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JOSÉ BELQUIOR GONÇALVES NETO

OCCURRENCE AND CAPTURE OF ELASMOBRANCHS BY ARTISANAL FISHERIES OFF THE STATE OF CEARÁ, BRAZIL, WITH EMPHASIS ON LANDINGS AT THE MUCURIPE INLET IN FORTALEZA.

FORTALEZA
2024

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Orientador: Dr. Vicente Vieira Faria

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Às raras probabilidades infinitas deste universo que nos trouxe até aqui.

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“Caminante, son tus huellas, el camino y nada más; Caminante, no hay camino, se hace camino al andar. Al andar se hace el camino, y al volver la vista atrás se ve la senda que nunca se ha de volver a pisar. Caminante no hay camino, sino estelas en la mar.” (Antonio Machado, 1912)

RESUMO

Os elasmobrânquios (tubarões e raias) desempenham papéis cruciais nos ecossistemas marinhos atuando como reguladores da cadeia trófica. Contudo, suas populações estão em declínio devido a uma soma de fatores, que incluem aspectos inerentes de sua biologia, tais como reprodução tardia e baixa prolificidade, que se somam à sobrepesca e degradação de habitat. O Brasil, é responsável pela captura e comercialização de várias espécies de elasmobrânquios, o que contribui para que o Brasil seja um dos países líderes em consumo de elasmobrânquios. Além disso, problemas na identificação correta das espécies capturadas leva a uma pesca ilegal*,* não declarada e não regulamentada (INN) de espécies ameaçadas de extinção. Esta problemática é agravada quando a maioria das capturas é realizada por frotas de pequena escala, pois o caráter artesanal desta atividade dificulta o acesso as informações pesqueiras. Um dos estados com predominância na pesca artesanal e com histórico na captura de elasmobrânquios é o Ceará. Entretanto, a dispersão nas informações disponíveis dificulta uma avaliação geral do estado da pesca deste grupo no estado. Por esta razão, o presente estudo realizou: (a) um primeiro capítulo que avalia a viabilidade do uso de metodologias alternativas para a identificação de espécies de elasmobrânquios capturadas no Ceará, um método alternativo para coleta de dados baseada na análise em vídeos em uma rede social (YouTube), (b) histórico de captura e desembarques de elasmobrânquios no Ceará e na enseada do Mucuripe, em Fortaleza, que demonstrou-se um dos principais pontos de desembarque pesqueiro de tubarões e raias do estado, através de revisão de literatura e amostragens de campo; e (c) um estudo de identificação de um exemplar de lamniforme desembarcado pela pesca artesanal no Mucuripe – através de sequenciamento de DNA. O exemplar foi identificado como pertencendo à espécie *Isurus oxyrinchus* e foi discutida a importância da correta identificação das espécies, bem como os registros históricos de outro tubarão lamniforme com ocorrência na região, o tubarão branco *Carcharodon carcharias*. A cogestão e o uso de fontes alternativas de dados podem ajudar a desenvolver um setor pesqueiro mais sustentável e ações de conservação ao longo da costa do Ceará são urgentemente necessárias.

Palavras-chave: Pesca de pequena escala; Tubarões; Raias.

ABSTRACT

Elasmobranchs (sharks and rays) play crucial roles in marine ecosystems by acting as regulators of the trophic chain. However, their populations are in decline due to several factors, including intrinsic biological traits such as late reproduction and low fecundity, compounded by overfishing and habitat degradation. Brazil is responsible for the capture and trade of several elasmobranch species, making it one of the leading consumers of elasmobranchs globally. Additionally, issues with the accurate identification of captured species contribute to illegal, unreported, and unregulated (IUU) fishing of endangered species. This problem is exacerbated when most captures are conducted by small-scale fleets, as the artisanal nature of these activities hinders access to reliable fishery data. Ceará is one of the states where artisanal fishing predominates and has a history of elasmobranch captures. However, the scattered nature of the available information complicates an overall assessment of the fishing status of this group in the state. For this reason, the present study undertook: (a) an initial chapter evaluating the feasibility of alternative methodologies for identifying elasmobranch species captured in Ceará, using an alternative data collection method based on video analysis from a social network (YouTube); (b) a review of the history of elasmobranch catches and landings in Ceará and at the Mucuripe Embayment in Fortaleza—one of the state's main landing sites for sharks and rays—through literature review and field sampling; and (c) a species identification study of a lamniform specimen landed by artisanal fishing at Mucuripe through DNA sequencing. The specimen was identified as Isurus oxyrinchus, and the importance of correct species identification was discussed, along with historical records of another lamniform shark species occurring in the region, the white shark (*Carcharodon carcharias*). Co-management and the use of alternative data sources can help develop a more sustainable fisheries sector, and conservation actions along the coast of Ceará are urgently needed.

Keywords: Small-scale fisheries, Sharks; Rays.

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APRESENTAÇÃO

Os peixes cartilaginosos são um grupo diversificado de peixes que inclui tubarões, raias e quimeras. Coletivamente, esses organismos compõem a classe Chondrichthyes, e se distinguem dos peixes ósseos por várias características notáveis, como a ausência de bexiga natatória, presença de escamas do tipo placóide (dentículos dérmicos) e, como indicado pelo nome do grupo, possuem um esqueleto cartilaginoso. Os condrictes são divididos em dois subclasses: (a) Holocephali, que inclui as quimeras; e (b) Elasmobranchii, que inclui os tubarões e as raias. Os tubarões e as raias, também denominado como elasmobrânquios, são encontrados em quase todos os ambientes marinhos e alguns de água doce, desempenhando papéis cruciais como predadores no topo da cadeia alimentar. A sua diversidade biológica e evolutiva é marcada por adaptações fascinantes, que permitem a sobrevivência em uma vasta gama de condições ambientais (Dulvy; Forrest, 2010; Ebert; Dando; Fowler, 2021). As espécies de elasmobrânquios são fundamentais para a regulação da vida marinha. Sua presença, ou asuência pode indicar o estado de saúde de ecossistemas marinhos (Bornatowski *et al.*, 2014; Juan-Jordá *et al.*, 2022).

Os tubarões geralmente possuem um corpo alongado e fusiforme, adaptado para natação rápida e caça ativa, com uma boca anteroventral que não se estende além do focinho (Compagno, 2001). Em contraste, as raias exibem um corpo achatado dorsoventralmente, ideal para uma vida bentônica. Suas bocas estão localizadas na parte inferior do corpo, permitindo-lhes alimentar-se de organismos no substrato oceânico. Adicionalmente, enquanto a maioria dos tubarões possui barbatanas peitorais menores e mais rígidas, as raias caracterizam-se por grandes barbatanas peitorais que se fundem à cabeça, formando um disco amplo que facilita a camuflagem e o movimento em fundos arenosos ou lamacentos (Helfman *et al.*, 2009; Last *et al.*, 2016). Essas adaptações também são cruciais para entender a vulnerabilidade das espécies de acordo com o habitat que utilizam. As características de adaptação das espécies ao habitat seja substrato, pelágico, oceano ou costeiro podem ser mais ou menos impactadas pelas ações antrópicas diretas ou indiretas.

As estatísticas globais são claras quanto ao declínio de diversas populações de elasmobrânquios em nível global e regional. Diversos fatores como a sobrepesca e degradação de habitats são comumente reportados como características principais para o declínio de populações de elasmobrânquios (Barbosa Martins; Sinclair, 2024). Além disso, e a problemática da identificação "incorreta", e da falta de informações básicas acerca das espécies capturadas torna o comércio de elasmobrânquios insustentável ambientalemente (Dulvy *et al.*, 2021; Jaiteh; Loneragan; Warren, 2017; Oliver *et al.*, 2015; Sherman *et al.*, 2023).

A gestão pesqueira é baseada, fundamentalmente, em dados disponíveis para avaliar os estoques pesqueiros, estipular cotas de captura, além de estabelecer estratégias para conservação das espécies sobrepescadas. Países em desenvolvimento são particularmente mais suscetíveis às falhas em programas para gerenciamento de recursos pesqueiros devido à dificuldade em promover métodos tradicionais como monitoramento embarcado ou acompanhamento de desembarques (Arthur *et al.*, 2022; Berkes, 2001; Machado *et al.*, 2021).

O Brasil possui um histórico de captura de elasmobrânquios e detém atualmente o título de país que mais consome elasmobrânquios, sendo que o país também comercializa espécies ameaçadas não identificadas corretamente. A sistematização para uma coleta de dados efetivos é custosa e, sobretudo, de baixo interesse por parte das autoridades governamentais (Paiva, 2004; Kotas *et al.*, 2023). Todo este cenário dificulta a adoção de medidas que possam diminuir o impacto da pesca sobre as espécies marinhas (Giareta *et al.*, 2021; Lennox *et al.*, 2022), o que reforça a urgência por estudos científicos que abordem esta problemática, incluindo, a obtenção de tanto dados científicos inéditos, quanto dados obtidos através de diferentes tipos de revisões de literatura. Particularmente no caso das revisões, estas tendem a ser um ponto base importante para guiar próximos passos em ações para conservação (Wosnick *et al.*, 2023b).

Historicamente negligenciada, a pesca, e em particular a de elasmobrânquios, tem testemunhado um renovado interesse por parte de diversas iniciativas destinadas a reformar o setor. Em 2023, a versão final do Plano de Ação Nacional para a Conservação dos Tubarões e Raias Marinhos Ameaçados de Extinção (PAN Tubarões) foi divulgada, oferecendo uma análise abrangente da situação atual das capturas dessas espécies e propondo novas estratégias de conservação em nível nacional (Kotas *et al.*, 2023). Além disso, em 2024, o Governo Federal introduziu o Plano Nacional da Pesca Artesanal. Este documento representa uma ruptura com as abordagens anteriores, visando estrategicamente o desenvolvimento da pesca artesanal para torná-la uma atividade mais sustentável e capaz de garantir maior segurança alimentar (Brasil, 2024). O plano também enfatiza a importância de incluir pescadores e pescadoras artesanais no processo de formulação e monitoramento das políticas públicas relacionadas ao setor.

Dados pesqueiros organizados e dispobilibizados publicamente a nível nacional são escassos. São dependentes da realização de projetos como o caso do PETROBRAS (2023) ou restritos a secretarias/institutos de pesquisas estaduais. Dentro deste contexto, a pesquisa reportada como primeiro capítulo utilizou metodologias alternativas (análise de vídeos em uma rede social, o YouTube) para o levantamento de dados acerca de elasmobrânquios capturados pela pesca artesanal. Isto foi feito com o objetivo de testar a viabilidade de se usar este tipo de fonte de dados para identificar espécies de elasmobrânquios capturadas no estado do Ceará. O conteúdo deste capítulo foi publicado no presente ano na forma de artigo científico também no periódico *Ocean and Coastal Management*.

O terceiro capítulo abordou o histórico de captura de elasmobrânquios na costa do Ceará, tendo como ênfase o desembarque de elasmobrânquios na enseada do Mucuripe, em Fortaleza. Esta enseada é um dos principais pontos de desembarque pesqueiro do estado do Ceará. Para isso, foram utilizados dados oriundos da literatura científica, bem como dados inéditos através de amostragens de desembarques na enseada.

Por fim, as amostragens de desembarque pesqueiro realizadas na enseada do Mucuripe mencionadas no capítulo anterior levaram ao registro de um exemplar de lamniforme que, baseado nas partes comercializadas do exemplar (torso), se assemelhavam morfologicamente a um exemplar de tubarão branco, *Carcharodon carcharias*. Porém, a partir do uso de sequenciamento de DNA, o exemplar foi identificado como *Isurus oxyrinchus*. Esta pesquisa culminou em um quarto capítulo da presente tese e destacou a importância da correta identificação de espécies durante os registros de desembarque, além de ter permitido revisar sobre a ocorrência deste grupo ao largo do Ceará. O conteúdo deste capítulo foi submetido e aceito para publicação na forma de artigo científico no periódico *Ocean and Coastal Research*.

HIPÓTESES

Hipótese 1: Dados pesqueiros compartilhados em redes sociais são efetivos para identificaar espécies de elasmobrânquios ameaçadas.

Objetivos para a hipótese 1

a) Analisar a viabilidade de imagens provenientes de fontes alternativas para identificação de elasmobrânquios capturados no Ceará
b) Classificar as espécies em relação ao nível de ameaça (Brasil e Internacional – IUCN redlist)
c) Sugerir abordagens alternativas para a coleta de dados básicos sobre as capturas de elasmobrânquios no Estado

Hipótese 2: O estado do Ceará desempenha um papel central na captura e desembarque de elasmobrânquios no Brasil.

Objetivos para a Hipótese 2:

a) **Avaliar os registros de captura e desembarque de elasmobrânquios no Ceará:** Examinar e analisar os registros presentes na literatura científica entre os anos de 1960 e 2020.
b) **Categorizar os tipos de publicações sobre elasmobrânquios no Ceará:** Identificar e classificar os tipos de publicações que abordam a captura e desembarque dessas espécies.
c) **Avaliar a diversidade de espécies de elasmobrânquios registradas:** Investigar a presença e frequência das diferentes espécies de elasmobrânquios mencionadas na literatura científica.

Hipótese 3: Há uma redução significativa no número de elasmobrânquios desembarcados na Enseada do Mucuripe ao longo dos últimos 20 anos.

Objetivos para a Hipótese 3:

a) **Comparar os registros de desembarque em diferentes períodos:** Analisar os dados de desembarque de elasmobrânquios na Enseada do Mucuripe, comparando os períodos de 2006 a 2015 e de 2016 a 2020.
b) **Identificar as espécies com maior ocorrência e as tendências de diminuição:** Documentar quais espécies foram mais frequentemente desembarcadas e quais mostraram declínio nos registros ao longo do tempo estudado.

Hipótese 4: Existe uma alta probabilidade de erro na identificação morfológica de lamnídeos desembarcados no Ceará, resultando em registros imprecisos das espécies.

Objetivos para a Hipótese 4:

1. **Caracterizar os registros de das duas principais espécies de lamnídeos no Atlântico Sudoeste Equatorial:** Documentar e analisar os registros existentes de lamnídeos, com ênfase especial nos tubarões-anequim (*Isurus oxyrinchus*) e tubarões-brancos (*Carcharodon carcharias*), na única região do Atlântico Sudoeste Equatorial que ocorrem conconcomitantemente.
2. **Utilizar marcadores moleculares para identificação precisa de lamnídeos:** Aplicar técnicas de biologia molecular para identificar corretamente as espécies de lamnídeos desembarcadas pela pesca de pequena escala na região do Ceará.
3. **Investigar as razões da exclusividade dos registros de grandes lamnídeos no litoral do Ceará:** Analisar os fatores que contribuem para que grandes lamnídeos sejam registrados somente no litoral do Ceará, explorando aspectos ecológicos, geográficos e de práticas de pesca.

CAPÍTULO 1 - USING SOCIAL MEDIA IMAGE TO IDENTIFY THREATENED ELASMOBRANCH SPECIES CAUGHT BY A SMALL-SCALE FISHERY IN A DATA-POOR AREA.

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Abstract

Sharing fishing activity via social media attracts millions of views. The data from these shares includes key information for a fisheries database such as the species present in the catches and in many cases the number of specimens caught. Many countries in the Global South do not have official information about basic data on fishing activity, especially small-scale activity. In many of such countries like Brazil, overfishing poses a significant threat to numerous threatened species, including elasmobranchs, due to the frailty of fisheries management and law enforcement. The lack of a national (Brazil) data collection program makes sharing data on social media a potential source of fisheries related information. Hence, this study aimed to verify the potential of social media data to describe artisanal fishing and identify elasmobranch species caught by a small-scale fleet in a data-poor Equatorial Southwest Atlantic region. The identification of elasmobranch species was made based on 250 videos shared by local fishers publicly on social media (Youtube™). Among these, sharks and rays were observed in 19 (8%) and 42 (17%) videos, respectively. A total of 98 specimens were recorded, of which 80% could be identified to a species level. Most of the records comprised the stingrays *Hypanus berthalutzae* and *Hypanus guttatus*, while *Ginglymostoma cirratum* was the most recorded shark. More than half of the elasmobranch species recorded are listed at some level of threat according to the IUCN Red List. According to the Brazilian legislation, at least 20% of the species identified in these videos are considered Endangered (EN) or Critically Endangered (CR). Therefore, fishing activity shared via social media can be considered effective in identifying threatened elasmobranch species, as well as providing data on species occurrence, number of specimens, or rare sightings. It is suggested that fishing activity shared via social media be used in parallel with traditional methods (e.g.

on-board data and landing observations) to obtain fisheries information and data about endangered species in data poor areas.

