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**LAÍS RAMOS BARCELLOS**

# A PESCA COM ESPINHEL PELÁGICO NO ATLÂNTICO SUDOESTE: HISTÓRICO E GESTÃO

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Tese apresentada ao Programa de Pós-Graduação em Biologia Animal da Universidade Federal de Pernambuco, como requisito parcial para obtenção do título de doutora em Biologia Animal.

Orientadora: Profa. Dra. Rosângela de Paula Lessa
Co-orientador: Prof. Dr. Marcelo Francisco de Nóbrega

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Aprovada em: ___/___/____

**COMISSÃO EXAMINADORA**

_______________________________________
Dra. Bruna Martins Bezerra/ UFPE

_______________________________________
Dr. Fabio dos Santos Motta / UNIFESP

_______________________________________
Dr. Francisco Marcante Santana / UFRPE

_______________________________________
Dra. Maria Lúcia Góes de Araújo / UFS

_______________________________________
Dr. Getúlio Rincón Filho/ UFMA

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## RESUMO

A pesca no Oceano Atlântico Sul começou com uma abordagem exploratória, marcada por incentivos fiscais e arrendamentos de frotas internacionais, sem uma visão conservacionista, o que causou lacunas nos registros de dados pesqueiros. Na década de 1990, espécies antes raramente capturadas passaram a ser exploradas como captura acessória, devido à mudança nos petrechos da pesca espinheleira, que substituíram o multifilamento pelo monofilamento. Essa alteração permitiu maior captura de peixes-espada em detrimento de atuns, atendendo à demanda do mercado e fornecendo subprodutos. O tubarão-azul passou a ser classificado como "captura incidental previsível" pela Instrução Normativa 10/2011 (MPA/MMA), sendo frequentemente capturado na pesca direcionada a atuns e peixes-espada. Alguns estoques da espécie já apresentavam declínio devido à sobrepesca. A avaliação do estoque do Atlântico Sul feita pela Comissão Internacional para a Conservação dos Atuns e de Espécies Afins do Atlântico (ICCAT) indicou que, embora improvável que estivesse sobrepescado ou sujeito à sobrepesca, a pesca insustentável ocorreu durante anos, sem dados pesqueiros confiáveis. Nos últimos 30 anos, o tubarão-azul foi capturado mais que as espécies-alvo em diversos períodos. Índices de abundância confiáveis são essenciais para ajustes nas avaliações dos estoques pesqueiros.. Este estudo contribui para a gestão da pesca nacional, tanto do tubarão-azul quanto de outras espécies capturadas incidentalmente no Atlântico Sul.

**Palavras-chave**: Pesca industrial, bycatch, índices de abundância

# ABSTRACT

Fishing in the South Atlantic Ocean began with an exploratory approach, characterized by tax incentives and leasing of international fleets, without a conservationist perspective, which led to gaps in fishery data records. In the 1990s, species that were previously rarely captured began to be exploited as bycatch, due to a change in longline fishing gear, which replaced multifilament lines with monofilament ones. This change allowed for a higher capture of swordfish at the expense of tunas, meeting market demand and providing by-products. The blue shark was classified as "predictable incidental catch" by Normative Instruction 10/2011 (MPA/MMA), and it was frequently caught in tuna and swordfish-targeted fisheries. Some stocks of the species had already shown signs of decline due to overfishing. The stock assessment for the South Atlantic conducted by the International Commission for the Conservation of Atlantic Tunas (ICCAT) indicated that, although it was unlikely to be overfished or subject to overfishing, unsustainable fishing practices occurred over several years, with no reliable fishery data. Over the last 30 years, the blue shark has been caught more frequently than target species during various periods. Reliable abundance indices are essential for adjusting stock assessments. The implementation of better indices in protected areas is necessary to improve future surveys and support management measures. This study contributes to national fisheries management, both for the blue shark and other species incidentally captured in the South Atlantic.


**Palavras-chave**: Industrial Fisheries, bycatch, Abundance indexes

**SUMÁRIO**

# 1. INTRODUÇÃO

## 1.1 PROBLEMATIZAÇÃO

Mudanças antropogênicas, como a sobrepesca, alterações climáticas e poluição por derramamento de óleo, têm alterado a abundância de espécies oceânicas, especialmente grandes predadores de níveis tróficos altos (Pinnegar et al., 2000; Peterson et al., 2003; Hutchings & Baum 2005; Baum & Worm, 2009; Polovina et al., 2009; Doney et al., 2012). Ainda há pouco conhecimento sobre predadores oceânicos extintos, porém a explotação exaure populações marinhas de peixes em 50% a 70%, e a gestão pesqueira atual depende de avaliações de estoques para estimar parâmetros populacionais das espécies focais a partir da estrutura etária ou histórico do comprimento de capturas, biomassa, esforço de pesca e inspeções independentes da pesca. (Hillborn et al. 2003; FAO 2007).

Em 2011, a região Nordeste do Brasil continuou registrando a maior produção de pescado do país, com 454.216,9 t, respondendo por 31,7% da produção nacional. As regiões Sul, Norte, Sudeste e Centro-Oeste registraram 336.451,5 t (23,5%), 326.128,3 t (22,8%), 226.233,2 t (15,8%) e 88.944,5 t (6,2%), respectivamente (IBAMA, 2011).

Os tubarões são predadores de topo de cadeia, e possuem uma função crucial nos ecossistemas marinhos, regulando presas e controlando a estrutura da comunidade (Heithaus, 2004). Diferentes modalidades de pesca exploram uma grande diversidade de tubarões para consumo humano, e para o comércio de suas barbatanas, além de serem capturados como fauna acompanhante ou *bycatch* (Musick, 2005). Os elasmobrânquios no Brasil continuam sendo largamente explorados, com declínios de suas populações em grande escala, e com fiscalização da pesca de espécies ameaçadas quase nula, dificultando o manejo dos estoques de elasmobrânquios, além da falta de informações básicas sobre seus aspectos biológicos e dados de captura, assim como os efeitos da sobre pesca das espécies (Lessa et al., 1999, Motta et al.,, 2002; Amaral & Jablonski, 2005; DI DARIO, 2015; Barreto et al., 2017).

A atual exploração indiscriminada dos tubarões pode resultar em alterações na estrutura populacional como consequência da pesca excessiva, tais como uma diminuição no tamanho da população, e mudanças na estrutura etária e em parâmetros como fecundidade e taxas de crescimento e mortalidade (Stevens et al., 2000). A explotação é considerada a principal causa que leva a extinções restritas a escalas locais ou regionais (Dulvy et al., 2003).

A pesca direcionada a atuns e peixes-espada capturam como bycatch várias espécies de peixes ósseos e cartilaginosos, e algumas espécies se encontram em risco de extinção por conta dessa ameaça (Barcellos et al., 2025). O tubarão-azul (*Prionace glauca*) é um predador de topo de cadeia alimentar em ecossistemas marinhos temperados e tropicais (Hussey et al., 2015). Esse animal difere de outros tubarões pelágicos devido a seu crescimento rápido e maturação sexual precoce (Smith et al., 1998). Por conta de sua ampla distribuição, o tubarão-azul é capturado em abundância nas pescas de espinhel pelágico, com 20 milhões de indivíduos pescados por ano globalmente, sendo a espécie de elasmobrânquio é a mais capturada pela pesca industrial que ocorre no oceano Atlântico (ICCAT, 2018). Apesar de ser uma das espécies mais capturadas, é considerada “captura previsível” nacionalmente, de acordo com a Instrução Normativa (IN) 10/11 (MPA/MMA), que se encontra vigente até o presente momento. Atualmente, se encontra na categoria Quase-Ameaçada (NT) na Lista Vermelha da IUCN e Vulnerável no Sul do Brasil (Camhi, et al., 2009; Brasil, 2014), A pesca do tubarão-azul ocorre em conjunto com a pesca direcionada a atuns e peixe-espada, e seus respectivos status de ameaça globalmente são: *Thunnus obesus* (VU), *Thunnus albacares* (NT), *Thunnus alalunga* (NT) e *Xiphias gladius* (LC) (Barcellos et al., 2025).

O país já possuia INs com recomendações dadas pela Comissão Internacional para a Conservação dos Atuns do Atlântico (ICCAT) a respeito de cotas de captura para espécies-alvo, como a IN nº17 (MAA, 1999) que estabelece cotas para o espadarte, e a IN nº 12 (MPA/MMA, 2024) que estabelece cotas para o tubarão-azul (Barcellos et al., 2025).

Apesar de recomendações internacionais relacionadas à pesca pelágica no Atlântico serem direcionadas ao Brasil, a escassez de dados de captura permanece como um problema para muitas frotas nacionais e internacionais que operam na região. Os procedimentos para monitorar e controlar as capturas e desembarques de espécies sobreexplotadas costumam ser incompletos, com erros de identificação de espécies, falta de fiscalização e apreensão de espécies proibidas, tendo como consequência várias espécies em risco de extinção devido à falha na governança (Barcellos et al., 2025).

Em 2021, o Brasil instituiu a Rede Pesca através do Decreto nº 10.736 (Brasil, 2021), que retornou com o controle do desembarque e programas de observação de bordo, um passo importante para que os dados de pesca do país sejam levados a sério em análises estatísticas, já que há um histórico de falta de confiança nos dados.

O declínio das populações de grandes tubarões se dá devido à ação de pesca direta ou indireta, sua baixa resiliência à pesca e perda do habitat, e a tendência é aumentar com o tempo (Myers & Worm, 2003; Simpfendorfer et al., 2011). A pesca industrial utiliza espinhéis para captura de atum e afins afeta os elasmobrânquios diretamente por eles serem fauna acompanhante, composta por 10% do total de animais pescados em 2017. Índices de abundância confiáveis desempenham um papel fundamental no ajuste da avaliação analítica de estoques pesqueiros, sendo particularmente críticas para o tubarão-azul por conta da incerteza sobre níveis históricos de mortalidade por bycatch (Maunder & Starr, 2003; Maunder & Punt, 2004; Aires-da-Silva et al., 2008). Desta forma, faz-se necessárioum melhor índice de abundância em áreas de proteção ambiental para melhorar a qualidade de futuras avaliações e das decorrentes propostas de proteção das espécies pescadas como fauna acompanhante. Características da história de vida dos animais no Atlântico Sul ainda são desconhecidas ou escassas.

O presente estudo pode contribuir com essas úteis informações para a gestão nacional da pesca. Ainda, O presente estudo pretende analisar o histórico de captura da espécie no Oceano Atlântico Sul a fim de fundamentar como a pesca influenciou a população e a fauna acompanhante ao longo do período analisado. A hipótese do trabalho é testar se a mudança do petrecho de pesca ocorreu devido à mudança da espécie alvo e como isso alterou a fauna acompanhante.

## 1.2 Objetivos

### 1.2.1 Objetivo Geral

Analisar, com base de dados de desembarque, o histórico de captura de espécies-alvo e fauna acompanhante no Oceano Atlântico Sul, assim identificando possíveis variações de aspectos populacionais e ecológicos em aproximadamente três décadas de exploração.

### 1.2.2. Objetivos Específicos

● Avaliar informações das capturas de peixes oceânicos, utilizando as planilhas de bordo dos programas ECOTUNA, PROBORDO e PROTUNA em águas oceânicas do Atlântico Sul para identificar as tendências de captura durante os anos;

● Avaliar como as mudanças nos petrechos de pesca promoveram modificações nos aspectos populacionais;

● Identificar a composição das capturas considerando a estrutura etária (jovens e adultos) para sugerir medidas para o ordenamento pesqueiro do tubarão-azul e fauna acompanhante no Atlântico Sul.

## 1.3 PROCEDIMENTOS METODOLÓGICOS

Uma revisão sistemática de literatura utilizando plataformas de busca foi utilizada para explorar a grande quantidade de dados da pesca e encontrar padrões consistentes, além de detectar relações entre as variáveis.

Foram utilizados dados de pesca de frotas direcionadas a captura de atuns, espadartes e agulhões, separados por três programas de observação de bordo em três períodos diferentes: ECOTUNA, PROBORDO e PROTUNA. O primeiro programa foi direcionado a pesquisa independente e equipado com espinheis pelágicos de multifilamento, e os outros programas relacionados a observação de bordo com utilização de monofilamento pelas frotas de pesca pelágica.

Os dados de pesca do ECOTUNA foram coletados no Atlântico Sudoeste Equatorial de 0º a 10º S de latitude e de 25º a 40º W de longitude usando um navio de pesquisa (Riobaldo, IBAMA) de um levantamento de pesquisa independente da pesca, que durou de 1992 a 2000. Nesses anos foram realizadas 30 expedições, totalizando 227 lances de pesca com espinhel pelágico empregando 97463 anzóis. Nesta tese, foram utilizados dados de 1992 a 1999, excluindo 1994 e 2000 devido ao esforço muito baixo e 1998 em que nenhuma expedição foi realizada. O ECOTUNA forneceu dados sobre o cenário de capturas nos anos analisados, explorando o Nordeste do Brasil, separando a área em quadrantes. A embarcação foi equipada com um espinhel multifilamento estilo japonês, de amarra tradicional, com 26 km de extensão e 100 ramais medindo 1,5 mm de diâmetro e 1 m de comprimento, utilizando seis anzóis em jogos alternados e sardinha como isca principal. A linha principal tinha espaçamento de 40 m entre as alças de inserção das linhas secundárias, esta medindo 8 m e confeccionada em poliamida com 3 mm de diâmetro (Vasconcelos et al., 2001).

