) showed that the common or regional names attributed to the shark species being marketed did not correspond to their taxonomic classification. The sale of distinct species, or even members of different genera, under the same commercial name, such as "sacurí", "milhor verde" or "lombo preto", is a common practice. As many as five different species were being marketed as "sacurí", for example, which impedes the understanding of the true diversity of species being marketed (Rodrigues-Filho et al., 2009). This study obtained sequences of the 12S/16S molecular marker from 122 samples of tissue obtained from shark meat being sold in markets in Bacuriteua and Bragança (Pará) between October 2005 and December 2006, and showed that all the sequences identified belonged to species of the order Carcharhiniformes, including six carcharhinid species and four sphyrnids. *Carcharhinus porosus* accounted for the largest number of individuals, with 57 of the specimens (Rodrigues-Filho et al., 2009).

While the commercial fishing of sawfish (*Pristis*) has been prohibited in Brazil since 2004, Palmeira et al. (2013) showed that these animals continue to be captured and sold in the fish markets of the towns of Bragança and Vigia in Pará. In a sample of 44 specimens collected from the two localities, the analysis of the markers 16S and Cyt *b* indicated that 24 specimens (55%) were *Pristis perotetti*. This study further emphasizes the negative implications of using a single common (sawfish) indiscriminately to refer to distinct species and even groups, given that the other 20 specimens were all from sharks (Carcharhinidae: *Carcharhinus leucas*, *C. limbatus*, *C. porosus*, *C. acronotus*, *Sphyrna lewini*, *Galeocerdo Cuvier*; Ginglymostomatidae: *Ginglymostoma cirratum*).

Conclusions

The ongoing increase of environmental impacts caused by human activities, in particular medium-and large-scale fisheries, are increasingly threatening the remaining stocks of many shark and stingray species. Scientific research into the biology and population ecology of the elasmobranchs, together with the mobilization of society and government bodies with regard to current conservation questions, will be essential for the re-evaluation of public policies, and the formulation of effective measures to counter the current threats to Elasmobranchii. By reinforcing the scientific resources (especially at the graduate level) and qualified researches, it can only be hoped that the growth of teams in universities and other research institutes will contribute to the expansion of the scientific understanding of the problem in hand.

Despite the importance of more detailed studies on the different aspects of the biology and life history of the Elasmobranchii in Brazil, taxonomic analyses are of fundamental relevance, as they are for any group of animals. A good knowledge of the phylogeny and systematics of the study group is an essential prerequisite for the development of reliable research in conservation biology.

While there have been important recent advances in the field in Brazil, the country's northern region still lags far behind the other regions. One major problem is the lack of data on the volume of catches and the possible dumping of elasmobranchs on the open sea. These data are of fundamental importance for the management of stocks, given that they provide indices of the size of a species' population, contributing to the development of more adequate management practices for the local fishery fleets. Given this, and the overall lack of research on the biology and ecology of sharks and rays, information on the conservation status of most of the species that occur in the study area is scant, despite the importance of these data for the adequate regulation and monitoring of fishery ports and local fish markets.

References

Abercrombie DL, Clarke SC, Shivji, MS. 2005. Global-Scale genetic identification of hammerhead sharks: Application to assessment of the international fin trade and law enforcement. Conservation Genetics (6): 775-788.

Almeida MP, Barthem, R B, Viana AS, Charvet-Almeida P. 2009. Factors affeting the distribution and abundance of freshwater stingrays (Chondrichthyes: Potamotrygonidae) at Marajó Island, mouth of the Amazon River. Pan-American Journal of Aquatic Sciences, 4(1): 1-11.

Araújo MLG, Charvet-Almeida P, Almeida MP, Pereira H. 1998. Freshwater Stingrays (Potamotrygonidae): status,

conservation and management challenges. AC20 Inf. 8.

Araújo MLG, Duncan WLP, Melo SV. 2005. Plano de Monitoramento de Arraias de Água Doce. 78 p.

