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Thematic Review

Research trends on elasmobranchs from the Brazilian Amazon Coast: a four-decade review

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Abstract: Elasmobranchs exhibit the biggest population declines among vertebrates, being considered one of the groups with the highest risk of extinction. The Brazilian Amazon Coast (BAC) is considered a priority area for elasmobranch conservation, as many species are endemic to the region, and most of them are threatened with extinction. The present study made a scientometric analysis using the IRAMUTEQ method (***I****nterface de* ***R*** *pour les* ***A****nalyses* ***M****ultidimensionnelles de* ***T****extes et de* ***Q****uestionnaires*) to evaluate the trends of research with elasmobranchs in BAC in the last four decades. Ten research trends were identified, highlighting "Biodiversity", "Reproduction", "Trophic Ecology" and "Conservation". However, most of the publications found are aimed at understanding the diversity and abundance of species in the region, with the number of studies focused on reproduction, feeding and other aspects of the biology and ecology of elasmobranchs in the BAC being less expressive. Although the research area "Conservation" stood out in the search, the amount of relevant information so that management and conservation measures can be implemented is still low. Lastly, despite following the global trend of studies with elasmobranchs between 2000 and 2010, investigations into the BAC need to advance, especially considering the poor level of basic information on most species (Biology and population dynamics) and the incomplete knowledge of specific composition of elasmobranch species in the entire area, aspects relevant to conservation and more applied studies that rely on more recent methodologies and technologies.
Keywords: *Biodiversity; Chondrichthyes; conservation; scientometric analysis.*

Tendências de pesquisa sobre elasmobrânquios na Costa Amazônica Brasileira: uma revisão de quatro décadas

Resumo: Elasmobrânquios apresentam os maiores declínios populacionais entre os vertebrados, sendo considerado um dos grupos com maior risco de extinção. O Litoral Amazônico Brasileiro (BAC) é considerado uma área prioritária para conservação de elasmobrânquios, pois várias espécies são endêmicas da região, e a maioria delas estão ameaçadas de extinção. O presente estudo fez uma análise cientométrica aplicando o método IRAMUTEQ (***I****nterface de* ***R*** *pour les* ***A****nalyses* ***M****ultidimensionnelles de* ***T****extes et de* ***Q****uestionnaires*) para avaliar as tendências de pesquisas com elasmobrânquios no BAC nas últimas quatro décadas. Dez tendências de pesquisa foram identificadas, destacando-se "Biodiversidade", "Reprodução", "Ecologia trófica" e "Conservação". Entretanto, a maioria das publicações encontradas é voltada para o conhecimento da diversidade e abundância das espécies na região, sendo o número de estudos voltados para a reprodução, alimentação e outros aspectos da biologia e ecologia de elasmobrânquios do BAC menos expressivo. Apesar da área de investigação "Conservação" ter se destacado na busca, a quantidade de informações relevantes para que medidas de manejo e conservação possam ser implementadas ainda é baixa.

Por fim, apesar de seguir a tendência mundial de estudos com elasmobrânquios entre 2000 a 2010, as investigações sobre o BAC precisam avançar, especialmente considerando o baixo nível de informações básicas sobre a maioria das espécies (biologia e dinâmica populacional) e o conhecimento incompleto da composição específica das espécies de elasmobrânquios em toda a área, aspectos relevantes para a conservação e estudos mais aplicados e que contem com metodologias e tecnologias mais recentes.

Palavras-chave: *Biodiversidade; Chondrichthyes; conservação; análise cientométrica.*

Introduction

Elasmobranchs are cartilaginous fish represented by sharks and batoids with about 1,200 species currently described (Weigmann 2016) distributed in tropical, subtropical, temperate, and cold waters. Species can be found from coastal regions to great depths across the planet (Compagno et al. 2005, Last et al. 2016, Nelson et al. 2016). Due to their high position in the aquatic food webs, sharks and batoids are important for ecosystem balance through lower-trophic level population control (Heithaus et al. 2010). They also contribute to food security in underdeveloped and developing countries, as well as generate income for traditional communities through fishing and tourism (Rigby et al. 2019). However, elasmobranchs suffer intense anthropic pressure, mainly due to overexploitation, bycatch, habitat loss, climate change, and pollution (Dulvy et al. 2017, Pacoureau et al. 2021). Due to their biological characteristics, such as low growth rates, late maturation, low fertility, and long gestation periods with small litters, sharks and batoids exhibit low population recovery potential (Vooren & Klippel 2005).