Os dois outros programas utilizados se baseavam em acompanhar a pesca industrial de espinhel pelágico monofilamentoso (programa PROBORDO, 2005 – 2011/ programa PROTUNA, 2018 - 2022). Para espinheis de monofilamento utilizados no PROBORDO e PROTUNA, a linha principal consistia em 3 mm de diâmetro e 315 m entre as bóias. Os anzóis eram Mustad 9/0 com 6 anzóis entre as bóias. A linha secundária media 2 mm de diâmetro e era de poliamida. A isca foi lula e foram utilizados atratores luminosos (bastão de luz e eletrolúmen) (Hazin et al., 2008).

Observadores de bordo anotaram as coordenadas geográficas em que os tubarões oceânicos e fauna acompanhante foram capturados, assim como seu comprimento total (TL, cm), comprimento interdorsal (ID, cm), comprimento zoológico (CZ, cm), sexo e período de captura.

Tabela 1. Relação Bayesiana de comprimento-peso e Tamanho de maturação sexual ($L_{50}$), assim como suas referências. TL: Comprimento Total para tubarões; FL: Comprimento Furcal.

| Species | CTa | CTb | Cza | CZb | ($L_{50}$) | Ref. CT | Ref. CZ | Ref($L_{50}$) |
|---|---|---|---|---|---|---|---|---|
| *Isurus oxyrinchus* | 0.0038 | 3.03 | 9.45E-06 | 3.018 | 180.1 cm TL | Froese et al. (2014) | Mejuto et al. (2008) | Canani et al. (2020) |
| *Prionace glauca* | 0.0101 | 2.86 | 0.00267 | 3247 | 228 cm TL | Lessa et al. (2004) | Ayers et al. (2004) | Hazin et al (1994); Hazin et al. (2000) |
| *Thunnus alalunga* | 0.03136 | 2.78 | 0.0147 | 3013 | 90 cm FL | Froese et al. (2014) | ICCAT (2003) | Punt et al. (1995) |
| *Thunnus albacares* | 0.00778 | 3.11 | 0.0278 | 2855 | 95 cm FL | Smallwood et al. (2017) | Frota et al. (2004) | Wild (1994) |
| *Thunnus obesus* | 0.01413 | 3.02 | 0.0119 | 3090 | 95.5 FL | Froese et al. (2014) | Fagundes et al. (2000) | Mooney-Seus et al. (1997) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Xiphias gladius* | 0.00372 | 3.15 | 0.0056 | 3150 | 125 cm FL | Froese et al. (2014) | Frota et al. (2004) | Hazin et al. (2001) |

## [1]CAPÍTULO 1

# Historical changes in conservation measurements on target, predictable bycatch and bycatch species caught by pelagic longline fisheries in Southwest Atlantic Ocean

Authors: Barcellos, L.R.; Da Silva, T.E.F.; Lessa, R.P.T.

**ABSTRACT**

The history of fishing in South Atlantic ocean begins with an exploratory approach involving tax incentives and leases from international fleets without a conservationist vision (as was the case in other areas), causing a gap in fishing data records. In the 1990s, species not commonly caught before were also exploited as bycatch due to change in targeted species from tunas to swordfishes to fulfill market demands and supply by-products. Some agencies for fisheries management were established throughout the years, but only in the 2000s, the Ministry of Fisheries and Aquaculture was created, promoting regulatory measures and recommendations to the country. However, conflicts with the industrial fisheries sector were constant due to competing commercial interests. International recommendations regarding pelagic fisheries for the Atlantic were followed by Brazil, but the scarcity of catch data remained a problem for many fleets operating in the region. Procedures to monitor and control catch and landings of overexploited species were incomplete, and several species are at some risk of extinction based on governance failure. This work aims to compile national and international management measures applied over the years to fleets operating horizontal longline catching targeted, predictable bycatch and bycatch species in Southwest Atlantic Ocean, and to outline the changes that have occurred during this period.

## 1. INTRODUCTION

The history of natural resource protection in Brazil began with Federal Law

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nº 5.197/1967 (Wildlife Protection Law) [1], which established the basis for the protection of wildlife in the country. The law covers terrestrial and marine species, prohibiting activities such as hunting, capture, transport, commercialization, consumption or possession of wild animals without an environmental license. Furthermore, it defines environmental crimes related to wildlife and appoints the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) as the body responsible for implementing national environmental policies.

In the same year, Brazil began investing in the fishing sector through government tax incentives to develop certain activities or certain locations. Fishing was one of the activities encouraged among others as part of a regional and economic development strategy, such as tourism, occupation of new territories, exploratory surveys of the North and Northeast regions of the country, and extraction of natural resources[2],[3]. Public policies on fisheries subsidies in Brazil highlighted the high fiscal incentive for the sector but did not take into account investments involving research on fish stocks, consequently increasing overfishing without measuring future problems, such as overexploitation of the resources and changes in the ecosystem [3].

However, the history ofr pelagic fishing of other nations in the South Atlantic Ocean began earlier, in 1950, with countries such as China, Japan, Korea, and Taiwan exploiting the tuna fishery stocks of Brazil, Uruguay, and South Africa due to high commercial demands in their respective countries [4]. Fleets of these nations in the South Atlantic Ocean were leased to attract foreign trade to their territories, establishing agreements between foreign fishing companies and regional ones [5]. According to Hazin et al. (2007) [6], Japan was the first country to operate a longline fleet targeting tuna species (*Thunnus alalunga*, *T. albacares*, and *T. obesus*). In the 1990s, fishing strategies in the South Atlantic Ocean began to shift due to market demands, and fleets from China-Taipei, Honduras, Morocco, and the UK altered their targets to swordfish [7]. Spain began fishing in the Southwest Atlantic in 1990, primarily targeting swordfish, but also the blue shark and mako shark, depending on fluctuations in meat prices and the abundance of fish caught [8] [9] [10]. As a result, Japan and Spain were responsible for nearly all fish caught by longline fleets in the 1990s, remaining currently the leading nations fishing the main species in the Southwest Atlantic, along with Portugal, Korea, and China-Taipei [11].

Before the 1990's, conservation actions were a distant idea, but during the development of the fishing sector, there was an increase not only in production, but also in the exploitation of species that were not commonly caught before due to the economic shift in target from tunas to swordfishes [12],[13],[14]. In 1998, provisions of the Wildlife Protection Law were withdrawn by Law nº 9.605/1998, which establishes criminal and administrative sanctions arising from harmful conduct and activities to the environment; in addition to introducing several provisions on environmental crimes, including protection of wild fauna [15]. Also in 1998, shark species were increasing in landings, and finning was mentioned for the first time in National Ordinance nº 121/1998 by IBAMA [16], [3], [5].

The Special Secretariat for Fisheries and Aquaculture (SEAP) was created in 2003, and consequently, licenses, authorizations, creation of public policies and international agreements were introduced [17]. The Special Secretariat became Ministry of Fisheries and Aquaculture (MPA), gaining ministerial status in 2009, where it implemented the legislation of the National Policy for Sustainable Development of Aquaculture and Fisheries [18], legislation which aims to ensure the sustainability of fisheries resources and promote management practices that guarantee the continuity of fishing activities, respecting biodiversity and aquatic ecosystems, both marine and continental [19]. In 2015, MPA was reduced again to a secretariat-level organization affiliated to the Ministry of Agriculture, Livestock and Food Supply (MAPA), and in 2017, the responsibility for fisheries management was transferred to the Ministry of Development and Foreign Trade [17]. Due to the presidential power transition, the country underwent a weakening of the environmental agenda from 2019 to 2022, which resulted in the ineffectiveness of the management plans in place during this period. In 2023, the Ministry of Fisheries was detached from the Ministry of Agriculture, Livestock, and Food Supply through Law nº 14.600, of July 19, 2023 [20] and reactivated and redefined through Decree nº 11.624 of August 1, 2023 [21]. In addition to regulating Law nº

11.959, of June 29, 2009 [18], Ministry of Fisheries and Aquaculture (MPA) and Ministry of the Environment (MMA) are now responsible for implementing public policies and strategies for the participatory management of the sustainable use of fishing resources, organizing and maintaining the General Register of Fishing Activities, establishing standards and criteria for organizing the use of fishing resources and aquaculture, in coordination with the Ministry of the Environment and Climate Change, and granting licenses, permits and authorizations for the practice of aquaculture and fishing modalities in the national territory [19]. The Brazilian fishing monitoring has undergone a series of changes, initially conducted by the Brazilian Institute of Geography and Statistics (IBGE), and then transferred to the IBAMA, and, more recently, to the MPA, before being discontinued shortly thereafter. Monitoring of fishing landings in an integrated and institutionalized manner has not been carried out by the federal government since 2007, with systematic collection of statistics being paralyzed [22]. From 2008 to 2012, data from the Statistical Bulletins of Fisheries and Aquaculture published by MPA projected estimates based on data historically collected by federal agencies [22]. The country is one of the signatories to an agreement/convention with the International Commission for the Conservation of Atlantic Tunas (ICCAT), the agency that has been making recommendations and establishing catch quotas for oceanic fisheries since 1950, and has continued to comply with the data submission requirements to the present day, even when reports are considered incomplete by the Food and Agriculture Organization (FAO) [23].

Due to Ordinance from MMA 445/2014 [24], the list of threatened species resulted in new restrictions for the capture of species at risk of extinction in the categories Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN) and Vulnerable (VU), where it ensured its full protection, including, among other measures, the prohibition of capture, transportation, storage, custody, handling, processing and commercialization of threatened species. In 2022, this list was updated through Ordinance 148/2022 [25]. The fishing industry did not agree with this ordinance, despite the government's relaxation while allowing the sustainable fishing of VU species [26].

This work aimed to compile recommendations and laws surrounding national and international fishing standards directed to stocks of target, predictable bycatch and bycatch species caught by industrial pelagic longline fisheries in the southwest portion of the Atlantic Ocean, considering changes in conservation status of species and legislative advancements in the control and command of fishing.

## 2. METHODS

The study was based on Normative Instruction (NI) nº 10/2011 from MPA/MMA [27], which was amended by NI nº 14/2014 [28] and NI nº 46/2015 [29]. This NI approves the general rules and organization for legally permitting fishing vessels to access and use fishing resources sustainably, defining fishing modalities, species to be captured and permitted areas of operation.

Still in accordance with NI 10/2011 [27], Art.2, items XIV, XVII, XVIII defines the concepts of Target Species, Predictable Bycatch Fauna and Bycatch Species respectively, as:

XIV - Target Species: species of commercial interest, main object of the Prior Fishing Permit and Fishing Authorization, on which the fishing effort is directed;

XVII - Predictable Bycatch Fauna: set of species capable of commercialization, captured naturally during fishing for Target Species, which coexist in the same area of occurrence, substrate or depth, whose capture cannot be avoided, observing the regulations established in a specific norm;

XVIII - Bycatch Species: set of species that are caught incidentally during fishing for Target Species, which cannot be commercialized, coexisting in the same area of occurrence, substrate or depth, whose capture must be avoided because they are protected by specific legislation or International Agreements, which, when captured, must be released alive or discarded in the fishing area, or landed for research purposes when authorized in a specific norm, and their occurrence recorded on Onboard Maps.

The species were separated by six fishing methods that use horizontal longline in activities along the marine territory of Brazil according to NI 10/2011 [27]: Surface longline or Buoy longline targeting tunas; Surface longline or Buoy longline targeting swordfish; Surface longline - with live bait or Itaipava longline targeting dolphinfish; Surface longline or Buoy longline targeting dolphinfish; Bottom longline targeting groupers/jacks; Bottom longline (Table 1).

Six species were chosen based on their frequency as Predictable Bycatch, as well as all Target species according to NI 10/2011 [27]: Shortfin mako (*Isurus oxyrinchus*), Blue shark (*Prionace glauca*), Yellowfin tuna (*Thunnus albacares*), Albacore tuna (*Thunnus alalunga*), Bigeye tuna (*Thunnus obesus*) and Swordfish (*Xiphias gladius*). From that, research was conducted on the global conservation status of these species according to the International Union for Conservation of Nature (IUCN) and the National List of Endangered Species [24] [25].

Data on National Recommendations, Laws, Decrees and NI's were compiled through research on Brazilian federal government websites (GOV.BR). Also, legislations and regulatory norms from three international commissions and conventions were compiled due to its importance on regulating fishing on threatened species in South Atlantic, controlling catch limits, ensuring trade rules and monitoring conservations status of migratory species: Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES); Convention on the Conservation of Migratory Species of Wild Animals (CMS); and International Commission for the Conservation of Atlantic Tunas (ICCAT).

CITES is an international agreement to which Countries voluntarily adhere and which aims to ensure rules for the international trade of wild animals and plants, preventing it from generating greater impacts on the species and increasing its risk of extinction. Species listed in Appendix II of CITES are those that could become extinct if their trade is not strictly regulated [30]. CMS is an international environmental treaty that aims to conserve migratory species of wild animals and their habitats around the world. CMS Appendix II includes migratory species with an unfavorable conservation status that require international agreements for their conservation and management. It also encompasses species whose conservation status would substantially benefit from international cooperation achievable through such agreements [31]. ICCAT is an intergovernmental organization with binding legal force for its members. This Committee sets maximum catch limits through quotas and recommendations, promoting the conservation of tuna species and other migratory fish species in the Atlantic Ocean (referred to as tuna-like) and adjacent seas and ensuring the sustainable use of these resources [32].The public statistical database provided by ICCAT for the six species previously chosen was used to infer trends in catch from 1993 to 2022 for the South Atlantic Ocean (Figure 1). Catch values for *T. obesus* were not included in Figure 1 because the database combined Mediterranean and Atlantic ocean catches.

## 3. RESULTS AND DISCUSSION

Catches of tuna and swordfish overlap catches of some shark species, which are considered by ICCAT as “tuna-like”. In Brazil, of approximately 180 known marine elasmobranch species, almost all occupy areas where some fishing activity occurs and, probably, more than 100 species constantly interact with fishing [33]. Elasmobranchs have limited capacity to withstand anthropogenic pressures due to their life history characteristics, including late sexual maturity, low fecundity and slow growth rates [34], [35], [36].

