Vol. 61, p. 213-241, jan./jun. 2023. DOI: 10.5380/dma.v61i0.80221 e-ISSN 2176-9109

UFPR

DMA DESENVOLVIMENTO E MEIO AMBIENTE

BIBLIOTECA DIGITAL DE PERIÓDICOS BDP | UFPR

revistas.ufpr.br

Small-scale fisheries and their interactions with marine megafauna: implications for the conservation of threatened species

A atividade pesqueira artesanal e suas interações com a megafauna marinha: implicações para a conservação de espécies ameaçadas

Angela Zaccaron da SILVA[1], Hugo BORNATOWSKI[1], Camila DOMIT[1]*

[1] Universidade Federal do Paraná (UFPR), Pontal do Paraná, PR, Brasil.

* E-mail of contact: cadomit@gmail.com

Article received on March 25, 2021, final version accepted on March 7, 2022, published on April 27, 2023.

ABSTRACT: Marine megafauna is of intrinsic importance to ecosystems, but it also provides essential services for ocean health and resilience through ecological roles in the structure and dynamics of marine communities. However, bycatch by coastal fisheries has been identified as a global threat to megafauna species, compromising the persistence of threatened populations, indicating it must be systematically monitored, evaluated, and have its impacts mitigated. This study uses the *DAPSI(W)R(M)* framework as a tool for understanding the interactions between coastal threatened marine megafauna species and small-scale fisheries, with a focus on bycatch and activities carried out on the inner shelf of the state of Paraná, southern Brazil. The results allowed to identify research and management strategies that promote or enhance actions to reduce the impacts of bycatch, as well as knowledge gaps and challenges encountered, providing subsidies for the ecosystem approach and integrated management of the coastal zone of the state of Paraná.

Keywords: marine megafauna; bycatch; coastal fisheries; DAPSI(W)R(M).

RESUMO: A megafauna marinha tem importância intrínseca aos ecossistemas marinhos, e também fornece serviços essenciais para a saúde e resiliência do oceano por meio de funções ecológicas na estrutura e dinâmica das comunidades marinhas. Entretanto, a captura incidental por pescarias costeiras tem sido identificada como uma ameaça global para as espécies da megafauna, comprometendo a persistência de populações ameaçadas de extinção e, portanto, deve ser monitorada sistematicamente, avaliada e ter seus impactos mitigados. O presente estudo utiliza o modelo conceitual *DAPSI(W)R(M)* como uma ferramenta para compreensão das interações entre espécies costeiras da megafauna marinha ameaçadas de extinção e a atividade pesqueira

artesanal, com enfoque nas capturas incidentais e atividades realizadas na plataforma interna ao longo do estado do Paraná, sul do Brasil. A partir dos resultados foi possível identificar estratégias de pesquisa e gestão que promovam ou potencializam as ações para redução dos impactos da captura incidental, assim como lacunas de conhecimento e desafios encontrados, fornecendo subsídios para a abordagem ecossistêmica e gestão integrada da zona costeira paranaense.

Palavras-chave: megafauna marinha; captura incidental; pesca costeira artesanal; DAPSI(W)R(M).

1. Introduction

The population decline of some marine megafauna species has been documented by several authors in recent years (Lewison *et al.*, 2004; 2014; Soykan *et al.*, 2008). Marine megafauna, a group composed of large vertebrates such as mammals, turtles, and large fish, have common characteristics such as late sexual maturity, slow growth, and low reproductive potential, resulting in low capacity for population increase and high vulnerability to various anthropogenic threats (Lewison *et al.*, 2004; Peckham *et al.*, 2007; Tavares *et al.*, 2019). Megafauna species contribute to the resilience and health of marine ecosystems and also provide essential services by regulating the structure and dynamics of aquatic communities, both at global and regional scales (Myers *et al.*, 2007; Heithaus *et al.*, 2008; Estes *et al.*, 2011). Important components of this dynamic are top predator species (Heithaus *et al.*, 2008; Estes *et al.*, 2011) and foragers, which regulate nutrient cycling (Tavares *et al.*, 2019).

However, impacts such as interactions with fishing gear, collision with vessels, ingestion of marine debris, and contamination by pollutants, as well as degradation and loss of habitats worldwide, threaten megafauna and contribute to the susceptibility of species to extinction (Dulvy *et al.*, 2003; Lewison *et al.*, 2004; Schipper *et al.*, 2008; IUCN, 2021). Many species are particularly vulnerable to bycatch by coastal and oceanic fisheries, which are considered their main global threat and an important driver of their population decline (Lewison *et al.*, 2004; 2011; Soykan *et al.*, 2008; Crespo *et al.*, 2010; Wallace *et al.*, 2013; De Castro *et al.*, 2021). In general, bycatch is defined as the unintentional catch of marine organisms that are not target species during fishing operations (Hall *et al.*, 2000).

Bycatch of megafauna species by industrial fisheries has been widely reported worldwide (Lewison *et al.*, 2004; Wallace *et al.*, 2013; Worm *et al.*, 2013). However, despite several studies showing a high occurrence of this type of catch in small-scale fisheries (Peckham *et al.*, 2007; Alfaro-Shigueto *et al.*, 2011), including bycatch rates higher than those found by industrial fleets in some fisheries (Peckham *et al.*, 2007; 2008), the impacts caused to marine megafauna are rarely addressed (De Castro *et al.*, 2021). In addition, the use of shallow coastal areas for breeding, feeding, shelter-seeking, and protection by these species has potential overlap with the main areas used by coastal small-scale fisheries, increasing the risk of interactions (Wallace *et al.*, 2013; Komoroske & Lewison, 2015). In this scenario, the effects related to bycatch by small-scale fisheries can jeopardize

vulnerable or threatened populations and, therefore, should be assessed, monitored, and have their impacts mitigated (Soykan *et al.*, 2008; De Castro *et al.*, 2021).

Worldwide, it is estimated that small-scale fisheries employ approximately 90% of the people directly dependent on fishing activities, providing food security and nutritional quality, as well as income generation to local economies while sustaining the livelihoods of fishing communities in coastal areas (Berkes *et al.*, 2001; FAO, 2005). In Brazil, small-scale fisheries are one of the most traditional activities for coastal and estuarine communities and constitute, in many cases, their main protein source (Isaac *et al.*, 2006; Andriguetto-Filho *et al.*, 2014; Zamboni & Martin-Dias, 2020). Despite the enormous social and economic importance of this activity, which represents about 53% of national fisheries production and most fishing vessels, the monitoring of landings is scattered, limited, or non-existent, compromising the effectiveness of fisheries management in the country (Isaac *et al.*, 2006; Vasconcellos *et al.*, 2007; Zamboni & Martin-Dias, 2020). In addition, the intrinsic characteristics of small-scale fisheries, such as the large number of vessels landing at dispersed points along the coast; the versatility of fishers who change methods, gear, and fishing areas quickly and frequently to maximize their catches; the limited space for onboard observers on vessels; and fishers's mistrust to provide information on bycatch, make it difficult to assess these impacts on marine megafauna in coastal regions (Peckham *et al.*, 2007; Vasconcellos *et al.*, 2007; De Castro *et al.*, 2021).