Brazil has one of the largest coastal zones on the planet, with approximately 8.500 km in length, of which 2.975 km are part of the Brazilian Amazon Coast (BAC), composed by the states of Amapá, Pará, and Maranhão (Pereira et al. 2009, Brazil 2018). The BAC is one of the most important fishing centers in the country due to its high productivity (Stride et al. 1992, Lessa et al. 1999a, Marceniuk et al. 2019). In 2011, BAC's fishing productivity was 138,864 tons, representing 25% of the national production (553,670 tons) (Brazil 2011). The BAC is also a global hotspot for maintaining and preserving elasmobranch stocks, mainly due to the high irreplaceable values of endemic species calculated for the region (Dulvy et al. 2014). Currently, 34 species of sharks and 36 species of batoids are found within the BAC (Marceniuk et al. 2019), highlighting endemic species at high risk of extinction, such as the Daggernose shark, *Isogomphodon oxyrhynchus* (Müller & Henle, 1839), and the Wingfin stingray, *Fontitrygon geijskesi* (Boeseman, 1948) (Wosnick et al. 2019), both occurring mainly on the Amazon Coast and listed respectively as Critically Endangered (CR) and Not Evaluated (NE) by the Chico Mendes Institute for Biodiversity Conservation (ICMBio 2018).

Understanding elasmobranchs' population dynamics in the region is imperative for management plans and conservation policies aiming at the recovery of Amazonian stocks and sustainability of local fisheries (Lessa et al. 2016). Therefore, the assessment of research trends helps to understand the evolution of scientific knowledge, the rise of new technologies, and to track new challenges for conservation. Globally, the most significant research trend in the last 15 years has been growth rate estimates and basic biometric data (Awruch et al. 2018), both relevant to demographic analysis, population status assessment, and stock assessments. Considering only South America, the main research trends were impacts of fishing, reproductive aspects, and taxonomy (Awruch et al. 2018). In Brazil, the activities proposed by the National Action Plan for the Conservation of Endangered Marine Sharks and Rays (PAN-tubarões) (ICMBio 2021) were based on information available from published studies and reports, and rely on specific actions aiming to improve fisheries management in the country to minimize the impacts on threatened species and raise awareness on fishers and civil society on the importance of elasmobranch conservation. Despite the great amount of information for BAC fauna, studies focused on elasmobranchs are still scarce, and inventories are outdated, posing an extra challenge for the implementation of management measures appropriate to the current scenario. As management/conservation strategies depend on the knowledge available, the present study aimed to survey available data to detect temporal research trends and to identify the knowledge gaps as a way to guide future studies and decision-making at the regional level.

Material and Methods

Past data from Bibliometric Indicators (IBs) were compiled from "white literature" (79%) obtained from indexing and reference databases using the keywords "Chondrichthyes", "Elasmobranch" "Amazon". The search also considered "gray literature" (21%), represented by publications with restricted distribution or without an editorial board, among them scientific-technical reports, academic monographs, and Master thesis (e.g., Almeida et al. 1998, Paz & Almeida 2003, Santos 2004). Studies from other countries that are part the Amazon coast were disregarded, to direct regional management and future studies focusing on the Brazilian territory. A total of 110 studies were selected (Supplementary material).

Data were analyzed using the software IRAMUTEQ (***I****nterface de* ***R*** *pour les* ***A****nalyses* ***Mu****ltidimensionnelles de* ***T****extes et de* ***Q****uestionnaires*) (Kami et al. 2016), to support data processing and statistical analysis through encoding and compartmentalization of literature, leading to the visual and graphical representation of essential information contained in the text (Camargo & Justo 2013). The software creates a dictionary of words through Chi-square tests ($\chi 2$), revealing the associative strength between words and their respective class.

The associative strength is considered to be significant when the test is greater than 3.84, representing p<0.0001 (Souza et al. 2018).

The analyzes of studies carried out with elasmobranchs within the BAC in the last four decades (1976-2020) was carried out in three stages: the definition of the textual corpus, established by compiling the 110 abstracts of the documents considered; the establishment of the Initial Context Units (ICU), and the establishment of the Elementary Context Units (ECU) (i.e., text fragments that are scaled by the software itself according to the size of the textual corpus and that are obtained from the ICUs). The units were set considering each document category (e.g., scientific articles, scientific-technical reports, or texts) and according to the scope of each study.

Next, a Descending Hierarchical Classification (DHC) was applied, compiling the data in a dendrogram that illustrates the similarities and differences between the word classes. This analysis aims to obtain UCE classes that, at the same time, have similar vocabulary, and vocabulary different from the UCE of other classes (Camargo & Justo 2013). A Similitude Analysis to detect co-occurrences and connections between the words, and a Word Cloud to simplify the vocabulary distribution through graphical representations based on word grouping with the highest number of repetitions were also used.

Results

1. Overall distribution and research trends

A total of 10 research trends were identified in the 110 studies considered. For some studies, more than one research trend was identified, totaling 134 entries for the textual analysis. The scope Biodiversity was the most significant (43.3%; n = 58), followed by Reproduction (14.9%; n = 20), Diet and Feeding Ecology (11.2%; n = 15), Conservation (10.4%; n = 14), Morphometry (5.2%; n = 7); Genetics (4.5%; n = 6), Fisher Ecological Knowledge (4.5%; n = 6), Age and Growth (3.0%; n = 4), Biochemistry (1.5%; n = 2), and Accidents with Fishers (1.5%; n = 2). This pattern indicates that Biodiversity, Reproduction, Diet and Feeding Ecology and Conservation were the most relevant research trends in the past four decades (Figure 1).

