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Tópicos Integrados de Zoologia 2

José Max Barbosa Oliveira-Junior
Lenize Batista Calvão
(Organizadores)

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APRESENTAÇÃO

O e-book **"Tópicos Integrados de Zoologia 2"** é composto por oito capítulos que abordam distintos tópicos de uma especialidade da biologia que estuda os animais, a Zoologia. Com muita satisfação convidamos os leitores a lerem o e-book que traz temas relevantes sobre atualidade dentro da área de estudo.

Nessa segunda edição, o e-book disponibiliza temas diversificados de conhecimentos e áreas de interesse. A transformação das características naturais dos diversos sistemas terrestres e aquáticos no globo devido as alterações antrópicas estão aumentando continuadamente. Buscar ferramentas efetivas de conservação da biodiversidade exige um conhecimento técnico e também abrangente. Uma vez que, diferentes organismos apresentam distribuições geográficas distintas, bem como requerimentos muito específicos seja de habitat e de alimentação, que devem ser levados em consideração no planejamento de conservação da diversidade. Outro aspecto importante a ser destacado é a importância de coleções estruturadas a nível de espécie para preencher lacunas taxonômicas, que contribuiu para avaliação da vulnerabilidade das espécies. Diante desse arcabouço, dentro do e-book **"Tópicos Integrados de Zoologia 2",** os seguintes tópicos são abordados (i) monitoramento e novos registros de espécies exóticas invasoras; (ii) levantamento e contribuição de coleções entomológicas. Interessante que esse estudo foi realizado na Mata Atlântica um dos biomas com grande concentração de desmatamento; (iii) registro da primeira ocorrência de um bivalve de água doce; (iv) hábitos alimentares específicos de peixes de água doce; (v) efeitos negativos que a construção das hidrelétricas causam no bem estar de populações de peixes; (vi) uso de organismos bioindicadores da qualidade da água; (vii) uso de biomarcadores para estudos genéticos de populações; e (viii) uma revisão de estudos genéticos no litoral amazônico para aprimorar o conhecimento sobre os estoques da região e suas dinâmicas em relação a pesca.

Demonstramos acima a diversidade de conteúdos que a Zoologia abrange e sua importância, desta forma, apresentamos os oito capítulos que integram esse e-book, que demonstram em seus objetivos de forma aplicada e holística vários tópicos da Zoologia.

A você leitor(a), desejamos uma excelente leitura.

José Max Barbosa Oliveira-Junior
Lenize Batista Calvão

SUMÁRIO

CAPÍTULO 8

ESTUDOS MOLECULARES APLICADOS A CONSERVAÇÃO DE ELASMOBRÂNQUIOS NO LITORAL AMAZÔNICO

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RESUMO: Os elasmobrânquios são um grupo antigo e diverso de animais que habitam ecossistemas aquáticos amplamente distribuídos pelo globo. Com maturação tardia e produção de poucos descendentes, esses organismos estão atualmente entre os grupos de vertebrados com maior número de espécies ameaçadas de extinção. Dentre os principais ameaça as populações estão a sobre-exploração por meio da pesca predatória e a degradação de habitats ocasionadas pela ação antrópica. Somado a isso, há um grande quantitativo de espécies sobre as quais não se tem informações suficientes que permitam avaliar o seu real estado de conservação. Um dos obstáculos impostos à conservação deste grupo é a não identificação correta dos indivíduos capturados durante atividades pesqueiras e carência de mais estudos que relacionem a atividade pesqueira sobre a diversidade genética. Nesse cenário, o uso de ferramentas moleculares tem se mostrado promissor uma vez que, mesmo negligenciadas, servem de instrumentos na a elaboração de planos e legislações para conservação dos elasmobrânquios. A esse respeito, esta revisão se propôs a mostrar estudos genéticos no litoral amazônico que podem auxiliar na melhor compreensão dos estoques da região e suas dinâmicas em relação a pesca, discutir as principais causas de ameaça aos elasmobrânquios bem como o uso de ferramentas moleculares com fins de conservação, com ênfase em exemplos de espécies que habitam a região do Litoral Amazônico.

KEYWORDS: Tubarões; Raias, Identificação Molecular, Diversidade Genética, Amazônia.