INTRODUCTION

Videos containing material about fishing can be found online on a wide variety of platforms. Small-scale fishing videos are particularly popular with millions of views. The videos consisted of a "virtual logbook" of commercial, and recreational fishing activity and a few records of fish sales. Species can be identified from these videos, and in many cases the number of specimens can be accessed. As soon as information on social media shows the occurrence of threatened or rare species, it also indicates that they could still being captured. Naturally, there are limitations in relying solely or primarily on social media data for fisheries management (Lennox *et al.*, 2022). However, sharing photos and videos with relevant metadata (e.g. location, date, time, habitat, occurrence, species captures) allows access from anywhere in the world by searching for specific keywords (Cranswick *et al.*, 2022; El Bizri *et al.*, 2015).

The use of alternative data sources has emerged to address information on the biodiversity caught in regions where traditional data collection methods are limited or unavailable (Bargnesi *et al.*, 2020; Gouraguine *et al.*, 2019). Social media has proven to be a useful tool for obtaining primary information species identification (Allison *et al.*, 2023; Araujo *et al.*, 2022; Boldrocchi and Storai, 2021; Monkman *et al.*, 2018). Content published on social media provides, often in real-time. information that was not previously publicly available.

Still, data available on social media can provide key information of rarely sighting species (Cranswick *et al.*, 2022), report illegal wildlife sales (Sardari *et al.*, 2022), increase understanding of biodiversity, especially on threatened species (Chowdhury *et al.*, 2023), composition of species caught by recreational fishing (Giovos *et al.*, 2018; Vitale *et al.*, 2021), understand the public's perception of fishing activities, or as a tool to provide ecological information (Ballejo *et al.*, 2021; Sbragaglia *et al.*, 2022). Gathering fishing data from online sources can offer insights into species presence/absence, seasonal patterns, and fishing effort (Lennox *et al.*, 2022). Additionally, fishing data available on social media may become a primary source of data for studies of biodiversity evaluating shared catch compositions in fishing groups (Giglio *et al.*, 2020), or to contribute to measure fishing effort accounting for the harvest per unit of fishing effort (Vitale *et al.*, 2021). This information helps traditional data collection methods, especially in data-poor countries.

The lack of financial resources and infrastructure to monitor catches often makes wildlife monitoring impractical or difficult to sustain in developing countries (Danielsen *et al.*, 2005). Alternatives to traditional methods such as on-board observations and monitoring landings have emerged for collecting fisheries data (Lennox *et al.*, 2022). Addressing data scarcity and doing scientific research is crucial for providing a solid basis for fishery management, particularly in data-poor areas like Brazil, which is one of the southern countries where no fishing data is available. A significant gap of over a decade has been observed in the collection of fisheries data in Brazil (e.g. species capture, production, number of vessels, fishing zones, fishing market value) (Gonçalves-Neto *et al.*, 2021).

Elasmobranchs (i.e. sharks and rays) are one of the most caught groups off the Brazilian coast, including several threatened species (Pincinato *et al.*, 2022). Overfishing and habitat degradation are among the main causes for a decrease in elasmobranch population stocks (Dulvy *et al.*, 2014). Due to the life-history characteristics of most elasmobranch species (i.e., late sexual maturation, slow growth and low fecundity), elasmobranchs are one of the most vulnerable groups to fishing pressure (Booth *et al.*, 2019). Still, illegal, unreported, and unregulated (IUU) fisheries occur in areas without proper fisheries management or enforcement (Field *et al.*, 2009; Lack and Sant, 2008).

In Brazil, both small- and large-scale fishing fleets act directly and indirectly on threatened shark and ray species (Booth *et al.*, 2019; Kotas *et al.*, 2023). The capture and trade occur with little or no proper identification (Feitosa *et al.*, 2018; Macfadyen, 2022; Merten Cruz *et al.*, 2021). These capture data are crucial given the inaccessibility of fishery data due to the neglect of public policies (Barbosa-Filho *et al.*, 2014). In some Brazilian states in Equatorial Southwestern Atlantic (Northeast Brazil) small-scale fisheries are predominant. This fishing fleet is mainly characterized by sailboats popularly known as “jangadas, “botes” or “paquetes” (de Nóbrega and Lessa, 2007). Small wooden or fiberglass boats with no motor propulsion (or if with one it is often an adapted engine with little power), without any georeferencing, communication system, or fish location systems (e.g. radars and sonars). These artisanal characteristics combined with a lack of organization in the fisheries sector makes it difficult to access data without a regional or national official data collection.

The lack of official information on elasmobranch species catches and landings poses a challenge to improve and further develop management and fisheries analysis. In this study, we conducted a pilot study to test whether data posted on social media are useful for describing artisanal fishing and identifying elasmobranch species caught by a small-scale fleet in a data-poor region of the Equatorial Southwest Atlantic.

MATERIAL AND METHODS

Data collection and data analysis

An analysis of video footage was conducted to assess shark and ray catches. One of the social media platforms with the largest content distribution and use as an information source in Brazil is Youtube™ (El Bizri *et al.*, 2015; Magalhães *et al.*, 2021; Velho *et al.*, 2020). Brazilian fishing channels in this media varied in terms of subscribers and audience, with a single channel reaching over 40 million views. Videos posted publicly on Youtube™ by fishers from Ceará who created and/manage these accounts were chosen randomly and analyzed. All videos were searched using the platform's native search tool in the same way that the public searches for content. The keywords searched in Portuguese were: "Pesca artesanal Ceará" (Artisanal fisheries Ceará), "Pescador amador Ceará" (Ceará amateur fisher), "Pesca tubarão Ceará" (Shark Fishing Ceará) and "Pesca de cação Ceará" (Cação is a popular label used for any type of shark, regardless of species), "Pesca arraia Ceará " (Ray fisheries Ceará), and "Pesca artesanal Mucuripe" (Mucuripe artisanal fisheries). We also used YouTube's own filter for recommendations by date from 2019 to 2023. In addition, we collected the main metadata present in the video whenever it was publicly available (Table 1).

Among all the videos recommended in the search, the selection criteria for analyzing the videos were: (1) video posted of some fishing or landing on the beaches of Ceará; (2) content focused on commercial or amateur fishing; and (3) fishing conducted by Ceará State fleet and landing along the Ceará coastline. All videos had to meet three criteria. Videos showing beach fishing activities or fishing landings were also counted whenever they were recommended by the searched keywords.

Table 1. Metadata extracted from each Youtube™ video analyzed when available. Videos were posted publicly by fishers during fishing activity in Ceará State coastal waters, Equatorial Southwestern Atlantic.

Metadata information	**Format and tags**
Date posted	dd/mm/yyyy
Duration	in minutes
Location	The city tagged by fishers
Biological information	
Shark visualization	Yes/No
Ray visualization	Yes/No
Identification	To the lowest possible taxonomic level.
Fisheries Information	
Type of vessel	No vessel/Sailboat /Motorized
Fishing Gear	Handline/Angling/Longline/Baited traps/Cast net/Spearfishing
Fishing area	When any information is available that refers to the nearest city to the fishing site
Shark caught	Number of sharks caught
Ray caught	Number of rays caught
Days of fishing	When available, information indicating the number of days employed in the capture (days on board)
Number of fishers	When available, information indicating the fishing effort employed by numbers of fishers on the vessel (fishers boarded)

The videos were analyzed to identify the elasmobranch species at the lowest taxonomic level possible. For each species, its conservation status was determined, following The International Union for Conservation of Nature Red List of Threatened Species (herein after IUCN Red List) and Brazilian Legislation (Brasil, 2022). When available, the posting date information was always compatible with the week the video was recorded.

The Shannon index $H' = - \Sigma(p\_i * \ln(p\_i))$ was calculated as a basis for determining the species evenness index in order to assess the evenness of the species caught. The Pielou $(J' = \ln(S) / H')$ evenness index was computed to assess the equitability of species distribution across samples.J′ represents the Pielou evenness index, H′ is the Shannon index, S denotes the total number of species in the community.

Ethical disclaimer

The use of public data posted on social media was chosen because it is a primary source of data in a data-poor fishing location (Monkman *et al.* 2018). The information was used for descriptive and qualitative purposes about a specific fishing activity in the Equatorial Southwest Atlantic. The anonymity of the fishers was maintained. Furthermore, there was no intention of confronting or making value judgments about the activities carried out during the fishing activity and the species caught. Ethical approaches were adopted in the collection of fishery data based on social networks following the existing delineation in literature (Di Minin *et al.*, 2021; Sbragaglia *et al.*, 2021)(Di Minin *et al.*, 2021; Sbragaglia *et al.* 2021). The study was limited to what has been published on-line. Therefore, it would have been impossible to predict what other captures took place when cameras were turned off, even eventually of other threatened species.

RESULTS

Elasmobranch captures composition

A total of 98 elasmobranchs were recorded out of the 250 videos analyzed; 23 Sharks in 19 videos (7,6%) and 75 rays in 42 (16,8%) videos. Most specimens (88,7%) depicted on the videos were identified to the species level. In total, 11 species of elasmobranchs (seven sharks and five of rays) were recorded (sharks = 7; rays = 5; Table 2).

Table 2. Shark and ray species captured along the coast of Ceará, Equatorial Western Atlantic and displayed in videos posted by the fishers. Videos were made publicly available by them at YouTube™. The number of specimens of each species as well as its percent

Category/ Identification	Common name	n (%)
Shark		
Ginglymostoma cirratum	Nurse Shark	7 (30,4)
Squalus sp.		4 (17,4)
Mustelus canis	Dusky Smoothhound Shark	3 (13,0)
Carcharhinus falciformis	Silky Shark	3 (13,0)
Sphyrna lewini	Scalloped Hammerhead	2 (8,7)
Isurus sp.		1 (4,3)
Carcharhinus limbatus	Blacktip Shark	1 (4,3)
Galeocerdo cuvier	Tiger Shark	1 (4,3)
Hexanchus griseus	Bluntnose Sixgill Shark	1 (4,3)
Total		23
Ray		
Hypanus berthalutzae	Southern Stingray	33 (44,0)
Hypanus guttatus	Long Nose Stingray	29 (38,7)
Hypanus sp.		7 (9,3)
Styracura schmardae	Atlantic Chupare	4 (5,3)
Gymnura micrura	Smooth Butterfly Ray	1 (1,3)
Aetobatus narinari	Whitespotted Eagle Ray	1 (1,3)
Total		75

The main shark species identified in the videos were *Ginglymostoma cirratum, Mustelus canis, Carcharhinus falciformis,* and *Sphyrna lewini* (Table 2). The capture of four females of *Squalus* sp. (apparently all pregnant), was recorded. As for the rays, *Hypanus berthalutzae* and *Hypanus guttatus* appeared as the main species identified followed by *Styracura schmardae*. The species were shown in videos in several situations: (1) capture after baited; (2) being killed after capture; (3) species already captured thrown on the boat's deck or floor; and (4) species already captured stored with the gear and or species being sold in a fishing port (supplementary material). The Pielou evenness index for the dataset was 0.7.

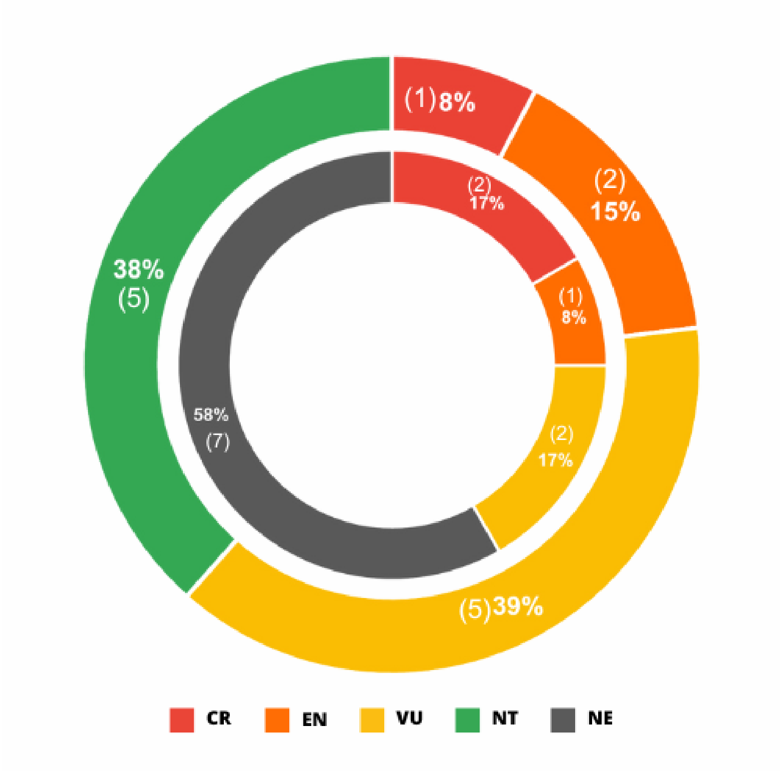

Figure 1. Distribution of threat categories for shark and ray species captured along the coast of Ceará, Equatorial Southwest Atlantic. Records of captures are based on videos made publicly available at YouTube™ by fishers. The global threat status (IUCN Red List) is shown on the outer circle, while the regional threat status level (Brasil, 2023) is shown on the inner circle. CR - Critically Endangered, EN - Endangered, VU - Vulnerable, NT - Near Threatened, NE – Not Evaluated.

Almost all of the species caught are listed under categories of risk of extinction globally (IUCN Red List) or regionally at country level (Brasil, 2023). More than half of the elasmobranch species were listed as Near Threatened (NT = 38%) or Vulnerable (VU = 39%). At the regional level, 17% of the species are listed as 'Critically Endangered' (CR), 17% as 'Vulnerable', while more than half (58%) lack information about extinction risk assessment by the Brazilian legislation (Figure 1). The most threatened species listed by regional or international authorities were S. lewini, C. falciformis, Aetobatus narinari, and *Styracura schmardae*.

Fisheries activity

Overall, 250 videos posted between 2019 and 2023 were analyzed, comprising 4,903 minutes (equivalent to 81.7 hours) of audiovisual material published on Youtube™ sharing fishing activities. The videos selected belonged to channels with thousands of subscribers (7,000 to 327,000 subscribers). The interest of the public was also reflected by number of views; altogether the selected videos had more than 10 million views. The most recorded fishing activity was recreational fishing (69%). The videos have an opening, often indicating the day of the recording, when fishers indicate which week of the year they go fishing (e.g. Holy Week, Carnival, Christmas, first week of the month) and where and what they were going to fish. During the videos usually the fishers inform the status of the catch, if it was a good day of catch or not. The main aim of these videos was to share the work activity and its challenges. To share fishing tips, catching techniques, and information about the animals they catch, as well as to record the "adventure" of catching large specimens. The fishers directly related fishing to the Christian religion by thanking what is "offered by the sea". It can be seen in the comments that this is also a characteristic of the public to relate what is caught to "blessings".

Fishers chronicle their activities with personal smartphone or specialized underwater cameras such as action cameras, creating a visual record from landing to activity highlights. The duration of the fishing trip varied depending on the type of fishing, whether it was for recreation or non-commercial purposes, which usually lasted for a day, or artisanal fishing for commercial purposes, which lasted between three and five days. In one of the videos analyzed, the use of sonar to locate shoals was shown. Some sailing boats used motors (i.e. engines for propulsion) in longer journeys (approximately 30km off the coast, close to the continental shelf break). Motors were also sometimes used to help them back to shore faster on windless days. The fishing gears recorded in videos were handline, longline, angling, baited trap, and cast net (locally known as tarrafa) (Table 3). During spearfishing, only snorkeling gear was used. Spearfishing usually took place in points where target species were known to aggregate or were detected using fish aggregating devices (FAD). Handline fishing was done without specific apparatuses such as gloves, shoes, or personal protective equipment (PPE).

Table 3. Number of videos analyzed in the present study by type of gear used by fishers for elasmobranch captures along the coast of Ceará, Equatorial Southwest Atlantic. Videos were made publicly available at YouTube™ by fishers. Type of gears is shown by Type of fishing. Artisanal fishing activities described in the videos had 3,6 ± 0,8 fishers involved, on average. Sport fishing activities described in the videos had 1,8 ± 1,6 fishers involved, on average. Videos in the category 'unknown' show elasmobranchs being landed.

Type of gear	Type of fishing			
Cast net	Artisanal	Recreational	Unknown	Total of videos
Angling	2	55	0	57
Baited trap	11	1	0	12
Cast net	0	15	0	15
Drift net	0	1	0	1
Handline	63	31	0	94
Longline	2	0	0	2
Spearfishing	0	67	0	67
unknown	0	0	2	2
Total (%)	78 (31,2%)	170 (68%)	2 (0,8%)	250

DISCUSSION

The present study underscores the potential of social media as a tool for accessing previously unavailable elasmobranch fisheries landing composition and identifying illegal catches. Owing to the fact that our findings revealed that a substantial portion (80%) of the specimens posted on social media videos (Youtube™) could be successfully identified at the species level. Therefore, these online and freely available tools may serve as preliminary data for analyzing the composition of elasmobranch species caught in this area.