More specifically, in the first temporal window (1970-1980), most studies published (n = 8) were on Biodiversity, followed by Reproduction (n = 4), and Morphometry (n = 1). As for the second temporal window (1990), the same research trend was observed, with studies on Biodiversity (n = 10), Reproduction (n = 4) and Diet/Feeding Ecology (n = 3) being the most prevalent. One study on Morphometry was also retrieved, as well as two studies on Age and Growth. Considering the third temporal window (2000-2009), more research areas were covered, with a prevalence of studies on Biodiversity (n = 20), followed by Diet and Feeding Ecology (n = 11), Reproduction (n = 8), and Morphometry (n = 4). The remaining portion referred to Age and Growth (n = 2), Conservation (n = 2), and Genetics (n = 1). Lastly, for the fourth temporal window (2010-2020), studies on all research areas, except Age and Growth were performed, with the prevalence of Biodiversity (n = 20) and Conservation (n = 12), followed by Fisher Ecological Knowledge (n = 6), Genetics (n = 5), Reproduction (n = 4), Accidents with Fishermen (n = 2), Biochemistry (n = 2), and lastly Morphometry and Diet/Feeding Ecology (one study each).

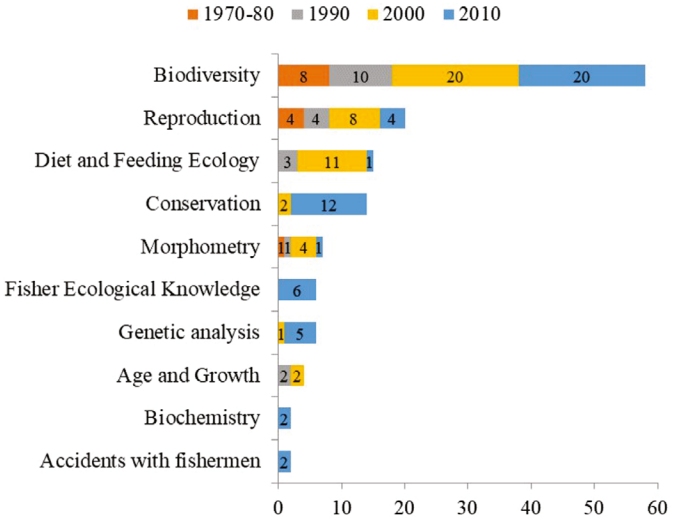

Figure 1. Research trends with focus on the scope of the literature published in the past four decades. Data is presented in number of trends (n = 10).

2. Descending Hierarchical Classification (DHC)

The corpus used in the DHC was categorized into 450 Text Segments (ECU), 15.572 occurrences (i.e., repeated words), 2.634 stemmed words (i.e., reduced forms that unite all the inflections of a verb), and 2.161 active forms (i.e., significant words). Of the 450 ECU, 381 were actively used, with a recovery rate of 84.67%, that is, the ECU that was used for DHC, and which continued under analysis. A percentage of use of 70% or more is necessary as if the retention is lower, the corpus is not adequate for this type of analysis, or that its content is very diverse, not allowing hierarchize the textual content (Souza et al. 2018).

The corpus was divided into two subcorpus and the dendrogram generated five classes based on similar vocabulary and the grouping of statistically significant words. Subcorpus 1 was divided into two distinct clusters: Class 1 + Class 5, and Class 3 + Class 4. Both clusters were formed from the classification of text segments according to their respective vocabularies and divided based on the frequency of reduced forms (words already lemmatized), obtaining ECU classes that present similar vocabulary to each other, and vocabulary different from UCE from other classes. In the cluster 1-5, the words with the greatest statistical association were: “Brazil”, “Maranhão”, “shark”, “tropical”, “coast”, “occurrence”, “elasmobranch” (19.2%; class 1), and “catch”, “longline”, “net”, “vessel” and “artisanal” (23.1%; class 5). This cluster indicates that 42.3% of the research carried out with elasmobranchs from the BAC were based on data from artisanal fisheries (Figure 2).