MOLECULAR STUDIES APPLIED TO ELASMOBRANCH CONSERVATION THROUGHOUT THE AMAZON COAST

ABSTRACT: Elasmobranchs are an ancient and diverse group of animals that inhabit aquatic ecosystems widely distributed around the globe. Due to late maturation and the production of few offspring, these organisms are currently among the most endangered species of all vertebrates. Overexploitation through predatory fishing and habitat degradation caused by anthropic activities are among the main threats to this group. In addition, a high number of species lacking information to assess their actual conservation status is noted. One of the obstacles to the conservation of this group is the incorrect identification of individuals caught during fishing activities and the lack of further studies that associate fishing activities to genetic diversity. In this regard, the use of molecular tools has shown promise, as they serve as instruments in the development of elasmobranch conservation plans and legislation. In this context, this review aims to show genetic studies on the Amazonian coast that can help in better understanding the stocks of the region and their dynamics in relation to fishing, discuss the main causes of threat to elasmobranchs as well as the use of molecular tools for purposes conservation, with emphasis on examples of species that inhabit the region of the Amazon Coast.
KEYWORDS: Sharks, Rays, Molecular identification, Genetic diversity, Amazon.

1 | INTRODUTION

Sharks and rays (subclass Elasmobranchii), along with chimeras (subclass Holocephali), make up the current Chondricthyes class representatives. These fish are known as cartilaginous fish, due to their non-ossified skeletons, and have inhabited aquatic ecosystems on planet Earth for at least 400 million years. They are currently active as top-chain predators in marine and estuarine environments worldwide, playing important trophic web equilibria roles (COMPAGNO, 2001; SZPILMAN, 2004; STEVENS, 2005; AGUIAR & VALENTIN, 2010; BLOCK et al., 2011).

Approximately 1300 species of living Chondricthyes have been described (FRICKE et al., 2019), which share a predominantly cartilaginous skeleton and an internal fertilization reproductive strategy mediated by claspers (GROGAN, & LUND, 2004; NELSON et al., 2016). According to the International Union for Conservation of Nature's Red List of Endangered Species (IUCN, 2019), 19% of all assessed shark and rays species are listed in one of the current extinction threat categories (Critically Endangered categories - CR, Endangered - EN or Vulnerable - VU), while another 10% are categorized as Near Threatened (NT). In addition, approximately 40% are placed in the Insufficient Data (DD) category, meaning that information concerning their distribution and population abundance does not allow for assessments regarding their actual conservation status, which, in turn, indicates that many species may be at risk of extinction (DULVY et al., 2014). Thus, elasmobranchs are one of the vertebrate groups comprising the highest number of threatened species worldwide (DULVY et al., 2014; SIMPFENDORFER & DULVY, 2017; GROSS, 2019).

Given the current threat status of sharks and rays, the adoption of appropriate management programs for their conservation is imperative, although their implementation faces several obstacles (HEUPEL et al., 2015; DULVY et al., 2017; ESPINOSA et al.,2018; MACKERACHER et al., 2018). These include the non-identification of species caught during fishing activities which, in turn, imposes significant challenges, as this prevents the identification of species under greater fishing pressure, resulting in obstacles concerning statistical surveys that reflect the actual population status of elasmobranch species (HOLMES et al., 2009; GEMAQUE et al., 2017). In Brazil, for example, official fishing statistics use the generalist terms "*cação*" and "*arraia*" or "*raia*" to group non-discriminated species from different taxonomic families, according to normative instruction Number 29 of September 23, 2015. This normative instruction establishes the correlation between common fish names and their respective scientific names to be adopted in marketed products inspected by the Ministry of Agriculture, Livestock and Supply and destined for national marketing (MAPA, 2015).

In this context, molecular methodologies, such as DNA Barcoding, may be applied to correctly identify different species, as they allow for better accuracy in elasmobranch identification (WARD et al., 2005, HOLMES et al., 2009; ASIS et al., 2014; BINEESH et al., 2017; FIELDS et al., 2015; SEMBIRING et al., 2015; VAN DER MERWE & GLEDHILL, 2015; CHUANG et al., 2016; STEINKE et al., 2017; *ALMERÓN-SOUZA* et al., 2018; FEITOSA et al., 2018; FERRETE et al., 2019; HAQUE et al., 2019; HELLBERG et al., 2019; MUTTAQIN et al., 2019; RODRIGUES-FILHO et al., 2020). Thus, the DNA Barcode technique serves as a basic tool in the implementation of shark and ray management plans aiming at conservation actions.