It can be seen from Table 1 that several species of elasmobranch are caught as Predictable Bycatch or Bycatch in all six modalities of horizontal longline fisheries in Brazil. As for Bycatch, these are the elasmobranchs classified at some category of extinction risk following the latest national assessment: *Alopias superciliosus* (EN), *Cetorhinus maximus* (CR), *Negaprion brevirostris* (EN), *Galeorhinus galeus* (CR), *Ginglymostoma cirratum* (VU), *Isogomphodon oxyrhynchus* (CR), *Pristis perotteti* (CR), *Squatina guggenheim* (CR), *Squatina oculta* (CR), *Sympterygia acuta* (EN). *Sympterygia bonapartii* (EN). As for Predictable Bycatch, *Atlantoraja castelnaui* (EN), *A. cyclophora*, (VU), *Mustelus schmitt* (CR), *Mustelus fasciatus* (CR) and *Rioraja agassizii (*VU).

*Atlantoraja platana* is nationally classified as DD but globally EN, a similar situation for *Squalus acanthias* as it is VU globally and DD nationally. This highlights the urgent need for more data on life history for those species so that they can be assessed properly, as there is a high chance that they are experiencing population decline in Brazil.

Several bony fishes are also experiencing risk of extinction due to overfishing and are caught as bycatch not only in horizontal longlines, but in vertical longlines, gillnets, trawls and pits [27]: *Epinephelus itajara* (CR), *Epinephelus morio* (VU), *Epinephelus niveatus* (VU), *Kajikia albida* (VU), *Lopholatilus villarii* (VU), *Lutjanus cyanopterus* (VU), *Lutjanus purpureus* (VU), *Makaira nigricans* (EN), *Mycteroperca bonaci* (VU) and *Polyprion americanus* (CR). Some of those are considered target in hand-line fisheries, as *L. cyanopterus* and *M. bonaci*.

Brazil's government assessed some species that were classified as DD by IUCN and this reflects the commitment of the MMA to assess all species occurring within the national territory. Some species are protected by existing law for being threatened, such as *Polyprion americanos* (CR) and *Lutjanus purpureus* (VU).

Table 1. Species caught by six different horizontal longline fisheries practiced throughout the Exclusive Economic Zone and territorial sea, classified as Target, Predictable Bycatch or Bycatch by NI 10/2011 (MPA/MMA),their most recent global and national conservation status (according to IUCN and MMA IN nº 445/2014 + updates, respectively). Legend: 1: Surface longline or Buoy longline targeting tunas; 2: Surface longline or Buoy longline targeting swordfish; 3: Surface longline - with live bait or Itaipava longline; 4: Surface longline or Buoy longline targeting dolphinfish; 5: Bottom longline targeting groupers/jacks; 6: Bottom longline. IUCN Status: EX: Extinct; CR: Critically Endangered; EN: Endangered; NT: Near Threatened; LC: Least Concern; DD: Data Deficient; and NE (Not Evaluated). **Species of interest are in bold.**

| Species | Target | Predictable bycatch | Bycatch | IUCN status | MMA status |
|---|---|---|---|---|---|
| *Acanthocybium solandri* | | *1,2,3,4* | | LC | LC |
| *Alectis ciliaris* | 5 | | | LC | LC |
| *Alopias superciliosus* | | | *1,2,3,4,6* | VU | EN |
| *Atlantoraja castelnaui* | | *1,2,3,4,5* | | CR | EN |
| *Atlantoraja cyclophora* | | *2,3,4,5* | | EN | VU |
| *Atlantoraja platana* | | *1,2,3,4,5* | | EN | DD |
| *Auxis thazard* | | *1,2,3,4* | | LC | LC |
| *Breviraja spinosa* | | *1,2,3,4,5* | | LC | LC |
| *Caranx bartholomaei* | 5 | | | LC | LC |
| *Caranx hippos* | 5 | | | LC | LC |
| *Caranx latus* | 5 | | | LC | LC |
| *Carcharhinus falciformis* | | *1,2,3,4,5,6* | | VU | CR |
| *Cathorops spixii* | 6 | *5* | | NE | LC |
| *Cetorhinus maximus* | | | *1,2,3,4,6* | EN | CR |

| | | | | | |
|---|---|---|---|---|---|
| *Coryphaena hippurus* | 3,4 | *1,2* | | LC | LC |
| *Elagatis bipinnulata* | 5 | | | LC | LC |
| *Epinephelus itajara* | | | *5* | VU | CR |
| *Epinephelus morio* | 5 | | | VU | VU |
| *Epinephelus niveatus* | 5,6 | | | LC | VU |
| *Galeorhinus galeus* | | | *1,2,3,4,6* | CR | CR |
| *Ginglymostoma cirratum* | | | *1,2,4,6* | VU | VU |
| *Helicolenus lahillei* | | *6* | | NE | LC |
| *Isogomphodon oxyrhynchus* | | | *1,2,3,4* | CR | CR |
| *Istiophorus albicans* | | *1,2,3,4* | | NE | LC |
| ***Isurus oxyrinchus*** | | ***1,2,3,4,5,6*** | | **EN** | **CR** |
| *Kajikia albida* | | | *1,2,3,4* | LC | VU |
| *Katsuwonus pelamis* | | *1,3,4* | | LC | LC |
| *Lepidocybium flavobrunneum* | | *1,2,3,4* | | LC | LC |
| *Lopholatilus villarii* | 6 | | | NE | VU |
| *Lutjanus cyanopterus* | | *5* | | VU | VU |
| *Lutjanus jocu* | | *5* | | DD | NT |
| *Lutjanus purpureus* | | *5* | | NE | VU |
| *Lutjanus synagris* | | *5* | | NT | DD |
| *Makaira nigricans* | | | *1,2,3,4* | VU | EN |
| *Mola mola* | | *1,2,3,4* | | VU | LC |
| *Mustelus fasciatus* | | *1,2,3,4,6* | | CR | CR |
| *Mustelus schmitt* | | | *1,2,3,4,6* | CR | CR |
| *Mycteroperca acutirostris* | 5 | | | LC | DD |
| *Mycteroperca bonaci* | 5 | | | NT | VU |
| *Mycteroperca microlepis* | 5 | | | VU | DD |
| *Negaprion brevirostris* | | | *1,2,3,4* | VU | EN |
| *Notarius grandicassis* | 6 | | | LC | LC |
| *Polyprion americanus* | | | *5* | DD | CR |
| ***Prionace glauca*** | | ***1,2,3,4,5,6*** | | **NT** | **NT** |
| *Pristis pectinata* | | | *1,2,3,4,6* | CR | CR |
| *Pristis perotteti* | | | *1,2,3,4,6* | CR | CR |
| *Pseudopercis numida* | 6 | | | LC | DD |
| *Rajella purpuriventralis* | | *1,2,3,4,5* | | LC | LC |
| *Rhincodon typus* | | | *1,2,3,4,6* | EN | VU |
| *Rioraja agassizii* | | *1,2,3,4,5* | | VU | VU |
| *Ruvettus pretiosus* | | *1,2,3,4* | | LC | LC |
| *Sarda sarda* | | *1,2,3,4* | | LC | LC |
| *Scomber colias* | | *1,2,3,4* | | LC | LC |
| *Scomberomorus brasiliensis* | | *1,2,3,4* | | LC | NT |
| *Scomberomorus cavalla* | | *1,2,3,4* | | LC | NT |
| *Seriola dumerili* | 5 | | | LC | LC |
| *Seriola fasciata* | 5 | | | LC | LC |
| *Seriola lalandi* | 5 | | | LC | LC |
| *Squalus acanthias* | | *1,2,3,4,6* | | VU | DD |
| *Squalus blainville* | | *1,2,3,4,6* | | DD | DD |
| *Squalus cubensis* | | *1,2,3,4,6* | | LC | DD |
| *Squatina guggenheim* | | | *1,2,4,6* | EN | CR |
| *Squatina occulta* | | | *1,2,4,6* | CR | CR |
| *Sympterygia acuta* | | *1,2,3,4,5* | | CR | EN |
| *Sympterygia bonapartii* | | *1,2,3,4,5* | | NT | EN |
| *Tetrapturus pfluegeri* | | *1,2,3,4* | | LC | DD |
| ***Thunnus alalunga*** | **1** | | | **LC** | **LC** |
| ***Thunnus albacares*** | **1** | | | **LC** | **LC** |
| *Thunnus atlanticus* | | *1,2,3,4* | | LC | LC |
| ***Thunnus obesus*** | **1** | | | **VU** | **LC** |
| *Thunnus thynnus* | | *1,2,3,4* | | LC | EN |
| *Trachinotus carolinus* | 5 | | | LC | LC |
| *Trachinotus falcatus* | 5 | | | LC | LC |
| *Trachinotus goodei* | 5 | | | LC | LC |

| | | | | |
|---|---|---|---|---|
| *Trachinotus marginatus* | 5 | | LC | LC |
| *Trachurus lathami* | 5 | | LC | LC |
| ***Xiphias gladius*** | **2** | ***1,3,4*** | **NT** | **LC** |

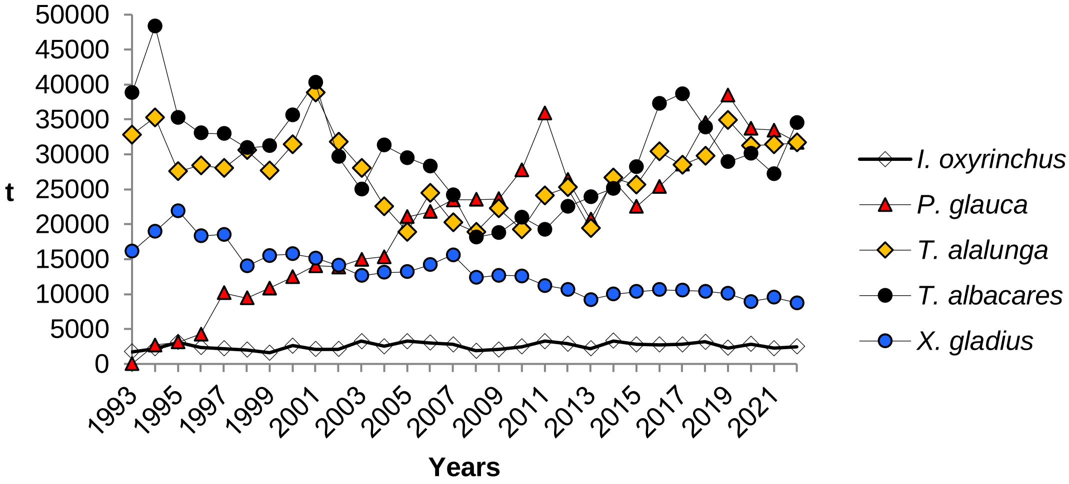


Figure 1. Yield trend in tons (t) for Target and Predictable Bycatch species caught by pelagic longline between 1993 and 2022 in South Atlantic Ocean according to public statistical data from ICCAT (SCRS Catalogues for main species 1993-22).

### 3.1 Target Species

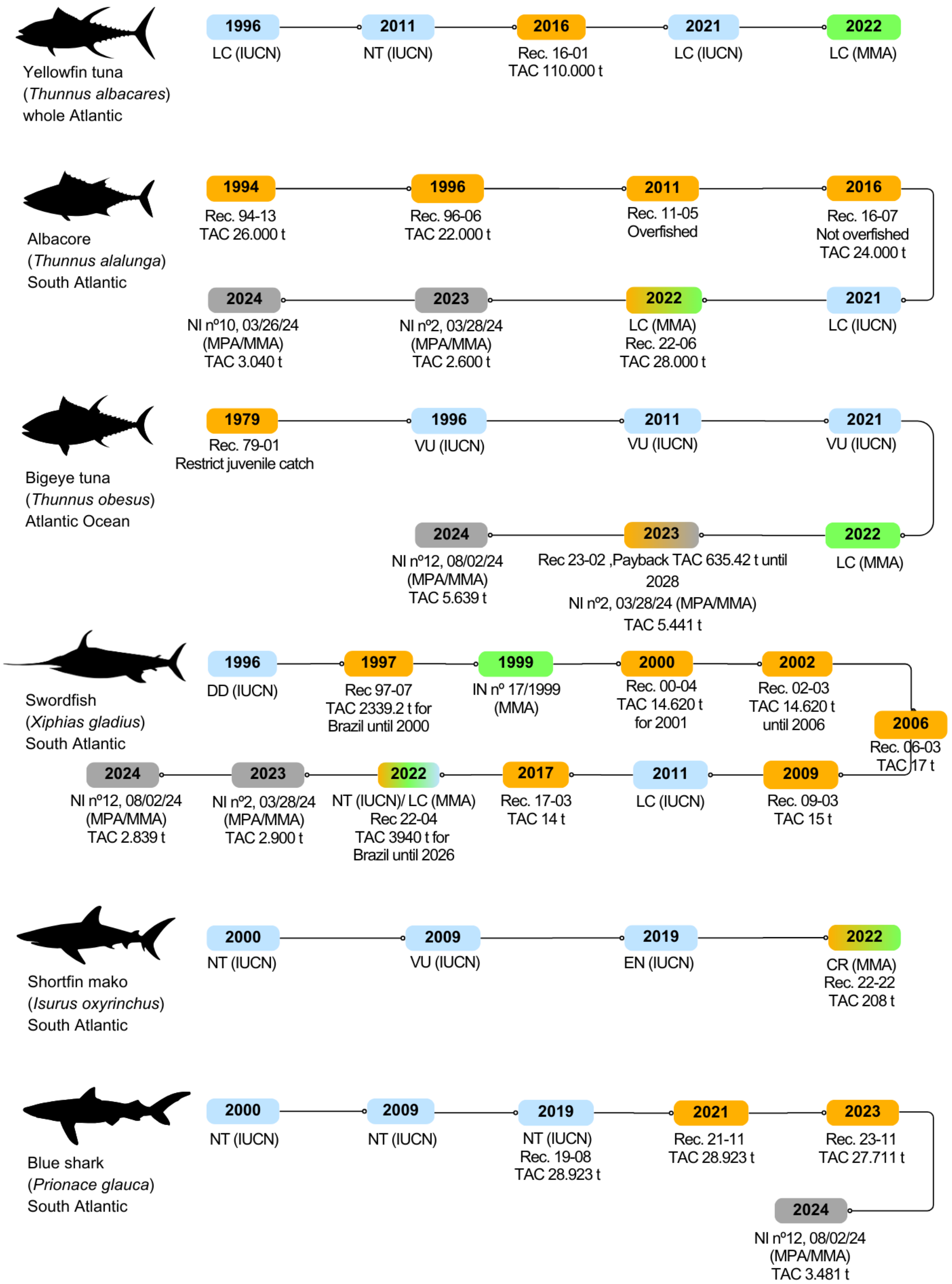


Figure 2. Timeline history of Recommendations (Rec.) and the Total Allowed Catch (TAC, t) proposed by ICCAT, as well as international (IUCN) and national (MMA) assessments and normative instructions (NI) for the six main species caught in longline fisheries in jurisdictional waters of Brazil and ICCAT's Convention area. Blue: IUCN/ Orange: ICCAT/ Green: MMA/ Grey: MPA/MMA.