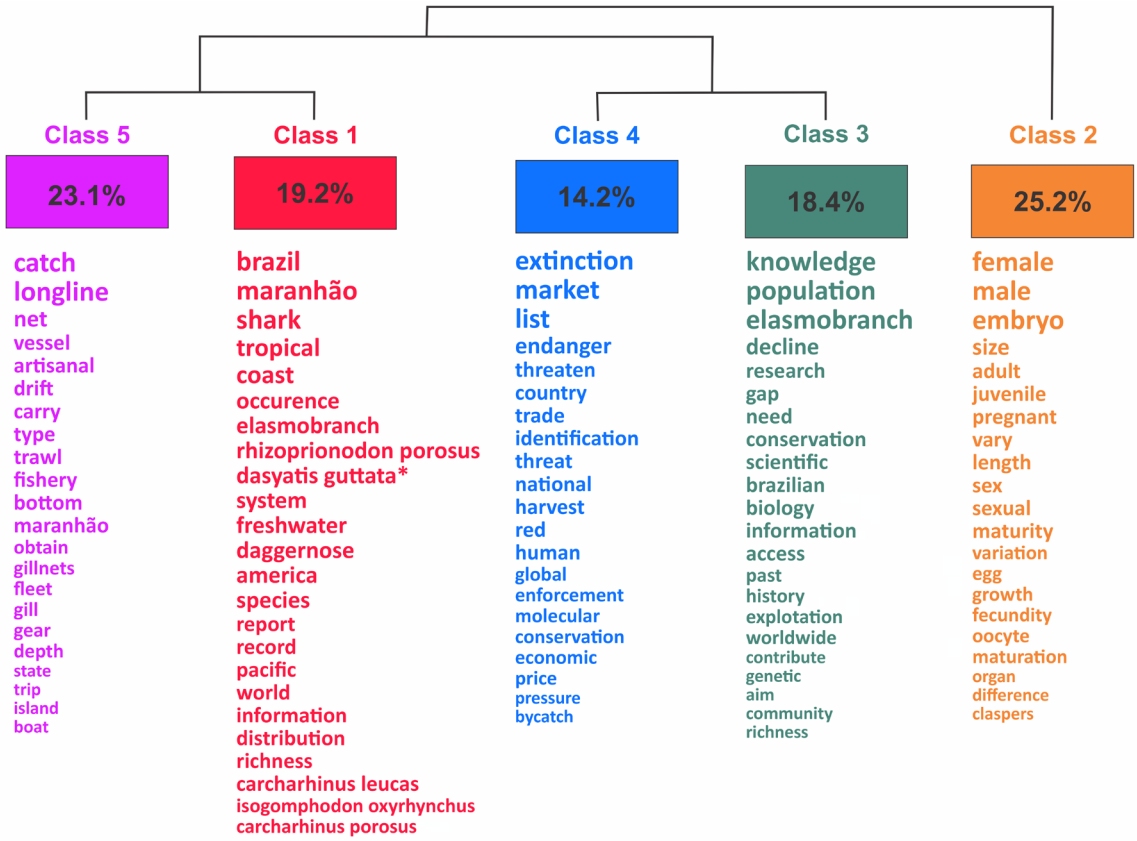

Figure 2. Dendrogram of the Descending Hierarchical Classification (DHC) of the words with the highest number of repetitions. *Reclassified as *Hypanus guttatus*.

In the cluster 3-4, the words with the greatest statistical association were: “knowledge”, “population”, “elasmobranch”, “decline”, “research” (18.4%; class 3), and “extinction”, “market”, “list”, “endanger”, “threaten”, “country”, “trade” e “identification” (14.2%; class 4). According to this cluster, 32.6% of research conducted with elasmobranchs from the BAC collected data relevant to threatened species management/conservation, based mostly on information available from commercial fisheries and local trade markets (Figure 2). Lastly, Subcorpus 2 was composed by a single Class (2), in which the words with the greatest statistical association were “female”, “male”, “embryo”, “size”, “adult”, “juvenile” and “pregnant”. This set of words indicates that 25.2% of the research carried out with elasmobranchs on the BAC aimed to elucidate basic reproductive aspects of species commonly caught by the artisanal fleet of the region (Figure 2).

3. *Similitude analysis*

Trough the Similarity Analysis it was possible to identify the connection between words distinguishing common parts from specificities in terms of significant words in the text. Thus, the tree of maximum similarity showed a high degree of connectedness between the words: “shark”, “Maranhão”, “Brazil”, “coast”, “female” and “male”. The highest occurrence was registered for the word “shark” (120), followed by the words - “Maranhão” (88), “Brazil” (87), “coast” (86), “female” (71) and “male” (60) (Figure 3). Moreover, there was a strong connection between the words - “species”, “fish”, “shark”, Maranhão” and “coast”, evidenced by the thickness of the connecting lines between them (Figure 3). These results also corroborate the research trends evidenced by class 2, represented by the strong connection between the words “female” and “male”, both being directly correlated with the words - “embryo”, “adult”, “juvenile”, “size” and “sexual” (Figure 3 and Figure 4).