Some factors were important for species identification: resolution of the videos, presentation of the elasmobranch to the camera, recording of the fishing moment, and fishers talking about the popular name. Regarding the capture of threatened species, at the global level, most species identified (62%) are listed in some category of threat by IUCN Red List. At the regional level (Brazil), the situation is not less worrying: 42% of the species are under some level of threat. This percentage is smaller than that at the global level, but it may reflect an underestimation for the problem given that the remaining of the species have not been assessed yet. Several of these species have already been recorded as captures by small-scale fisheries off Ceará such as *G. cirratum*, *Sphyrna lewini*, *C. falciformis* etc. (Pinheiro *et al.*, 2023; Santander-Neto and Faria, 2020), but the present results showed this continues to happen and there is no need to hide such action – in fact the opposite is what happens – the capture is voluntarily exposed. Although there were more records of *H. berthalutzae* and *H. guttatus*, there was moderate equitability between the elasmobranch species caught.

Because of the impact that small-scale fishing can also have on fish stocks (Damasio *et al.*, 2020) it is crucial to assess the real impacts of this activity since small-scale fishing is predominant in the Northeastern Brazil, a region with socioeconomic conflicts and neglected fishing sector (Gonçalves-Neto *et al.*, 2021; Lopes and Villasante, 2018). In Ceará, there are approximately 4,000 boats make up the small-scale fleet (Castro e Silva, 2004). Most of these fishers lack formal education and, in some localities live on an extremely low income of around 130 Euros a week (Queiroz *et al.*, 2020)(Queiroz *et al.*, 2020). The marine fishing activity is focused on catching lobsters, a resource which has declined over the years, and teleosts, mainly snappers (Lutjanidae), mackerels (Scombridae), tarpons (Megalopidae) and groupers (Serranidae) (Castro e Silva, 2004). Moreover, historically, elasmobranchs are landed from small-scale fisheries too (Santander-Neto and Faria, 2020).

The results obtained in the present study showing endangered species captured and publicly exhibited is a call for conservation measures. However, simply labeling all fishers as 'illegal' without considering other factors, such as their social and economic situation, is inappropriate (Karper and Lopes, 2014; Simpfendorfer *et al.*, 2021). This is a controversial and complex issue in the Global South countries where social and economic factors must be taken into account (Fathonah and Anwar, 2023; Karper and Lopes, 2014; Marimin *et al.*, 2022; Shafira *et al.*, 2023). Despite this, effective law enforcement acts directly on the conservation of species, especially illegal fishing, and trade in threatened species. There must therefore be a balance between conservation actions and the application of penalties (Ferretti *et al.*, 2020; Techera and Klein, 2011; Ward-Paige, 2017).

Alternative actions such as pay-to-conserve and pay-to-release have already shown promise in elasmobranch fisheries in Brazil (Wosnick *et al.*, 2021), but there is always a gap as to who and how to finance these actions. Although rare, some voluntary conservation actions were recorded in the present study. The release of small specimens and explanations about aspects of elasmobranch biology may be interpreted as positive aspects. Although at a glance it may appear contradictory, involving fishers in conservation actions has proven to be an effective strategy for fisheries management (Giareta *et al.*, 2021; Leduc *et al.*, 2021; Wever *et al.*, 2012). Encouraging voluntary participation, engaging them in primary data collection, and attributing protagonism to regional fishers under well-established protocols may be new steps towards obtaining information on elasmobranch fisheries in data-poor areas. A multidisciplinary approach is a viable possibility for accessing previously unavailable data, as well as being used as a basis for sustainable fishing (Lloret *et al.*, 2015; Phillipson and Symes, 2013). Data available on social media, data recording in audiovisual format, local ecological knowledge, are some examples of the multidisciplinarity needed to reliably collect obtain data in the absence of State and or traditional data collection methods.

Would "going on social media" be a last resort to obtain fishing data in this region? The use of all available assessment tools to obtain more information on catches is supported by the presence on video of species listed as endangered or critically endangered. Collecting data through social media is not the only solution, but it is the most viable at the moment. Collecting data via interviews or surveys using Local Ecological Knowledge involves various financial costs and also security issues depending on the location. Regardless, the data shared on social media can be used in conjunction with other traditional methods thanks to a wide availability of free data online. Systematizing data collection through audiovisual and automated means could be a viable and perhaps low-coast solution, as well as directly engaging fishers as collaborators in this process. Collecting fisheries data in data-poor locations requires multiple data sources to obtain a more reliable picture.

Sharing fishing experiences, including the capture and release of elasmobranch species, It provides key information for faunal assessment, the presence of species in the region, illegal catches and fishing activity that was previously unexplored. The use of social media data for identifying elasmobranch species catches in this region has here shown effective, but it requires methodological improvements, such as an automated catch identification system. In this way, in a situation of lack of traditional fisheries monitoring methods, it would be desirable to have the participation of fishers to develop alternative and collaborative community-based monitoring projects to collect data regarding species composition, fishing areas, gears and practices.

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CAPÍTULO 2 - Characterization of Elasmobranchs Caught by Fishing Off the Coast of Ceará, Brazil, in the Southwest Atlantic (1948-2024)

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Abstract

Elasmobranchs (sharks and rays) play a crucial role in maintaining the balance of marine and coastal ecosystems; however, many species face threats due to overfishing and habitat degradation. In the state of Ceará, despite the predominance of fishing activity along the coast, little is known about the actual status of catches of this group due to data collection gaps. In this context, this study investigates the history of elasmobranch catches and landings in the state (1948-2024), focusing on the Mucuripe cove in Fortaleza. The aim was to compile records on the species captured and landed, the number of specimens landed, and to compare five distinct periods of landing monitoring between 2006 and 2020. The study compiled records from 84 documents between 1948 and 2024. The analysis identified 87 elasmobranch species, with over 34,000 specimens caught/landed. The primary species were *Ginglymostoma cirratum*, *Carcharhinus falciformis*, *Carcharhinus limbatus*, *Rhizoprionodon* spp., *Hypanus berthalutzae*, and *Hypanus guttatus*. Over 7,000 tons of elasmobranchs were landed between 1991 and 2020. From 2006 to 2020, some species saw a reduction in the number of specimens landed over the study periods, notably species of the genus *Rhizoprionodon*. Most species recorded at the Mucuripe landings lack national extinction risk assessments or are listed as Critically Endangered or Endangered, underscoring the urgent need for more effective management and conservation policies.

INTRODUCTION

The state of Ceará, located in the Southwest Equatorial Atlantic, is characterized by extensive fishing activity along its 574 km of coastline. This activity extends through 23 municipalities and at least 110 mapped fishing points, predominantly of an artisanal or small-scale nature. The state's coastline is organized into four distinct zones: (i) Eastern Coast; (ii) Fortaleza (capital) and metropolitan area; (iii) Western Coast; and (iv) Far Western Coast (Nascimento, 2022). The small-scale fleet comprises approximately 4,000 vessels (Castro e Silva, 2004). , and the majority of the fishermen, who number around

22,720 registered in the state, including 15,412 men and 7,308 women (Brasil, 2023), lack formal education and, in some localities, subsist on an extremely low weekly income of about 130 euros (Queiroz *et al.*, 2020). One of the main fishing landing areas is located at Mucuripe Cove in Fortaleza. Historically, the city of Fortaleza served as a crucial landing and trading point during the colonial period, significantly contributing to the development of the city (Barbosa; Barbosa, 2006; Lima, 2022; Ramos Menezes *et al.*, 2019).

Specifically, Mucuripe Cove is a region of great historical, cultural, and fishing importance. The area is renowned for its significance in literary and musical works that express the labor involved in the local fishing activity (Lima, 2018; Ramos Menezes *et al.*, 2019). In fishing terms, Mucuripe Cove is one of the primary fish landing points in the state of Ceará, crucial for the local economy and the subsistence of many families who depend on artisanal fishing (Marques; Cruz; Feitosa, 2021).

Marine fishing activity in Ceará focuses on the capture of lobsters (Freitas, 2023; Nascimento, 2022) and teleosts, mainly snappers (Lutjanidae), mackerels (Scombridae), tarpons (Megalopidae), and groupers (Serranidae) (Castro e Silva, 2004; Freitas, 2023). Additionally, studies indicate that the region is also a strategic point for the landing of various species of elasmobranchs (Santander-Neto; Faria, 2020), highlighting its relevance for marine biodiversity and scientific research on this group. The elasmobranch fishery production in Ceará is recurrent (Furtado-Neto; Barros Júnior, 2006; Jucá-Queiroz *et al.*, 2011), including species from deep-sea to coastal and migratory species (Jucá-Queiroz *et al.*, 2008; Santander-Neto *et al.*, 2007, 2011).

However, like the entire Brazilian coast, Ceará is affected by issues regarding the species captured/commercialized and the lack of information about the catches (Almerón-Souza *et al.*, 2018). This issue is further exacerbated by the predominantly artisanal fishing activity, which lacks any official state monitoring for the acquisition, standardization, and recording of fishery data regarding this group (Vidigal *et al.*, 2022).This situation is concerning, as various endangered species are historically captured and sold without proper record-keeping in an official database or correct identification (Almerón-Souza *et al.*, 2018; Bernardo *et al.*, 2020). The group of elasmobranchs, which includes sharks and rays, is among the most vulnerable to decline, having species that, due to their biological characteristics such as late reproduction and low fecundity, are susceptible to factors like overfishing and habitat degradation ((Dulvy *et al.*, 2021; Pacoureau *et al.*, 2021; Sherman *et al.*, 2023). Therefore, accessing basic data related to catches and landings is essential for data-poor regions (Seminara *et al.*, 2024). It is not uncommon to find publications (academic or otherwise) about the capture of threatened species in the region (Diário do Nordeste, 2015; Globo, 2022). However, without a solid database, it is not possible to ascertain the health status of the shark and ray populations in this area.

Access to what is caught and sold allows for targeted conservation actions for threatened species (Freire *et al.*, 2021; Seminara *et al.*, 2024). Nonetheless, it is common for biological and fishery data not to be available through traditional methods such as onboard data collection or fishery landings (Gonçalves-Neto *et al.*, 2024). The absence of a robust system for monitoring and recording catches hampers the assessment of the state of fish stocks and the implementation of public policies that ensure the sustainability of this practice.

Moreover, reliance on traditional methods such as Catch Per Unit Effort (CPUE) in areas with limited data has resulted in a greater number of studies and approaches using alternative methods such as Landing Per Catch Unit (LPUE) (ICCAT, 2007; Kerby *et al.*, 2013; Leitão *et al.*, 2022; Metri; Perez, 2014). The lack of data standardization also requires that more robust statistical methods be used as a tool to visualize trends concerning fishery catches and landings (Maunder; Punt, 2004). Based on the reality of landings at Mucuripe Embayment, accessing information about the species caught, the volume of the catch, but primarily using historical data on the presence and absence of species, can help indicate temporal trends regarding the current catch situation in various fisheries (Freire *et al.*, 2021; Pauly; Zeller, 2016). Therefore, the objective of this study was to characterize the historical and recent records of the capture and landing of elasmobranchs in Ceará, focusing on Mucuripe Embayment, Fortaleza.

MATERIAL AND METHODS

Scientometric Review

Literature Review

The review was conducted in two stages of searching. The first stage involved the use of scientific article indexing platforms such as Google Scholar, Scopus, and Web of Science. Additionally, journals from specific platforms such as Marine Sciences Archive and the Institutional Repository of the Federal University of Ceará were also accessed.

The search terms included "Sharks Ceará," "Sharks Mucuripe," "Ray Ceará," "Rays Mucuripe," "Elasmobranchs Ceará," and "Elasmobranchs Mucuripe," searched in both Portuguese and English. The second stage was carried out through standard search and ranking on search engines like Google and Bing using similar terms as in the first part. This second search aimed to find newspaper articles, reports, and technical briefs, etc.

Document Selection

All articles published in journals in Portuguese or English that addressed the fishing or landing of elasmobranchs in Ceará were selected. There was no restriction regarding the year of publication. In addition, gray literature documents such as PhD theses, dissertations, undergraduate theses, conference abstracts, reports, and newspaper articles were also selected. This was done with the intent of creating a historical series of records of elasmobranchs in Ceará, focusing on the Mucuripe Embayment.

To avoid data repetition and overlapping information, the selected documents underwent a second filtering to keep only the document with the highest hierarchical level of publication following this order of priority: journal articles, doctoral theses, master's dissertations, undergraduate theses (TCC), conference abstracts, reports/briefs/minutes, and newspaper articles. This approach prevented the repetition of data included in scientific articles, but which were also (at least partially) presented at conferences, monographs, dissertations, or theses. Thus, a higher level of reliability about the information used in this study was ensured.

Data Analysis

Bibliographic Data Analysis in Ceará

The data from academic documents were categorized into a spreadsheet: Title, Author, Decade, Year of Publication, Type of Document, Journal/Congress, Study Area/Theme (Identification, Migration, Zoological Collection, Physiology, Reproduction, Toxicology, Education, Feeding, Genetics, Morphology, Biology, Fauna, Occurrence, Fishing). When available, data were also collected regarding the capture or landing zone, the number of specimens recorded, the number of sharks, the number of rays, and production in kilograms. The documents were also organized by year, decade, and study area/theme. Once cataloged, a timeline was created with the types of documents and an overview of the main study areas addressed. For a historical review of elasmobranch occurrences based on literature, the specimens of elasmobranchs captured, sighted, or landed in Ceará were added.

The total number of specimens recorded for Ceará over the years and specifically for Mucuripe Embayment in Fortaleza was summarized. Additionally, the difference between the number of shark and ray specimens recorded by the selected documents in the same period was also summarized. The number of appearances and citations of species among the documents was compiled to assess the species that were most studied. Lastly, at the state level, the total production in kilograms of elasmobranch species captured during all periods of the study was compiled.

Data Analysis for Mucuripe Embayment

Given the historical importance of the Mucuripe Embayment as a fishing landing site, a specific analysis for the port of Mucuripe was conducted to assess fishery landings over the years. Since data collection in the region was systematically carried out between 2006 and 2020, academic works from this period were selected that considered the number of specimens per species of elasmobranch landed, in addition to the sample size for each study period.

Scientific articles that only considered a specific group (shark or ray) were not included in the analysis. Data standardization was performed based on current names of genera and species, replacing old names such as *Dasyatis* with *Hypanus* (e.g., *Dasyatis americana*, *Hypanus americanus* with *Hypanus berthalutzae*), *Rhinobatus* with *Pseudobatos*. Sharks or rays without identification were standardized as Other Sharks/Other Rays. Specimens that were not correctly identified or lacked a basis for identification were standardized as 'Unidentified'.

Five sampling periods were chosen, four periods recorded in the literature and a final field sampling period conducted for this study. Period A: 2006-2008, 102 samplings (Santander-Neto; Faria, 2020); Period B: 2008-2009, 46 samplings (Venancio, 2010); Period C: 2010-2011, 30 samplings (Gonçalves-Neto, 2015); Period D: 2015-2017, 97 samplings (Santos, 2017); and Period E: 2018-2020, 63 samplings (current study). An exception: the study conducted by Arthaud (1999) followed shark landings at Mucuripe Embayment from 1998-1999. However, as it was restricted to sharks, this study was not added to the total elasmobranch comparisons but was included in analyses involving only shark landings.

The samplings conducted by this study followed the same methodology as previous periods, with weekly monitoring of landings at Mucuripe Embayment, preferably on Sundays between 5 AM and 7 AM. Specimen identification was carried out using guides to the lowest possible taxonomic level (Ebert; Dando; Fowler, 2021; Figueiredo, 1977; Gomes *et al.*, 2019). Whenever possible, the weight of the specimens was also recorded, and tissue samples were collected for deposit in a collection. In addition to the number of specimens, measurements were taken for sharks: total length, standard length, interdorsal length, and records of weight and sex of the specimens. For rays, the following were recorded: disk width, disk length, weight, and the sex of the specimens.

To determine whether there is a difference in the number of elasmobranchs landed at Mucuripe over the last two decades, comparisons were made of 1) the absolute numbers of elasmobranchs landed in each period; 2) the relative number of specimens of each species in relation to the number of samplings per period and 3) the absolute and relative numbers of the main species of rays and sharks.

Diversity indices were determined for each period of fishery landing. Analyses were conducted separately for each landing period, allowing a direct comparison between them. The Shannon index was used to determine species diversity, while the Pielou index was used to assess the evenness in the distribution of catches among species. Groups cataloged/recorded as Genus + sp. were considered distinct groups from the species related to the same genus to maintain the principles of diversity analysis.

For species that showed a possible disparity in the number of occurrences between the years (in absolute or relative numbers), a specific comparison was made between the sampling periods, also adding comparative documents that assessed only one sample group (sharks or rays).