The first assessment for yellowfin tuna (*T. albacares*) by the IUCN Red List was in 1996, and was classified as Least Concern (LC), whereas in 2011's assessment, this species was classified as NT (Figure 2). The most recent assessment occurred in 2021 and categorized the species as LC again, with an 8–17% decline globally over the three generations (a measure used by IUCN) [37], [38]. A single stock for the entire Atlantic is currently assumed by the Standing Committee on Research and Statistics (SCRS), the that develops and recommends policies and procedures to ICCAT, which assessed this stock as not at risk of depletion. The only Recommendation regarding the yellowfin tuna (Rec. 16-01) indicates a Maximum Sustainable Yield (MSY) of 121,298 t over an annual Total Allowable Catch (TAC) at 110,000 t/year, and remains valid until SCRS next assessment [39].

Another important fisheries resource is the albacore tuna (*T. alalunga*) which is classified as LC by IUCN and MMA (Table 1) [40]. There have been recommendations on catch limits for the southern stock of the Atlantic since 1994 with Rec. 94-13 [41], claiming that the species was already suffering from overexploitation, with a TAC of 26,000 t to be effective for the population's recovery. In Rec. 96-6, the TAC was 22,000t [42], and based on more robust data, TACs began to increase over the years, with catches being considered sustainable and the stock not overexploited. After 10 years, recommendation 07-03 [43] reduced its MSY and once again considered the population overexploited, as well as in 2011 with Rec. 11-05, which stated that the population of albacore tunas was likely to be overfished or experiencing overfishing [44]. In 2016, SCRS concluded that the stock was, most probably, not overfished and overfishing was not occurring, setting a TAC of 24,000 t and extending the TAC until 2022 [45], [46]. The most recent Recommendation by ICCAT (Rec. 22-6), elaborates that according to the 2020 SCRS conclusions, *T. alalunga* stock is, most probably, not overfished and overfishing is not occurring, with TAC at 28,000 t from 2023 to 2026 [47], indicating that TACs were effective throughout the years (Figure 2). Brazil's government created the Permanent Committee for the Management of Fisheries and the Sustainable Use of Tunas and Tuna-like species (CPG – Tunas and Tuna-like) through Decree nº 10.736, July 29$^{th}$, 2021 [48]. With that, CPG – Tunas and Tuna-like established through Interministerial Ordinance MPA/MMA nº 2, of March 28, 2023 [49], a catch limit of 2.600 t for Territorial Sea, Exclusive Economic Zone (EEZ), and international waters for Brazilian fishing vessels, and quota has increased to 3040 t through Interministerial Ordinance MPA/MMA nº 10, of March 26, 2024 [50].

The bigeye tuna (*T. obesus*) is the only target species captured by the Surface longline or Buoy longline targeting tunas (Table 1) that is currently at some level of risk according to the IUCN since its first assessment in 1996 [51], where it was considered VU with a decline of 29–32% estimated for the past three generations [52]. Although its stock is considered VU globally and has had ICCAT recommendations restricting the capture of juvenile individuals in the Atlantic since 1979 through Rec. 79-01 [53], the latest national assessment considered *T. obesus* LC in 2022 (Figure 2). With the creation of CPG – Tunas and Tuna-like, ICCAT has recognized that the country had strengthened the National Regulatory Framework through CPG – Tunas and Tuna-like through Rec. 23-02, which also states that Brazil overharvested 1587,34 t of *T. obesus* in 2022, recommending paying back with catch limits of 355.34 t for 2024 and 308 t for 2025 to 2028 [54]. Brazil’s government established through Interministerial Ordinance MPA/MMA nº 2, of March 28, 2023 [49] a catch limit of 5.441 t in jurisdictional waters and Interministerial Ordinance (MPA/MMA) nº. 5, of September 22, 2023 [55] allocated this catch limit in quotas across the licensing modalities established in the Interministerial NI 10/2011, with 1722,30 t for horizontal longline fisheries [55] [27]. The most recent catch quota for *T. obesus* is 5639 t for the whole territory, with MPA/MMA directing 1980 t of this quota for horizontal longline through Interministerial Ordinance nº 12, August 2, 2024) [56].

Another really important resource for Brazilian fisheries is the swordfish (*Xiphias gladius*). Its targeted fisheries affect several other species, reflecting in almost every species caught as Bycath or Predictable Bycatch by surface longline or buoy longline (Table 1). The first international stock assessment for this species occurred in 1996, being considered Data Deficient (DD) by IUCN, than in 2011, this species was considered LC [57] and is currently considered

NT for its decreasing number of mature individuals in nature and overfishing throughout the years where it has been overexploited [58]. Despite ICCAT restrictions for minimum size/weight catches since 1990 for the entire Atlantic [59] and being considered NT globally [58], it is currently assessed as LC nationally [25] (Figure 2). In 1997, ICCAT recommended a TAC at 2339.2 t for the South Atlantic stock [60] and following this, national NI nº17/1999 [61] was the first recommendation to establish limits set by ICCAT for the capture of tuna and tuna-like species (especially for *X. gladius*) by the current chartered fleet employing longline gear, as well as by permit holders, with tunas as target. The Recommendation 02-03 [62] limited annual TACs for Brazil, totaling 16,940 t for the years 2003 to 2006, and the SCRS continued recommending TACs at 17t for 2007 to 2009, then reduced it to 15 t in 2010, and again in 2018 to 14 t, without exceeding the TAC in any year according to the landing reports (Figure 1) [63], [64], [65], [66], [67]. The current recommendation by ICCAT is an annual TAC at 3940 t for Brazil [68] and a catch limit of 2900 t was established for the Brazil through Interministerial Ordinance from MPA/MMA nº 2, of March 28, 2023 [49], being reduced to 2839 t through Interministerial Ordinance MPA/MMA nº 10, of March 26, 2024 [50].

### 3.2 Predictable Bycatch and Bycatch

Catches in the North Atlantic are showing a decreasing trend, whereas those in the South Atlantic are increasing [69]. Over the years, could be noticed that catches of tunas and billfishes have been replaced by swordfish and blue sharks in Southwest Atlantic [14]. Barreto et al. [5] reports an increase in catches of sharks and swordfishes in South Atlantic between 1998-2007 (also shown in Figure 1) due to commercial interests, where fishing strategy changed by the use of monofilament gear and circular hooks to catch more of those fishes due to lower visibility of the lines.

The ICCAT classifies sharks as “tuna-like” because they frequently appear in fisheries for targeted species throughout the entire Atlantic. However, management measures for sharks cannot be the same as those for tunas because sharks have low reproductive capacity, a long life cycle and late sexual maturation [34], [35], [36] while tuna lay thousands of eggs per year and have a short life cycle [70]. The first time that ICCAT was concerned with implementing studies on shark species considered bycatch was in 1995 through Rec. 95-2, which joined efforts with FAO to collect biological data, stock abundance and bycatch magnitude, in addition to trade data and coordinate functions for regional and sub-regional fisheries management activities [71]. Resolution 03-10 of 2003 is still in force and resolves that each CPC provide the Working Group of the Sub-Committee on By-catch with the information on their shark catches, effort by gear type, landings and trade of shark products, and fully implement National Plans of Action in accordance with FAO International Plan of Action for the Conservation and Management of Sharks [72]. Other Recommendation that is still valid is Rec. 04-10 [73], which states that CPCs report data for shark catches, take necessary measures to require that their fishermen fully utilize their entire catches of sharks, undertake research to identify ways to make fishing gears more selective, conduct research to identify nursery areas, and require their vessels to not have onboard fins totaling more than 5% of the weight of sharks onboard. Also, fishing vessels are prohibited from retaining on board, transshipping or landing any fins harvested in contravention of this Recommendation, and has prohibited retention, catch or commercialization for some species of sharks (which are EN and CR, as *Alopias superciliosus* and *Carcharhinus falciformis* [74] [75].

The Brazilian market is one of the world's top consumers of shark meat, driven by both domestic demand and export markets. Shark meat is often sold in fish markets and restaurants under generic terms like "cação", which can refer to various species, including those that are threatened [17]. An important fisheries resource that is listed as Predictable Bycatch in every category for Table 1 is the shortfin mako (*I. oxyrinchus*), which is classified as EN globally by IUCN and CR nationally (Table 1; Figure 2) [76][25]. Thefirst global assessment for this species occurred in 2000, where it was classified as NT as IUCN already stated that its meat had high market value and lack of adequate and proper records of catches [77]. For the assessment of 2009, *I. oxyrinchus* was raised in its threaten category, being classified as VU due to fishing pressure and its vulnerable life history assets, and, of course, continued to increase in market values for its meat and fins [78]. The latest global assessment so far (2019) raised even more its risk of extinction, now classified as EN with evidence of population declines in several areas, better knowledge of its reproductive cycle, and continued enhancement of its meat and fins market value [76]. For Brazil, this species is suffering a great overfishing and its population is currently classified as CR [25].

The Recommendation 22-22 by ICCAT [79] acknowledges that *I. oxyrinchus* is vulnerable to overfishing and that the South Atlantic stocks are at significant risk of decline, requiring a long time for rebuilding even with significant catch reductions. It also, states that the Contracting Party and Cooperating non-Contracting Party, Entity or Fishing Entity (CPCs) should implement a fishery management plan for this species immediately to try to counteract overfishing, and should implement a maximum retention allowance of 60% of their average annual catch from 2012 to 2021, which is expected to be 1295 t for South Atlantic, and 208 t for Brazil specifically [79]. This stipulated catch limit is below the registered in Figure 1, which is about three t per year, showing that catches for this species maintained constant throughout the years but with a high probability of poor data of catch records. This species is included in Appendix II of both CMS and CITES, reflecting the importance of reducing its “accidental” capture so that extinction does not occur.

Since 1997, a part of the Brazilian longline fleet has targeted some species of sharks, with the Blue shark (*Prionace glauca*) always dominating the elasmobranch bycatch in landings (Figure 1) [13]. This species has uncertainties when trying to assess conservation status for being considered the most resilient species to overfishing among all elasmobranchs [80]. According to the report Assessment of the Sustainable Potential of Living Resources in the Exclusive Economic Zone (2006) [81], the Blue shark bycatch in Brazil had the highest relative abundance of all bycatch species landings and already had a high rate of exploitation. Some studies have already pointed out that the blue shark has become the target of different fleets in Brazil, being captured more than the officially targeted ones, representing between 85 to 90% of the total elasmobranchs caught by pelagic longline fisheries [17], [82],

[83], [84], [85]. This trend can also be noticed in Figure 1, showing that the catch from 2011 for this species exceeded all targeted catches.

Stevens et al. [36] presented the first global assessment for *P. glauca*, classifying it as NT, justifying that this species had a widespread occurrence in the world's oceans and the heaviest catch of sharks, with 10 to 20 million individuals per year. With high catches over the years, IUCN classified it as NT in 2009 [58] and continued to be NT in the latest international assessment so far [59] (Figure 2). The main argument for this status came with conclusive fishery assessments indicating declines in population for the Atlantic Ocean, estimating a 20-29% reduction over three generations. A regional assessment in a federal state of Brazil (Rio Grande do Sul) considered *P. glauca* as VU, and the population may be jeopardized even more if this fishing pressure is maintained [86],[87]. The first national assessment for *P. glauca* occurred in 2010, being classified as NT [36], and since then, legal conflicts have been constant due to commercial interests because the blue shark is not explicitly considered a target for national industrial fishing, and with new ordinances to repress overfishing, a constant conflict between the government and those mainly responsible for international leases has prevented this species for receiving proper attention.

Recommendation 19-08 [88] established a TAC for *P. glauca* at 28,923 t for the stock of South Atlantic and maintained this TAC until 2021 by Recommendation 21-11 [89]. The assessment that ICCAT provided for the South Atlantic stock estimated that it was unlikely to be overfished and not subject to overfishing. However, there was an unsustainable harvest during 1991–2011, and any future increase in fishing mortality could cause the stock to be overfished or experience overfishing [90]. In 2023, Recommendation 23-11 [91] established by SCRS reports that the stock for South Atlantic blue shark was not overfished but subjected to overfishing, and acknowledged that the TAC in Rec. 19-08 has been exceeded in recent years (Figure 1). However, a TAC of 27.711 t or less would immediately stop overfishing,. In 2024 was the first time Brazil stablished a catch quota for the blue shark through the Interministerial Ordinance from MPA/MMA nº. 10, of March 26, 2024 [50], limiting a quota of 3.481 t for EEZ and international waters for Brazilian fishing vessels.