Camhi M, Fowler S, Musick J, Bräutigam A, Fordham S. 1998. Sharks and their relatives. Ecology and Conservation. Species Survival Commission, World Conservation Union, Gland, Switzerland. Occasional Paper of the IUCN Species Survival Commission, 20.

Cerutti-Pereyra F, Meekan MG, Wei N-WV, O'Shea O, Bradshaw CJA, Austin CM. (2012) Identification of rays through DNA barcoding: an application for ecologists. PLoS ONE, 7, e36479.

Charvet-Almeida P. 2001. Ocorrência, biologia e uso das araias de água doce na baia do Marajó (Pará,Brasil), com ênfase na biologia *Plesiontrygon* (Cho ndrichthey:Potamotrygonidae). Dissertação de mestrado. Belém. Universidade Federal do Pará and Museu Paraense Emílio Goeldi. 213p.

Charvet-Almeida P, Araújo MLG, Rosa RS, Rincón G. 2002. Neotropical Freshwater Stingrays: diversity and conservation status. Shark News, 14:47-51.

Clarke SC, Magnussen JE, Abercombie DL, Mcallister MK, Shivji MS. 2006. Identification of Shark Species Composition and Proportion in the Hong Kong Shark Fin Market Based on Molecular Genetics and Trade Records. Conservation Biology (20): 201-211.

Compagno LJV. 1984. FAO Species catalogue Vol 4. Sharks of the world. Na annotated and illustrated catalogue of shark species known to date. Parts 1, 2/ FAO Fish. Synopsis.(125) vol 4: 1-655.

Compagno, LJV, Cook SF. 1995. The exploitation and conservation of freshwater elasmobranchs: status of taxa and prospects for the future. In: The Biology of Freshwater Elasmobranchs. OETINGER, M. I.; ZORZI, G. D. (eds.). Journal of Aquariculture e Aquatic Sciences, 7: 62-90.

Cruz VP. 2013 Estudos genéticos em raias do gênero Potamotrygon (Chondrichthyes: Myliobatiformes: Potamotrygonidae) na Bacia do Rio Paraná. UNESP. Botucatu, São Paulo.

Davidson LNK, Krawchuk MA, Dulvy NK. 2015. Why have global shark and ray landings declined: improved management or overfishing? John Wiley and Sons Ltd, FISH and FISHERIES. DOI: 10.1111/faf.12119.

Dudgeon CL, Blower DC, Broderick D, Giles JL, Holmes BJ, Kashiwagi T, Kruck NC, Morgan JAT, Tillett BJ, Ovenden JR. 2012. A review of the application of molecular genetics for fisheries management and conservation of sharks and rays. Journal of Fish Biology (2012) 80, 1789–1843.

Duncan WP, Inomata SO, Fernandes MN. 2010. Comércio de raias de água doce na região do médio Rio Negro, estado do Amazonas, Brasil. Revista Brasileira de Engenharia de Pesca, 5(2): 13-22.

Diaz-Neto. 2011. Proposta de plano de gestão para o uso sustentável de elasmobrânquios sobre-explotados ou ameaçados de sobre-explotação no Brasil. Brasília.

Feldheim KA, Chapman DD, Simpfendorfer CA, Richards VP, Shivji MS, Wiley TR, Poulakis GR, Carlson JK, Eng R, Sagarese S. (2010). Genetic tools to support the conservation of the endangered smalltooth sawfish, Pristis pectinata. Conservation Genetics Resources 2, 105–113. doi:10.1007/S12686-010-9175-8

Ferreira EJG, Zuanon JAS, Santos GM. 1998. Peixes Comerciais do Médio Amazonas: Região de Santarém, Pará. IBAMA, Brasilia, P. 17-22.