RESULTS

Scientometric Review

Out of 105 documents found, 84 dated between 1948 and 2024 were selected for analysis (Figure 1). The first academic record on elasmobranchs in Ceará is by Rocha (1948) and consists of a listing of the state's fauna. Until the early 2000s, only monographs and reports were found. A few other works from the 1960s to the 1980s reported aspects of elasmobranch physiology and morphology in the region (Freitas, 1976; Furtado-Neto, 1985; Menezes, 1966). The largest number of documents on elasmobranchs in Ceará was produced in the 2000s. The decades with the highest number of documents citing elasmobranchs in Ceará were between 2000 and 2010, accounting for approximately 90% of all publications (Figure 2). The main formats of publications during this period were conference abstracts, published articles, and monographs (Table 1)

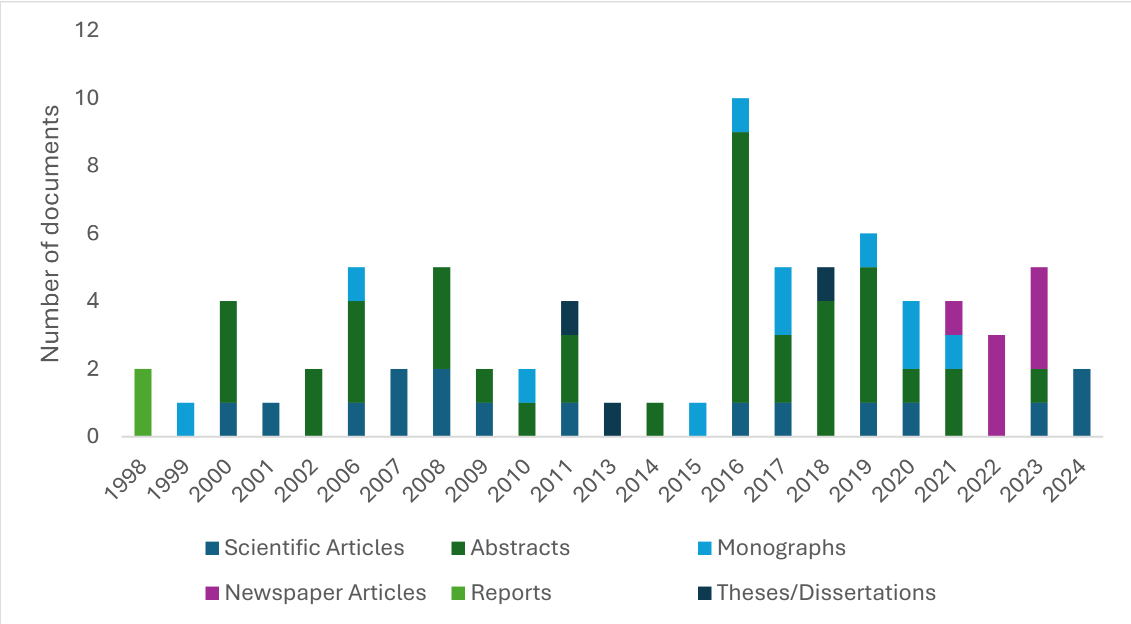

Figure 1. Distribution of types of literature on the records, catches, and landings of elasmobranchs in Ceará, between 1948 and 2024.

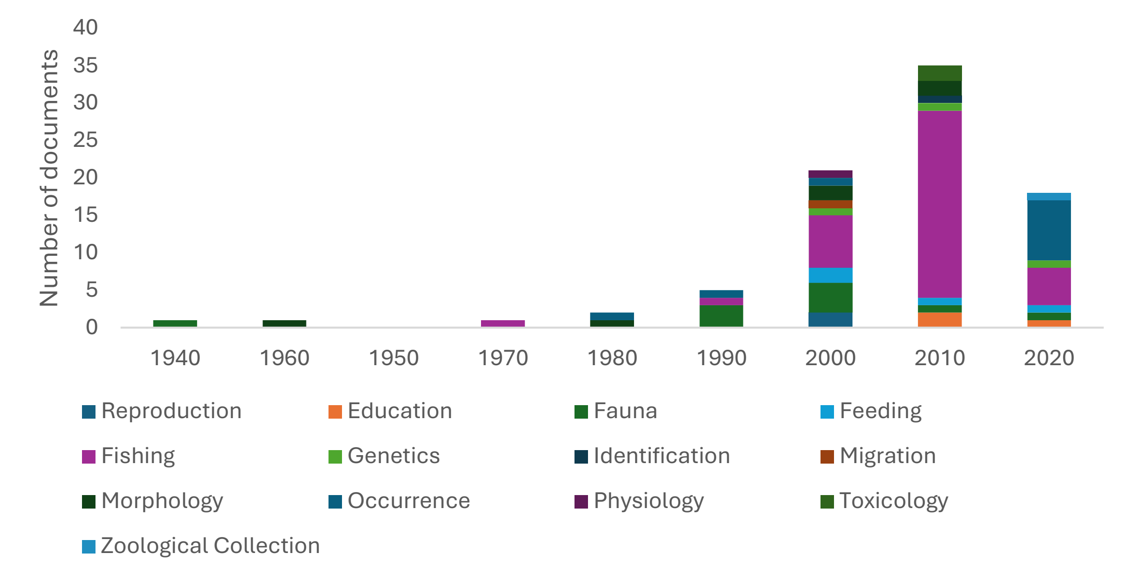

Figure 2. Distribution of publication types between the 1940s and 2020s

Table 1 Types of publications and their proportion in relation to the studies selected in the literature review on elasmobranchs caught and landed in Ceará between the 1940s and 2020.

Tipo de publicação	Número de publicações	%
Abstracts	38	45,2
Scientific articles	19	22,62
Monographs	13	15,48
Media	8	9,52
Theses/Dissertations	3	3,57
Reports	2	2,38
Book/chapters	1	1,19
Total	84	100

Among the main study areas, fishing was the most addressed theme in the selected documents, representing over 45% of the total. This was followed by the areas of Occurrence and Fauna (faunal surveys) (Table 2).

Table 2 The main topics covered in studies on elasmobranchs in Ceará between the 1940s and 2020 and the respective proportion in relation to the studies selected in the literature review.

Study area	Number of documents	%
Fishing	39	46,4
Occurrence	11	13,1
Fauna	10	11,9
Morphology	6	7,1
Feeding	4	4,8
Education	3	3,6
Genetics	3	3,6
Reproduction	2	2,4
Toxicology	2	2,4
Identification	1	1,2
Migration	1	1,2
Physiology	1	1,2
Zoological Collection	1	1,2
Total	84	100,0

Composition of Elasmobranchs Recorded in Ceará Between 1948 and 2024

A total of 34,427 elasmobranchs were recorded in Ceará between 1948 and 2024. Of these, 20,072 were recorded from artisanal fishing landings at the Mucuripe Embayment. The total number of shark specimens was 17,895, distributed among 30 species, nine genera, and one group of unidentified sharks ("other sharks"). The most frequently recorded shark species during this period were *Ginglymostoma cirratum* (nurse shark; n = 24 documents); *Carcharhinus limbatus* (blacktip shark; n = 16); *Galeocerdo cuvier* (tiger shark; n = 15); and "Other sharks" (unidentified specimens), n = 14 documents (Table 3).

A total of 16,532 ray specimens were recorded, distributed among 20 species, four genera, and one group of unidentified rays ("other rays") (Figure 5). The most frequently recorded ray species during this period were *Hypanus guttatus* (Southern stingray; n = 29 documents), *Hypanus berthalutzae* (Brazilian cownose ray; n = 25 documents), *Hypanus marianae* (Flame stingray; n = 12 documents), and *Aetobatus narinari* (spotted eagle ray; n = 12 documents) (Table 4).

Table 3. Number of citations in the bibliography respective number of specimens recorded in published documents in relation to the shark species reported for the state of Ceará. The table is divided between specimens identified at the level of species, genus, other sharks (sharks categorized as dogfish), and unidentified sharks.

Categories		**Number of Appearances Across the 84 Documents**	**Number of Recorded Specimens**
Shark species			
	Alopias superciliosus	1	
	Carcharhinus acronotus	10	927
	Carcharhinus falciformis	8	37
	Carcharhinus leucas	7	10
	Carcharhinus limbatus	16	374
	Carcharhinus longimanus	1	
	Carcharhinus obscurus	5	14
	Carcharhinus perezi	1	
	Carcharhinus plumbeus	2	1
	Carcharhinus porosus	4	16
	Carcharhinus signatus	4	8
	Carcharodon carcharias	4	2
	Cirrhigaleus asper	1	2
	Etmopterus bigelowi	2	4
	Galeocerdo cuvier	15	310
	Ginglymostoma cirratum	24	1707
	Heptranchias perlo	4	22
	Hexanchus griseus	2	2
	Isistius brasiliensis	1	
	Isurus oxyrinchus	5	5
	Mustelus canis	9	273
	Negaprion brevirostris	1	
	Prionace glauca	2	
	Pseudocarcharias kamoharai	1	
	Rhincodon typus	2	1
	Rhizoprionodon lalandii	4	47
	Rhizoprionodon porosus	9	747
	Sphyrna lewini	10	6
	Sphyrna mokarran	7	60

	Sphyrna tiburo	2	
	Sphyrna tudes	1	
	Sphyrna zygaena	2	3
	Squalus cubensis	5	309
	Squalus megalops	1	
	Squalus mitsukurii	3	65
	Odontaspis ferox	1	1
Genders			
	Alopias sp.	1	1
	Carcharhinus sp.	6	683
	Isurus sp.	1	1
	Mustelus sp.	2	18
	Rhizoprionodon sp.	9	1719
	Scyliorhinus sp.	2	1
	Sphyrna sp.	9	296
	Squalus sp.	3	10
	Other sharks	12	10209
	Unidentified Sharks	2	4
	Total	224	17895

Table 4. Number of citations in the bibliography respective number of specimens recorded in published documents in relation to the species of rays reported for the state of Ceará. The table is divided between specimens identified at species, genus and other ray levels.

Categories		**Number of Appearances Across the 84 Documents**	**Number of Recorded Specimens**
Ray species			
	Aetobatus narinari	12	68
	Breviraja spinosa	1	1
	Dasyatis geijskesi	1	1
	Gymnura altavela	1	1
	Gymnura micrura	7	82
	Hypanus berthalutzae	26	9344
	Hypanus guttatus	29	2309
	Hypanus marianae	12	172
	Mobula birostris	2	4
	Mobula hypostoma	1	1
	Mobula thurstoni	2	2
	Narcine brasiliensis	3	1
	Pristis pectinata	2	3
	Pseudobatos percellens	7	34
	Pteroplatrygon violacea	1	
	Rhinoptera bonasus	6	73
	Rhinoptera brasiliensis	1	3
	Styracura schmardae	4	7

	Urotrygon microphthalmum	1	
Gêneros			
	Dipturus sp.	2	2
	Hypanus sp.	4	705
	Mobula sp.	1	
	Pseudobatos sp.	2	8
	Rhinoptera sp.	9	233
	Other rays	10	3478
	Rays undentified	1	
	Total	148	16532

Fishery Production

Studies recorded 7,729.87 tons of elasmobranchs caught or landed in Ceará between 1991 and 2020. Of this total, 7,642 tons were recorded in a single study (Furtado-Neto & Barros Junior, 2006). The remaining studies accounted for 87.8 tons of elasmobranchs. The category "other sharks" was the most frequently recorded. At the species level, *Hypanus berthalutzae*, *Sphyrna* sp., *Ginglymostoma cirratum*, *Hypanus guttatus*, and *Galeocerdo cuvier* were the species that recorded volumes above five tons (Figure 3).

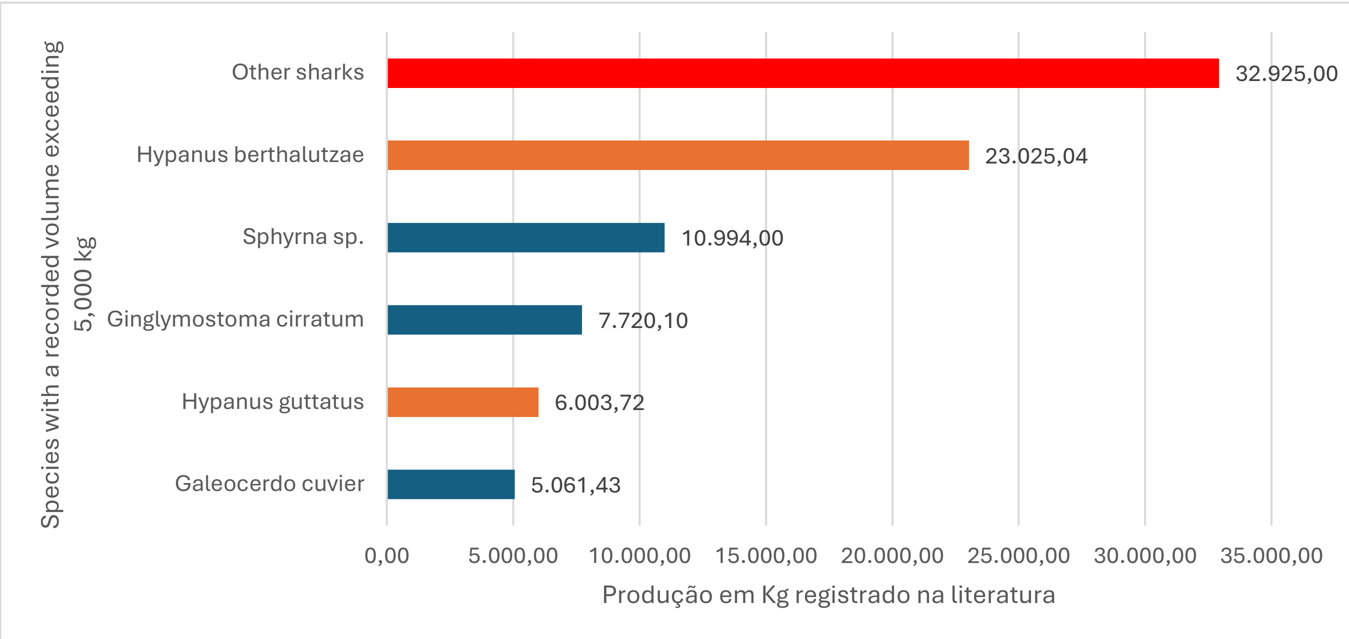

Figure 3. Species recorded in the literature with their respective production in kg. Marked in red unidentified groups (Basílio, 2011; Furtado-Neto; Barros Júnior, 2006; Jucá-Queiroz *et al.*, 2011; Parada, 2019).

The number of elasmobranch records exceeded 1,000 specimens per year starting in the second half of the 2000s. Concurrently, the records of elasmobranchs from studies conducted on landings at the Mucuripe Embayment also surpassed 1,000 specimens (Figure 4). Sharks showed a higher number of records compared to rays, with two peaks recorded in 2008 and 2011, exceeding 4,800 and 5,000 specimens, respectively (Figure).

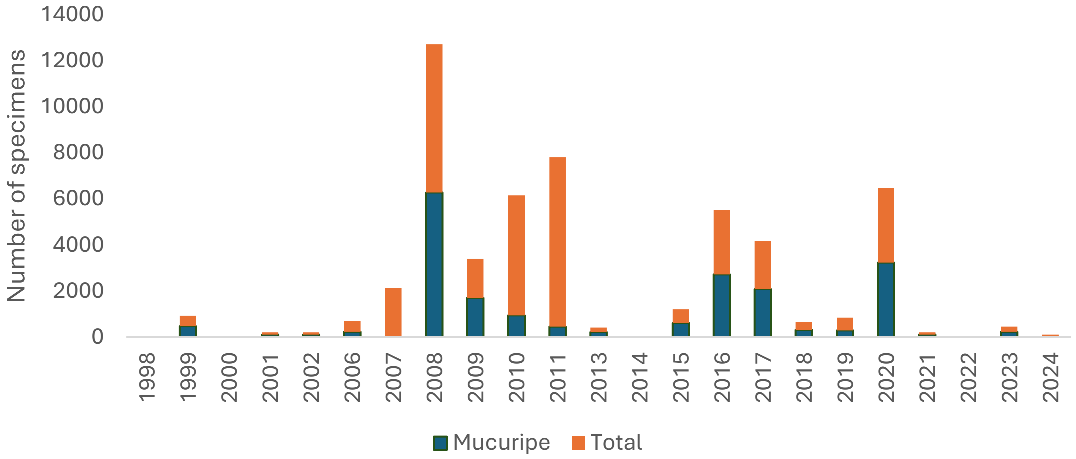

Figure 4. Number of elasmobranch specimens recorded in the selected documents. In orange, the total number for Ceará; in blue, the representativeness of Mucuripe Embayment in the total data reported by the studies.