Several studies have discussed and evaluated management proposals for the mitigation of marine megafauna bycatch in coastal fisheries (Lewison *et al.*, 2004; 2011; De Castro *et al.*, 2021). However, to overcome global challenges such as maintaining marine biodiversity and its ecological processes, as well as ensuring sustainable development of human activities and food security for coastal communities, it is necessary to adopt an approach that recognizes the complexity of marine-coastal systems, their regionalities, and the integration of social, economic, and ecological components (Lewison *et al.*, 2016; Elliott *et al.*, 2017). In this regard, the *DAPSI(W)R(M)* framework (proposed by Elliott et al., 2017) aims to develop a better understanding of the impacts of anthropogenic activities on the environment along the causal chain: *Drivers*, *Activities*, *Pressures*, *State changes*, *Impacts (on welfare)*, and *Responses (as measures)*. This framework has been used as an approach for structuring and analyzing environmental problems in marine systems in order to guide public policies aimed at managing human activities (Lewison *et al.*, 2016; Patrício *et al.*, 2016).

Thus, this study uses the *DAPSI(W)R(M)* framework as a tool for understanding the interactions between coastal threatened marine megafauna species and small-scale fisheries, with a focus on the activities carried out on the inner shelf of the state of Paraná, southern Brazil. This approach helps to identify regional initiatives that promote or enhance the impact reduction of these interactions, as well as knowledge gaps or challenges encountered, serving as a guide to regional coastal management and a model for the management of broader territories.

2. Methodology

2.1. Study area

The coast of the state of Paraná is home to an estimated population of 302,000 inhabitants (IBGE, 2022) distributed in seven coastal municipalities, which develop various economic activities, such as fishing, aquaculture, and activities related to agriculture, industry, ports, and summer tourism (Pierri *et al.*, 2006; Paraná, 2019). Approximately 68 fishing communities depend on the natural resources and services provided by the region's marine ecosystems for their livelihoods and income (Andriguetto Filho *et al.*, 2006; Paraná, 2019).

With approximately 100 kilometers of coastline, the Paraná coast has wide sandy beaches and an extensive and shallow inner continental shelf (Lana *et al.*, 2001; Angulo *et al.*, 2006). The coastal plain is cut off to the north by the Paranaguá Estuarine Complex (PEC) (~612 km² surface area) and to the south by the Guaratuba bay (~50 km² surface area). This region is part of a large interconnected subtropical estuarine system, considered a natural heritage and an important wetland area on the southern Brazilian coast (UNESCO, 1999; MMA, 2017), which hosts a great diversity of natural habitats and associated fauna (Lana *et al.*, 2001). Several species of marine megafauna use the region as a sheltering and protection area for key life-history stages (Costa & Chaves, 2006; Félix-Hackradt & Hackradt, 2008; Zappes *et al.*, 2016; Domit *et al.*, 2021).

In this study, several coastal marine megafauna species that are exposed to the impacts of fishing activities were assessed, including small coastal cetaceans, sea turtles, sharks, and the Atlantic goliath grouper. This evaluation might serve as a model for other threatened megafauna species that also occur in the region. The term 'threatened species' is understood here as species and populations assessed by the criteria established by the International Union for Conservation of Nature (IUCN) and listed as Critically Endangered (CR), Endangered (EN), or Vulnerable (VU) in national (ICMBio, 2018a) or global (IUCN, 2020) assessments.

Among the small coastal cetaceans, Guiana dolphin (*Sotalia guianensis*) (VU - ICMBio, 2018b) and franciscana dolphin (*Pontoporia blainvillei*) (CR - ICMBio, 2018b) are species that frequently use coastal and estuarine regions for resting, feeding, breeding, and parental care (Rosas *et al.*, 2002; Filla & Monteiro-Filho, 2009; Santos *et al.*, 2009; Zappes *et al.*, 2016; Domit *et al.*, 2020a; 2021). The Paranaguá Estuarine Complex is home to one of the most abundant populations of Guiana dolphin, estimated at approximately 1,800 individuals (Miranda, 2017), which are sighted throughout the year in small groups formed by adults and with constant presence of calves, indicating the importance of this region for the species (Filla & Monteiro-Filho, 2009; Miranda, 2017; Moura *et al.*, 2021). Franciscana dolphin is endemic to the Southwest Atlantic and inhabits areas shallower than 30 meters deep (Secchi *et al.*, 2021). Due to their high vulnerability to bycatch and the loss of important habitats, the franciscana dolphin is currently considered the most threatened small cetacean in the Southwest Atlantic (Danilewicz *et al.*, 2010; Domit et al., 2020a; Secchi *et al.*, 2021). In Paraná, the occurrence of juvenile and adult franciscana dolphins has been observed

in coastal and estuarine waters (Santos, *et al.*, 2009; Zappes *et al.*, 2016; Sucunza *et al.*, 2020).

Regarding sea turtles, the coast of Paraná stands out as an important region of recruitment, development, and feeding area for juvenile green turtles (*Chelonia mydas*) (VU - ICMBio, 2018c) (Guebert-Bartholo *et al.*, 2011; Gama *et al.*, 2016; 2021; Cantor *et al.*, 2020), as well as an area of displacement and connection between Southwest Atlantic regions (González-Carman *et al.*, 2012; Fuentes *et al.*, 2020). The green turtle is distributed along the Brazilian coastline, mainly in coastal and estuarine regions, and thus at higher risk of interactions with small-scale fisheries (Gallo *et al.*, 2006; Marcovaldi *et al.*, 2006; Fiedler *et al.*, 2020; Fuentes *et al.*, 2020).

Also, the southern region of Brazil is a hotspot and global priority area for several elasmobranch species (Davidson & Dulvy, 2017; Derrick *et al.*, 2020), and the coast of Paraná is home to about 61% of shark and ray species occurring in the country (Bornatowski *et al.*, 2009; Bornatowski & Abilhoa, 2012). Some shark species perform ontogenetic migrations throughout their distribution, using shallower coastal regions as areas for calving, nursery, and juvenile development (Costa & Chaves, 2006; Bornatowski, 2008; Kotas *et al.*, 2012). Among the endangered shark species, the occurrence of scalloped hammerhead shark (*Sphyrna lewini* and *S. zygaena*) (CR - ICMBio, 2018d) and the sand tiger shark (*Carcharias taurus*) (CR - ICMBio, 2018d) stands out (Costa & Chaves, 2006; Bornatowski *et al.*, 2011; Bornatowski & Abilhoa, 2012; Afonso & Chaves, 2021).

The Atlantic goliath grouper (*Epinephelus itajara*) (CR - ICMBio, 2018d) is one of the threatened bony fishes with occurrence in Paraná, and it's registered throughout the year in consolidated bottom environments such as the Currais Archipelago, Figueira and Itacolomis Islands, as well as in artificial substrates (Félix-Hackradt & Hackradt, 2008; Hackradt & Félix-Hackradt, 2009; Bueno *et al.*, 2016). This is the largest fish in the family Serranidae, and has slow growth, high longevity, aggregative behavior, and sedentary nature with some degree of territorialism, being especially vulnerable to fishing pressure (Giglio *et al.*, 2014; Bertoncini *et al.*, 2018). Studies conducted in the region have shown that Paraná's coast is an important area of population concentration and reproductive aggregation of the Atlantic goliath grouper, presenting a well-structured population of adult individuals (Félix-Hackradt & Hackradt, 2008; Bueno *et al.*, 2016).