The Amazon rainforest, an equatorial rainforest region, comprises about 6.7 million km^2, crossing the borders of nine South American countries. It represents one of the most important biodiversity centers on the planet, sheltering about 2.5 million insect species, tens of thousands of plants, more than 2,000 birds and mammals and about 2,200 fish species (DA SILVA et al., 2005; ALBERT AND REIS, 2011). The coastal area of the Amazon, which comprises the coastal regions of five countries (Colombia, Venezuela, Guyana, Suriname, French Guiana and Brazil), however, requires as much attention concerning conservation than other parts of the Amazon, mainly due to intense interactions between anthropogenic activities and Amazon coast biodiversity, including bony and cartilaginous fish).

This review discusses the main threats to elasmobranchs and the use of molecular tools for the conservation of this group, with emphasis on examples involving species inhabiting the Amazon coast.

2 I ELASMOBRANCHS AS A FISHING RESOURCE

Elasmobranch commercialization as a fishing resource has always been a common activity for coastal human populations, who make use of elasmobranch meat and some by-products. This trade has, however, become increasingly and continuously exploited globally, sometimes in an flawed manner, resulting in extinction risks to several species (FAO, 1999; MUSICK 2005b; CERUTTI-PEREYRA et al., 2012; SEMBIRING et al., 2015; FIELDS et al., 2015; STEINKE et al., 2017; GEMAQUE et al., 2017; ALMERÓN-SOUZA et al., 2018; MUTAQIN et al., 2019)

Among elasmobranchs, sharks are a particularly important fishing resource, caught by diverse fishing gears in different areas worldwide. Their importance is partly due to the finning trade, which displays high commercial value (CARDEÑOSA et al*.,* 2018). However, catching sharks only for their fins is a waste, as medium-sized sharks provide about 3% fins, 35% fillet, 13% liver rich in vitamins A and D, 9% skin, that can be used for making leather goods, and 40% waste that can be processed into animal feed meal (SZPILMAN, 2004; JABADO et al., 2015; TRAN, 2019).

In this context, sharks and rays exhibit different fisheries interests for both the worldwide market and for regional Brazilian markets. No targeted fisheries concerning most skates and rays are observed. However, some species are the target of sport fishing, of bottom trawl nets used in shrimp fishing, or caught as accompanying fauna (bycatch) alongside other target species and discarded after they are already found dead in fishing nets (NUNES et al., 2005; LESSA et al., 2016;). Because of this, some ray species are critically endangered i.e. the sawfish or swordfish (*Pristis pristis*, Linnaeus, 1758), one of the most threatened elasmobranch species in the world, listed by the IUCN as critically endangered (KYNE et al., 2013).

Accordingly, the effects of elasmobranch fishing occur through both intentional and incidental fishing and in industrial or artisanal bycatch form (MUSICK, 2005a). These have been identified as the main aggravating factors in the decreases of elasmobranch population stocks worldwide (DULVY et al., 2014; IUCN, 2019). In Brazil alone, over 19,600 tons of sharks and rays were caught in marine and continental environments in 2011 (MPA, 2011) and it is estimated that overfishing may have caused the decline of over 80% of the abundance of some sp4ecies (ICMBio, 2010). In addition, as of 2011, no fisheries statistics reports have been produced in Brazil (ICMBio, 2020).

In addition to extreme fishing actions, elasmobranchs are k strategists, a decisive factor concerning this taxon's vulnerability to fishing. K strategist fish generally exhibit low hatchling production and late maturation, resulting in issues concerning their use as a fishing resource (BORNATOWSKI & ABILHOA, 2012). Thus, the contribution of the natural biological characteristics of these organisms, the constant changes caused to their habitats and the fact that they are an overexploited fishing resource, categorize elasmobranchs as one of the most threatened groups of vertebrates worldwide (LUCIFORA et al., 2011; DULVY et al., 2014).

3 I ELASMOBRANCH EXTINCTION AND CONSERVATION RISKS

DULVY et al. (2014), in a wide systematic survey, concluded that approximately a quarter of all 1,041 shark, ray and chimera species on the IUCN red list are under threat, while only a third is considered safe. The main threats to these organisms are, according to these authors, over-intentional and incidental fishing, which cause serious population stock declines. Among endangered species, individuals with large body sizes and who live in shallow waters are at greater risk, as they are more vulnerable to fishing activities. In addition, habitat loss, catch and climate change are also noted as threats (DULVY et al., 2017).