Ferreira, PVG. 2006. Pesca de Tubarões com espinhel na costa norte do Brasil: Estudo de Caso de uma embarcação artesanal do distrito de Icoaraci, Município de Belem-PA. Trabaho de conclusão de curso, UFRA. 73p.

Herbert PDN, Cywinska A, Ball SL, Waard JR. (2003). Biological identifications through DNA barcodes. Proceedings of the Royal Society B 270,

313–322.

Holmes B, Steinke D, Ward R. 2009. Identification of shark and ray fins using DNA barcoding. Fisheries Research 95 (2–3): 280–288.

Hopkins C. 2011. External actors, high value resources and threatened species: Shark fin commodity chains of Northern Madagascar, interception for conservation. Master Thesis. Imperial College London, 64p.

Kekkonen M, Herbert PDN. 2014. DNA barcode-based delineation of putative species: efficient start for taxonomic workflows. Molecular Ecology Resources. 14, 706–715.

Kotas JE, Petrere MJr, Azevedo VG, Dos Santos S. 2005. A pesca de emalhe e de espinhel de superfície na Região Sudeste-Sul do Brasil. Série documentos Revizee – Score Sul, 72p.

Lasso CA, Rosa RS, Sánchez-Duarte P, Morales-Betancourt MA, Agudelo-Córdoba E. 2014. Rayas de agua Dulce (Potamotrygonidae) de Suramérica. Parte I. Colombia, Venezuela, Ecuador, Peru, Brasil, Guyana, Surinam y Guayana Francesa: diversidad bioecologia, uso y conservación. Colombia. Serie Editorial Recursos Hidrobiológicos y Pesqueros Continentales de Colombia and Instituto de Investigación de los Recursos Biológicos Alexander von Humboldt (IAvH). Bogotá, D.C. 368 pp.

Last PR, Séret B. 2016. A new Eastern Central Atlantic *skate Raja parva* sp. Nov. (Rajoidei: Rajidae) belonging to the *Raja miraletus* species complex. Zootaxa 4147 (4): 477-489.

Last PR, Henderson AC, Naylor GN. 2016a. *Acroteriobatus omanensis* (Batoidea: Rhinobatidae), a new guitarfish from the Gulf of Oman. Zootaxa, 4144 (2): 276-286.

Last PR, White WT, Naylor G. 2016b. Three new stingrays (Myliobatiformes: Dasyatidae) from the Indo-West Pacific. Zootaxa 4147 (4): 377-402.

Lessa R, Batista VS, Santana FM. 2016. Close to extinction? The collapse of the endemic daggernose shark (Isogomphodon oxyrhynchus) off Brazil. Global Ecology and Conservation, 7, 70-81.

Lessa RPT, Santana F, Paglerani R. 1999a. Age, growth and stock structure of the oceanic whitetip shark, *Carcharhinus longimanus*, from the southwestern equatorial Atlantic. Fish. Res., Holland, v. 42, p. 21-30.

Lessa R, Santana F, Rincon G, El-Deir ACA. 1999b. Biodiversidade de elasmobrânquios do Brasil. Necton-elasmobrânquios. Recife-PE.

Lessa R., Vooren CM, Araújo MLG, Kotas JE, Charvet-Almeida P, Rincón G, Santana FM, Gadig OB, Sampaio C. 2005. Plano nacional de ação para a conservação e o manejo dos estoques de peixes elasmobrânquios no Brasil. Recife: Lessa et al., 2005. 99 p.

Musick, J. A. 1998. Endangered marine fishes: criteria and identification of North American stocks at risk. Fisheries 23(7):28–30.

Musick JA, Ellis J. K. 2005. Reproductive Evolution of Chondrichthyans. In. HAMLETT, W. C. (ed.). Reproductive Biology and Phylogeny of Chondrichthyans. Sharks, Batoids and Chimaeras. Enfield: Science Publishers. Cap. 3. p. 45- 79.