2.2. Literature review

An extensive literature review was conducted for information collection and analysis within the scope of this study, considering publications in scientific journals, academic documents, and technical reports and following a methodological process composed of four steps (c.f Petticrew & Roberts, 2008) (Figure 1):

i) determine the objectives and research questions guiding the review;

ii) develop a search protocol to explore the literature database (database used and search descriptors);

iii) track search results based on a set of predetermined criteria; and

iv) conduct a literature analysis considering the *DAPSI(W)R(M)* framework (c.f. Elliott *et al.*, 2017).

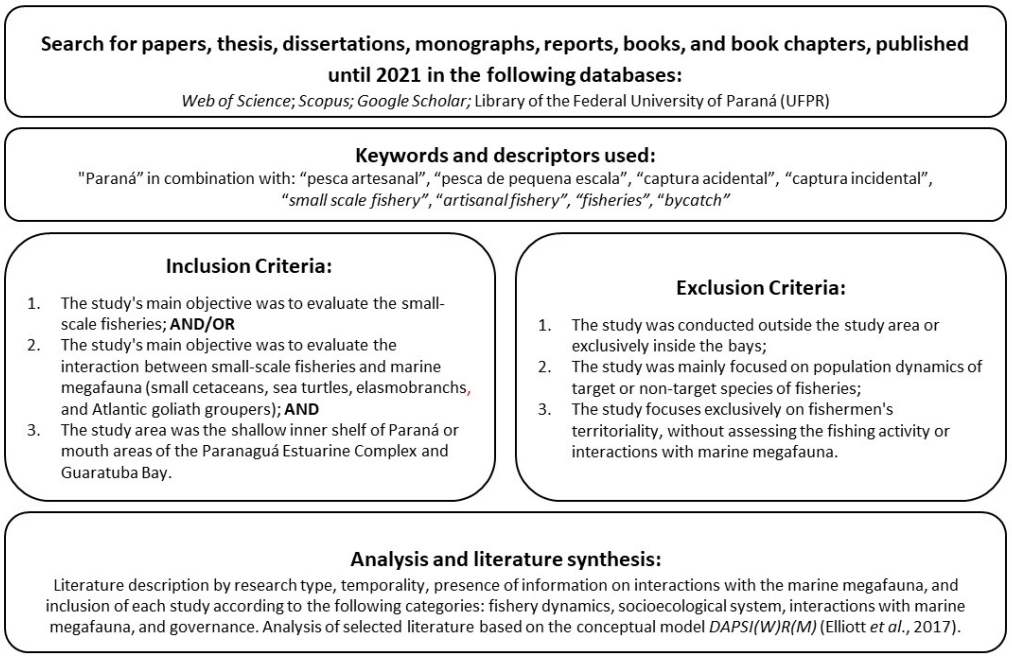

FIGURE 1 – Flowchart of the steps performed during the literature review.
SOURCE: The authors.

The search engines *Web of Science*, *Scopus*, *Scielo*, and *Google Scholar* were defined as literature databases since they encompass a variety of academic journals related to the topics discussed. In addition, we considered the online collection of the library of the Federal University of Paraná (http://www.portal.ufpr.br/) as another significant source of documents and academic papers conducted in the region. For the analysis, all types of scientific production published until 2021 were considered, including papers, thesis, dissertations, monographs, reports, books, and book chapters. The keywords used were "pesca artesanal", "pesca de pequena escala", "captura acidenta", "captura incidental[1]", "*small scale fishery*", "*artisanal fishery*", "*fisheries*", "*bycatch*", all in combination with "Paraná". Other studies were identified from the references cited in the previously selected documents, which increased the search and made the review even more complete. Publications related to the same study were grouped together and counted only once (e.g., academic papers and respective scientific publications). After checking the publications found and excluding

[1] In this study, bycatch species are understood as a "set of species that cannot be commercialized, incidentally caught during fishing of the target species, which coexist in the same area of occurrence, substrate, or depth of fishing activity, whose capture should be avoided because they are protected by specific laws or international agreements", according to Federal Ordinance MPA/MMA nº 10/2011.

duplicate documents, the following were removed from the analysis:

i) studies conducted outside the study area or exclusively inside the bays;

ii) studies focused on population dynamics of target or non-target species of fisheries; or

iii) studies focused exclusively on socio-cultural and socio-political dimensions of the fishers's territoriality, without assessing fishing practices or the interactions with the marine megafauna.

The papers were analyzed descriptively and classified according to:

i) type of research (scientific paper, thesis, dissertation, monograph, technical report, book, or book chapter);

ii) year of research publication; and

iii) presence of information on fisheries and interactions with marine megafauna.

Considering the main theme of each paper, they were classified within one of the following categories (Table 1): fisheries dynamics, socioecological system, interactions with marine megafauna, and governance. For a better evaluation and understanding of the taxonomic groups analyzed in this review, the following subcategories were created regarding the category "Interactions with marine megafauna": small cetaceans, sea turtles, elasmobranchs, and Atlantic goliath grouper.

TABLE 1 – Description of the subjects included in the different categories

Category	Description
Fisheries Dynamics	Studies that described the main characteristics of the fishing activity in the region, including characterization of the communities, fishing gear, vessels, target species, landed production, and technological alternatives.
Socioecological system	Studies with an integrated approach between social, economic, and ecological aspects of the fishing activity in the region. Studies that exclusively evaluated economic aspects of fishing communities were also included.
Interactions with marine megafauna	Studies that evaluated the interactions of marine megafauna in small-scale fisheries, as well as measures to reduce and mitigate these interactions. These studies were included in the subcategories: small cetaceans, sea turtles, elasmobranchs, and Atlantic goliath grouper
Governance	Studies that evaluated governance issues, management strategies, and the sustainability of small-scale fisheries

SOURCE: The authors.

2.3. Data analysis through DAPSI(W)R(M) framework

The *DAPSI(W)R(M)* framework is a policy-oriented approach and can be used for categorizing and to structure environmental problems (Elliott *et al.*, 2017). It evolved from previous versions, such as DPSIR (European Commission, 1999), which aimed to assess the causes, consequences, and responses to environmental changes related to human activities along a cause-effect chain. In the *DAPSI(W)R(M)* framework, social drivers (*Drivers*) are related to basic human needs, which can be met through socio-economic activities (*Activities*) (e.g., fishing, ports, building infrastructure). The effects of these activities produce pressures (*Pressures*) on the marine environment, such as overexploitation of marine resources, bycatch of threatened species, nutrient inputs, among others. Each of these pressures leads to various changes in the state of the environment (*State*), transforming the natural system which in turn may have an impact on social welfare (*Impact on welfare*). Consequently, these pressures, changes in the environmental state and the generated impacts require a response from society using regulatory measures (*Response as measures*) that, if successful, will prevent drivers and pressures from causing changes in the natural state or reduce their negative impacts (Elliott *et al.*, 2017).

This framework was used to structure an understanding of the interactions between small-scale fisheries and threatened marine megafauna. Thus, for this literature review, information on these interactions was extracted and analyzed in each results section in an integrated manner, with quantitative and/or qualitative data, according to the information availability.