Although traditionally considered secondary products, the consumption of animal protein derived from sharks and rays in the form of meat, fins, liver, skin and cartilage is significant, especially in the coastal regions of developing countries (FAO, 1999; MUSICK, 2005b). In addition, increased international demands for shark fin soup, considered a high commercial value delicacy in Asian countries, has led to predatory finning for decades (GEMAQUE et al., 2017).

On the other hand, accompanying fauna (bycatch) comprises several organisms captured incidentally when capturing higher commercial value fishing resources (BONANOMI et al., 2017). However, as they are the object of lesser interest, sharks and rays are often discarded, either dead or with little chance of survival, usually without any control concerning their diversity and quantitative records (BONANOMI et al., 2018).

In this context, an aggravating lack of knowledge is still noted regarding the elasmobranch fauna of some regions (LESSA et al., 2016; GEMAQUE et al., 2017). The aforementioned causes contribute to the current conservation status of most elasmobranchs, with a significant number of threatened species and lack of knowledge concerning most elasmobranch representatives (IUCN, 2019). This evidences the need for mechanisms and tools capable of interfering in elasmobranch population declines caused by human activities.

The increases in commercial elasmobranch exploitation have generated the need for more adequate policies and management systems, which are becoming increasingly difficult to implement due to a lack of information on the biology and fishing activities of many sharks and rays (FURTADO-NETO & BARROS-JÚNIOR, 2006). Therefore, to understand the biological and population aspects of these species, as well as the effects of predatory fishing on these populations is paramount for the adequate management of these resources (CORREIA, 2009). In view of the need for such information, and especially regarding low fishing sustainability on a global scale, FAO has developed an international action plan for shark management and conservation, given their high commercial importance. This plan is aimed at developing and implementing national action plans with the objective of guaranteeing the management and conservation of elasmobranch stocks, with the main established recommendation being the collection of capture and landing data at a species-specific level (FAO, 1999).

The absence of this information has drawn the attention of scientists, organization conservations, the media and the general public (BAUM & WORM, 2009; CAMHI et al., 2009; HEITHAUS et al., 2010; KOLDEWEY & MARTIN-SMITH, 2010). Since the 1950s, fishing laws that regulate international fishing markets have existed to protect elasmobranchs and other fish species, so much so that some pre-existing laws have been changed specifically to protect this group (International Plan of Shark Action and Conservation and Management - IPOA-Sharks, 2019).

In 2014, the Brazilian Ministry of the Environment approved a National Action Plan for the Conservation of Endangered Marine Sharks and Rays (PAN-Sharks and Rays; Ordinance No. 445, of 12/17/2014) with the general objective of "mitigating the impacts on marine elasmobranchs threatened with extinction in Brazil and its environments, for the purpose of short-term conservation "(BRASIL, 2014, p. 1), aiming at benefiting 55 endangered elasmobranch species (ICMBio, 2010). The plan envisaged 67 actions with nine specific objectives, similar to the IPOA-Sharks. However, monitoring and fishing activity inspection deficiencies have also been pointed out in the plan itself as difficulties in implementing strategies for the conservation of target species (ICMBio, 2010), indicating that any attempt to implement conservationist policies for these organisms will face several barriers.

4 I MOLECULAR IDENTIFICATION

An important step to increase knowledge concerning elasmobranchs is species identification. The difficulty in correctly identifying cartilaginous fish is due to the fact that they arrive either already in processed state in markets, or only their fins are landed, making morphological identification impossible (VOOREN & KLIPPEL, 2006). Because of this, molecular markers have been widely applied to identify species exhibiting economic interest (WARD et al., 2005; KYLE & WILSON, 2007; SEVILLA et al*.,* 2007; HOLMES et al., 2009; ASIS et al., 2014; BINEESH et al., 2015; FIELDS et al., 2015; SEMBIRING et al., 2015; VAN DER MERWE & GLEDHILL, 2015; CHUANG et al., 2016; STEINKE et al., 2017; *ALMERÓN-SOUZA* et al., 2018; FEITOSA et al., 2018; FERRETE et al., 2019; HAQUE et al., 2019; HELLBERG et al., 2019; MUTTAQIN et al., 2019; RODRIGUES-FILHO et al., 2020).