In addition, the central block presents a set of the words most frequently associated in the literature analyzed, highlighting “fishery”, “specimen”, “capture”, “elasmobranch”, “study”, “*Rhizoprionodon porosus*”, “*Carcharhinus leucas*”, “*Carcharhinus porosus*”, “*Isogomphodon oxyrhynchus*”, “*Sphyrna tiburo*”, “*Dasyatis guttata*” (reclassified as *Hypanus guttatus*) and “*Aetobatus narinari*” (Figure 3). More specifically, it was possible to identify research trends at the species level, indicating which elasmobranchs were the main focus of investigations within the BAC so far. However, conclusions must be drawn with caution since most studies in the region rely on artisanal fishing, thus, it is likely that the most studied species are the result of opportunistic sampling, rather than preference for scientific investigations or priorities for conservation (Figure 3 and Figure 4).

4. *Word cloud*

The Word Cloud analysis allowed to group the words according to their frequency, corroborating both the DHC and the Similarity Analysis and reinforcing the research trends “Biodiversity” (e.g., elasmobranch, shark and study), “Reproduction” (e.g., female, male and reproductive) and “Conservation” (e.g., management, endanger, threat, and extinction) for the elasmobranchs of the BAC (Figure 4).

Figure 3. Connectedness of the most recurrent words in the literature analyzed based on the Similitude Analysis. Thicker lines represent more connectivity between words, and larger words represent greater occurrence.

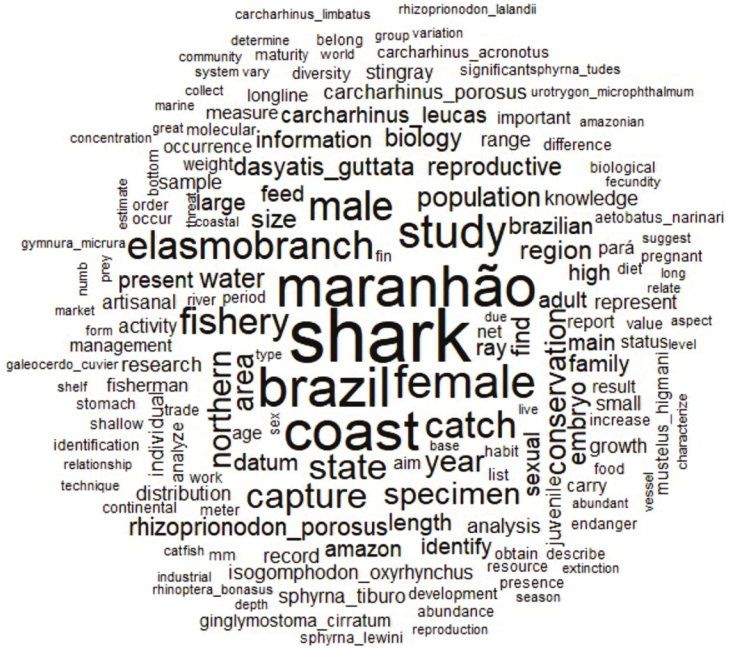

Figure 4. Word cloud with the most frequent words of the textual corpus. The size of the word indicates its frequency of occurrence, with larger words being the most representative.

Discussion

The analyzes performed in the present study showed a greater concentration of research trends within the fields of Biodiversity, Reproductive Biology, Feeding Ecology and Conservation, with different approaches over 44 years that will be discussed briefly next. Furthermore, considering the historical importance of the studies performed in the BAC for the Brazilian elasmobranch research scenario, and the status of the region as a global hotspot for elasmobranch conservation, our discussion will revisit some important milestones.

Studies on the diversity and abundance of species that occur in the region were predominant in relation to other areas of investigation during the entire temporal window evaluated in the present study. Even though it has been carried out since the 70s, studies on elasmobranch biodiversity reached its peak in the 2000s, and continue to be the main research trend in the region. In the global context of research trends with cartilaginous fish (Awruch et al. 2018), the topic biodiversity is not evident, but rather diluted into different subcategories within the identified clusters (i.e., population dynamics and spatial ecology). This indicates that at the BAC, the main research trend is different from that observed at the global level, being less applied and more focused on basic survey that have ceased to be a trend in other parts of the globe in recent decades. However, considering the challenges for elasmobranch research and conservation in Brazil, the need for baseline studies such as those prevalent in the BAC is understandable, especially in a scenario of lack of public investment for research and biodiversity conservation (Magnusson et al. 2018).

As for the second main research trend (i.e., Reproduction) there was a temporal constancy in the publications, with a peak in the 2000s. However, considering the diversity of species found in the region and the importance of reproduction data for management measures, the region still lack data for most species. Considering the global research scenario, the BAC follows the same trend, however, to a lesser extent. Interestingly, reproduction studies at the global level also peaked in the 2000s (i.e., 2002-2006), however, there was a very significant drop from 2011 onwards, indicating that this is no longer a global research trend (Awruch et al. 2018). In Brazil, and consequently also in the BAC, reproduction and diet studies are predominant (personal communication from the authors). Collecting basic biological data is imperative to guide conservation measures (Stroud & Thompson 2019) and also to pave the way for future studies using non-lethal methodologies (Awruch et al. 2008). However, few advances have been observed in this regard, since in the BAC, to date, reproduction data of studied species have not translated into guidelines for proper management. Thus, it is imperative that this topic continues to be investigated, but also be directed to policy makers in order to bring subsidies for species conservation.