3. Results and discussion

3.1. Literature review on small-scale fisheries in the inner shelf of the state of Paraná

After applying the selection criteria described in the methodology, 73 studies were selected (see Supplementary Material), including scientific papers (n=32), thesis (n=9), dissertations (n=17), monographs (n=6), technical reports (n=4), books and book chapters (n=5). This survey showed an increase in the number of publications since 2000 (93%; n=68) (Figure 2), mainly scientific papers. However, it was evident that part of the information is still retained as "gray literature" (thesis, dissertations, monographs, and technical reports), which are difficult to access in public repositories.

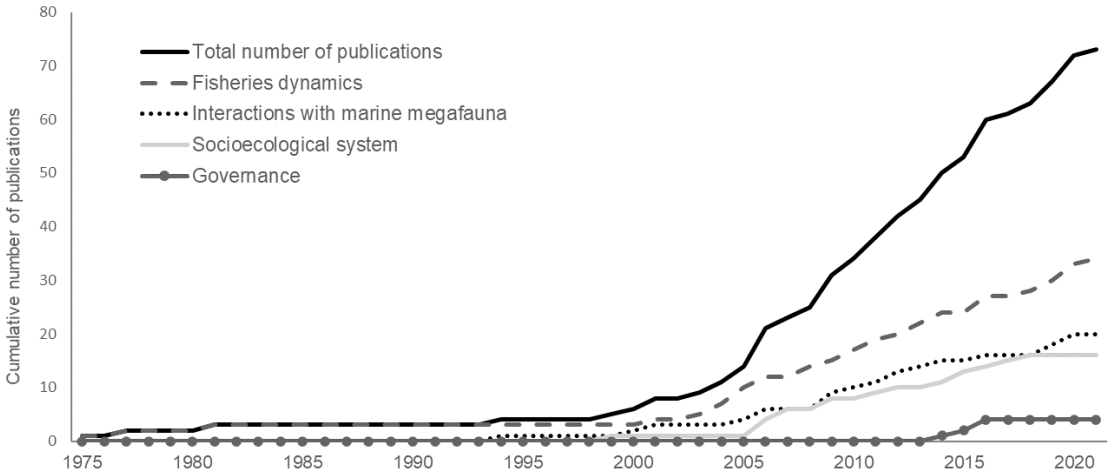

FIGURE 2 - Cumulative number of publications selected by this study over time, considering the total number of publications and the different categories.

SOURCE: The authors.

The selected publications were classified into four major categories: fisheries dynamics, socioecological system, interactions with marine megafauna, and governance. Most publications (46.6%; n=34) were classified as fisheries dynamics (Figure 2), which described the characteristics of fishing communities and their practices, such as fishing gears, vessels type, target species, fishing production, and experiments on bycatch reduction in bottom trawl fisheries. Integrated studies that assessed the social, economic, and ecological components within the socioecological approach (21.9%; n=16) have been developed in the region since 1999, with an increase in the number of publications since 2005. In addition, only four studies have addressed the governance issue (5.5%) in a recent period. Studies that assessed marine megafauna interactions with fishing activities (26%; n=19) focused on small cetaceans (n=8), sea turtles (n=6), and elasmobranch species (n=7). Only two papers had a multi-taxa approach, evaluating the interactions of fisheries with cetaceans and sea turtles. Despite the occurrence of Atlantic goliath grouper catches with longline and spearfishing, no study in the analyzed literature has as its main focus the evaluation of these interactions.

Regardless of the classification of the evaluated studies into categories, thirty-six reported regional interactions of fishery activity with marine megafauna, mainly in relation to elasmobranchs (n=23), small cetaceans (n=8), sea turtles (n=9) and Atlantic goliath grouper (n=4). Most of these studies indicated that gillnets (77.8%; n=28), including modalities such as fixed gillnets, driftnets, and trammel nets, are the main fishing gears that incidentally captures marine megafauna species. In addition, megafauna interactions with bottom trawls (n=7), purse seines (n=2), longlines (n=4), and spearfishing (n=1) were also reported in the analyzed literature (Figure 3).

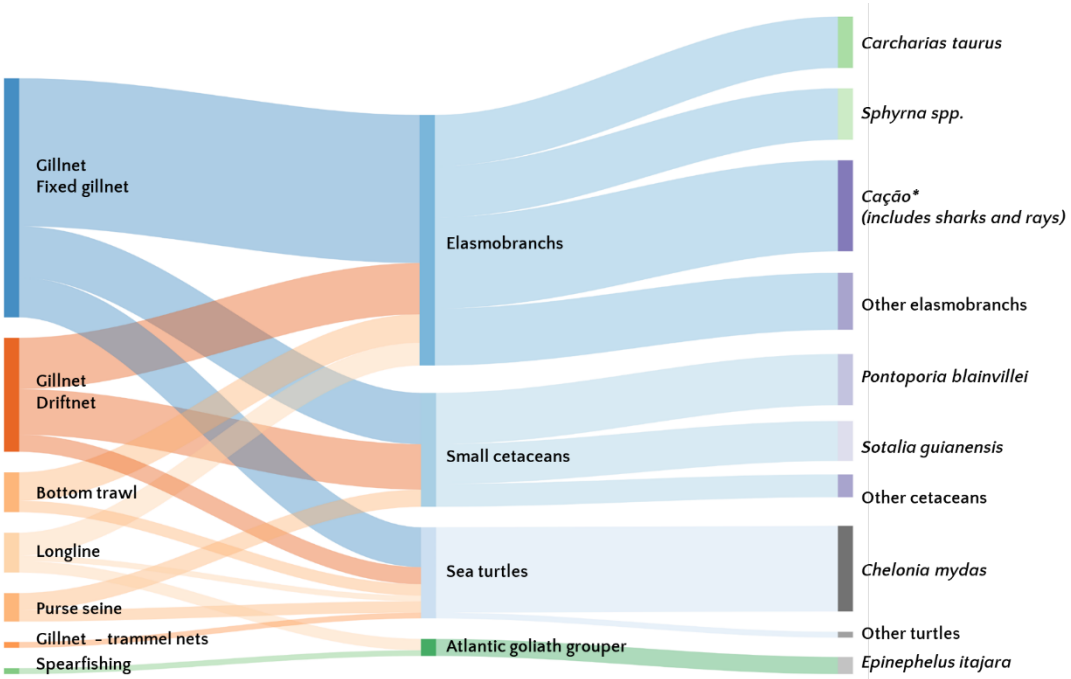

FIGURE 3 - Sankey diagram representing the number of publications in relation to: i) fishing gear, ii) marine megafauna group with reported fishery interaction, and iii) megafauna species reported in the literature, the focus of this study. The width of the nodes is proportional to the number of publications in which the interaction is cited.

SOURCE: Prepared by the authors, produced with the SankeyMATIC platform (http://sankeymatic.com/)

Considering all the literature evaluated, only 15 studies (20.5%) addressed some information specific on the bycatch of marine megafauna. Of these, seven showed quantitative data on these captures and three presented spatial data on the areas of overlap between the occurrence of species and fishing activities. Most of these studies (78%) used methodologies that accessed the fishers's knowledge, either through informal conversations or targeted interviews.