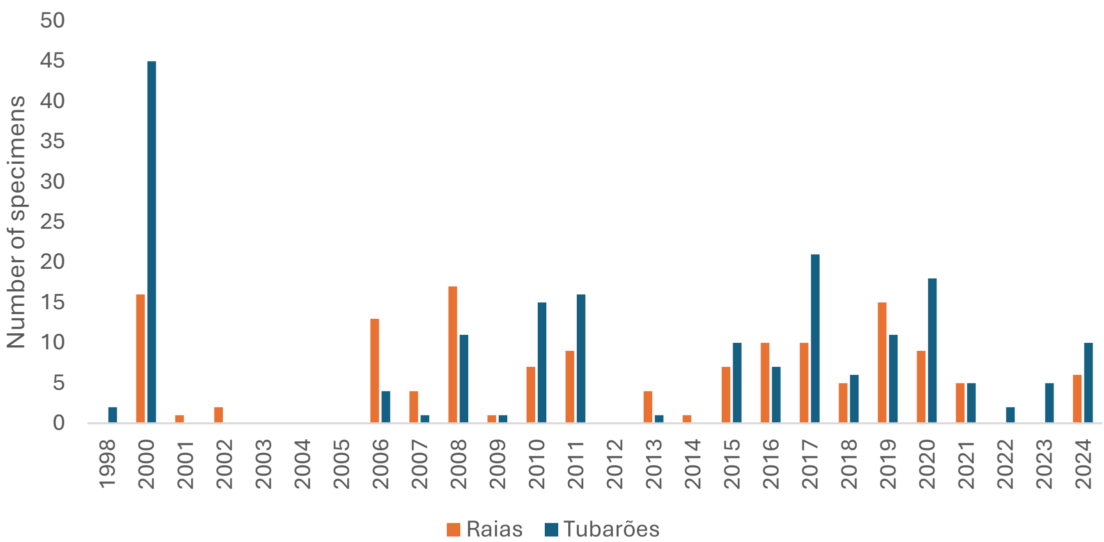

Figure 5. Total number of specimens recorded in each landing monitoring period by shark and ray categories. The data are distributed according to the year of publication of the selected documents.

Results of Landing Monitoring from the Present Study (2018-2020)

Between December 2018 and March 2020, a total of 633 elasmobranchs were recorded during 63 sampling days, comprising 414 rays and 219 sharks. Rays showed higher absolute numbers of occurrence in landings throughout the entire sampling period, except for March 2019 (Figure 6). Notably, January 2019 had the highest number of elasmobranchs landed, while August 2019 recorded the lowest number. A chi-square statistical analysis revealed a p-value of 0.0076, indicating a significant difference in the distributions of rays and sharks across the months. This suggests that the distribution of rays and sharks varies significantly over the sampling period.

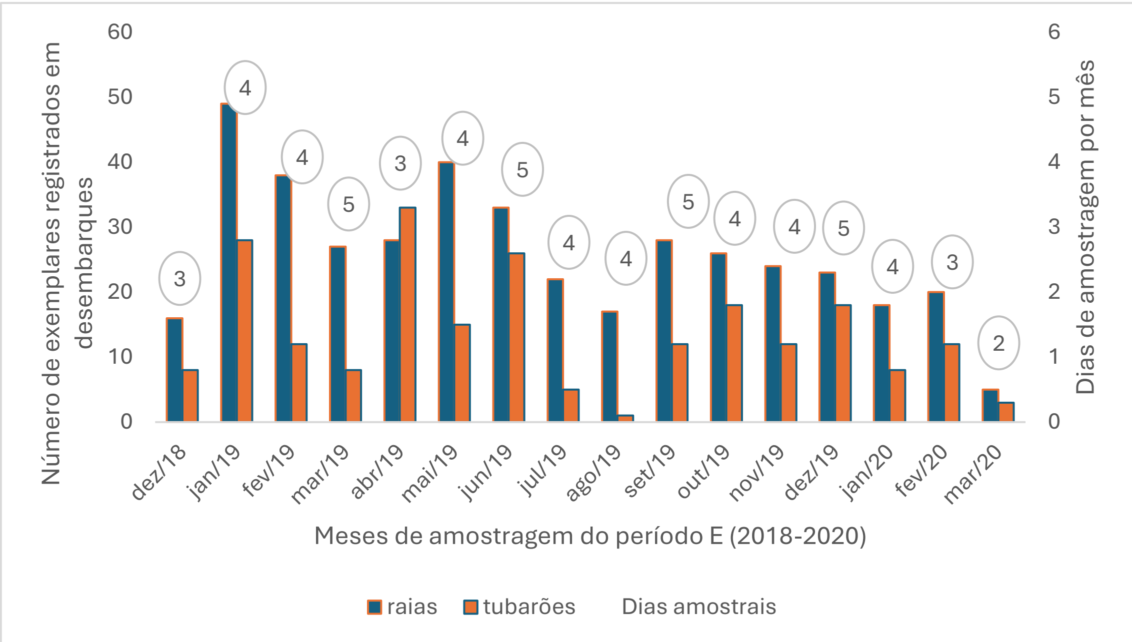

Figure 6. Time series of the total monthly number of elasmobranchs landed at Mucuripe Embayment, Fortaleza, Ceará, between 2018-2020.

A total of 16 shark groups were cataloged, including 11 species, 4 identified only at the genus level, and one unidentified group ("Other sharks"). For rays, 9 groups were cataloged, including 4 species, 4 identified only at the genus level, and one unidentified group ("Other rays") (Figure 7). Notable findings include rare records of *Mobula* sp. and the carcass of an unidentified lamnid specimen at the genus or species level.

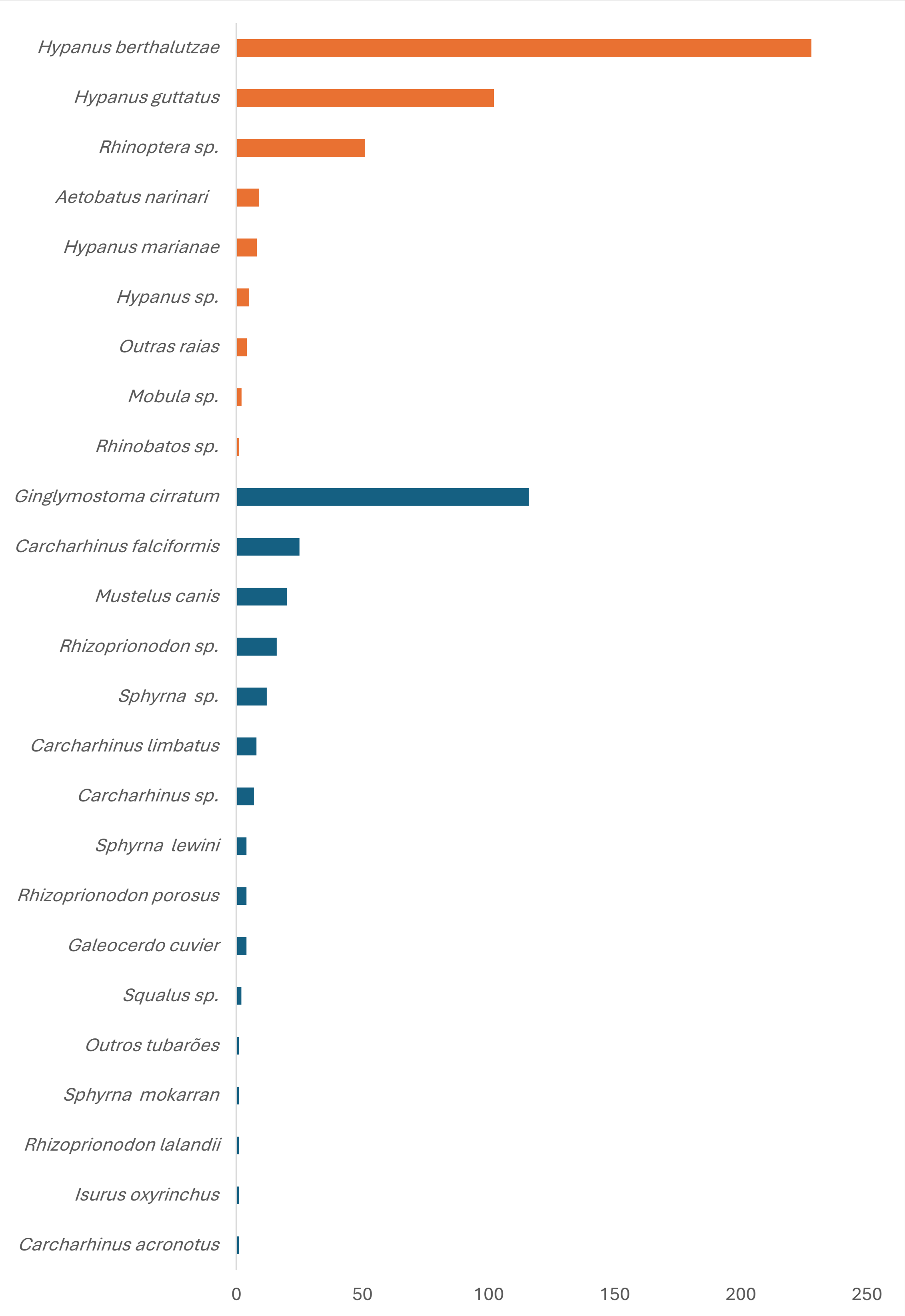

Figure 7. Absolute number of elasmobranchs landed during 63 sampling days between 2018-2020 at Mucuripe Embayment, Fortaleza, Ceará. In orange, the main species and genera of rays; in blue, the main species and genera of sharks.

During this sampling period, a total of 2,656.3 kg of elasmobranchs were recorded landed at Mucuripe Embayment. Among the most significant species in this record were *H. berthalutzae* (1,122.7 kg), *H. guttatus* (413.7 kg), and *G. cirratum* (320.9 kg).

Comparison of Landing Periods in the Mucuripe Region (2006 to 2020)

The total number of specimens recorded in landings varied from 3,238 between 2006 and 2008 to 634 specimens between 2018-2020. Considering the sampling days for each period, the relative numbers decreased from 30 specimens per landing day to 20 between 2008-2011 and 10 specimens between 2015-2020 (Figure 8).

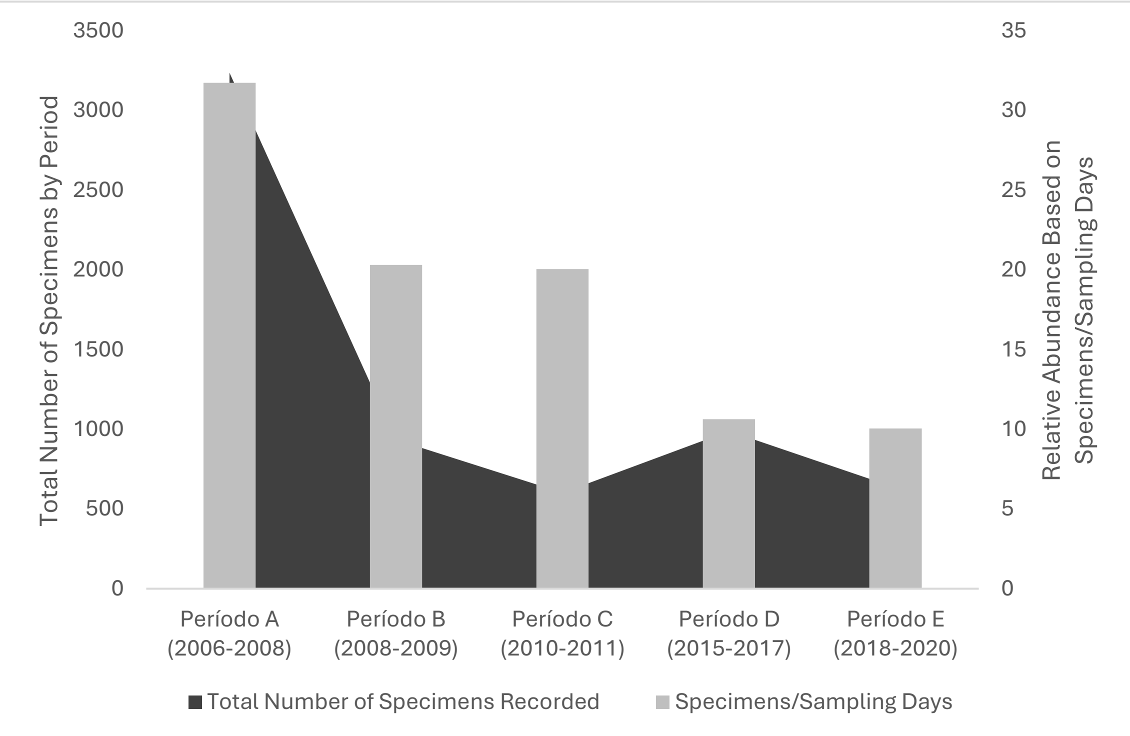

Figure 8. Number of specimens (total and relative) per landing monitoring period of elasmobranchs at Mucuripe Embayment, Fortaleza, Ceará, Brazil. In dark gray, the total values recorded for each evaluated period. In light gray, the values relative to the number of samplings conducted in each period.

Comparison of Ray Landings Between 2006-2020

Considering only the ray group, the species and genera that occurred in all five landing monitoring periods were *Hypanus berthalutzae*, *Hypanus guttatus*, *Rhinoptera* sp., and *Aetobatus narinari*. Once again, *Hypanus berthalutzae* stands out as the species with the highest number of records, consistently exceeding 200 identified specimens in each observation period. Furthermore, in relative terms (number of specimens/number of samplings per period), *H. berthalutzae* maintained the highest occurrence in landings, consistently exceeding four specimens per landing, with a peak in the first sampling period at 16 specimens per fishing landing (Table 5).

Table 5. Total and relative numbers of ray specimens recorded in fishery landings at Mucuripe Embayment, Fortaleza, Ceará, Brazil, occurring in all sampling periods between 2006 and 2020. The relative number represents the ratio between the number of specimens observed during the study period and the number of samplings conducted in that period.

Period	*Hypanus guttatus*		*Hypanus berthalutzae*		*Aetobatus narinari*		*Rhinoptera* sp.	
	Total / relative		Total /relative		Total /relative		Total / relative	
A - 2006-2008	147	1,44	1686	16,53	21	0,21	51	0,50
B - 2008-2009	32	0,70	386	8,39	11	0,24	65	1,41
C - 2010-2011	52	1,73	251	8,37	9	0,30	39	1,30
D - 2015-2017	160	1,65	484	4,99	8	0,08	2	0,02
E - 2018-2020	102	1,62	228	3,62	9	0,14	20	0,32

Comparison of Shark Landings Between 2006-2020

Six species and two shark genera were recorded as occurring across all five landing analysis periods. The absolute number of sharks from the genus Rhizoprionodon decreased from 400 to fewer than 20 individuals across the sampling periods. In relative terms, the decrease was from four to less than one specimen per sampling day (Table 6).

Table 6. Total and relative number of shark specimens recorded across all sampling periods of fishery landings at Mucuripe Embayment, Fortaleza, Ceará, Brazil, between 2006 and 2020.

Período	*G. cirratum*		*Rhizoprionodon* spp.		*C. limbatus*		*G. cuvier*		*Sphyrna* spp.		*C. acronotus*		*M. canis*	
	Total	Relative	Total	Relative	Total	Relative	Total	Relative	Total	Relative	Total	Relative	Total	Relative
A - 2006-2008	200	1,96	456	4,47	98	0,96	20	0,20	18	0,18	51	0,50	91	0,892157
B - 2008-2009	62	1,35	350	7,61	7	0,15	10	0,22	3	0,07	10	0,22	10	0,217391
C - 2010-2011	73	2,43	123	4,10	12	0,40	5	0,17	5	0,17	4	0,13	10	0,333333
D - 2015-2017	108	1,11	50	0,52	14	0,14	10	0,10	12	0,12	2	0,02	15	0,154639
E - 2018-2020	116	1,84	16	0,25	8	0,13	4	0,06	12	0,19	1	0,02	20	0,31746

Case Study (Rhizoprionodon spp.)

Arthaud (1999) analyzed the composition of fishery landings with a focus on sharks. When comparing the data from 1998-1999 with the same five subsequent study periods (2006-2020), the number of *Rhizoprionodon* records in landings—both at the genus level and by species (*Rhizoprionodon porosus* and *Rhizoprionodon lalandii*)—also decreased. During Period E (present study), the lowest number of Rhizoprionodon specimens was recorded across the entire historical series, whether at the genus or species level (Figure 12). Between 2006-2008, in addition to 456 specimens recorded at the genus level, 348 *Rhizoprionodon porosus* and 38 *Rhizoprionodon lalandii* were identified. Between 2008 and 2017 (Periods B, C, and D), landing monitoring did not include species-level separation, recording only at the genus level (Figure 9).