Similar trend was observed to the topic "Feeding Ecology", with a peak in the 2000s that is also observed at the global scenario (Awruch et al., 2018). Despite being a traditional research area, it was only in the 1990s that the first study of diet for elasmobranchs was published in the BAC. In addition, the number of publications is negligible, configuring a large knowledge gap regarding trophic interactions and feeding patterns for most species that occur in the region. Moreover, to date, molecular studies (i.e., DNA barcoding of the stomach) that do not require the sampling effort of traditional studies (i.e., stomach content analysis) have not been carried out in the region, going against the global trend of elasmobranch feeding ecology. Thus, it is clear that, even identified as a research trend, more studies on this topic should be carried out, aiming to increase knowledge about the natural history of the species found in the BAC.

Lastly, although Conservation has stood out as a research trend at BAC, the amount of relevant information so that management and conservation measures can be implemented is still incipient. As noted for the global trend (Awruch et al., 2018), it was only from 2010 onwards that the topic "Conservation" started to represent a significant portion of published studies, indicating that BAC, despite generating few data towards conservation, follows the global trend. Interestingly, despite housing a large number of Conservation Units (i.e., Maranhão state) (IMESC 2020), and "Marine Protected Areas" being is a very relevant subtopic in the "Conservation cluster" of the global scenario, so far, no investigation on the importance of BAC marine protected areas for elasmobranchs was carried out, configuring a large knowledge gap about the effectiveness of this management strategy for sharks and batoids conservation. Furthermore, considering the identified subtopics in the global scenario (e.g., taxonomy, phylogeny, paleobiology, genetics, physiology, and parasites) (Awruch et al. 2018), the BAC is a region that still lacks studies, especially those that rely on more advanced methodologies and techniques. Furthermore, even though artisanal fishing is the main threat to elasmobranchs in the region, few studies focused on fisher's experiences and knowledge have been carried out, pointing to a historical neglect of traditional ecological knowledge.

As for specific information on BAC elasmobranchs, the first published studies date from 1976 and 1978 with a focus on exploring fishery resources in general. These studies, carried out by the Northeast Development Agency (SUDENE) and the Superintendence of Fisheries Promotion (SUDEPE), aimed to boost commercial fishing in the area, in addition to characterizing the profile of the artisanal fleet in the Maranhão State (SUDEPE 1976) and on the BAC continental shelf (SUDENE 1976), as well as to access the regional production chain (Emerenciano 1978). In this context, SUDENE carried out exploratory/experimental fishing campaigns and detected a great diversity and abundance of fish species with potential commercial value, including elasmobranchs. This suggested sustainable potential was based on the abundance of juveniles caught in coastal waters, highlighting *Galeocerdo cuvier* (Péron & Lesueur, 1822), *Ginglymostoma cirratum* (Bonnaterre, 1788), *Carcharhinus* spp., and *Sphyrna* spp. (SUDEPE 1976, Emerenciano 1978). The expectation was that juveniles were part of a larger stock in the high seas (SUDENE 1976). During this period, oceanic motorized fishing (back then with only a few adapted boats) began to explore deeper regions, with reports of large volumes of adults of *G. cuvier, Carcharhinus leucas* (Müller & Henle, 1839), *C. limbatus* (Müller & Henle, 1839) and *C. obscurus* (Lesueur, 1818) (SUDENE 1976). Such capture volumes strengthened the idea that shark fishing could be quite profitable.

It was in the 1980s that studies on elasmobranch abundance began to stand out, indicating that research groups realize that the artisanal fishing landing could be an opportunity to investigate this group of vertebrates with increasing commercial interest. The same occurred worldwide, but at a faster rate. Researchers from several countries began to focus their efforts on understanding the impacts of fishing through data from commercial landings (Thorson 1987), in addition to investing efforts in assessing regional diversity and abundance, so that temporal analyzes of fish stocks could be carried out (Wosnick et al. 2020a).