Packer L, Gibbs J, Sheffield C, Hanner R. 2009. DNA barcoding and the mediocrity of morphology. Molecular Ecology Resources. 9 (Suppl. 1), 42–50.

Palmeira CAM, Rodrigues-Filho LFS, Sales JBL, Vallinoto M, Schneider H, Sampaio I. 2013. Commercialization of a

critically endangered species (largetooth sawfish, *Pristis perotteti*) in fish markets of northern Brazil: Authenticity by DNA analysis. Food Control. 34:249 e 252.

Pinhal D. 2010. Aplicação da genética molecular no manejo e conservação de tubarões / Danillo Pinhal. Botucatu, São Paulo.

Rodrigues-Filho LFS, Pinhal D, Sodré D, Vallinoto M. 2012. Shark DNA Forensics: Applications and Impacts on Genetic Diversity, Analysis of Genetic Variation in Animals, Prof. Mahmut Caliskan (Ed.), ISBN: 978-953-51-0093-5.

Rodrigues-Filho LFS, Rocha TC, Rêgo PS, Schneider H, Sampaio I, Vallinoto M. 2009. Identification and phylogenetic inferences on stocks of sharks affected by the fishing industry off the Northern coast of Brazil. Genetics and Molecular Biology, 32, 2, 405-413.

Rosa RS, Charvet-Almeida P, Quijada CCD. 2010. Biology of the South American Potamotrygonid Stingrays. In: Sharks and their relatives II: biodiversity, adaptive physiology, and conservation. Carrier JF, Musick JA, Heithaus MR. CRC Press, 241-286.

Rosa RS, Gadig OBF. 2014. Diversidade dos Chondrichthyes Marinhos no Brasil. Arquivos de Zoologia. São Paulo. Vol. 45(esp.).

Rosa RS, Menezes NA. 1996. Relação preliminar das espécies de peixes (Pisces, Elasmobranchii, Actinopterygii) ameaçadas no Brasil. Revista Brasileira de Zoologia, 13: 647-667.

Séret, B. 2006. Guia de identificação das principais espécies de raias e tubarões do Atlântico oriental tropical, para observadores de pesca e biólogos. Tradução Portuguese Rui COELHO IUCN Union mondiale pour la Nature.

Sodré D, Rodrigues-Filho LFS, Souza RFC, Rêgo PS, Schneider H, Sampaio I, Vallinoto M. 2012. Inclusion of South American samples reveals new population structuring of the blacktip shark (*Carcharhinus limbatus*) in the western Atlantic. Gen. Mol. Biol. 35, 752–760.

Szpilman M. 2004. Tubarões no Brasil: Guia prático de identificação. Rio de Janeiro: Aqualittera e Mauad, 160p.

Tavares W, Rodrigues-Filho LFS, Sodré D, Souza RFC, Schneider H, Sampaio I, Vallinoto M.. 2013. Multiple substitutions and reduced genetic variability in sharks. Elsevier.

Toffoli DR. 2006. História evolutiva de espécies do gênero *Potamotrygon* Garman, 1877 (Potamotrygonidae) na Bacia Amazônica. PPGBTRN. Manaus-AM.

Veríssimo A, McDowell JR, Graves JE. 2012. Genetic population structure and connectivity in a commercially exploited and wide-ranging deepwater shark, the leafscale gulper (*Centrophorus squamosus*). Mar. Freshwater Res. 63, 505–512.

Vooren CM, Klippel S. 2005. Ações para a conservação de tubarões e raias no sul do Brasil (Igaré, pp. 213–228). Porto Alegre.

Ward RD, Zemlak TS, Innes BH, Last PR, Hebert PDN. 2005. DNA barcoding Australia's fish species. Phil. Trans. R. Soc. B 360.

Weigmann S. 2016. Annotated checklist of the living sharks, batoids and chimaeras (Chondrichthyes) of the world, with a focus on biogeographical diversity. Journal of Fish Biology.