3.2. Evaluation of the interaction between small-scale fisheries and marine megafauna considering the DAPSI(W)R(M) framework

The description of the steps according to the DAPSI(W)R(M) framework in relation to the context of the interaction between small-scale fisheries and coastal marine megafauna species (Figure 4) are detailed below.

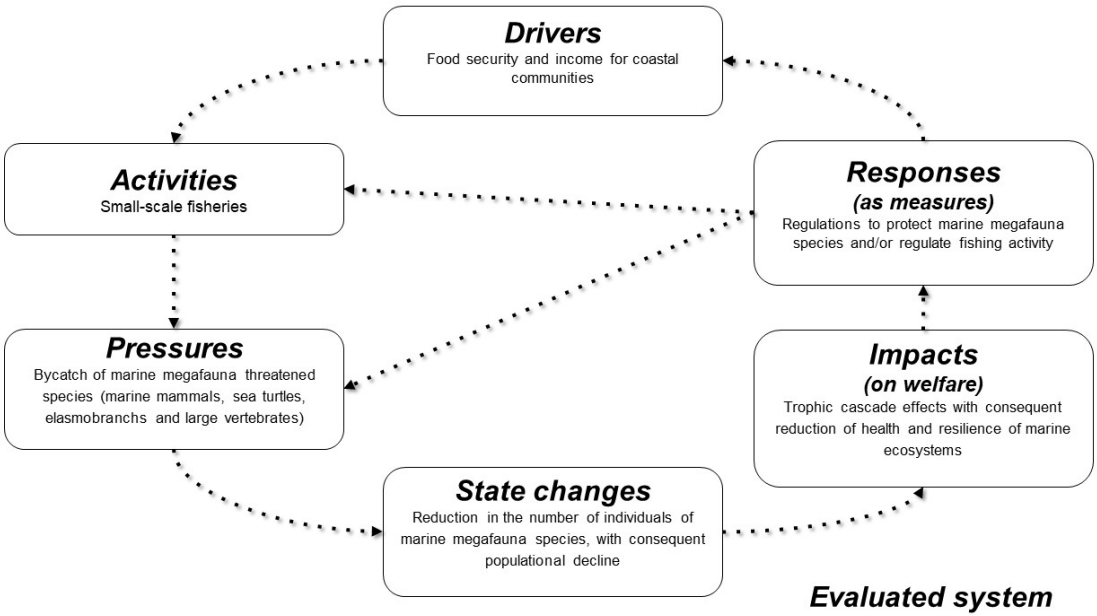

FIGURE 4 - Stages of the DAPSI(W)R(M) framework in the context of the interaction of small-scale fisheries with marine megafauna species.
SOURCE: Prepared by the authors, based on Elliott et al. (2017).

3.2.1. Social drivers that lead to small-scale fisheries

According to the framework proposed by Elliott *et al.* (2017), social drivers are related to basic human needs (e.g., food, energy, security, stability, or recreation), which can be achieved through human activities. Thus, in the evaluated context, we may include as main social drivers the need for food, income, a healthy environment, and economic-social stability for the communities of the Paraná coast (FAO, 2005; Borges *et al.*, 2006; Pierri *et al.*, 2006). We understand that the social drivers that lead to the development of small-scale fisheries also encompass other components, including the social, cultural, and political dimensions, which have been historically constituted and are part of the livelihoods of the small-scale fishers in the region. However, these dimensions transcend the proposal of the present study, and, therefore, were not evaluated here.

The small-scale fisheries on the Paraná coast involve approximately 6,000 fishers living in 68 fishing communities, which are distributed along the ocean shore or in the bays (Mendonça *et al.*, 2017; Paraná, 2019). Both in the local and regional context, small-scale fisheries have great social and economic importance, as more than 70% of small-scale fishers have this activity as their main occupation and source of income (Borges *et al.*, 2006; Mendonça *et al.*, 2017). However, Borges *et al.* (2006) observed that fishers in a more vulnerable

condition are usually related to traditional fishing systems and live in remote fishing communities, located in the inner areas of the bays.

Considering the natural complexity of the Paraná coast, Andriguetto-Filho (2002; 2003) identified six fishing production systems. In general, these fishing systems present themselves as a continuous gradient from a strictly artisanal or even subsistence extreme, characterized by a greater diversity of fishing practices carried out mainly inside the bays; passing through communities that explore both estuarine and inner shelf regions, with more homogeneous fishing practices; to a semi-industrial fishing system, more technological and entrepreneurial, represented mainly by the bottom trawling fleet based in the municipality of Guaratuba (Andriguetto-Filho, 2002; 2003)

Despite the difficulty in defining the size of the Paraná's fleet, according to Andriguetto-Filho *et al.* (2006), estimates suggest that about 1,600 vessels operate in the region. However, a more recent socioeconomic characterization project of the fishing activity (PETROBRAS, 2015) indicates the presence of 463 small-scale fishing vessels in operation. In general, most of the fleet is formed by non-motorized canoes and/or small vessels (6-14m), with limited fishing autonomy (11-36HP) and little fish storage capacity, making fisheries daily and carried out in areas near the coast (~10) (Andriguetto-Filho *et al.*, 2006; PETROBRAS, 2015). Nonetheless, some vessels designed for bottom trawling have greater autonomy and, consequently, greater capacity to operate, allowing them to fish along the entire Paraná coast and neighboring states (PETROBRAS, 2020).

The fishery production is diversified, corresponding to approximately 2 thousand tonnes of fish landed annually (PETROBRAS, 2020). There is a great diversity of fishing modalities practiced in the region (~65 modalities) that catch about 72 commercial species (Andriguetto *et al.*, 2006; Robert *et al.*, 2012). However, gillnets are the most commonly used gear, which employ different fishing techniques to capture fish and shrimp, and also bottom trawlers that are used to capture shrimp (Andriguetto-Filho *et al.*, 2006; Robert & Chaves, 2006; Afonso & Chaves, 2021).

Gillnets are widespread and present in a variety of modalities, including fixed gillnets, driftnets, trammel nets, and purse seine (Andriguetto Filho *et al.*, 2006; Afonso & Chaves, 2021). These fisheries occur throughout the shallow inner shelf, and fishers use opportunistic strategies of changing gear and mesh sizes according to seasonal variation of fish resources (Andriguetto-Filho *et al.*, 2006; Robert & Chaves, 2006). Mesh sizes vary according to the target species, usually between 5 and 22 cm, and can reach 40 to 60 cm to large sharks (Bornatowski *et al.*, 2011; Afonso & Chaves, 2021). The main target species are weakfish (all year round); mullets, mackerels, and flounders (autumn and winter); croakers, leatherjackets, and common snooks (spring and summer) (Andriguetto-Filho *et al.*, 2006).

It should be noted that small-scale and industrial fleets from the neighboring states of Santa Catarina and São Paulo also operate in the region (PETROBRAS, 2020), which may contribute to increased fishing effort and impacts on the megafauna analyzed. Afonso & Chaves (2021) alert to the fact that fish stock conservation strategies, as well as bycatch, do not depend only on user communities in Paraná, but demand a regional effort and territorial assessment of the fishery (as also evidenced by De Castro *et al.*, 2021).