At the BAC, the first inventory registered 1.732 individuals of 22 species (belonging to former 13 shark and 9 batoid orders) (Lessa 1986). For sharks, the families Carcharhinidae and Sphyrnidae represented 77.4% and 18% (respectively) of the total captured, with higher occurrence of *C. porosus* (Ranzani, 1839) (43%) and *S. tiburo* (Linnaeus, 1758) (9.4%). For batoids, the catch in number was lower (4.6%). This inventory was very important as it expanded our knowledge on BAC diversity, being the first record of *C. porosus*, *C. acronotus* (Poey, 1860), *Hypanus guttatus* (Bloch & Schneider, 1801) (in figure 3 as former *Dasyatis guttata*) and *F. geijskesi* in the region. During this period, the suggested sustainable potential for shark capture was 23.500 tonnes/year (65%) of a total of 36.000 tonnes/year for fish in general (SUDENE 1984, Stride 1988) given the high biomass detected (Lessa 1986). This condition would depend on a series of factors to achieve this productivity, such as the gear used in the captures (e.g., gillnets and longlines, bait used and hook size). Concomitantly, Martins-Juras et al. (1987) published a list of estuarine fish from the state of Maranhão, with elasmobranchs representing 16.7% of the region's species richness. Studies on reproductive aspects also started in the 80s, generating relevant data for *C. porosus* (Lessa 1986-87), *I. oxyrhynchus* (Lessa 1987), and *Rhizoprionodon lalandii* (Müller & Henle, 1839) (Lessa 1988). Addressing fertility, growth rates, sexual maturation size, and minimum/maximum catch sizes is essential to ensure fisheries management and population recruitment (Lessa 1986, Awruch et al. 2018). However, in Brazil, management and conservation plans were not yet discussed at that time, as the impacts of fishing were not yet observed.

In the 90s, diversity studies were complemented by investigations about the population dynamics bringing new information on habitat use, population estimates, and basic biology data such as morphometry, diet, and age and growth (Almeida 1991, Batista & Silva 1995, Lessa & Almeida 1997, Lessa & Almeida 1998, Lessa & Santana 1998, Lessa et al. 1999a, Lessa et al. 1999b). The species list was once again updated, with the first report for *Urotrygon* spp. (Stride et al. 1992). During this period, the high productivity of shark fishing in the dry period has been reported, and guidelines for reducing juvenile catches through the use of larger meshes have been suggested (Stride et al. 1992). In fact, the use of smaller meshes was very harmful, particularly for *C. porosus* (Lessa et al. 1999a), a small-sized shark that uses the BAC as a nursery area (Lessa et al. 1999b).

While commercial fishing continued to benefit from the bycatch of *Rhizoprionodon porosus* (Poey, 1861) and *C. porosus* (Almeida & Carneiro 1999), studies on the reproductive aspects of *Sphyrna tiburo* (Silva & Lessa 1991, Lessa & Silva 1992, Menni & Lessa 1998), *S. tudes* (Valenciennes, 1822), *S. lewini* (Griffith & Smith, 1834) (Stride et al. 1992, Menni & Lessa 1998, Almeida et al. 2011), *C. acronotus* (Menni & Lessa 1998, Almeida et al. 2011) and *C. limbatus* (Stride et al. 1992, Menni & Lessa 1998, Almeida et al. 2011) were initiated. At the same time, in the global scenario, the first conservation measures were proposed (i.e., IPOA-Sharks, FAO), pointing to a growing concern of the international community regarding the sustainability of elasmobranch fishing.

In the early 2000s, the global research trends further diversified, with new technologies and methodologies being used (e.g., genetics and physiology). Additionally, studies of taxonomy and anatomy stood out, aiming at updating the group's phylogeny. In contrast, in South America (from 2002 to 2006), studies on reproductive biology and age and growth still prevail (Awruch et al. 2018). At the BAC, the 2000s were the most representative, with 46.2% of the total of studies being published in this period. The studies still focused on species diversity (Almeida & Vieira 2000, Alencar et al. 2001, Nunes et al. 2005) and reproductive aspects (Machado et al. 2000, Santos et al. 2000, Motta et al. 2009) but also diet (Silva & Almeida 2001, Costa & Almeida 2003) and aspects increasingly related to conservation (Almeida et al. 2006). The REVIZEE Program has also generated results causing an incalculable increase in the information available for elasmobranchs across the country, including the BAC. It was also in this decade that oceanic species were first described in the region, among them *Prionace glauca* (Linnaeus, 1758), *Isurus oxyrhincus* (Rafinesque, 1810), *I. paucus* (Guitart, 1966), *Alopias superciliosus* (Lowe, 1841), *A. vulpinus* (Bonnaterre, 1788), *Pseudocarcharias kamohara*i (Matsubara, 1936) and *Mitsukurina owstoni* (Jordan, 1898) (Asano-Filho et al. 2007, Almeida et al. 2008, Holanda & Asano-Filho 2008).

Also, it was in the 2000s that papers related to shark fishing as bycatch, the trade of threatened species, and industrial fisheries began to be published (Pinheiro & Frédou 2004, Lessa et al. 2006, Oliveira et al. 2007). More specifically, incidental capture in fisheries targeting *Scomberomorus brasiliensis* Collette, Russo & Zavala-Camin, 1978, *Cynoscion acoupa* (Lacepède, 1801), and *C. leiarchus* (Cuvier, 1830) also impacted elasmobranch populations mainly due to the low selectivity of fishing apparatus and large volumes of neonates and juveniles caught (Almeida et al. 2006). It was during this period that the Brazilian academic community established measures to deal with the reported declines, most of them resumed in the National Action Plan for the Conservation and Management of Elasmobranch stocks in Brazil (SBEEL 2005). Governmental measures also emerge, highlighting the Normative Instructions of the Ministry of the Environment (MMA) nº 05 (21/05/2004), nº 52 (08/11/2005), nº 166 (18/07/2007), nº 05 (MPA/MMA 15/04/2011), nº 14 (MPA/MMA 26/12/2012), nº 29 (MAPA 23/09/2015), and Ordinances nº 125 (04/12/2014), nº 445 (17/12/2014), nº 163 (08/06/2015), and nº 73 (26/03/2018).