Fisheries management for blue sharks can be compared to that of tunas but is not biologically applicable because tunas have really different life histories when compared to most sharks. The age of maturity for *P. glauca* is around 5 years; therefore fishing recruitment at 7 years would minimize the impact on this species [92]. CMS protects *P. glauca* as it is a highly migratory species and it is currently in Appendix II of the Convention. CITES restricts and controls international trade of Blue shark, which has been included in Appendix II in 2023. With this inclusion in the CITES Appendix, NI nº 26/2023 and nº22 from November 4$^{th}$, 2024 states that the issuance of the CITES Import License is a prerequisite for the shipment of exports and imports of Blue shark specimens, parts, products, and by-products [93] [94].

### 3.3 National Action in Command and Control

Since 2007, the federal government has not conducted monitoring of fishing landings in an integrated and institutionalized manner, leading to the suspension of systematic statistical data collection. Between 2008 and 2012, the Statistical Bulletins of Fisheries and Aquaculture published by MPA provided estimates based on data historically collected by federal agencies [95]. However, official data were not reported to FAO for the period from 2014 to 2019. For the years 2020 and 2021, only partial catch data were reported, which were considered highly incomplete [23]. Decree nº 3607/2000 [96] is a normative document from the Brazilian government that establishes specific rules and guidelines on the implementation of CITES on the international trade of species to protect certain species against excessive trade and IBAMA is the administrative authority designated to regulate the trade of specimens included in Annexes I, II and III of CITES to ensure their survival through the granting of a License or issuance of a Certificate.

Prohibitions on finning, species protections, and international and regional management actions, such as fisheries agreements (ICCAT), and wildlife conservation agreements (CITES and CMS) are some basic management actions for the conservation of sharks, with Regional Fisheries Management

Organizations (RFMOs) working cooperatively with CITES and CMS to provide comprehensive fishery data and conservation programs that address both fishing and trade of pelagic sharks. In 2004, elasmobranch species were listed as threatened nationally due to overfishing through NI n° 05/2004 [97], which prohibited the retention of catches. In 2012, following NI nº14 from MPA jointly with Ministry of Environment and Climate Changes (MMA) [98], which amended Ordinance nº 121/1998 from IBAMA [99] to provide standards and procedures for landing, transport, storage, and commercialization of sharks and rays, besides prohibiting the practice of finning in Brazil. The NI nº16/2015 [100] regulated Art. 4th of NI nº14/2012 [98] and defined the necessary procedures to monitor the control of shark landings captured in Brazilian jurisdictional waters and on high seas by national or foreign leased vessels as well as the storage, conservation, processing, transport, marketing or export of fins.

The most significant mark for conservation in Brazil was the implementation of OrdinanceI 445/2014 [24], where the list of threatened species originating from NI nº 05/2004 [97] as updated and fully protected when classified as EW, CR, EN and VU. From this point on, conflicts with the fishing industry sector were constant due to commercial interests, with some management ordinances regarding the protection to these endangered species rescinded or not implemented, and rules on capture and retention not followed [3] [26] [101]. Between 2019 and 2022, the management of the MPA/MMA was discontinued/undermined due to changes in the country's presidency with different priorities, which directly affected the non-implementation of several fisheries regulations. Returning to the prior guidance in 2023, environmental issues regained the appropriate attention from the federal government, leading to the issuance of Ordinance 354/2023 [102], which repealed MMA Ordinances nº 299 and 300/2022 [103] [104], and some acts of the MMA were reinstated, such as Ordinance 445/2014 [25]. In addition, Ordinance 300/2022 [104] established catch limits for the country's main target species and recognized the National List of Endangered Species [102], also updating the National List including five species of sharks and their respective extinction risk status in Ordinance MMA nº 148, June 7, 2022 [25], with *I. oxyrinchus* being classified as CR, the status that precedes extinction. A measure for the protection of species was the establishment of the National System of Conservation Units (SNUC) by Federal Law nº 9985/2000 [105], which is responsible for the conservation and sustainable use of natural resources by creating, implementing, and managing Conservation Units in the national territory. Another important measure was the creation of the Environmental Protection Area and Natural Monument of Saint Peter and Saint Paul Archipelago through Decree nº 9.313 [106], an important conservation measure due to the abundance of juvenile sharks in the area [61]. A Joint Ordinance with MMA and Navy established measures, criteria and standards for permitted fishing activities in the Archipelago [107].

There are important conservation efforts in the National Plan of Action for the Conservation of Endangered Marine Sharks and Rays, which aims to implement integrated strategies for endangered species that include research measures, monitoring, fishing control, environmental education, and public awareness. Furthermore, it seeks to ensure the conservation of essential habitats for these species and promote the sustainable use of marine resources, thus guaranteeing the preservation of marine biodiversity and the sustainability of economic activities related to fishing [108].

Also, there are efforts in the control and monitoring of fisheries through the National Collaborative Network for the Sustainable Management of Fisheries Resources (Rede Pesca Brasil) [44]. The CPG – Tunas and Tuna-like is represented by bodies and entities of the federal, state, district or municipal public administration and society involved with fishing activities, aiming to subsidize management for sustainable use of fishing resources in the country. It is expected that the creation of the CGP – Tunas and Tuna-like, it improves the conservation of species already protected by international agreements. Based on recommendations by this Committee, ICCAT directed a Recommendation to Brazil to compensate for the overharvest *T. obesus*, also recognizing the country's commitment to maintaining the goals of ICCAT's management and conservation plan for tropical tunas [54]. The CGP – Tunas and Tuna-like established very important measurements through Interministerial Ordinance MPA/MMA nº 2, of March 28, 2023 [49] with catch limits for *T. alalunga*, *T. obesus* and *X. gladius* in Territorial Sea, Exclusive Economic Zone (EEZ), and international waters for Brazilian fishing vessels. In 2024, they continued to establish catch limits for the same species and added *P. glauca*, an important measure to prevent the species from reaching depletion [50]. In the view of these facts, it is concluded that Nations and RFMOs should elevate the priority of research into shark bycatch-reduction methods and related gear modifications to improve fisheries' selectivity, such as using fabricated baits that are attractive to teleost but not to sharks, reducing the soak times of longlines so that sharks that are caught will have a better chance of being released alive. Furthermore, another important management approach is fishing restrictions, such as catch limits, and closing fishing grounds in times and areas where shark catches are high, particularly where reproductive females are present [109].

## 4. CONCLUSION

Over the years, changes in public policies and losses of more accurate data contributed to overfishing of target species and predictable bycatch for pelagic longline fisheries, preventing more effective management by governments.

Government actions, such as the first cycle of the National Action Plan for sharks, are important to preserve the future of predictable bycatch shark species. Also, some conservation measures are being put into practice, such as the performance of CPG – Tuna and Tuna-like in recommending catch quotas and surveying fisheries data.

After several decades of exploration, this sector which is so important for Brazil both economically and socially, has gained attention. The problem of shark management, although not recent, may be overcome; however, the deficiencies in the control and monitoring system of landed fishery production in the country, coupled with the absence of a national onboard observer program, prevent an accurate assessment of the true scale of irregular fisheries [85]. Effective management for oceanic sharks is hampered by this poor data, as well as sharks' highly migratory nature, low reproductive rates, relatively low value, and lack of a consistent voice for sharks in the society [109].

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# CAPÍTULO 2

## ANALYZING CATCHABILITY OF PELAGIC LONGLINE FISHING GEAR IN EQUATORIAL ATLANTIC OCEAN

**Authors:** Laís Ramos Barcellos; Marcelo Francisco Nóbrega; Matheus Assis Oliveira; Leandro Augusto de Souza Jr.; Camila Araújo; Rosângela Paula Teixeira Lessa.

**ABSTRACT**

The pelagic longline fishery in Brazil has undergone significant changes since its inception in the 1950s, particularly regarding gear modifications and the targeting of specific species. The shift to monofilament longlines in the early 1990s, along with changes in bait and operational strategies, primarily targeted swordfish and led to increased bycatch of species such as the blue shark, albacore, and bigeye tuna. The study analyzed catch data from three distinct programs (PROBORDO, ECOTUNA, and PROTUNA). While blue sharks were considered predictable bycatch, they emerged as the fourth most caught species in the PROBORDO sample, highlighting their significant capture rates following gear changes. The results indicated that shorter hook submersion times led to higher survival rates for certain species, such as the swordfish. Additionally, the monofilament gear was more effective in catching blue shark, albacore, and bigeye tuna, while larger swordfish individuals were more commonly captured using monofilament lines. The life-stage compositions also reflected a shift in target towards more mature individuals, with the blue shark being predominantly captured as adults, a concerning information as it may indicate a reduction in reproductive populations, especially in areas like the Equatorial South Atlantic Ocean. The findings underscore the importance of effective fishery management, particularly in protecting juvenile populations and implementing catch quotas for at-risk species. The introduction of fishing quotas for blue sharks and ongoing management discussions highlight the need for a more sustainable approach to pelagic fisheries, focusing on the preservation of apex predators and the health of marine ecosystems.

## INTRODUCTION

Anthropogenic changes, such as overfishing, climate change, and oil spill pollution, have altered the abundance of oceanic species, especially large predators of high trophic levels (Pinnegar et al., 2000; Peterson et al., 2003; Hutchings & Baum 2005; Baum & Worm, 2009; Polovina et al., 2009; Doney et al., 2012). With selected targets and some species incidentally caught, pelagic longline fishing is one of the main large-scale and most widespread fishing activities in the world, with tuna and tuna-like species being an important resource for industrial and artisanal fisheries (Tasker et al., 2000; Arrizabalaga et al., 2011; Lucena-Frédou et al., 2017).

There is still little knowledge about extinct oceanic predators, but exploitation depletes marine fish populations by 50% to 70%, and current fisheries management relies on stock assessments to estimate population parameters of focal species from age or historical length structure of catches, biomass, fishing effort and independent fisheries inspections (Hilborn et al. 2003; FAO, 2007). As reported by IBAMA (2011), the Northeast region of Brazil have the highest production of fish in the country, with 454,216.9 t, accounting for 31.7% of national production as for South, North, Southeast and Midwest regions, 336,451.5 t (23.5%), 326,128.3 t (22.8%), 226,233.2 t (15.8%) and 88,944.5 t (6.2%), were respectively registered.

Experimental programs offer valuable alternatives to predict future fish population trends (Ward, 2008). In 1992, Brazil invested in a research program that used multifilament longline gear, which was predominant at the time, in the southwest equatorial portion of the Atlantic. Scientific expeditions conducted by the Revizee project studied Brazil's Exclusive Economic Zone (EEZ) and consolidated sovereignty over the 200 nautical miles it encompasses. This research represents an important historical record of how industrial pelagic fishing operated at the time, using this method for catching tuna.

In 1994, a significant change occurred in fishing gear, with a commercial shift toward swordfish. The implementation of monofilament instead of multifilament led to a subsequent change in bycatch species (Hazin et al., 2008; Barcellos et al., 2025). This new fishing method began to catch not only swordfish but also tuna and other similar species.

Determining the absolute population size of key marine species is challenging, so fisheries scientists frequently estimate relative abundance, assuming that it is proportional to catch per unit effort (CPUE) and can thus be estimated from time series CPUE data (Hilborn and Walters, 1992). CPUE data can be obtained from two sources: fishery-independent sampling (e.g., research surveys) or fishery-dependent data (e.g., catch and effort data from commercial or recreational fishers). Fishery-independent data from well-designed surveys are preferred over fishery-dependent data, as they are less prone to biases associated with data from commercial or recreational fishers, such as changes in fishing gear, methods, and targeting practices over time (Hilborn and Walters, 1992).

Catchability measures the interaction between resource abundance and fishing effort (Arreguín-Sánchez, 1996). It can be measured through abundance indices, assuming that it is proportional to CPUE, where the catchability coefficient links catch and fishing effort for each fishing method, accounting for the local density of vulnerable animals at the time they were caught. The present study aims to compare the CPUE for the catchabilities of fishing methods used in three different periods, understanding how changes in methods and target species have influenced the capture of other species over time.

**METHODS**

A systematic literature review using search platforms was used to explore national fisheries data and papers that used the same database as this work: ECOTUNA, PROBORDO and PROTUNA. This allowed highlightening trends in catch for three different periods and two different fishing gears: the 90’s (ECOTUNA, multifilament), from 2004 to 2011 (PROBORDO, monofilament), and from 2018 to 2020 (PROTUNA, monofilament).

Fishing data were used from a scientific expedition and foreign industrial fishing boats (Spain, Honduras, United Kingdom, Japan, Morocco, Panama and Portugal) targeting tunas, swordfish and sailfish, and equipped with pelagic longlines of multifilament and monofilament, in addition to data available in the spreadsheets of the National Fishing Database for Tuna and alike (BNDA) and

FishStatJ. Data was filtered to use only catch through longline fisheries in Equatorial Atlantic ocean (Figure 1). PROTUNA was interrupted due to the COVID-19 pandemic and had a limited area range, but data were useful when comparing different types of gear because the program overlapped ECOTUNA's area and used different gear configurations (Figure1).