3.2.2. Pressures of small-scale fisheries to marine megafauna

According to Elliott *et al.* (2017), pressures resulting from human activities are the mechanisms of change that can result in alterations in the natural system (environment) and subsequently in the social system (human welfare). Fishing activity exerts different pressures on marine ecosystems (FAO, 2011; 2021), and the interaction with marine megafauna is a growing factor of concern, as these are the first species to undergo intense population decline (Dulvy *et al.*, 2003; Lewison et al., 2004; Peckham *et al.*, 2007; Soykan *et al.*, 2008; Alfaro-Shigueto *et al.*, 2011; De Castro *et al.* 2021). Considering the context of the current assessment, small-scale fisheries exert pressure on different threatened species of marine megafauna caught incidentally (MPA/MMA, 2011). Ghost fishing and other potential pressures from small-scale fisheries are also relevant in terms of conservation but will not be analyzed in this study (complements in Chaves & Robert, 2009).

Some authors have recorded reports for Paraná of positive interaction between dolphins and fishers, in which dolphins lead the schools of fish towards the riverbanks, while fishers wait to cast their nets and capture the schools (Przbylski & Monteiro-Filho, 2001). However, negative interactions are the most observed, with the Guiana dolphin (*Sotalia guianensis*) and the franciscana (*Pontoporia blainvillei*) being the most incidentally caught cetacean species in coastal small-scale fisheries throughout Brazil (Crespo *et al.*, 2010; Domit *et al.* 2020a; 2021), including Paraná (Domit *et al.*, 2020b). Here, several studies have reported bycatch of these species by small-scale fisheries, with a higher frequency of capture in bottom-set gillnets, especially during winter (Przbylski & Monteiro-Filho, 2001; Rosas *et al.*, 2002; Ott et al., 2002; Rosso-Londoño, 2010; Robert *et al.*, 2012; Domit *et al.*, 2020a; 2021). For franciscana dolphins, Rosas *et al.* (2002) estimated an average mortality of 10 individuals/year in small-scale fisheries in Paraná and suggest that the characteristics of this fishery, which is carried out close to the coast, results in high mortality of immature individuals (about 75%). In addition, high stranding rates of cetaceans have been recorded throughout the Paraná coast, with a higher incidence of Guiana dolphins (54.7% among all stranded cetaceans) and franciscana dolphins (17%) (Domit *et al.*, 2020b). The areas with high numbers of strandings of Guiana dolphins are close to estuarine areas, probably reflecting a higher chance of interaction with multiple anthropogenic activities. In fact, Domiciano *et al.* (2016), studying small cetaceans stranded on the coast of Paraná, identified that around 61% of these animals presented as cause of death the bycatch in fishing gear, mainly by gillnets.

The green turtle (*Chelonia mydas*) is the sea turtle species with the highest occurrence in the Paraná region and, consequently, with the highest frequency of interaction with small-scale fisheries, mainly in gillnet fisheries (López-Barrera *et al.*, 2012; Guebert *et al.*, 2013; Petrucci, 2019), and, less frequently in other fishing modalities (Pina & Chaves, 2005; Robert *et al.*, 2012; Domit *et al.*, 2020b; Cantor *et al.*, 2020). Lopez-Barrera *et al.* (2012) reported a bycatch rate of juvenile green turtles of 13%, but with a high mortality rate (~63%) in fixed gillnet fisheries, especially in the colder periods of the year, which coincides with the months of greatest use of this gear in the region.

Some authors relate the increased catch rates in this period to a greater displacement of individuals in search of food and, consequently, a greater probability of interaction with fishing gears (Guebert -Bartholo *et al.*, 2011; Lopez-Barrera *et al.*, 2012). In this regard, according to Fuentes *et al.* (2020), a high proportion of the foraging areas used by green turtles were exposed to cumulative impacts from human activities, including small-scale fisheries. In addition, several other factors may contribute to the occurrence of bycatch, such as the type of substrate where the nets are set, the seasonality, and the immersion time of the nets, which has been pointed out as a determining factor in the survival rates of stranded sea turtles (Guebert-Bartholo *et al.*, 2011; Lopez-Barrera *et al.*, 2012). Additionally, Cantor *et al.* (2020) observed a high incidence of mortality and stranding of juvenile green turtles in the study region, emphasizing the need for identification of the key habitats for this species and the assessment of exposure to multiple threats, with a primary focus on coastal fisheries.

Regarding elasmobranchs, fixed gillnet fisheries targeting these species are quite widespread in the region (Loyola e Silva & Nakamura, 1975; Costa & Chaves, 2006; Robert & Chaves, 2006; Fuzetti, 2007; Bornatowski *et al.*, 2011; Bornatowski & Abilhoa, 2012; Chaves *et al.*, 2019; Afonso & Chaves, 2021). Fishing monitoring data (PETROBRAS, 2020) recorded about 19 tonnes of elasmobranchs landed by the Paraná fleet in 2019. In general, a significant portion of these landings is formed by neonate and juveniles, in addition to the occurrence of pregnant females (Costa & Chaves, 2006; Bornatowski *et al.*, 2009; Bornatowski *et al.*, 2011; Bornatowski & Abilhoa, 2012; Afonso, 2016; Chaves *et al.*, 2019). This fact, associated with the high incidence of threatened species in the landings (Costa & Chaves, 2006; Bornatowski *et al.*, 2011; Bornatowski & Abilhoa, 2012; Chaves *et al.*, 2019; Bernardo *et al.*, 2020), has raised concern regarding the conservation and maintenance of populations that use or depend on coastal regions for food and reproduction.

Chaves *et al.* (2019), in one year of fishery monitoring in the municipality of Matinhos, also located at the Paraná coast, recorded the landing of 4,941 elasmobranchs (~6 tons.). This amount was composed of 14 species of shark and 12 species of rays (50.7% and 49.3% of the total landed, respectively), of which 11 species were classified as threatened. Catches of elasmobranchs with gillnets (mesh sizes between 4 and 40 cm) were recorded throughout the year, but more frequently during spring and summer. These results are corroborated by previous studies (Costa & Chaves, 2006; Bornatowski *et al.*, 2011; Bornatowski & Abilhoa, 2012; Afonso, 2016; Bernardo *et al.*, 2020), which also reported landings of different threatened elasmobranch species, highlighting the strong pressure that local fishing activity exerts on the viability of these populations. Bernardo *et al.* (2020) point out that, among the shark species listed as threatened, hammerhead sharks (*S. lewini* and *S. zygaena*) are one of the most caught and traded species in the region. In general, fisheries conducted in shallow coastal areas catch small, neonatal, and immature individuals, and those conducted around the islands and in deeper areas (> 20nm) catch larger and adult/subadult animals. The sand tiger shark (*Carcharias taurus*), tiger shark (*Galeocerdo cuvier*), blacktip shark (*Carcharinhus limbatus*), dusky shark (C*archarinhus obscurus*), and hammerhead sharks (*Sphyrna lewini* and *S. zygaena*) are among the

species caught (Bornatowski *et al.*, 2011; Chaves *et al.*, 2019; Afonso & Chaves, 2021), in addition to several species of rays, also relevant in terms of marine conservation.