Due to the need for more precise identification, molecular tools have increasingly been applied, circumventing the difficulties imposed by the absence of morphological diagnostic characteristics (CHAN et al*.,* 2003; ALVARADO BREMER et al., 2005; MENDONÇA et al., 2009). The molecular identification of different hammerhead sharks (*Sphyrna* genus, Rafinesque 1810), for example, is a clear instance of the potential use of these tools applied to conservation and management actions (SEE TAVARES et al., 2013). The heads of species belonging to this genus, their main identifying structure, are usually removed at sea, resulting in doubts concerning landed species (FIELDS et al. 2015, HELLBERG et al. 2019).

This type of doubt caused by elasmobranch processing is aggravated by the imprecise nomenclature used to designate each species, resulting in uncertainties concerning the real exploration and commercialization status of this group, as well as with regard to the species substitutions practice. The Brazilian Ministry of Agriculture, Livestock and Supply (MAPA) normative instruction no. 29 of 2015, which establishes a correlation between common names and respective scientific names, has intensified this problem, as the use of common names (cação, shark and ray) is used to designate all elasmobranch species marketed in the country (MAPA, 2015).

Oliveira (2012), for example, sought to assess the hammerhead shark trade in the city of Bragança, in the state of Pará, Brazil, in order to determine the importance of molecular tools (multiplex PCR) in species discrimination and characterize the local hammerhead shark trade. Of the 100 samples obtained from markets and fairs sold as hammerhead sharks, only 25 were in fact Sphyrnidae (*Sphyrna tiburo,* Linnaeus, 1758 – 16 samples, *Sphyrna tudes,* Valenciennes, 1822 - four samples and *Sphyrna lewini,* Griffith & Smith, 1834 – five samples). This demonstrates not only the commercialization of endangered species, but also commercialization “fraud” or complete ignorance of what is sold by marketers, since the sharks already arrive processed at fairs and markets in the form of “cigars” (gutted and with no head of fins).

Palmeira et al. (2013) clearly indicates elasmobranch fraud/sale ignorance, as well as illegal trade, throughout the Amazon coast. In order to assess the commercialization of a critically endangered ray species, *P. pristis* (the largetooth sawfish), whose fishing is prohibited in Brazil (IUCN, 2019; ICMBio, 2019), 44 fillet samples sold at Vígia and Bragança city fairs, in the state of Pará, Brazil were sampled. The findings indicate that this species is still commercialized in the study area, as 24 samples were positively identified as *P. pristis*, characterizing illegal trade. In addition, the substitution of this species by other elasmobranchs was also observed, as other shark species are also sold as *P. pristis* (namely, *Carcharhinus leucas* Müller & Henle, 1839*, Carcharhinus limbatus* Müller & Henle, 1839*, Carcharhinus porosus* Ranzani, 1839*, Carcharhinus acronotus* Poey, 1860*, S. lewini, Galeocerdo cuvier* Péron & Lesueur, 1822 and *Ginglymostoma cirratum* Bonnaterre, 1788). These results are certainly associated not only to noncompliance with current laws, as several threatened species are still being marketed (*P. pristis*, *C. porosus*, *S. lewini* and *G. cirratum* (see MMA Ordinance nº 445, of 17 December 2014, IUCN, 2020), but also fraud, since the products in fact sold do not correspond to reported products by traders, either deliberately or due to lack of knowledge.

Rodrigues-Filho et al. (2009), applying molecular identification through the 12S16S marker, compared the specificity relationship between the different names attributed by sellers to shark "cigars" on sale in fairs and markets in the cities of Belém, Vígia and Bragança, in the state of Pará, Brazil. No correlations between the common names given by local fishers and traders were observed, to the point of noting several species traded under the same common name. It is also important to note that even very specific common names for some local species (ex.: Daggernose shark - *Isogomphodon oxyrhynchus,* Müller & Henle, 1839) were attributed to species belonging to other, quite distinct, genera (Table 1). A total of nine species were identified among 122 samples, as follows: *C. porosus, C. leucas, C. acronotus, Carcharhinus falciformes* Müller & Henle, 1839*, Carcharhinus perezi* Poey, 1876*, S. tudes, S. tiburo, Sphyrna mokarran* Rüppell, 1837 and *G. cuvier. C. porosus* (46.7%) and the *Rhizoprionodon* genus Whitley, 1929 (28,6%) were the most frequently sampled.