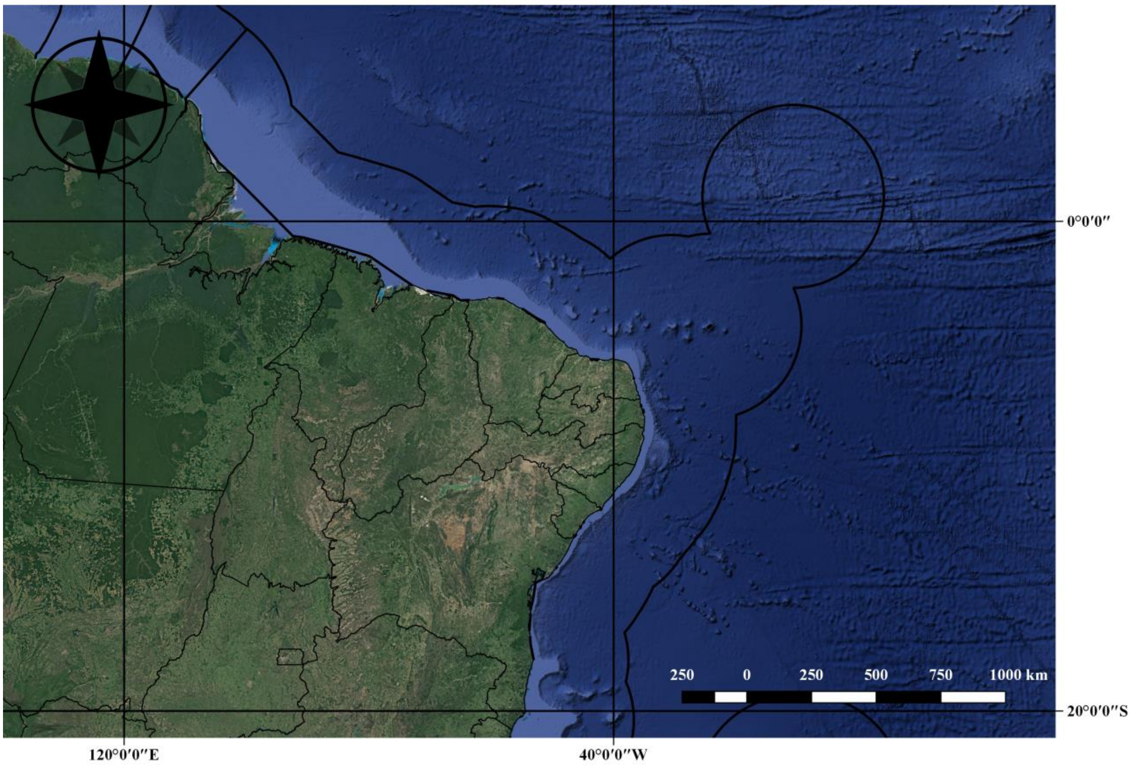



Figure 1. Equatorial Atlantic Ocean. The line delimits the Exclusive Economic Zone (EEZ) for northeastern Brazil.

The scientific survey called ECOTUNA took place between 1992 and 2000, using the fishing operation mode that occurred at the time (multifilament), in the Northeast region of Brazil (from 0º to 10º S latitude and from 25º to 40º W longitude) consisted of 26 km of extension, with 600 hooks and slings made of steel wire measuring 1.5 mm in diameter and 1 m in length. The secondary lines measured 8 m and were made of polyamide with a 3 m diameter. The main line had a spacing of 40 m between the insertion loops of the secondary lines, with sardines as the main bait. This type of scientific expedition is useful for characterizing the local fauna, managing to estimate abundance and capture per unit of effort in a way that does not affect populations when compared to the damage caused by longline vessels focused on the commercialization of oceanic fish (Vasconcelos et al., 2001).

After the change in target species, the longline fisheries was characterized by having a main line with a diameter of 3.0 mm and 315 m between the buoys, hooks made of Mustad 9/0 with 6 hooks between the buoys, a secondary line measuring 2 mm made of polyamide, squid as bait, in addition to the use of light attractors (light-stick and electrolumen) (Hazin et al., 2008). This was the gear used in PROBORDO and PROTUNA programs. The variables included in the spreadsheets were: date, month, year, program, trimester, cruise, station, moon phase, initial latitude/longitude, final latitude/longitude, hook immersion time, sea state, water temperature, wind strength, wind direction, current, thermocline, depth, number of hooks, species, total length, fork length, sex.

For frequency of species in the sample (Fig. 2), the same sexual maturation lengths were used for both males and females. The lengths of the sharks (*P. glauca* and *I. oxyrinchus*) were measured in Total Length (TL, cm), and the bony fish in Fork Length (FL, cm). Bayesian length-weight relationships were used to estimate the weight values, which were then utilized to calculate the catch per unit of effort CPUE (Table 4). The capture frequency of each species by sexual maturation stage was analyzed among the three programs using the ggplot2 package (Wickham, 2016).

The number of hooks (effort) and relative abundance indices were used to calculate the CPUE, dividing total captured weight (kg) per species by the submersion time of hooks (h) and the number of hooks multiplied by 1000, resulting in a unit kg/h/1000 hooks. CPUE was also calculated for each species (Table S1; Table 2).

For the catchability equation, the methodology of Ward (2008) was used, the main formula being (1):

(1) $$\frac{c_i}{e_i} = q_i n_i$$

Where catchability coefficient *qi* link catch *ci* and fishing effort *ei* for fishing operation *i*, and the local density of vulnerable animals *nt* at time *t*. The effect of type of gear was calculated by dividing the absolute frequency by species for each program.

Catch rates $u_1$ were derived from monofilament and linked to the species' local abundance $n_i$ and catchability $q_i$ through the catch equation (2) and (3):

(2) $$u_1 = \propto_1 q_i n_i$$

and

(3) $$n_i = \frac{u_1}{\propto_1 q_i}$$

Where *i* is the local time and area of interest and $\alpha_1$ is the effect of monofilament on catchability. For multifilament gear, $\alpha_2$ produces catch rates $u_2$ as equation (4):

(4) $$n_i = \frac{u_2}{\propto_2 q_i}$$

The two equations can be combined because local abundance $n_i$ can be assumed to be the same for both types of gear, as it follows (5), (6) and (7):

(5)

$$\frac{u_1}{\propto_1 q_i} = \frac{u_2}{\propto_2 q_i}$$

(6)

$$\frac{\propto_2}{\propto_1} u_1 = \frac{q_i}{q_i} u_2$$

(7)

$$\frac{\propto_2}{\propto_1} = \frac{u_2}{u_1}$$

The three fishing programs were analyzed and compared according to mortality (%), hook submersion time (h) and frequency of catch. Hook submersion time was calculated for each captured species, thus inferring variations in catch.

## RESULTS

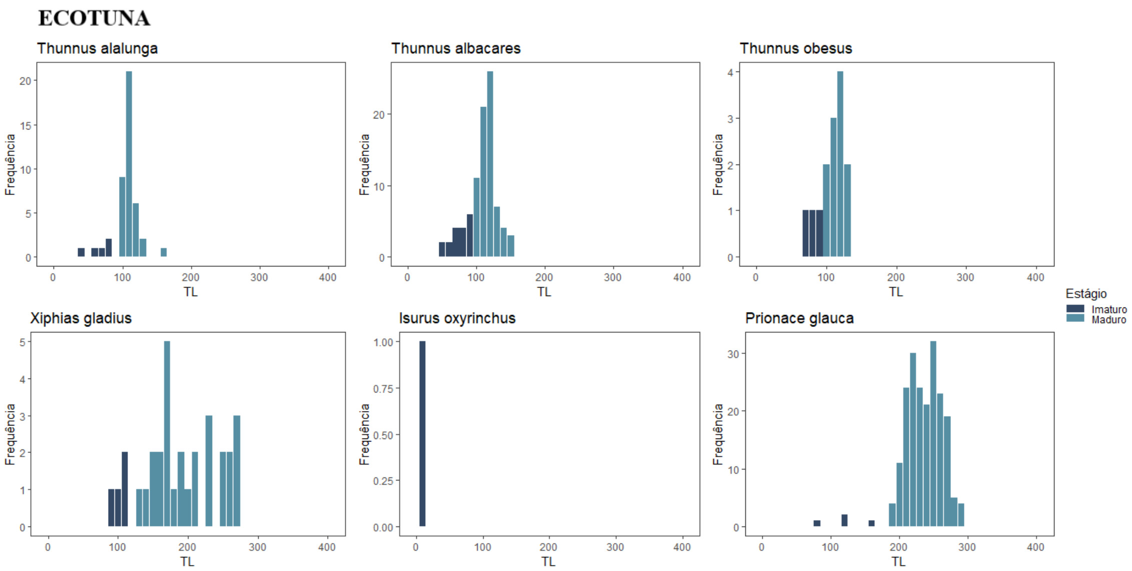
Table 1. Relative abundance of species caught alive or dead, mean submersion time of longline (Subm time, hour) and status of the captured animals, categorized as Alive or Dead in Equatorial Atlantic Ocean.

| | ECOTUNA | | | PROBORDO | | | PROTUNA | | |
|---|---|---|---|---|---|---|---|---|---|
| Species | Alive (%) | Dead (%) | Subm Time (h) | Alive (%) | Dead (%) | Subm Time (h) | Alive (%) | Dead (%) | Subm Time (h) |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Isurus oxyrinchus* | - | - | - | 69.1 | 30.9 | 14:36 | 100.0 | 0.0 | 10:13 |
| *Prionace glauca* | 96.0 | 4.0 | 8:40 | 36.0 | 64.0 | 11:24 | - | - | 10:03 |
| *Thunnus albacares* | 55.8 | 44.2 | 8:20 | - | - | 15:28 | - | - | 10:13 |
| *Thunnus alalunga* | 36.6 | 63.4 | 8:20 | - | - | 15:36 | - | - | 10:10 |
| *Thunnus obesus* | 57.9 | 42.1 | 8:40 | - | - | 16:12 | 69.2 | 30.8 | 10.14 |
| *Xiphias gladius* | 21.4 | 78.6 | 8:30 | 21.3 | 78.7 | 11:49 | 27.0 | 73.0 | 10:20 |

The Albacore (*Thunnus alalunga*) became a target after gear changes, as well as the Bigeye tuna (*T. obesus*), *X. gladius* and Yellowfin tuna (*T. albacares*). Although the Blue shark (*P. glauca*) is considered a predictable bycatch according to IN 10/2011 (MPA, 2011), it is the fourth most fished species in the entire PROBORDO sample (Table S2, supporting information).

The PROBORDO program had an average hook submersion time greater than 12 h for most of the analyzed species, while the ECOTUNA program had an average submerged time of 8:30 h, and the PROTUNA had most of the hooks submerged for 10 h (Table 1). The survival rate for the Swordfish (*Xiphias gladius*) did not show major differences in survival rates between programs. The Blue shark (*P. glauca*) had a great chance to survive when hooks were submerged for 8:40h, but this dropped to 36% by being brought onboard alive in PROBORDO, where hooks were submerged for 11:24h.



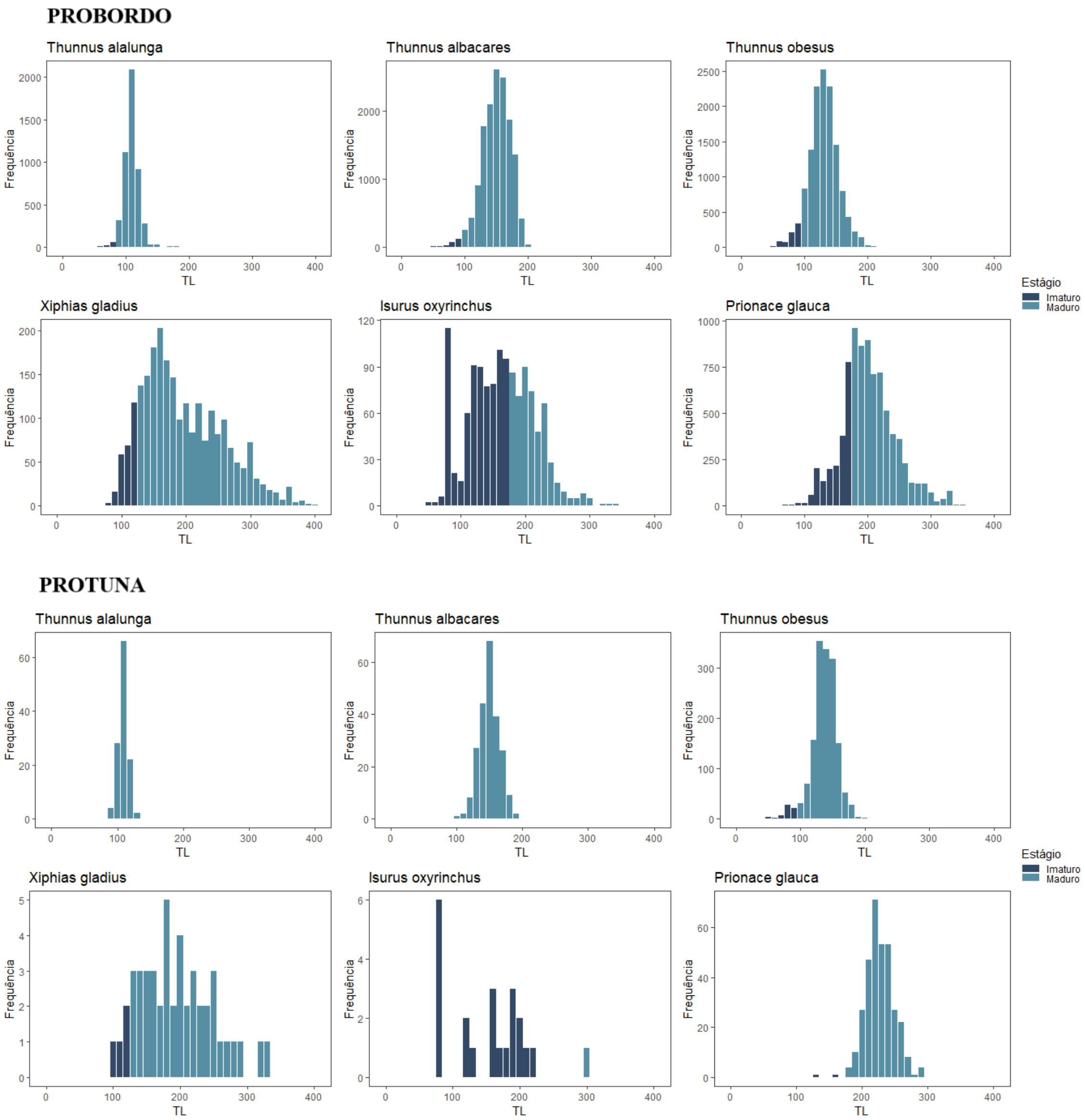



Figure 2. Catch frequency according to size (Sharks:TL, cm; Tunas and Swordfish: FL,cm) and Fishing Programs.