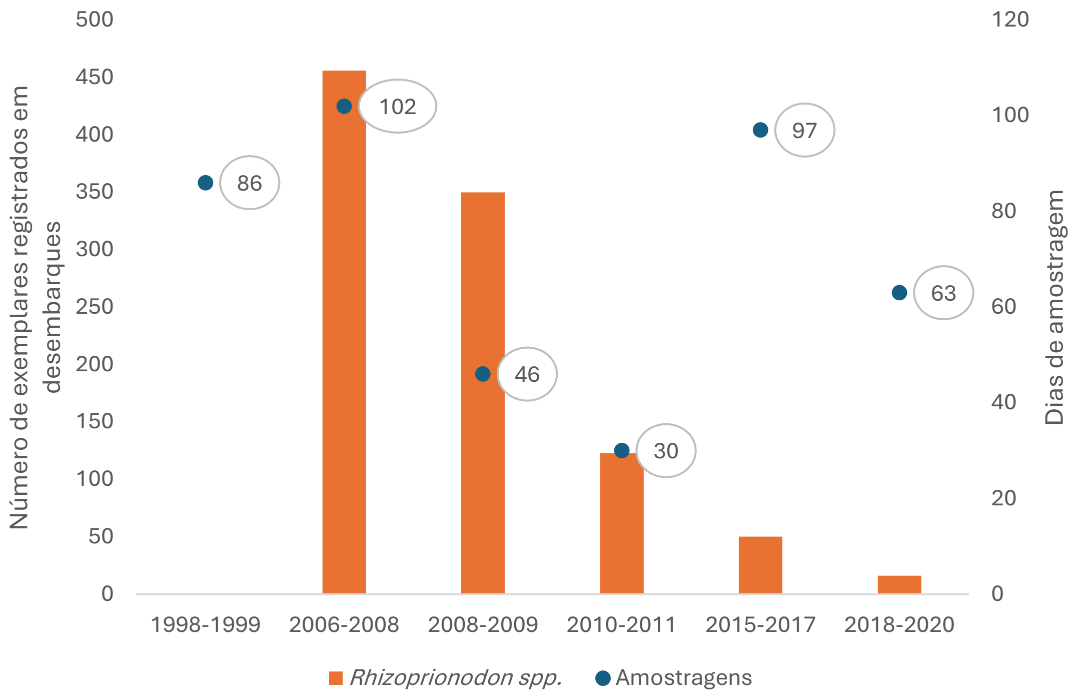

Figure 9. Comparison of Rhizoprionodon Genus Species Records Over the Years. Includes the landing sampling period from 1998-1999 conducted by Arthaud (1999), which analyzed only shark landings at Mucuripe Embayment.

More than 30 species of elasmobranchs landed at Mucuripe Embayment are under some level of threat. Notably, some are currently classified as Critically Endangered by Brazilian legislation, including hammerhead sharks (*Sphyrna* spp.), the shortfin mako (*Isurus oxyrinchus*), and, more recently added to the legislation, the silky shark (*Carcharhinus falciformis*). The main species considered vulnerable that have been commonly landed over the years include the nurse shark (*Ginglymostoma cirratum*), the Brazilian cownose ray (*Hypanus berthalutzae*), and the Endangered spotted eagle ray (*Aetobatus narinari*).

Fifteen species of elasmobranchs landed at Mucuripe Embayment are under some level of threat according to Brazilian legislation. Of these, seven species are categorized as Vulnerable, and five as Critically Endangered, representing the main threat categories. On the other hand, 30 species are considered threatened according to international lists, such as the International Union for Conservation of Nature (IUCN) Red List (Figure 16).

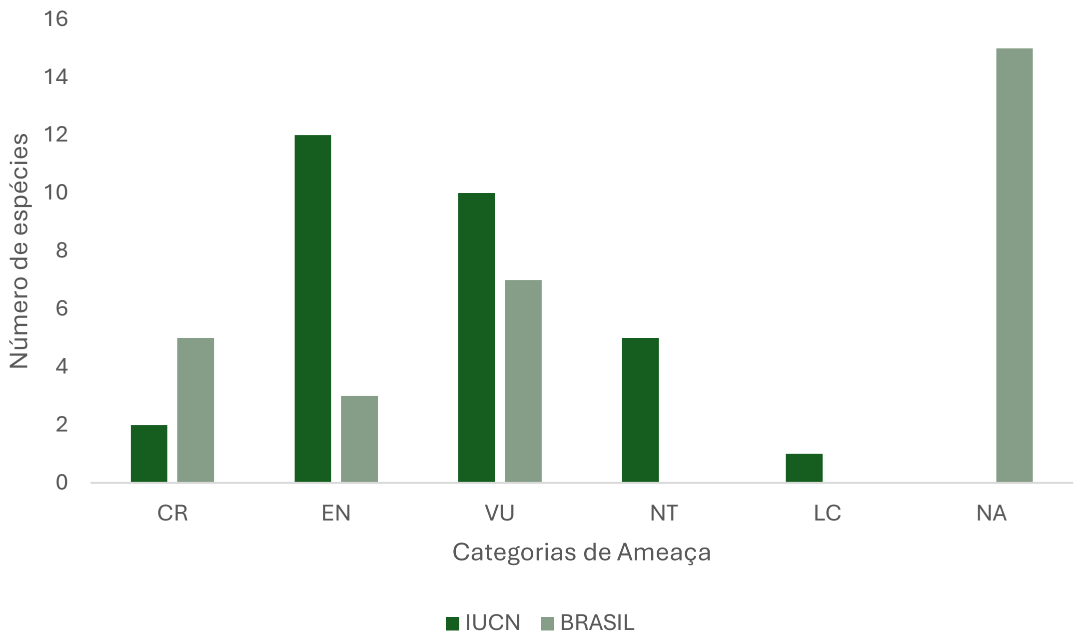

Figure 10. Number of Threatened Species Landed at Mucuripe Embayment According to Threat Categories Defined by the International Union for Conservation of Nature (IUCN) Red List and Brazilian Legislation. Categories include Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), and Not Evaluated (NE).

The diversity and evenness indices showed values ranging from 1.574 to 2.091 and 0.5171 to 0.6495, respectively. Period E exhibited the highest species diversity and evenness(Table 7).

Table 7. Biodiversity and Species Evenness Indices Across Sampling Periods of Fishery Landings at Mucuripe Embayment

Index	Period A	Period B	Period C	Period D	Period E
Shannon index	1,712	1,574	1,832	1,771	2,091
Pielou index	0,5194	0,5171	0,6466	0,5911	0,6495

DISCUSSION

This study establishes a timeline of publications on records, catches, and landings of elasmobranchs in the state of Ceará over the past 70 years. The documentation of over 34,000 elasmobranch specimens and 7,000 tons highlights Ceará as a focal point for targeted shark and ray fishing. It also underscores the importance of accurate fishery data collection and points to a significant change in the number of elasmobranch specimens landed at Mucuripe Embayment, in Fortaleza, over the years.

Scientometric Review

Of the 84 documents analyzed, more than 80% were produced and published after 1999. This coincides with the establishment of the Ceará Elasmobranch Study Group (ELACE) by Dr. Manuel Antonio de Andrade Furtado-Neto (1963–2019), a professor in the Department of Fisheries Engineering at the Federal University of Ceará. Dr. Furtado-Neto also implemented what could be considered the closest approach to a systematic monitoring of elasmobranch landings at Mucuripe Embayment. The earliest records of elasmobranchs in Ceará are primarily faunal surveys conducted by early naturalists in the state (Rocha, 1948) and basic studies on morphology and physiology (Furtado-Neto, 1985; Menezes, 1966). However, the lack of peer-reviewed scientific articles or official fisheries bulletins from state agencies may obscure data on the actual number of species captured in the state.

The publications that most connect information about sharks and rays to the general public are newspaper articles. These reports often highlight the occurrence of elasmobranch species with surprise, whether through sightings, commerce, or illegal captures (Diário do Nordeste, 2015; O Povo, Grupo de Comunicação, 2015; Siqueira, 2023), even though these animals are consistently present in fishery landings in the state capital (Falconery, 2022; Globo, 2022; Paulino, 2023). A historical contrast exists between a 1991 article asking, "Are there sharks in the Northeast?" and a 2023 report identifying 38 species in the state and discussing a mapping of sharks in Ceará. Public perception of reports on sharks and rays in the state has become increasingly positive over time (Vidal *et al.*, 2023).

The majority of documents are published as conference abstracts. Among the documents evaluated, there is a notable scarcity of data on fishery production (Basílio, 2011; Furtado-Neto; Barros Júnior, 2006). Limited access to technologies for more specific studies, such as molecular biology and physiology, further reinforces the concentration of studies on fisheries and faunal surveys. Additionally, logistical challenges in weighing animals during landings may hinder access to accurate catch volumes, as specimens often arrive eviscerated or cut, and in many cases, handling marketed specimens is not feasible.

Species identification for sharks and rays is a global issue (Almerón-Souza *et al.*, 2018; Giovos *et al.*, 2021), and it is particularly alarming in Brazil, a major hub for the illegal trade of endangered species (Bernardo *et al.*, 2020; Brasil, 2023). This explains why the category "other sharks" (>10,000 specimens) is the most frequently recorded in Ceará's publications, potentially underestimating the number of threatened species captured. The genus *Rhizoprionodon* ranks second in captures, with just over 2,000 specimens recorded in the literature. For rays, the situation differs slightly, with *Hypanus berthalutzae* leading in the number of specimens, ahead of the category "other rays." This is because, even when landed in "sliced" form (where the ray is landed without the cranial region, eviscerated, and cut into two parts), it is still possible to identify them.

The main reasons for misidentification can stem from the fact that sharks are often landed eviscerated, without heads or fins (commonly called "cigar"). This makes the identification process during landing activities particularly complex, especially for groups like Carcharhinidae.

Composition of Elasmobranchs

The number of species recorded in the literature surpasses what has been described for Ceará in recent studies on the Brazilian Northeast (Lima, 2022). Based on the 87 species recorded over the past 76 years, Ceará remains one of the states with the highest number of elasmobranch species recorded in the Northeast. It is evident that the biodiversity records of Ceará require better systematization, as sporadic sampling and landings do not allow for a reliable evaluation of the temporal evolution of species presence and absence. In data-poor regions, obtaining unpublished information is crucial for reconstructing fishery statistics (Freire *et al.*, 2021). Accessing unofficial data about catches allows for the observation of temporal trends in captures and landings, as well as the development of predictive models based on historical data (Cisneros-Montemayor *et al.*, 2020). Systematic monitoring of landings since the 2000s has guided much of the findings about capture records in Ceará. However, the periodicity of monitoring and the increase in capture records have not resulted in improved species identification. Therefore, investment in training and logistics for better field approaches and data collection is essential.

Fishery Landings at Mucuripe Embayment

The most recent sampling period (2018-2020), Period E, revealed a decline in elasmobranch occurrence, even though the most frequent species remained similar to previous periods, such as Hypanus berthalutzae and *Ginglymostoma cirratum*. Despite fewer sampling days compared to earlier periods, the number of elasmobranchs per sampling day decreased. Diversity and evenness indices remained stable across the five analyzed periods. A significant drop in elasmobranch numbers was observed, from 30 to 10 specimens per sampling day. Noteworthy is the sporadic record of the ray Mobula sp. and a decline in landings of sharks from the genus Rhizoprionodon.

The reduction in Rhizoprionodon records can be attributed to two main factors. The first is possible identification errors, although these are more common at the species level than at the genus level. Moreover, species from this genus are among the most documented and frequently landed at Mucuripe Embayment, making identification error less likely. The second possible factor is a decrease in captures, which may result from the absence of the species in the area or changes in fishing practices, such as a reduction in the use of less selective methods like nets, which previously resulted in dozens of specimens being landed in a single day. Other studies conducted between 2018-2020 in other regions of Ceará, such as Paracuru Beach, recorded over 100 specimens in one year of sampling (Parada, 2019). Thus, having only limited sampling days available does not allow for determining population declines due to a lack of robust data on abundance indices, such as CPUE or LPUE. However, under criteria A2(b) and (d) of the IUCN Red List for species extinction risk assessment, population reduction can be inferred, estimated, or suspected based on unknown causes or those that have not ceased (IUCN, 2022), based on observations over time. Therefore, the patterns detected in this study, as well as those reported by Pinheiro *et al.* (2023) for the same landing site, should be considered in future IUCN assessments.

In terms of capture volumes, data are scarce. Despite being an important parameter for assessing abundance, there are few records regarding the volume/production of shark and ray fisheries. The largest volume of elasmobranchs captured was restricted to the study by Furtado-Neto and Barros Junior (2006), which compiled official fishery statistics from Ceará between 1991 and 2003, witch identified Mucuripe Embayment, in Fortaleza, as one of the main ports, with a production of over 500 tons between 1991 and 2003.This study served as a baseline for comparison with the present period. When compared to data sampled between 2018-2020, a considerable difference is observed, with only 2 tons recorded in one year. Due to the scarcity of such data for Mucuripe landings (weight), it is suggested that data obtained between 2018 and 2020, based on weekly sampling, be subjected to the same analyses and extrapolations performed in the 1990s by the official fishery statistics agency. This could enable a more direct comparison between these periods.

Historical series are crucial for assessing the sustainability of fisheries and determining whether there have been changes in catches over time (Freire *et al.*, 2021; Pauly; Zeller, 2016). Specifically at Mucuripe, the main challenges for conducting a robust temporal analysis are: (a) lack of periodicity; (b) lack of systematic data collection, including species names, and information such as number of individuals, length, sex, weight, etc.; and (c) the nature of landing monitoring, which often does not allow for detailed work on elasmobranch identification due to the dynamics of landings and the sale of fishery products. For this reason, it is suggested that new protocols be established for field sampling. These protocols could establish priorities and step-by-step procedures for information collection, as the logistics of fishery landings often require choosing between examining a specimen and recording others being landed simultaneously.

Conservation of Elasmobranchs at Mucuripe

The decline in elasmobranch occurrence in landings at Mucuripe Embayment, although limited by the overdispersion of data, highlights the critical need for implementing rigorous monitoring and continuous data collection. Although little used in abundance studies (Metri; Perez, 2014), LPUE (Landing Per Unit Effort) has proven effective compared to CPUE in assessing abundance trends for various species worldwide (Kerby *et al.*, 2013; Leitão *et al.*, 2022; Tzanatos *et al.*, 2014; Woźniacka *et al.*, 2024). For this reason, it could be a viable technique to assess elasmobranch abundance in the region, provided that more data becomes available, such as fishing days, catch volume per boat, and the number of fishers.

The presence of rare and conservation-relevant species, such as the whale shark (Rhincodon typus) (Faria *et al.*, 2009), the shortfin mako (*Isurus oxyrinchus*) (see Chapter 4), *Mobula* spp., and *Sphyrna* spp. (Jucá-Queiroz *et al.*, 2008; Santander-Neto; Faria, 2020), reinforces this necessity. Long-term studies are essential for discerning population trends and underpinning effective management strategies (Gouraguine *et al.*, 2019; Kerby *et al.*, 2013). Literature reviews have been an important tool for understanding the dynamics of the occurrence and capture of shark and ray species in Brazil (Wosnick *et al.*, 2023b). In other regions of Brazil, conservation projects have demonstrated success in protecting elasmobranchs through continuous monitoring and environmental education initiatives (Giareta *et al.*, 2021; Rangel, 2023; Wosnick *et al.*, 2023a; Wosnick; Wosiak; Machado Filho, 2021). Implementing similar approaches at Mucuripe Embayment could not only improve the accuracy of collected data but also contribute significantly to preserving these species, whose existence is intrinsically linked to the health of global marine ecosystems (Dulvy *et al.*, 2014).

After years of collaboration between the fishing and scientific communities, it is urgent to establish action plans for environmental education in the region. Pilot actions such as training workshops to raise awareness of the most vulnerable local species, data collection training, and the distribution of educational materials (e.g., flyers) about local species can be implemented immediately. However, logistical limitations hinder long-term actions, including a lack of government interest, funding, and physical infrastructure for data collection. Therefore, in complex cases, participatory management is crucial, engaging the fishing community and broader society in elasmobranch conservation (Aximoff *et al.*, 2022; Bateman *et al.*, 2024; Séguigne *et al.*, 2023; Seminara *et al.*, 2023). Conservation efforts can begin by selecting model species (Globo, 2022), establishing zones of interest, among other approaches that make the cause a matter of public interest.