Common names	N	Scientific names
Sacurí	6	***Carcharhinus falciformis, Carcharhinus plumbeus, Carcharhinus porosus, Rhizoprionodon sp. , Sphyrna tudes*** **and** ***Sphyrna sp.***
Lomo Preto	2	***Carcharhinus falciformis e Rhizoprionodon sp.***
Milho Verde	5	***Carcharhinus acronotus, Carcharhinus porosus, Rhizoprionodon sp., Sphyrna tiburo*** **and** ***Sphyrna mokarran***
Flamengo	1	***Rhizoprionodon sp.***
Cação areia	4	***Carcharhinus acronotus, Carcharhinus porosus, Rhizoprionodon sp.*** **and** ***Sphyrna tudes***
Panã	2	***Carcharhinus leuca*** **and** ***Sphyrna mokarran***
Maxote	1	***Carcharhinus perezi***
Cação Pato	1	***Galeocerdo curvier***
Tubarão branco	1	***Sphyrna sp.***

Table 1 - Comparison of common elasmobranch names sold at fairs and markets in Belém, Vígia and Bragança, compared to the molecular identification results reported by Rodrigues-Filho et al. (2009). N - Number of different species for each common name.

For elasmobranchs, one of the most routinely applied methods to identify the lowest taxonomic level for several taxa is the DNA Barcode technique, which is simple and effective (HEBERT et al., 2003). This method uses a small fragment of the mitochondrial cytochrome oxidase subunit I (COI) gene, comprising approximately 648 nucleotides. A database was developed (BOLD platform - http://www.boldsystems.org/) in order to store information about all barcoded organisms, to assist in species identification (HEBERT et al., 2003).

Kolmann et al. (2017), Feitosa et al. (2018) and Rodrigues-Filho et al. (2020) have applied this technique for species identification throughout the Amazon coast. Kolmann et al. (2017) sought to understand the biodiversity of coastal sharks for the Guyana, analyzing a total of 132 samples. The authors reported than over 30% of the samples comprised hammerhead sharks (*S. lewini, S. mokarran, S. tudes, S. tiburo* and *Sphyrna media*), while *Rhizoprionodon lalandii* Müller & Henle, 1839, *Rhizoprionodon porosus* Poey, 1861, *Carcharhinus plumbeus* Nardo, 1827, *C. porosus, C. limbatus, C. acronotus, C. leucas, C. falciformes* and *G. cuvier* were also identified. Of the 14 identified species, *R. lalandii* (18.9%), *C. porosus* (17.4%) and *S. lewini* (17.4%) were the most frequently caught species.

Feitosa et al. (2018) identified fished shark species in several cities throughout the Brazilian Amazon coast (Belém-PA, Vígia-PA, Bragança-PA, Carutapera-MA, Raposa-MA and Tutoia-MA), reporting the occurrence of 17 species belonging to five different families (Figure 2), with *R. porosus*, *C. acronotus* and *C. porosus* as the most landed, at 33.1%, 15.88% and 9.81 %, respectively. This study was the first record for the *Squalus* genus on the Brazilian Amazon coast.

Concerning rays, Rodrigues-Filho et al. (2020) sampled 118 ray samples marketed at the cities of Belém-PA, Vígia-PA, Bragança-PA and Cidade do Amapá-AP using the DNA Barcode technique. The authors identified nine ray species, with *Hypanus guttatus* Bloch & Schneider, 1801 (33.05 %) as the most frequent, followed by *Aetobatus narinari* Euphrasen, 1790 (11.86 %) and *Narcine sp.* Henle 1834 (11.86 %). The other identified species comprised *P. pristis*, *Gymnura micrura* Bloch & Schneider, 1801, *Rhinoptera bonasus* Mitchill, 1815, *Hypanus berthalezai* Petean et al., 2020, *Fontitrygon geijskesi Boeseman, 1948* and *Rhinoptera brasiliensis* Müller & Henle, 1841.

Shark species	**Rodrigues-Filho et al. (2009)**	**Kolmann et al. (2017)**	**Feitosa et. al. (2018)**	**IUCN**	**ICMBio ordinance nº 445**
Sphyrna lewini	-	17.4	4.2	EN	CR
Sphyrna mokarran	1.6	10.6	9.34	EN	EN
Sphyrna tudes	4.9	6.0	2.33	VU	CR
Sphyrna tiburo	0.8	2.3	2.8	LC	CR
Sphyrna media	-	0.8	-	DD	CR
Sphyrna sp.	1.6	-	-	-	CR
Rhizoprionodon spp.	28.6	-	-	-	-
Rhizoprionodon lalandii	-	18.9	0.23	DD	NT
Rhizoprionodon porosus	-	3.8	33.1	LC	DD
Carcharhinus porosus	46.7	17.4	9.81	DD	CR
Carcharhinus limbatus	-	8.3	2.10	NT	NT
Carcharhinus acronotus	5.7	5.3	15.88	NT	NT