In the last decade (2010 to 2020), new methodologies have emerged, with studies focused on spatial ecology (Feitosa et al. 2020), and the impacts of environmental pollution on BAC elasmobranchs (Chaves 2019, Wosnick et al. 2021a, Wosnick et al. 2021b). Social demands and food safety issues also stood out, with studies aiming to assess accidents with marine stingrays involving artisanal fishers (Dias et al. 2016, Carvalho et al. 2019) and the potential risks of shark meat consumption to human health (Souza-Araujo et al. 2021, with data collected in 2017). Furthermore, the use of molecular techniques enabled the identification of endangered species such as *G. cirratum* (VU), *Sphyrna mokarran* (Rüppell, 1837) (EN), *Mustelus canis* (Mitchill, 1815) (EN), *S. tiburo* (CR), *C. porosus* (CR), *S. lewini* (CR), *S. tudes* (CR) and *I. oxyrhynchus* (CR) being sold in the region (Feitosa *et al.* 2018). Besides, molecular studies aiming to assess the commercialization of batoids also indicated that threatened species were sold indiscriminately (Rodrigues-Filho et al. 2020). More recently, studies on population genetics and conservation physiology started, aiming to evaluate the effects of fishing on the genotypic and phenotypic diversity of species threatened with extinction in the region.

Given the absence of official fisheries statistics programs in the country, alternative approaches such as access to traditional knowledge from fishing communities (Martins et al. 2018) and participatory monitoring of landings or of catches are becoming more and more popular (Aragão et al. 2019, Shiffman et al. 2020, Giareta et al. 2021). In fact, management measures based on traditional knowledge, the socioeconomic and cultural demands of fishing communities, and the inclusion of fishers in research activities have proved to be promising tools for the conservation of threatened elasmobranchs (Martins et al. 2018, Wosnick et al. 2020b, Giareta et al. 2021). Moreover, data recently obtained with artisanal fishers at BAC brought important discoveries on spatial ecology and physiological tolerance of Amazonian species (Feitosa et al. 2016, Feitosa et al. 2019, Feitosa & Nunes 2020), emphasizing the importance of traditional knowledge not only for fisheries data access but also to guide future studies based on non-lethal methodologies (e.g., eDNA, Telemetry, BRUV's) (Awruch et al. 2018, Rigby et al. 2019; Shiffman et al. 2020).

Conclusion

The Brazilian Amazon Coast is a priority area for elasmobranch conservation at a global level. So, it is imperative that previous published data be easily available to stakeholders and decision-makers as a subsidy for the management of Amazonian species. Papers focused on basic reproductive aspects, which are extremely relevant data for adequate fisheries management, were a trend between the 1970s and 1990s, and along with data on diversity and abundance were the most common/traditional studies with BAC elasmobranchs. Along with the global trend to guide threatened species conservation, from the 1980s onwards, there was an increasing interest to collect fisheries data, in addition to assessing the local production chain and the commercial potential of elasmobranch fishing. From the 1990s, the impacts of commercial fishing in the region began to be quantified, indicating that elasmobranch fishing could not be as sustainable as initially proposed.

The panorama of studies presented here can assist researchers and managers, directing their efforts towards knowledge gaps that hinder decision-making and the effective conservation of threatened species. Much remains to be done, as the BAC is home to endemic species at high risk of extinction and also species listed as DD, for which information for proper risk assessment are not available. Moreover, the overall level of basic biology on species described in the region is low. Thus, future studies must consider research areas still neglected (i.e., fisheries management, spatial ecology, conservation physiology, local ecological knowledge, and applied conservation), specific demands for the creation of recovery plans (i.e., survival rates, sublethal effects of capture and alternative options to mitigate incidental capture and associated mortality) and also in generating basic biology data for species found in the region. Even though many data needed for proper conservation are lacking, it is imperative that the region starts to mobilize efforts to implement management measures, as waiting until the necessary data are available may be too late for some species, as is the case of *I. oxyrhynchus*, *S. tudes, C. por*osus and many others.

Lastly, as the REVIZEE Program was one of the reasons for the improvement in the available information on BAC elasmobranchs, it is imperative that initiatives as REVIZEE be promoted. Furthermore, current knowledge of most commonly employed fishing modalities (i.e., trawling and gillnetting) cannot be overestimated as the information is either scarce or out-of-data as most information was collected several decades ago, thus emphasizing the importance of resuming monitoring programs.

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Conflicts of Interest

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

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