The state of Ceará, and particularly the Mucuripe region, has stood out over the years as an important landing point for sharks and rays. Despite the notable lack of specific public policies for the management and conservation of these marine animals, there is great potential to transform Mucuripe Embayment into a hub for marine life conservation and education. From the first naturalists who investigated the region's species to the most recent studies led by Prof. Manuel Antônio de Andrade Furtado-Neto, the region has a rich history of research and knowledge production about elasmobranchs. The cooperation between the academic community and maritime workers (fishers, fish handlers, and traders) has proven collaborative and can be further strengthened. Expanding this collaboration through training fishers in elasmobranch biology and engaging them in conservation actions could not only enrich local scientific and cultural knowledge but also foster greater awareness of the importance of conserving sharks and rays.

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CAPÍTULO 3 - WHITE SHARK OR SHORTFIN MAKO? LAMNID SHARKS IDENTIFICATION IN AN OVERLAPPING AREA OF THE EQUATORIAL SOUTHWESTERN ATLANTIC

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Abstract

Despite their worldwide distribution, the occurrence of Lamnidae species in tropical zones remain poorly understood. In the Equatorial Southwestern Atlantic, the Shortfin Mako, *Isurus oxyrinchus*, has been captured in commercial fisheries, whereas the White Shark, *Carcharodon carcharias*, is only rarely recorded. This study aimed to characterize lamnid records for the Equatorial Southwestern Atlantic, as well as to apply molecular markers to identify a lamnid carcass from the only area in the region where these two species are known to overlap (off Cear ά State, Northeastern Brazil). The landed carcass, although sold in the market as a White Shark, in fact was a Shortfin Mako, *I. oxyrinchus*, with a total of 99.6% and 100% match to its ND2 and D-loop mitochondrial DNA sequences, respectively. Despite the existence of a record of landings of elasmobranchs by artisanal and commercial fisheries from Cearά, lamnid landings in this region are still rare and comprise only four records for *I. oxyrinchus*, including juvenile

specimens. As for the White Shark, Ceará State remains the only region in the Equatorial Southwestern Atlantic to hold records (three) of *C. carcharias* (all of them adults). Oceanographic conditions in this region may contribute to the occasional presence of large lamnid specimens. Moreover, fishers seem to support the presence of both lamnid species in the region.

INTRODUCTION

Globally distributed, sharks of the family Lamnidae (Evans, 2015; Ebert et al., 2021) are one of the most popularly known group of sharks from documentaries to pop culture classics (Westbrook et al., 2019; Whitenack et al., 2021). These apex predators are a large, highly migratory, and fastswimming group of sharks that play a crucial role in marine ecosystems (Bonfil et al., 2005; Fallows et al., 2013; Santos et al., 2021; Barcellos et al., 2022). Despite being widely studied and reported in temperate and subtropical waters, there is still a lack of information on the occurrence and distribution of lamnid species in tropical waters (Christiansen et al., 2014; Barreto et al., 2016). One example of this gap is the two main lamnid species that occur in the Equatorial Southwestern Atlantic. The Shortfin Mako, *Isurus oxyrinchus* Rafinesque, 1810, has been widely reported by commercial fisheries in Brazil (Amorim et al., 1998; Barreto al., 2016) to occur from southern to more equatorial zones in the northeastern coast (Canani and Oddone, 2020). The other lamnid species is the White Shark, *Carcharodon carcharias* (Linnaeus, 1758), which has been rarely reported (Amorim et al., 2018); historically, there have been less than 30 White Shark records for the entire Brazilian coast (Soto, 2001; Gomes et al., 2019). Both species are listed as threatened in regional (Brazil) and global (IUCN) lists (Rigby et al., 2018, 2022; Brasil, 2022).

When based on complete specimens or some specific parts, as jaws for example, morphological characters such as tooth and jaw morphology may be sufficient to distinguish between Mako and White sharks (Gadig and Rosa, 1996; Ebert et al., 2021). However, in the context of fishery dependent studies or fisheries monitoring, most often, specimens are landed and commercialized as carcasses or parts of them (called “charutos” in Brazilian Portuguese) or isolated fins, which often does not enable species identification (Giareta et al., 2021). This is a problem for enforcement of fisheries management at national level and regulations that can be considered essential for species conservation efforts (Dudgeon et al., 2012; Wosnick et al., 2019). To overcome this challenge, molecular markers are considered an effective tool to elucidate important aspects for fisheries management (Heist, 2000; Dudgeon et al., 2012). In fact, molecular markers have been widely used for elasmobranch conservation, including understanding species' delimitation, population structure, and restraining illegal fishing and trade (Almerón-Souza et al., 2018; Faria et al., 2013; Naylor et. al., 2012; Rodrigues Filho et al., 2020). In the Equatorial Southwestern Atlantic, there are successful examples in the application of different molecular markers to elucidate sharks and rays occurrence records, misidentifications, and taxonomy (e.g. Santander-Neto et al., 2011; Faria et al., 2012; Petean et al., 2020; Sales et al., 2020). Thus, this study aimed to characterize lamnid records for the only region in the Equatorial Southwestern Atlantic with accounts for both Shortfin Mako and White sharks, as well as to apply molecular markers to identify a lamnid carcass landed by small-scale fisheries in the region.

MATERIALS AND METHODS

A bibliographic review was conducted on the occurrences of the two species with an emphasis on records for the coast of the State of Ceará, Brazil, which is the only locality in The Equatorial Southwestern Atlantic with overlapping of these two species. Scientific articles, gray literature, and records shared on social media were consulted to compile occurrence records. Furthermore, during a fishery landing sampling on May 19, 2019, in Mucuripe Inlet (Fortaleza, Ceará), a Lamnidae shark carcass was recorded. The carcass was preliminary identified as belonging to a White Shark based on the following diagnostic morphological characters proposed by Bigelow et al. (1948) and Compagno (2001): (a) body color pattern; (b) characteristics of second dorsal and anal fins; (c) shape of the caudal peduncle (d) presence of a lateral keel starting at the caudal peduncle and extending along the body. Samples were collected to elucidate species identification.

The 2nd dorsal and anal fins and muscle tissue samples were removed from the carcass and kept in chopped ice until arrival at laboratory facilities. The fins were initially fixed in 10% formaldehyde solution and later preserved in 70% ethanol and deposited in the Dias da Rocha Ichthyological Collection of the Federal University of Ceará (specimen catalog number CIDRO-B-316) for further analysis. Muscle tissue samples were preserved in 96% ethanol. The DNA was extracted using QIAamp DNA Minikit (QIAGEN) Quick-Start Protocol: QIAamp DNA Mini Kit, following the manufacturer's instructions. The extracted DNA was quantified using a microvolume spectrophotometer. After extraction, the DNA was submitted to a polymerase chain reaction (PCR) amplification to amplify fragments of the mitochondrial DNA.

A total of two mitochondrial DNA markers were selected, including gene ND2 and the

Control Region (D-loop). The ND2 has been proven to be a robust tool for elasmobranchs identification (Naylor et al., 2012) and has been used for species identification in this study area (e.g., Sales et al. 2020). Fragments of the Control Region have been used in phylogeographic studies involving representatives of the Lamnidae on a global scale (O'Leary et al., 2015; Andreotti et al., 2016; Corrigan et al., 2018). Thus, for both markers, sequences referenced are available in publicly accessible databases.

For ND2, the following primers were used to perform the reactions: Ilem-Mustelus 5'-AAGGACCACTTTGATAGAGT-3', Asn-Mustelus 5'-AACGCTTAGCTGTTAATTAA-3', and internal primer ND2-batoids-IFA 5'-CACTTYTGACTWCCAGAAGT-3' (Naylor et al., 2012). The cycle reaction was as follows: initial denaturation at 94°C for 2 min, 39 cycles of denaturation at 95°C for 30 s, primer annealing at 48°C for 30 s, extension at 72°C for 90 s and final extension at 72°C for 7 min. For the Control Region, the primers ElasmoCR-F (forward primer: 5'-TTGGCTCCCAAAGCCAAGATTCTG-3') and ElasmoCR-R (reverse primer: 5'-CCCTCGTTTTWGGGGTTTTTCGAG-3') were used (Stoner et al., 2003). The PCR program consisted of initial denaturation at 95°C for 7 minutes, followed by 40 cycles at 95°C for 30 seconds, 56°C for 30 seconds (hybridization), 72°C for 90 seconds (extension), and a final extension at 72°C for 7 minutes. The PCR was prepared with 100 ng of DNA template, 12.5 µl of AmpliTaq Gold 360 Master Mix (Life Technologies, Paisley, UK), 0.5 µM of final concentration for each primer, and ultrapure water to reach a total volume of 25 µl. PCR products were purified using ExoSAP-IT (Affymetrix, Inc., Santa Clara, CA, USA) following the manufacturer's guidelines. DNA was sequenced using a capillary sequencer (EZ-Seq service, Seoul, South Korea).

The DNA sequences were edited and aligned using the Geneious software version 7.1.5. The sequence was analyzed using the Basic Local Alignment Search Tool (BLAST; Altschul et al., 1990) in the GenBank database for species identification. The resulting 494 bp ND2 and 958 bp Control Region mtDNA sequences were added to the GenBank (accession numbers: OR554884 and OR567420, respectively). A dataset spanning 1,512 base pairs (bp) was assembled, comprising sequences from the ND2 (n = 494 bp) and control region (n = 1,018 bp) of mitochondrial DNA. This dataset incorporated sequences from the ND2 and control region obtained from a single specimen in the present study, originating from the Equatorial Southwestern Atlantic, along with 11 homologous Sequences for each of these mitochondrial genes and regions sourced from GenBank all derived from complete mitochondrial DNA sequences. The GenBank sequences included in the dataset for phylogenetic analysis as ingroup taxa were as follows: *Isurus oxyrinchus* (n = 4) [GenBank database No. MF537044 (Gorman et al. 2019) and MZ923831-MZ923833 (Mehlrose et al. 2022)]; Isurus paucus (n = 1) [KJ616742 (Chang and Chiang et al. 2016)]; Lamna nasus (n = 1) [KX610464 (Díaz-Jaimes et al. 2016)]; Lamna ditropis (n = 1) [KF962053 (Chang and Jang-Liaw et al. 2016)]; *Carcharodon carcharias* (n = 2) [KX389266 (Marra et al. 2016) and KC914387 (Chang and Shao et al. 2014)]. Conversely, sequences treated as outgroup taxa in phylogenetic analyses included: *Carcharias taurus* (n = 1) [KF569943 (Chang and Jabado et al. 2014)] and Cetorhinus maximus (n = 1) [KF597303 (Hester et al. 2015)]. For Bayesian inference (BI) analysis, the PartitionFinder 2 software (Lanfear et al. 2012) was employed to select the model of evolution, considering codon positions for the protein-coding ND2 and a single partition for the control region. Following the corrected Bayesian Information Criterion (BIC), these evolutionary models were chosen: HKY+G, HKY+I, and HKY for three partitions of ND2, and HKY+G for the control region. BI was performed using the MrBayes 3.2.6 software (Ronquist et al. 2012), running the dataset for 3×10^7 generations, with Markov chains sampled every 1,000 generations, and discarding the initial 25% of generations as burn-in. Convergence and effective sample size (ESS) values were assessed using a plugin in the Geneious software version 7.1.9.

The dataset was also subjected to maximum likelihood (ML) analysis using Randomized Accelerated Maximum Likelihood (RAxML) (Stamatakis 2006), with the GTR+G model of evolution and 10,000 bootstrap pseudoreplicates. Trees generated from analyses conducted in Geneious were edited using the FigTree software. Furthermore, a dataset comprising 791 base pairs (bp), consisting of 367 control region mtDNA sequences, was compiled for the haplotype network reconstruction. This dataset incorporated the control region sequence obtained in the present study, alongside 365 sequences from *I. oxyrinchus* sourced from various oceans Obtained by Corrigan et al. (2018) (MH759795 - MH760159), as well as one sequence from *Isurus paucus* obtained by Chang and Jabado et al. (2014) (KJ616742). The analysis utilized the TCS algorithm (Clement et al., 2002), implemented in the PopART software version 1.7.2 (Leigh and Bryant, 2015). Individual dashes were depicted along branches to denote mutational steps between haplotypes.

RESULTS AND DISCUSSION

The 494 bp for ND2 was 99,6% similar to four *Isurus oxyrinchus* (Lamniform: Isuridae) sequences available in GenBank (OM102488.1; OM102394.1; OM102381.1; and OM102395.1). As for the Control Region, the 958 bp fully matched (100% similarity) with 95 sequences available in GenBank (e.g., MH760157.1; MH760151.1; MH760146.1; The 494 bp for ND2 was 99.6% similar to four *Isurus oxyrinchus* (Lamniform: Isuridae) sequences available in GenBank (OM102488.1; OM102394.1; OM102381.1; and OM102395.1). As for the Control Region, the 958 bp fully matched (100% similarity) with 95 sequences available in GenBank (e.g., MH760157.1; MH760151.1; MH760146.1; MH760143.1; MH760142.1; MH760141.1; MH760139.1; MH760133.1; MH760124.1; and MH760122.1). In addition, this obtained Control Region sequence matches the most abundant haplotype found in a study that sequenced Shortfin Mako sharks sampled in the Northwestern Atlantic, Indian, and West Pacific Oceans (Corrigan et al., 2018). Therefore, both mtDNA markers were effective in identifying the lamnid carcass as belonging to an *Isurus oxyrinchus* specimen.

This carcass (Figure 3A) was being traded by a fisher as a White Shark (*C. carcharias*). In fact, this carcass was initially thought to be that of a White Shark based on its color pattern (Gonçalves Neto et al., 2022), an identification that was unquestionably opposed by the subsequently obtained molecular data presented here.

The match between the specimen examined in the current study and *I. oxyrinchus*, as indicated by BLAST analyses, was further supported by both Bayesian and Maximum Likelihood phylogenetic analyses. Specifically, the examined specimen clustered within a clade exclusively comprised of *I. oxyrinchus* individuals (Figure 1). Additionally, network analysis reinforced this finding, with the haplotype derived from the specimen aligning closely with the most prevalent haplotype documented globally by Corrigan et al. (2018) for *I. oxyrinchus* (*I. oxyrinchus* haplotypes differed from the one from *I. paucus* by 54 mutational steps) (Figure 2). Collectively, these molecular analyses consistently confirm the identity of the examined specimen as *I. oxyrinchus*.

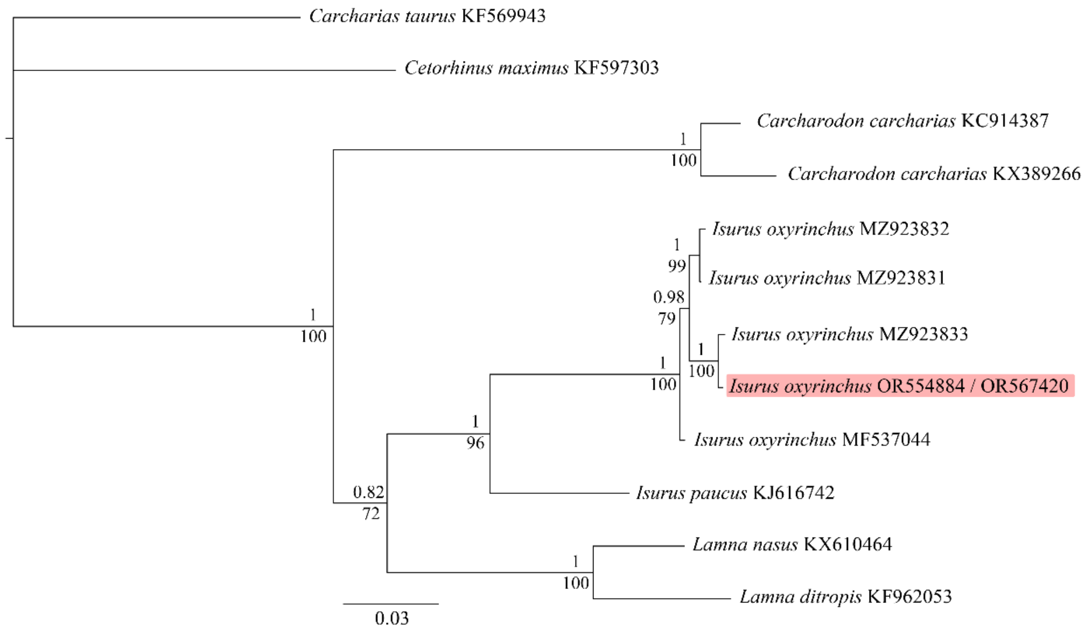

Figure 1. Clade consisting of conspecific DNA sequences retrieved from the GenBank database for the Shortfin Mako Shark, *Isurus oxyrinchus*, supplemented by sequences from a single specimen from the Equatorial Southwest Atlantic obtained in this study (highlighted in pink). Bayesian tree constructed from a combined 1,512 bp dataset of mtDNA ND2 (494 bp) and control (1,018 bp) region sequences employing the following evolutionary models: HKY+G, HKY+I, and HKY for three partitions of ND2, and HKY+G for the control region. Posterior Bayesian probabilities (BP) are indicated above each branch. The same topology was obtained via maximum likelihood (ML) analysis using the GTR+G model of evolution. Bootstrap values for ML are displayed below each branch. All DNA sequences sourced from the GenBank are derived from complete mitochondrial genomes