Carcharhinus leucas	0.8	0.8	3.97	NT	NT
Carcharhinus falciformis	3.2	0.8	2.57	NT	NT
Carcharhinus perezi	1.6	-	-	NT	-
Carcharhinus plumbeus	-	0.8	-	VU	CR
Carcharhinus plumbeus/altimus	3.2	-	-	VU/DD	CR
Isogomphodon oxyrhyncus	-	-	3.27	CR	CR
Galeocerdo cuvier	0.8	6.8	2.8	NT	NT
Mustelus higmani	-	-	1.86	LC	-
Mustelus canis	-	-	1.86	NT	EN
Squalus brevirostris/megalops	-	-	0.23	DD/DD	DD
Ginglymostoma cirratum	-	-	3.27	DD	VU
Ray species	**Rodrigues-Filho et al. (2020)**				
Hypanus guttatus	33.05			DD	LC
Hypanus berthalezai	8.47			DD	DD
Fontitrygon geijskesi	2.54			NT	DD
Gymnura micrura	10.16			DD	NT
Aetobatus narinari	11.86			NT	DD
Rhinoptera bonasus	10.16			NT	DD
Rhinoptera brasiliensis	1.69			EN	CR
Narcine sp.	11.86			-	-
Pristis pristis	10.16			CR	CR

Table 2 – Frequency of shark and ray species sold in fairs and markets throughout the Amazon coast, according to Rodrigues-Filho et al. (2009), Kolmann et al. (2017), Feitosa et. al. (2018) and Rodrigues-Filho et al. (2020). IUCN and ICMBio conservation statuses are listed, when available. DD – Data Deficient; LC – Least Concern; NT – Near Threatened; EN – Endangered; CR – Critically Endangered. (-) no information.

Some species are cited both in international and national extinction threat lists (IUCN, 2019; ICMBio, 2018) (Table 2). For example, Feitosa et al. (2018) observed the presence of 12 captured *I. oxyrhynchus* specimens, an endemic Amazon coast species reported as undergoing population declines (LESSA et al*.,* 2016). The authors stress the significant lack of information concerning elasmobranch species diversity throughout the Amazon coast.

Of the 30 identified elasmobranch species marketed in fairs, 23 are not listed in IUCN threat categories (DD: 10, LC: 3 and NT: 10), but instead, in the Data Deficient category. This is extremely worrying, as 43.3% of the reported species are deficient data or present little information. According to the Brazilian ICMBio list, however, this number drops from 23 to 14 species. An even more significant lack of information is noted for rays. In view of the fact that rays are a source of food and highly marketed in the Amazon region, and that an absence of adequate information to assess their risk of extinction based on population distribution and status is noted, it is probable that more species than currently estimated exist.

This information concerning the Amazonian coast follows the global view described by Davidson et al. (2016) and Dulvy et al. (2014), with a quarter of Chondrichthyes reported as at risk of extinction due to overfishing. According to the International Union for Conservation of Nature's Red List of Endangered Species (IUCN, 2019), 19% of the assessed shark and rays are listed in one of the three extinction threat categories (CR, EN and VU), while 10.45% are categorized as near threatened (NT). In addition, approximately 70.4% are listed as Data Deficient (DD) and Least Concern (LC), indicating that the available distribution and population abundance information does not allow for real conservation status assessments. Therefore, many species may be, in fact, at risk for extinction (DULVY et al., 2014) (Figure 1).

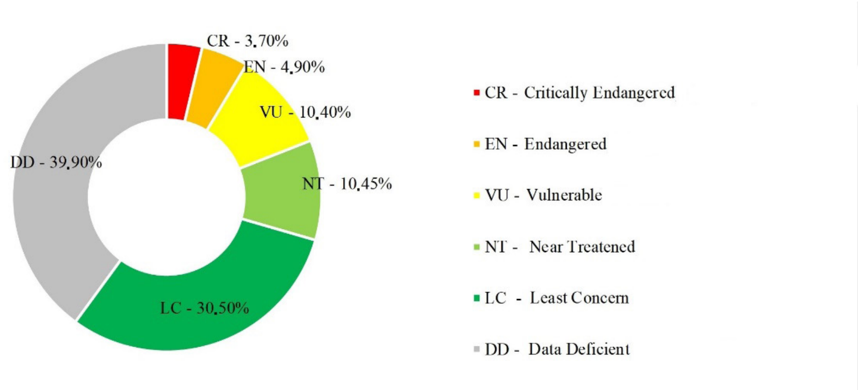

Figure 1 - Current numbers of threatened elasmobranch species according to IUCN categories.
Source: Modified from IUCN (2019).