Regarding the Atlantic goliath grouper (*Epinephelus itajara*), although protected by a fishing moratorium that prohibits its capture throughout Brazil since 2002 (IBAMA Ordinance No. 121/2002), illegal capture with longline or spearfishing still occurs in the state (Fuzetti, 2007; Félix-Hackradt & Hackradt, 2008). The combined effect of overfishing with the loss of habitats essential for the development of this species, such as mangroves and reef structures, has possibly accelerated the population decline of groupers throughout Brazil (Giglio *et al.*, 2014; Bertoncini *et al.*, 2018).

It is noteworthy that the species of cetaceans, sea turtles, and elasmobranchs (sharks and rays) highlighted here are national conservation priorities and are included in the *National Action Plans for the Conservation of Endangered Species - NAPs* (ICMBio, 2022), Brazilian public policies implemented that address the threats of incidental catches to all the taxonomic groups mentioned in this study.

3.2.3. Changes to the natural system and impacts on human welfare

The effects of single or multiple pressures from human activities can lead to changes in the state of the natural environment, such as changes in ecosystem components and processes, which can impact the potential benefits generated for society (Elliott *et al.*, 2017). Thus, the pressures exerted by fishing activity, including small-scale fisheries, on marine megafauna can lead to changes in the natural system, such as population decline and loss of functional diversity, with consequent changes in the structure and functioning of ecosystems, and potential impact on human welfare.

Changes to the natural system have been perceived by fishers who have reported a decrease in the abundance of fish resources, including some shark species (Costa & Chaves, 2006; Fuzetti, 2007; Caldeira, 2009). The sand tiger shark (*Carcharias taurus*), for instance, was an important component among the main fish species exploited by small-scale fisheries in the region (Sadowsky, 1967; Loyola e Silva & Nakamura, 1975). However, as early as the 1960s, Sadowsky (1967) pointed to signs of overexploitation of the species, suggesting that the fishery would probably collapse, mainly due to its biological characteristics such as low fertility, large amount of pregnant females caught, and its high commercial value. Currently, the populations of *C. taurus* in Southeast/South Brazil have been decimated (ICMBio, 2018d), mainly as a consequence of the accumulation of catches by small-scale (Vooren & Klippel, 2005; Bornatowski *et al.*, 2011; Chaves *et al.*, 2019) and industrial (Occhiali et al., 2012) coastal fisheries.

In addition to the sand tiger shark, fishing activity puts pressure on different strata of the hammerhead sharks (*Sphyrna spp.*), both by the small-scale fleet operating in coastal nurseries and by the industrial fleet that catches adult individuals (Vooren & Klippel, 2005; Kotas *et al.*, 2012). In national extinction risk assessments, population decline estimates of approximately 80% have been recorded for these species (ICMBio, 2018d). The ecological function of large sharks in controlling trophic structure was demonstrated by Bornatowski *et al.* (2014a; 2017), who observed direct (con-

trolling lower levels of the food chain through predation) and indirect (trophic cascades and apparent competition) effects, as well as other ecological processes described in the global literature. According to Bornatowski *et al.* (2011), measuring whether small-scale fisheries has significantly contributed to the decline of coastal and semi-coastal sharks in the region is still a methodological challenge that demands historical data from fisheries assessment. However, the capture of high numbers of neonate and juveniles, as well as the capture of pregnant females and large adult individuals with higher reproductive potential and fecundity, suggest a potential impact on the recruitment and renewal rates of these populations (Costa & Chaves, 2006; Bornatowski *et al.*, 2011; Bornatowski *et al.*, 2014b).

In addition to elasmobranchs, the perceived reduction in populations through the reduction in incidental catches of franciscana dolphin (Rosso-Londoño, 2010; Robert *et al.*, 2012) and sea turtles (Robert *et al.*, 2012; Petrucci, 2019) has been reported in the region by small-scale fishers. Fishers who were interviewed specifically about the historical catch of franciscana dolphin believe that the population size is decreasing - however, most relate this population reduction to the decrease in fish resources that are potential food for the species (Robert *et al.*, 2012). According to those interviewed by Robert *et al.* (2012), most fishers reported that has been a reduction in sea turtle bycatches (47.3%), followed by no change (39.2%), and an increase in bycatches (13.5%). Two fishermen commented that, in fact, the current amount of turtles is less than decades ago. However, even though population declines cannot be determined for these animals, mortality is intense and increasing, according to an evaluation of strandings along the Southeast/South regions of Brazil (Cantor *et al.*, 2020),

In addition, many marine megafauna species perform seasonal migrations (Lucifora *et al.*, 2002; Kotas *et al.*, 2012; González-Carman *et al.*, 2012), moving between distinct geographic areas for feeding and breeding. As the same individuals move between these areas, they are exposed to various anthropogenic threats with potential cumulative effects. Thus, local and regional impacts on these populations have meso-scale effects, which makes megafauna conservation a multi-scale challenge. Coordinated efforts and actions are needed globally, but action is needed in regional levels and involving small-scale fishing communities (Lascelles *et al.*, 2014; De Castro *et al.*, 2021).

3.2.4. Management responses as regulatory measures

Responses to changes resulting from drivers, activities, and pressures include prevention and mitigation strategies, which require scientific support to formulate appropriate regulations, as well as economic and technological mechanisms to implement more appropriate and participatory environmental management (Elliott *et al.*, 2017). In light of this context, regulatory instruments for the protection of threatened marine fauna and regional fisheries management that contribute to the protection of marine megafauna were analyzed (see Supplementary Material).

Several international agreements, recommendations, and actions focus on the conservation of biodiversity and the protection and recovery of threatened megafauna species. These guidelines

are described in documents generated by international institutions or agreements of which Brazil is a signatory, such as the Convention on Biological Diversity (CBD), the Convention on the Conservation of Migratory Species of Wild Animals (CMS), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the International Whaling Commission (IWC), and the Food and Agriculture Organization of the United Nations (FAO). Overall, these documents consider the problem of negative interaction with fishing activities as the main threat to the conservation of marine megafauna (FAO, 2011; 2021).

At the federal level, a set of policies have been adopted, and the National Lists of Threatened Fauna Species (MMA Ordinances No. 444 and 445/2014) are one of the main instruments used as they establish immediate legal protection for any listed species, functioning as an umbrella legal framework (Peres *et al.*, 2011). Based on the identification of the species' threat category and risk of extinction, which are listed in the *Red Book of the Brazilian Fauna Threatened with Extinction* (ICMBio, 1208a), the *National Action Plans for the Conservation of Threatened Species - NAPS* (ICMBio, 2022) are organized to identify and guide priority actions to mitigate threats and risks to populations. Currently, in Brazilian jurisdictional waters, action plans for franciscana dolphin, marine cetaceans, sea turtles, sharks, and rays are in force (ICMBio, 2022). The NAPs follow a prioritization approach established by multiple stakeholders, involving representatives from government, research, and social entities.

Following national guidelines, at a regional level the lists of threatened species, the *Red Book of the Threatened Fauna in the State of Paraná*, (Mikich & Bérnils, 2004), and the *Conservation Plan for Marine Tetrapods in Paraná* (IAP, 2009) were prepared. These documents gather information about the species evaluated in this study and guidelines for the recovery of the threatened populations in the state considering a regional approach. However, it is still in the governmental and research sphere, with no social participation.