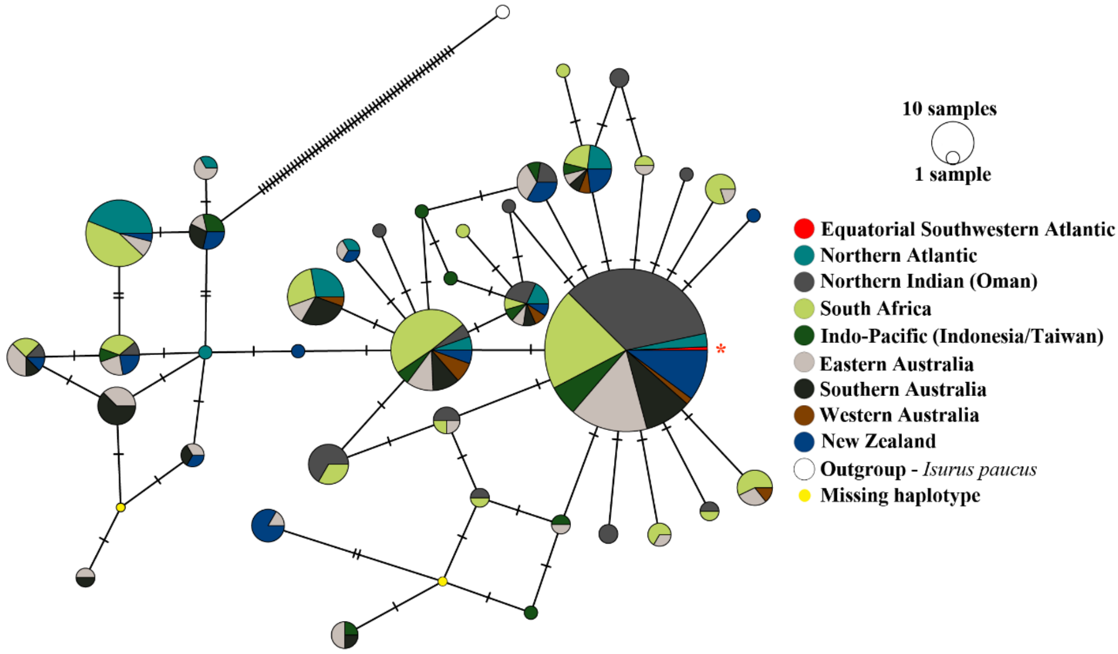

Figure 2. Haplotype network reconstruction (using the TCS algorithm) for the Shortfin Mako Shark, *Isurus*

oxyrinchus. The data encompass sequences obtained globally by Corrigan *et al.* (2018), supplemented with the Equatorial Southwest Atlantic haplotype acquired in this study (indicated by a red asterisk). Analysis was conducted on a 791 bp segment of the mitochondrial DNA control region. Each color represents a sampling locality or region. Circle size reflects the number of sequences/specimens for each haplotype. A total of two missing haplotypes are presented in yellow. Individual dashes along branches signify one mutational step between haplotypes. An outgroup haplotype from Longfin Mako Shark, Isurus paucus, obtained by Chang *et al.* (2014) was integrated into the analysis.

Obtaining a correct lamnid identification based only on common names can be misleading. Even in Brazilian literature, Shortfin Mako and White Shark are often listed in publications under different names, hindering species-level identification by their common names. Fishers' information from this region where the two species overlap in the Equatorial Southwestern Atlantic may also be difficult to use due to similar common names applied to them. The White Shark is locally called "Cação-espelho" (Mirror-shark; pers. comm. Jucá-Queiroz, B.) but also "Anequim-boto" (Gomes et al., 2019; Kotas et al., 2023), whereas the Shortfin Mako is called "Anequim" or "Cação Anequim" (Gadig, 2001; Gomes et al., 2019; Kotas et al., 2023).

Apart from nomenclature, the identification of large lamnid specimens can also be misleading when only morphological characters are assessed. An example is a recent video posted on social media by fishers from Acaraú (western Ceará State) (Figure 3B) that indicates the capture of a "White Shark" even though it can be inferred that it was, most likely, a large *Isurus oxyrinchus* (Shortfin Mako Shark) (estimated TL > 3m). This highlights that species records of the *Lamnidae* family without complete information are susceptible to misidentifications and erroneous occurrence records over the years, especially when dealing with scant data such as those provided by carcasses, landings, or fishing reports.

This is a major issue along the Equatorial Southwestern Atlantic, a region that can be characterized by poor fisheries data, lack of on-board activities, and only limited landings observations (Leduc et al., 2021; Seminara et al., 2024). In this sense, molecular analysis techniques such as DNA barcoding remain essential to assist in the correct identification of shark species (Dudgeon et al., 2012), especially of threatened species that are being traded. Avoiding misidentification between *Isurus oxyrinchus* (Shortfin Mako) and *Carcharodon carcharias* (White Shark) in this unique equatorial zone of occurrence is necessary to understand the occurrence of these species in tropical zones.

Despite catches by the Atlantic longliner fleet, there are few records of Shortfin Mako landings in the study region. Historically, other regions of the Equatorial Southwest Atlantic have recorded large catches of *Isurus oxyrinchus*, such as the spinner fleet operating in the states of Rio Grande do Norte and Pernambuco. However, records are scarce, apart from a few records made by naturalists in the middle of the 20th century (Table 1) in Ceará State. The first record for the species in the State of Ceará was performed by Rocha (1948). After this listing, only one specimen of *I. oxyrinchus* was reported stranded on Iparana Beach, in October 2000 (CIDRO-B-50) (Figure 3C), 52 years later. This present study also adds two new records of Shortfin Mako caught by small-scale fisheries landed in the Mucuripe Inlet (Fortaleza, Ceará): 1) the DNA-sequenced carcass (CIDRO-B-316) (Figure 3A) and 2) a photo of a juvenile specimen shared by an artisanal fisher via a private social media group (Figure 3D). For White Sharks, all the records of occurrence for the Equatorial Southwestern Atlantic are from Ceará State.

Table 1. Records of White Shark (*Carcharodon carcharias*) and Shortfin Mako (*Isurus oxyrinchus*) for the only region of the Equatorial Southwestern Atlantic where these species are known to overlap (off the coast of the state of Ceará, Northeatern Brazil).

Species/taxon	Popular name (locally – Brazilian Portuguese)	Source	Date	Locality	Reference
Isurus oxyrinchus	Anequim, ; Mako; Cação-cavalo Cação-anequim	Listed in a checklist	1948 or before	unknown	Rocha (1948)
		Beach stranded	10/21/2000	Caucaia	Present study; CIDRO-B-50
		Fisheries landed carcass	05/09/2019	Fortaleza	Present study; CIDRO-
		Fisheries landed juvenile	09/29/2020	Fortaleza	Present study
Isurus cf. *oxyrinchus*	-	~3 m TL female caught by small-scale fishers	2019	Acaraú	Youtube video https://youtu.be/UMCkb
Carcharodon carcharias	Cação-espelho; Anequim-boto	Listed in a checklist	1948 or before	unknown	Rocha (1948)
		Jaw	1990	Acaraú	Gadig & Rosa (1996)
		Jaw	1991	Acaraú	Gadig & Rosa (1996)

The landing point where the Shortfin Mako carcass was recorded (Mucuripe Inlet) has been monitored for artisanal fisheries landing studies for the last 20 years, specifically for elasmobranch landings. From 1999 to 2020, at least 6,918 elasmobranchs were recorded, with no lamnid records among these catches (Freitas, 1976; Santander-Neto and Faria, 2020).

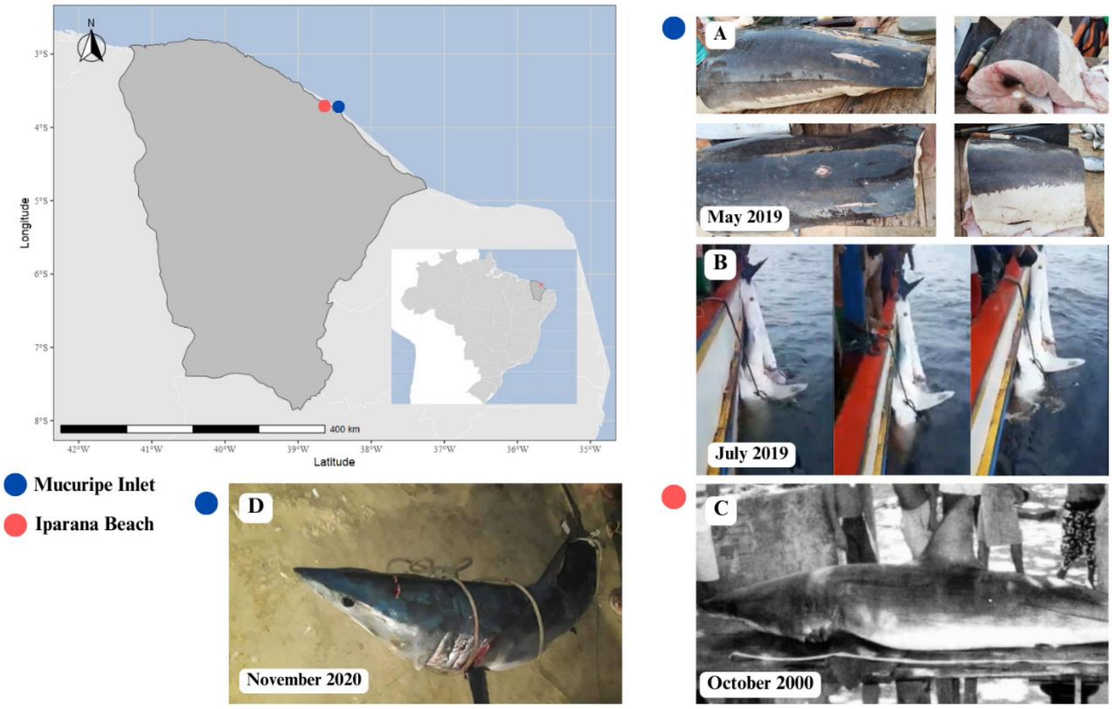

Figure 3. Catch records of Shortfin Mako for the only region of the Equatorial Southwestern Atlantic, where this species is known to overlap with White Shark (off the coast of Ceará State, Northeastern Brazil). A: Carcass traded in Mucuripe Embayment (Fortaleza; CIDRO-B-316); B: A likely Shortfin Mako caught by fishers off Acaraú; C: Stranded specimen in Iparana Beach (Caucaia; CIDRO-B-50); and D: Specimen landed for trade in the Mucuripe Embayment (Fortaleza). The blue and red represent the points of record where each specimen was landed.

Apart from these scant occurrence records, large specimens of lamnids are known by fishers to occur in this tropical region. Fishers' traditional knowledge also suggests that large specimens of lamnids are or have been sighted in deeper water fisheries. Fishers have reported specific behaviors inherent to White Shark. This species is known to patrol (Klimley et al., 2001; Colefax et al., 2020) a specific area and show their ventral side when inspecting prey (Klimley and Ainley, 1996; Fallows et al., 2013) or while surrounding boats. It is not known what makes this region suitable for lamnid sharks. Even though *Isurus oxyrinchus* is known to occur in the Equatorial Southwestern Atlantic (Gadig, 2001; Barreto et al., 2016; Comassetto et al., 2017), it is rarely caught and landed by small-scale fisheries (mostly sub-adult specimens having been caught mainly in oceanic areas). On the other hand, there are only three records of adult White Shark individuals in this region (Gadig and Rosa, 1996). Even though lamnids are tolerant to temperature variations, there is a clear preference for deeper waters, especially regarding White Sharks (Ebert et al., 2021).

About local oceanographic features, this region has strong currents arising from the Equatorial Current, North Brazil Undercurrent, and Brazil Current (Barros et al., 2007). These currents reach shallow seamounts exclusive to the Ceará and Rio Grande do Norte states (isobaths of up to -2,300 m), resulting in local high productivity upwelling zones (Silva et al., 2021). The records of these species in this area and the oceanographic features mentioned above could indicate that this region might provide conditions that favor their occasional presence. Moreover, *Carcharodon carcharias* and *Isurus oxyrinchus* have a wide temperature tolerance during their life cycle (Boustany et al., 2002; Abascal et al., 2011; Curtis et al., 2014). A constant thermocline with an average temperature of 19°-20°C (Silva et al., 2021) also makes this environment favorable for the habitat preferences of White Sharks but they are also known to reach shallower zones in the water column (Dewar et al., 2004; Spaet et al., 2020).

Moreover, the Ceará fishing fleet operates close to the continental shelf slope (from 90–360 m depths) and near seamounts, targeting high-value commercial species, such as snappers (*Lutjanus* spp.), billfishes (*Istiophorus platypterus*), groupers (*Epinephelus* spp. and *Mycteroperca* spp.), and tuna (*Thunnus* spp.) (Hazin et al., 1998, 2007; Jucá-Queiroz et al., 2011), also capturing lamnids.

The role of the Southwestern Equatorial Atlantic for habitat use and as a migration route for lamnids remains unknown, making it an important region for further research initiatives. Monitoring of the artisanal fisheries landings could provide information on the capture of lamnids. Another reason for urgently improving identification of lamnids landed in the region is that *Isurus oxyrinchus* has recently been listed as critically endangered (CR) in Brazil (Brasil, 2022), which prohibits its capture, transport, and commercialization. The Shortfin Mako has also been listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), under Appendix II (CITES, August 25, 2019; Sellheim, 2020), which, in brief, means that international trade can only take place if countries of origin provide non-detrimental findings (NDFs).

This study reinforces the need for greater attention to the identification of uncommon species in the region and more effective monitoring of small-scale fisheries landings, which also comprise catches of lamnid species. It also highlights the use of molecular markers in identifying shark species traded in the region. Finally, it is important to highlight the need to improve record-keeping and data collection in regional landings, as they indicate that lamnid specimens at different life stages are still present in the Equatorial Southwestern Atlantic, but often remain unrecord.

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CONCLUSÕES E CONSIDERAÇÕES FINAIS

Conclusões

- Apesar dos esforços esporádicos para o desenvolvimento do setor pesqueiro marinho brasileiro, a coleta de dados e planos de gestão a nível federal tem sido negligenciados institucionalmente faz décadas.
- O desenvolvimento sustentável da pesca deve estabelecer estabelecer três pilares de desenvolvimento (econômico, científico e social),
- A disponibilidade de dados pesqueiros na plataforma YouTube permite o acesso a dados não oficiais sobre a captura de espécies de elasmobrânquios no Ceará, bem como a identificação de espécies e localização das principais zonas de capturas.
- Mais da metade das espécies de elasmobrânquios registradas em capturas no Ceará e compartilhadas em registros no YouTube estão sob algum nível de ameaça.
- O histórico de capturas e desembarques no Ceará evidencia o estado como importante produtor pesqueiro de elasmobrânquios.
- A enseada do Mucuripe, em Fortaleza, é o porto mais estudado quanto aos elasmobrânquios.
- Os elasmobrânquios mais desembarcados na enseada do Mucripe, em Fortaleza, são o tubarão-lixa *Ginglymostoma cirratum*, tubarões do gênero *Carcharhinus* spp. e as raias do gênero *Hypanus* spp.
- O Tubarão mako, *Isurus oxyrinchus*, é esporadicamente desembarcado e comercializado na enseada do Mucuripe, em fortaleza.
- A costa do estado do Ceará é, até o presente momento, o único ponto de ocorrência de grandes exemplares de tubarões mako e tubarões branco, *Carcharodon carcharias*, em todo Norte e Nordeste do Brasil.

Considerações finais

Apesar dos esforços acadêmicos na produção científica acerca da biologia e composição faunística de elasmobrânquios capturados na costa do Ceará, é necessária uma política pública para coleta de dados em campo, o que pode servir como ponto de partida para uma correta identificação das espécies e o quanto delas tem sido capturado. Além disso, são urgentes ações direcionadas à pescadores, consumidores e demais agentes da sociedade diretamente ligados ao comércio dessas espécies voltadas à conservação de espécies ameaçadas desembarcadas na região.

A identificação molecular de um exemplar de *Isurus oxyrinchus* ressaltou a importância da correta identificação de espécies, principalmente espécies raras e Criticamente em Perigo, e do uso de ferramentas moleculares nesta problemática. Recomenda-se a elaboração de políticas públicas de amostragens e correta identificação visual e molecular de pescado para melhor compreender a dinâmica de ocorrência das espécies capturadas ou desembarcadas no Ceará.

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