Dulvy et al. (2014) estimate that, of the 487 species listed by the IUCN as Data Deficient, 66 are probably threat. These data indicate the urgent need to produce more information, whether molecular, ecological or reproductive, concerning Amazon coast species, and above all, for species that fall into the Data Deficient category.

5 I GENETIC DIVERSITY

The aforementioned studies demonstrate that monitoring shark and ray species through molecular identification and genetic diversity techniques is paramount to allow for management plans concerning the different elasmobranch species exploited throughout the Amazon coast. However, scarce genetic studies on elasmobranchs in this region are available to date, and molecular studies addressing only fishing activity relationships to genetic elasmobranch diversity are the most frequent.

These stocks are among the most vulnerable to the negative effects of fishing worldwide, indicating that genetic population characterization and stock evaluations are vital

(FEITOSA et al., 2018; RODRIGUES FILHO et al., 2020). In the case of *I. oxyrhynchus*, for example, studies indicate that this species continues to be affected, as fishing removes not only adult males and females, but also immature individuals, influencing stock replacements in the Amazon region, thus altering the status of this species from endangered to almost extinct (LESSA et al., 2016).

When investigating the genetic diversity of some Amazon elasmobranchs, Tavares et al. (2013) analyzed the genetic variability of four shark species frequently captured throughout the Amazon coast (*C. porosus, R. porosus, Sphyrna tudes* and *C. limbatus*) using mitochondrial markers. The results indicated high genetic diversity levels for *C. porosus*, *R. porosus* and *C. limbatus*, while a strong reduction in genetic diversity, in fact, one of the lowest levels ever reported for sharks, was noted for *S. tudes*. The authors attribute this drastic reduction to a strong fishing activities, emphasizing the need to adopt conservation policies for this fishing resource, as *S. tudes* is under a strong threat of extinction due to its restricted distribution and evident genetic decline.

Sodré et al. (2012) observed a relatively high diversity for *C. limbatus* populations, both in the Amazon and in other areas, similar to that of other populations worldwide, but exhibiting a much larger number of private alleles, indicating the absence of genetic connectivity among previously studied Central Atlantic *C. limbatus* populations (Keeney et al., 2003; Keeney et al., 2005; Keeney & Heist, 2006). This study, as well as previous studies on *C. limbatus*, also indicate strong genetic structure levels, attributed to philopatric female behavior.

Studies suggest that philopatric behavior, as well as other life patterns (viviparous reproduction, sedentary behavior and disjunct distribution) can limit the gene flow between populations, influencing population structure and genetic species diversity (KARL et al., 2012; SODRÉ et al., 2012; DOMINGUES et al., 2013). Sodré et al (2012) state that the Amazon coast *C. limbatus* population is genetically distinct from all other assessed populations, and that it should be considered a different management unit in order to protect stocks, as low migration levels between different stocks indicate the need for the adoption of independent management measures for each one (SCHREY & HEIST, 2003).

6 I CONCLUSIONS

The implementation of management plans for any fishing resource is based on ecology, reproduction and life history data, usually neglecting genetic information, mainly concerning the genetic diversity of populations vulnerable to exploitation, as well as that of several elasmobranch species (DOMINGUES et al., 2013; SIMPFENDORFER et al., 2011; OVENDEN et al., 2013). Unfortunately, the importance of molecular studies in the development of these plans has not yet been adequately recognized. However, all molecular inferences, whether concerning species identification or population genetics (genetic diversity, population structure), can indeed contribute as a source of information and conservation and sustainable management criteria for these stocks. This review demonstrates that genetic studies on the Amazon coast may aid in better understanding local stocks and their dynamics in relation to fishing. Furthermore, in addition to the implementation of further molecular studies, the information generated by these studies should also be applied to elasmobranch conservation plans and legislation development and implementation throughout the Amazon coast.

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