The length most captured using both types of gear were 100 to 200 cm for most species (Figure 3). Figure 3 illustrates the capture frequency of the species analyzed in this study according to their size and life stage. In all programs, *T. alalunga* was most frequently captured at 110 FL, cm, with higher catches in PROBORDO and PROTUNA. The size range of *X. gladius* increased with the use of monofilament, which ranged from 90 to 400 cm FL comparing to 90 to 280 FL, cm in ECOTUNA. Almost all sample caught of *I. oxyrinchus* were composed by immature individuals in all three programs.

Table 2. Catchability of pelagic species caught by longline fleets between 1992 and 2020.

| Species | ECOTUNA | PROBORDO | PROTUNA |
|---|---|---|---|
| *Isurus oxyrinchus* | 9.8 | 1.5 | 2.2 |
| *Prionace glauca* | 1.3 | 0.88 | 0.47 |
| *Thunnus alalunga* | 1.7 | 0.79 | 0.3 |
| *Thunnus albacares* | 0.9 | 1.67 | 0.81 |
| *Thunnus obesus* | 5.1 | 1.48 | 0.48 |
| *Xiphias gladius* | 1.2 | 1.37 | 0.43 |

For the catchability of species, *I. oxyrinchus* had the highest value of all samples and all programs. When analyzing changes in gear configuration, multifilament was more effective for catching *P. glauca, T. alalunga*, and *T. obesus*. When fisheries targeted *X. gladius*, catchability increased for the species, as well as for *T. albacares*.

Table 3. Bayesian length-weight values and Length at maturity ($L_{50}$) for both sex, as well as its references. TL: Total Length for sharks; FL: Fork Length for tunas and swordfish.

| Species | CTa | CTb | Cza | CZb | ($L_{50}$) | Ref. CT | Ref. CZ | Ref($L_{50}$) |
|---|---|---|---|---|---|---|---|---|
| *Isurus oxyrinchus* | 0.0038 | 3.03 | 9.45E-06 | 3.018 | 180.1 cm TL | Froese et al. (2014) | Mejuto et al. (2008) | Canani et al. (2020) |
| *Prionace glauca* | 0.0101 | 2.86 | 0.00267 | 3247 | 228 cm TL | Lessa et al. (2004) | Ayers et al. (2004) | Hazin et al (1994); Hazin et al. (2000) |
| *Thunnus alalunga* | 0.03136 | 2.78 | 0.0147 | 3013 | 90 cm FL | Froese et al. (2014) | ICCAT (2003) | Punt et al. (1995) |
| *Thunnus albacares* | 0.00778 | 3.11 | 0.0278 | 2855 | 95 cm FL | Smallwood et al. (2017) | Frota et al. (2004) | Wild (1994) |
| *Thunnus obesus* | 0.01413 | 3.02 | 0.0119 | 3090 | 95.5 FL | Froese et al. (2014) | Fagundes et al. (2000) | Mooney-Seus et al. (1997) |
| *Xiphias gladius* | 0.00372 | 3.15 | 0.0056 | 3150 | 125 cm FL | Froese et al. (2014) | Frota et al. (2004) | Hazin et al. (2001) |

Table 4. Correlation between three fishing programs.

| | *ECOTUNA* | *PROBORDO* | *PROTUNA* |
|---|---|---|---|
| ECOTUNA | 1 | | |
| PROBORDO | -0.17545 | 1 | |
| PROTUNA | 0.19108 | 0.791008 | 1 |

The PROBORDO and PROTUNA programs had higher correlation values

(Table 4), while ECOTUNA had little correlation compared to the other two programs.

## DISCUSSION

Pelagic longlining aiming at the catch of tunas began approximately in 1950 in northeastern Brazil (Paiva & Le Gall, 1975), and there are records of sharks being an important part of bycatch since then (Hazin et al., 1998). Over the years, it could be noticed that catches of tunas and billfishes have been replaced by swordfish and blue sharks (Frédou et al., 2015).

In 1992, the tuna fleet in Brazil used the Japanese multifilament longline as the main gear for pelagic fishing, mostly targeting Yellowfin tuna and Albacore (Hazin et al., 1998). However, the “tuna-like” species were caught in abundance, with *P. glauca*,*C. longimanus* and *I. oxyrinchus* standing out as bycatch (Table 2).

Changes in the method used by the fishing industry on the Brazilian coast occurred around 1994, when operations began at night, with squid instead of sardines as bait, using light attractors and monofilament longline (Hazin et al., 2008). These changes occurred due to the change in the target, which became Swordfish, and this consequently changed the bycatch. Fish with the highest occurrence in hooks generally aggregate in nature because they occupy almost the same trophic levels, having similar ecological roles when occupying the epipelagic and mesopelagic portions. Most of the species captured in the study are considered apex predators (>4.5) (Table S3 – supporting information), having as their ecological function of organizing aquatic communities since predatory pelagic species play a relevant role in the structure and functioning of ecosystems, through regulation in abundance and behavior of their prey (Preisser et al., 2005; Engelbrecht et al., 2019).

These animals often live in meso/epipelagic regions and occupy the same trophic levels (Supplementary Material). Responses to impacts in the food web are strong when long-lived species with high biomass and specialized diets (like blue sharks) are compared to yellowfin tuna, which has shorter generation times and very diverse diets (Griffiths et al., 2010).

According to Andrade et al. (2013), CPUEs were higher close to coast in equatorial waters. All these species are considered tropical and are regular resources in Equatorial Atlantic Ocean's stock, but the management of these large pelagic fish can be difficult due to highly migratory species (Carvalho et al., 2011). Different types of fishing exploit a great diversity of sharks for human consumption and for the trade of their fins, in addition to being captured as bycatch or target (Musick, 2005).

Transparent monofilament lines have increasingly replaced traditional materials in fishing, resulting in higher catch rates. The enhanced strength of monofilament lines allows for a thinner diameter, and their increased efficiency can, at least in part, be attributed to their reduced visibility. Bjordal (1983) observed that catch rates increased by 10-20% when traditional multifilament lines were substituted with monofilaments (Hovgård & Lassen, 2000).

The probability of catching an animal on a hook depends not only on the distribution and density of the species and the intensity of the fishing effort but also on the stochastic probabilities associated with the animal's interaction with the bait and the hook (Deriso and Parma, 1987). Experimental programs, such as ECOTUNA, are useful for estimating catchability because they allow the assumption that adjacent hooks access the same local abundance of pelagic species. This is particularly relevant, given that the longline action area is much smaller than the potential range of pelagic species (Hirayama, 1972). While catchability represents the interaction between fishing gear and animal behavior, fishing power is a characteristic of the fishing gear and methods used (Ward, 2008). Despite this distinction, both factors have the potential to skew abundance indices derived from catch rates. As shown in Table 2, the targeted species exhibited increased catchability, whereas *P. glauca* showed a decrease in the Northeast Equatorial Atlantic region. Supporting this, data from Barreto et al. (2016) highlight an increase in shark captures between 1998 and 2007, following changes in fishing practices. The introduction of monofilament gear and circular hooks, which reduce the visibility of fishing lines to animals, resulted in more targeted captures of sharks and swordfish—both highly valued commercially and particularly selective for this type of fishing.

The condition of the animal upon being brought on board was not recorded by onboard observers for certain species; however, management measures can still be proposed based on the available data, particularly in relation to the duration of the operation. Given that the hook submersion time in ECOTUNA was 8:30 hours (Table 2), it can be inferred that *X. gladius* is more likely to survive if the hook submersion time is reduced to below this threshold. The country implemented a fishing quota for the species andthis reduction in submersion time could be a key management strategy.

Pelagic sharks are top predators of the chain, and play a crucial role in marine ecosystems, regulating prey and controlling community structure (Heithaus, 2004). Large sharks are known for their high movement rates, which include extensive unidirectional migrations as well as rapid return migrations (Bonfil et al., 2005). The current indiscriminate exploitation of sharks is considered the main cause that leads to extinctions restricted to local or regional scales, but also may lead to significant changes in population structure due to overfishing, such as reductions in population size, alterations in age structure, and modifications in key parameters like fecundity, growth, and mortality rates (Stevens et al., 2000; Dulvy et al., 2003). Although *I. oxyrinchus* has catch quotas established by ICCAT, this species is nationally classified as CR, consequently its catch should be prohibited.

Temporal reductions in body size can also affect the capture rates of large predators (Ward, 2008).Notably, while some smaller species increased in size during Ward's study, thereby enhancing their catchability, the size of *A. solandri* decreased following the implementation of monofilament lines (Figure 3).

The introduction of monofilament lines notably enhanced the capture rates of various species, with *P. glauca* emerging as a target species, becoming the fourth most frequently caught species in PROBORDO (Barreto et al. 2016). Although *P. glauca* was not initially considered a target species (Table 2), it was captured more frequently than *T. alalunga* (the target species after the gear change) in both PROBORDO and PROTUNA. The change in fishing gear, which was designed to target species with similar physiologies, also attracted animals that were drawn to the same bait, primarily squid. The most significant increase in capture rates following the gear change was observed in the target species, which also led to the capture of anatomically similar species that occupy comparable positions in the food web (Table S3).

More than half of the fish stock of *P. glauca* was composed of adult individuals, an observation that Carvalho et al. (2010) and Barcellos et al. (2022) already noticed when estimating males and females for the same area studied, while it is believed that the same population also inhabits the southern Atlantic, where juvenile individuals are primarily captured (Montealegre-Quijano & Vooren, 2010).After years of being considered a bycatch and a sustainable fisheries resource, finally, the ICCAT recommended catch limits for *P. glauca*, and Brazil is already having public discussions through the Permanent Committee for the Management of Fisheries and Sustainable Use of Tuna and Tuna-like Species (CPG - Tunas and Tuna-like) that this is a target speciesestablishing a limit of catch of 3481 t per year (Barcellos et al., 2025).The Yellowfin tuna is the main resource of industrial fisheries with stock composed in its majority by juveniles under 115 FL cm as was also stated by Revizee Program (MMA, 2006), reporting that 75% of individuals were under the minimum reproductive size. A reduction in population size was noted by Duarte-Neto & Lessa (2004) attributed to fishing mortality over time. The present results can be a reflection of the reality of biodiversity in that time-space, 30 years ago when this fishing resource represented the second highest catch. The capture of juveniles observed during the period of scientific prospecting for *T. albacares* was 60.3%. According to Nóbrega et al. (2023), this proportion decreased annually to 31.2%. This may reflect both the rarity of finding immature individuals and their fish stock status, currently in decline, classified as LC by IUCN (Collette et al., 2021). Considering 23 years of exploration, when comparing sizes at first maturity, a dense dependence on the equatorial Atlantic stock is suggested, with a decrease of approximately 15.4 cm (Nóbrega et al., 2023). Travassos et al. (2009) categorized clusters based on the target capture composition, identifying that the highest proportion of capture for this tuna species was in the 1990s, reaching its peak in catches in 1994, and evidencing a reduction in catch in 2001, when fishing gear changed when Swordfish became the main target. These changes led to a decrease in fishery selectivity for monofilament longline with decreasing the average size, followed by a reduction in the MSY in the Atlantic Ocean, which is the reason for the stock not being considered as overfished (ICCAT, 2020; Collette, et al., 2021). Nevertheless, *T. albacares* disappeared from the discussions of the

Permanent Committee for the Management of Tuna and Tuna-like Species, with no catch quota established in the latest public meetings of the Committee.

The change in the fishing gear and the population reduction (LC) may have altered the size of the captured *X. gladius* individuals when compared to recent studies, such as that by Nóbrega et al. (2023), in which they found mostly adult individuals, which may indicate a possible stock collapse in the Atlantic due to the decrease in the probability of capturing juveniles. The TAC for 2007 through 2009 was 17,000 t, then reduced to 15000 t in 2010, and reduced again in 2018 to 14,000 t, without exceeding the TAC in any year according ~~to~~ the landing reports (ICCAT, 2017). Despite ICCAT restrictions recommendations for minimum size/weight catches since 2004, the population continues to decrease. Stock reduction is directly related to the capture of juvenile individuals (Myers et al., 1997). Management is highly recommended, especially for those species that are not targeted in industrial pelagic fisheries and are at risk of extinction, protecting important areas for their reproduction, as well as implementing catch quota of individuals that did not reach sexually mature sizes, and most important, having an effective monitoring program for EEZ portion of Equatorial South Atlantic Ocean portion.

## CONCLUSION

Large pelagic fish constitute one of the main fishing resources in the EEZ of Northeast Brazil, and because they are highly migratory, they are captured by several countries along the Atlantic Ocean. In order to obtain fishing control and consequently the ordering of their catches, a regional organization for fisheries management under ICCAT's responsibility is suggested. In addition, the country must vigorously monitor the maximum catch limits established to preserve the species, which, for the most part, are in different categories of extinction according to the IUCN Red List of Threatened Species.

The most basic information that helps fisheries management is catch and biometry data (Freire et al., 2014). According to Ward (2008), data from commercial fisheries are not reliable, and the suggestion to obtain more accurate abundance estimates would be mark-recapture studies or scientific expeditions. National onboard observation data is passed on to the Ministry of the Environment and Climate Change, which then forwards it to ICCAT. It would be beneficial if the data were made public to be considered more reliable.

Hook submersion time can be an important management measure, with fisherman being able to release fishes with less damage to its life. Another management action is to use nylon leader instead of steel leader, as steel leaders are known to mutilate animals and target sharks (Gilman et al., 2007; Peñalver et al., 2018).Elasmobranchs in Brazil continue to be widely exploited, with large-scale declines in their populations, and with almost no reporting for threatened species. This complicates the management of elasmobranch stocks, in addition to the lack of basic information on their biological aspects and capture data, as well as the effects of overfishing of the species (Lessa et al., 1999, Motta, 2002; Amaral & Jablonski, 2005; Di Dario, 2015; Barreto et al., 2017).

Many of the countries responsible for fishing in the Brazilian EEZ have exhausted their fishing resources and are exploiting Brazil's marine resources. The country urgently requires inspection in isolated areas, mainly in Conservation Units. Without proper supervision, management plans are nothing more than notes on populations on the verge of extinction.

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## SUPPORTING INFORMATION

Table S1. Relative abundance of species caught alive or dead, mean submersion time of longline (Subm time, hour) and status of the captured animals, categorized as alive or dead in Equatorial Atlantic Ocean.

| | ECOTUNA | | | PROBORDO | | | PROTUNA | | |
|---|---|---|---|---|---|---|---|---|---|
| Species | Alive (%) | Dead (%) | Subm Time (h) | Alive (%) | Dead (%) | Subm Time (h) | Alive (%) | Dead (%) | Subm Time (h) |
| *Thunnus alalunga* | 36.6 | 63.4 | 8:20 | - | - | 15:36 | - | - | 10:10 |
| *Thunnus obesus* | 57.9 | 42.1 | 8:40 | - | - | 16:12 | 69.2 | 30.8 | 10.14 |
| *Prionace glauca* | 96.0 | 4.0 | 8:40 | 36.0 | 64.0 | 11:24 | - | - | 10:03 |
| *Alopias superciliosus* | - | - | - | 60.7 | 39.3 | 12:17 | 85.7 | 14.3 | 10:20 |
| *Makaira nigricans* | 54.5 | 45.5 | 9:00 | 94.6 | 5.4 | 15:34 | 54.3 | 45.7 | 10:14 |
| *Carcharhinus signatus* | 84.6 | 15.4 | 8:10 | - | - | - | 25.0 | 75.0 | 10:12 |
| *Coryphaena equiselis* | 80.0 | 20.0 | 8:50 | - | - | - | - | - | - |
| *Coryphaena hippurus* | 90.9 | 9.1 | 7:50 | - | - | 15:52 | - | - | 10:20 |
| *Gempylus serpens* | 13.2 | 86.8 | 8:30 | - | - | - | - | - | - |
| *Isurus oxyrinchus* | - | - | - | 69.1 | 30.9 | 14:36 | 100.0 | 0.0 | 10:13 |
| *Carcharhinus longimanus* | 95.9 | 4.1 | 8:00 | - | - | 16:35 | 37.9 | 62.1 | 10:06 |
| *Ruvettus pretiosus* | 100.0 | 0.0 | 8:40 | - | - | 16:33 | 40.0 | 60.0 | - |
| *Pseudocarcharias kamoharai* | 100.0 | 0.0 | 8:10 | 21.3 | 78.7 | - | 50.0 | 50.0 | 10:30 |
| *Pteroplatytrygon violacea* | 100.0 | 0.0 | 8:50 | 56.7 | 43.3 | - | 91.3 | 8.7 | 10:03 |
| *Mobula birostris* | - | - | - | 98.0 | 2.0 | 15:01 | - | - | - |
| *Elagatis bipinnulatus* | 100.0 | 0.0 | 8:00 | - | - | - | - | - | - |
| *Istiophorus platypterus* | - | - | - | 92.5 | 7.5 | 15:20 | 85.7 | 14.3 | - |
| *Istiophorus albicans* | 44.5 | 55.5 | 8:30 | - | - | - | - | - | - |
| *Katsuwonus pelamis* | 15.4 | 84.6 | 8:10 | - | - | 15:50 | - | - | - |
| *Tetrapturus pfluegeri* | 64.1 | 35.9 | 8:00 | - | - | - | - | - | - |
| *Sphyrna lewini* | - | - | - | - | - | - | 100.0 | 0.0 | 09:35 |
| *Xiphias gladius* | 21.4 | 78.6 | 8:30 | 21.3 | 78.7 | 11:49 | 27.0 | 73.0 | 10:20 |
| Turtles | - | - | - | - | - | - | 100.0 | 0.0 | - |
| *Galeocerdo cuvier* | 100.0 | 0.0 | 9:00 | - | - | 13:32 | - | - | - |
| *Acanthocybium solandri* | 27.1 | 72.9 | 8:50 | - | - | 14:32 | - | - | 10:14 |
| *Tetrapturus albidus* | 62.9 | 37.1 | 8:10 | - | - | 16:24 | 51.7 | 48.3 | 10:13 |
| *Thunnus albacares* | 55.8 | 44.2 | 8:20 | - | - | 15:28 | - | - | 10:13 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Sphyraena guachancho* | 53.8 | 46.2 | 7:50 | - | - | 12:45 | - | - | - |
| *Seriola lalandi* | 0.0 | 100.0 | 5:30 | - | - | - | 100.0 | 0.0 | 10:58 |

Table S2. Catchability of oceanic species fished by the longline fleet between 1992 and 2020. Number of catches for each species (n); Catchability (Catch) for each program; Effect of multi and monofilament; as well as the comparison between programs.

| Species | ECOTUNA (n) | catch | PROBORDO (n) | catch | PROTUNA (n) | catch | Effect ECO | Effect PROB | CATCH ECO/PROB | CATCH ECO/PROT |
|---|---|---|---|---|---|---|---|---|---|---|
| *Acanthocybium solandri* | 85 | 6.7 | 42290 | 0 | 35 | - | 0.4 | 497.5 | 19.9 | 3.3 |
| *Alopias superciliosus* | 0 | - | 1023 | 0.03 | 9 | - | - | - | - | - |
| *Carcharhinus falciformis* | 0 | - | 1165 | 0.03 | 26 | - | - | - | - | - |
| *Carcharhinus longimanus* | 126 | 9.8 | 2015 | 0 | 39 | - | 0.3 | 15.9 | 0.7 | 4.1 |
| *Carcharhinus signatus* | 21 | 0.9 | 65 | 0.3 | 12 | - | 0.5 | 3.1 | 0.5 | 2.7 |
| *Coryphaena hippurus* | 285 | 1.2 | 22708 | 0 | 55 | - | 0.2 | 79.6 | 3.2 | 5.9 |
| *Istiophorus albicans* | 128 | 0.37 | 25882 | 0 | 36 | - | - | - | - | - |
| *Isurus oxyrinchus* | 2 | 29.3 | 4210 | 0.01 | 27 | - | 13.5 | 2105 | 84.2 | 9.2 |
| *Katsuwonus pelamis* | 8 | 0.7 | 1187 | 0 | 2 | - | 0.3 | 148.3 | 5.9 | 4.7 |
| *Makaira nigricans* | 32 | 1.7 | 18312 | 0 | 40 | - | 1.2 | 572.2 | 22.9 | 2.2 |
| *Prionace glauca* | 228 | 2.1 | 72917 | 0 | 528 | - | 2.3 | 319.8 | 12.8 | 2.5 |
| *Pseudocarcharias kamoharai* | 3 | 0.9 | 705 | - | 192 | - | 64 | 235 | 9.4 | 40.9 |
| *Ruvettus pretiosus* | 8 | 7.9 | 1915 | 0.01 | 0 | - | 0 | 239.3 | 9.6 | - |
| *Sphyrna lewini* | 1 | 1 | 692 | 0.01 | 2 | - | 2 | 692 | 27.7 | 2.3 |
| *Tetrapturus albidus* | 115 | 0.6 | 20720 | 0 | 46 | - | 0.4 | 180.1 | 7.2 | 3.3 |
| *Tetrapturus pfluegeri* | 63 | 1.9 | 9520 | 0 | 2 | - | 0.03 | 151.1 | 6.1 | 32.1 |
| *Thunnus alalunga* | 43 | 0.4 | 47980 | 0 | 152 | - | 3.5 | 1115.8 | 44.6 | 3.1 |
| *Thunnus albacares* | 140 | 1.5 | 102756 | 0 | 255 | - | 1.8 | 733.9 | 29.4 | 2.3 |
| *Thunnus atlanticus* | 0 | - | 1127 | 0.01 | 0 | - | - | - | - | - |
| *Thunnus obesus* | 14 | 1 | 68728 | 0 | 938 | - | 67 | 4909.1 | 196.4 | 42.8 |
| *Thunnus Thynnus* | 0 | - | 83 | 1.56 | 0 | - | - | - | - | - |
| *Xiphias gladius* | 106 | 6.8 | 169869 | 0 | 586 | - | 5.5 | 1602.5 | 64.1 | 4.3 |

Table S3. Most abundant species and their respective marine zones and trophic levels according to the diet composition of each animal.

| Species | Marine zone | Trophic level | Reference |
|---|---|---|---|
| *Thunnus alalunga* | Epipelagic/ mesopelagic | 4.3 | **Iverson, K.L.**, 1971. Albacore food habits. p.11-46. In L. Pinkas, M. S. Oliphant, and I. L. K. Iverson (eds.) Food habits of albacore, bluefin tuna, and bonito in California waters. Fish. Bull.152. |

| | | | |
|---|---|---|---|
| *Prionace glauca* | mesopelagic | 4.35 | **Harvey, J.T.**, 1989. Food habits, seasonal abundance, size, and sex of the blue shark, *Prionace gluaca*, in Montery Bay, California. Calif. Fish Game 75(1):33-44. |
| *Thunnus albacares* | epipelagic | 4.41 | **Maldeniya, R.**, 1996. Food consumption of yellowfin tuna, *Thunnus albacares*, in Sri Lankan waters. Environ. Biol. Fishes 47:101-107. |
| *Xiphias gladius* | Epipelagic/ mesopelagic | 4.53 | **Sabatié, R., M. Potier, C. Broudin, B. Seret, F. Ménard and F. Marsac**, 2003. Preliminary analysis of some pelagic fish diet in the eastern Central Atlantic. Col. Vol. Sci. Pap. ICCAT, 55(1):292-302. |
| *Thunnus obesus* | Epipelagic/ Mesopelagic | 4.49 | **Fuentes, H., E. Antonietti and A. Alano**, 1988. Espectro alimentario del patudo (*Thunnus obesus*) en la primavera austral de 1986 en el Pacifico sur oriental. In H. Salzwedel and A. Landa (eds.) Recursos y Dinámica del Ecosistema de Afloramiento Peruano. Bol. Inst. Mar. del Perú, Volumen Extraordinario. |

# 4. CONSIDERAÇÕES FINAIS

A gestão das populações de espécies explotadas no Brasil, especialmente aquelas espécies capturadas incidentalmente pelas frotas pesqueiras pelágicas, enfrentam desafios significativos que se devem à falta de dados precisos, ao baixo monitoramento das atividades pesqueiras e à ausência de programas nacionais eficazes de observação a bordo. Esses fatores têm contribuído para a sobrepesca de espécies-alvo e o aumento da captura acessória de elasmobrânquios, um problema que, apesar de histórico, precisa ser enfrentado com urgência para garantir a preservação das espécies ameaçadas.

Apesar dos avanços nos últimos anos, como a implementação do Plano de Ação Nacional para Tubarões e a recomendação de cotas de captura pelo Comitê Permanente de Gestão da Pesca e Uso Sustentável de Atuns e Afins (CPG - Atuns e Afins), a real eficácia dessas iniciativas é prejudicada pela carência de informações detalhadas sobre as capturas e as características biológicas das espécies. A pesca de tubarões, particularmente da espécie *Prionace glauca*, ainda carece de um controle rigoroso, sendo necessária a adoção de medidas que melhorem a seletividade da pesca e aumentem as chances de sobrevivência dos animais capturados acima da cota estabelecida. O uso de tecnologias como iscas artificiais mais seletivas e a redução do tempo de imersão das linhas são ações que podem contribuir substancialmente para a redução da mortalidade acessória.

Além disso, a criação de uma organização regional para a gestão da pesca, sob a responsabilidade da ICCAT, é fundamental para a regulamentação e o controle das capturas, considerando que os tubarões e atuns são espécies altamente migratórias, capturadas por vários países ao longo do Atlântico. O monitoramento rigoroso das cotas estabelecidas e o fechamento de áreas de pesca em períodos críticos, como durante o periodo reprodutivo, são estratégias adicionais que devem ser adotadas com maior força no Brasil, que precisa de uma fiscalização mais intensiva, especialmente em áreas isoladas e Unidades de Conservação.

A necessidade urgente de melhorar a coleta de dados pesqueiros, com ênfase na biometria e nas estimativas de abundância, é um passo fundamental para garantir que as populações de tubarões não sejam dizimadas. O uso de estudos de marca e recapturem, bem como expedições científicas mais frequentes, são alternativas eficazes para preencher essa lacuna de informação.

Em resumo, a gestão eficaz das espécies de atuns e afins no Brasil depende não apenas de uma maior integração entre políticas públicas, organizações internacionais e a comunidade científica, mas também da implementação de práticas pesqueiras sustentáveis que promovam a preservação desses animais, cujas populações estão cada vez mais vulneráveis. Sem uma ação decisiva e coordenada, o Brasil corre o risco de perder irremediavelmente espécies marinhas essenciais para o equilíbrio ecológico dos oceanos, além de comprometer o potencial econômico e social de sua indústria pesqueira.

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