The establishment of marine protected areas has been a globally adopted ecosystem-based management strategy (Hooker & Gerber, 2004; Maxwell *et al.*, 2020). In Brazil, the establishment of a representative system of marine protected areas is being carried out through the identification of *Priority Areas for the Conservation of Brazilian Biodiversity* (MMA, 2020). This management tool identifies spatially the areas of greatest importance for the maintenance of marine biodiversity, including areas that ensure the protection of threatened and migratory species. In Paraná, the study region was identified as a priority area and of extremely high biological importance (MMA, 2020), and some protected areas within the coastal marine biome have already been established (e.g., Superagui National Park, Currais Islands Marine National Park, Guaraqueçaba Environmental Protection Area, Guaraqueçaba Ecological Station, and Ilha do Mel Ecological Station).

Furthermore, a set of federal and state fishing regulations establish rules for the sustainable use of fishing resources, giving some protection to the megafauna species. These regulations include the control of fishing effort (restrictions on fishing gear and mesh sizes) and the protection of ecosystems (fishing restricted areas). However, for bycatch mitigation strategies to be effective, they must consider a set of information, such as *i*) fishing modality and

gear characteristics; *ii*) life cycle and ecological dynamics of species; and *iii*) spatial and temporal overlap of fishing activities with critical megafauna habitats (Uhlmann & Broadhurst, 2013). In addition, these strategies should consider the socioeconomic peculiarities of the fishing activity, as well as participatory systems and spaces for dialogue to formulate conservation strategies (De Castro *et al.*, 2021), ensuring engagement, effectiveness, and positive results for the nature conservation aligned with fishing sustainability.

4. Opportunities and challenges for mitigation of threatened megafauna bycatch

Based on the assessment carried out through the *DAPSI(W)R(M)* framework, it was possible to identify knowledge gaps and more effective management strategies and actions to minimize the pressures of fishing activity on marine megafauna. Therefore, Table 2 lists the opportunities identified that promote or enhance regional research and management strategies to reduce impacts, as well as knowledge gaps and challenges for the region.

TABLE 2 – Identified opportunities and challenges that promote or limit regional strategies for reducing the bycatch of threatened marine megafauna, according to the information and knowledge compiled from the reference literature.

Research and management strategies	**Opportunities**	**Challenges**
Engagement of fishing communities in conservation actions	Participatory research that involves local communities, especially using the ethno-ecological approach, should be more widespread since it helps to promote dialogue between social actors, integration between scientific and traditional knowledge, and incorporation of this knowledge into the construction of more effective strategies for reducing bycatch.	The mistrust of fishers and fishing communities towards the work developed by researchers hinders cooperation between the traditional and scientific communities, as well as the decision making and implementation of effective conservation strategies. Thus, the creation of continuous dialogue and the building of long-term mutual trust is necessary.
	Continuous communication strategies (environmental education, lectures, dissemination material) promote the appreciation and dissemination of information about the importance of marine megafauna to the health of ecosystems, valuing sustainable practices of exploitation of marine resources and contributing to a greater engagement of society in conservation and sustainability actions.	The lack of strategies for continued participation and representativeness of the fishers in the whole process of planning, research, and decision making makes the conditions unfavorable for participatory processes.
	The generation of income for coastal communities through activities related to fauna watching ecotourism and traditional practices, when carried out in an orderly manner, can help in the valuation and protection of marine fauna, as well as in strengthening local communities.	The devaluation of fishing culture and traditional practices reduces the participation and motivation of fishers to actively participate in research actions and management processes.

Data collection and quantitative assessments of marine megafauna bycatch	Continuous monitoring of fishing activities and bycatch crucial to support and to establish appropriate policies in space/time/social realities to reduce bycatches associated with the maintenance of economic activities. This can be achieved through systematic monitoring of fisheries landings, presence of onboard observers, the use of image tracking technologies, and other forms of participatory monitoring. In this sense, the *Fishing Activity Monitoring Program** carried out in the study area collaborates with surveys of basic data on small-scale fisheries.	The lack of systematic monitoring and official fishing statistics at the national level, which provide data on fishing effort, bycaught species, seasonality, and areas of operation of the fishing fleet, makes it difficult to evaluate the impacts of fishing on marine megafauna. The collection of basic data on small-scale fisheries in the region is being carried out by the *Fishing Activity Monitoring Program**. Despite the progress in building this database, the megafauna incidentally caught are not systematically recorded at the species level, making it difficult to monitor and evaluate the catch of threatened species (e.g., the grouping of several elasmobranch species into the general category "*cações*").
Modifications and development of technologies to reduce bycatch	Modifications in the use of fishing gear (e.g., depth of fishing gear, hook type, net and mesh size) and the management and release of incidentally caught fauna are measures that can be effective in reducing megafauna bycatch but should be encouraged for evaluation and regional adjustments for the fisheries of Paraná. The development of technological modifications in fishing gear (e.g., the use of LED and pingers in gillnets, and the bycatch reduction devices - BRDs), should be tested in the region to assess the feasibility and effectiveness in minimizing bycatch.	To encourage the adherence to the use of modifications and new technologies by fishers, the development of these strategies should be a continuous and participatory process of design, experimentation, analysis, and implementation, followed by continuous monitoring and evaluation of the proposed measures and indicators of success.
Effective management measures to reduce bycatch	The set of regulations for the protection of threatened megafauna species presents general guidelines, action plans for the recovery of the species, as well as management measures to reduce bycatch. New measures and adjustments to the regulations in force should be proposed and evaluated in a participatory way involving multiple stakeholders, through a systemic approach to multi-species protection. In addition, the socioeconomic and cultural components of the fishing activity must be considered, as well as the specificities of threatened species.	In general, the fishing and environmental regulatory framework are complex, with a large number of regulations and rules that are difficult to interpret. Thus, it is necessary to establish clear, objective, and integrated rules that are easily known and feasible for enforcement actions, in addition to the broad dissemination to all stakeholders involved. Potentially impacting illegal fishing practices are observed and described in the region. Thus, the regular and systematic implementation of existing rules is necessary, through effective and enforcement, as well as the opening of

Spatial management strategies, such as protected areas and fisheries restriction areas, are effective ecosystem-based conservation strategies. Data on the spatial and temporal patterns of strandings and bycatch are essential for identifying hotspots of bycatch, helping to evaluate the effectiveness of spatial strategies in effect, and indicating new priority areas for the of threatened marine species.	spaces for discussion and search for alternative fishing practices with less impact. For the effectiveness of management measures, it is necessary to understand the universe of fishers and vessels involved in small-scale fisheries and its productive and commercial dynamics. This can be done through constant maintenance and updating of the registry of vessels and fishermen in the fishing colonies, the strengthening of the associative movements and mapping of the productive chains.

SUBTITLE: * These activities are part of IBAMA's environmental condition to Petrobras for authorization of the oil and gas exploration activities in the Santos Basin Pre-salt region (Available at https://comunicabaciadesantos.petrobras.com.br/).

SOURCE: The authors.

5. Final considerations

The *DAPSI(W)R(M)* framework highlighted the interactions between the threatened coastal marine megafauna species, the small-scale fisheries, and the management strategies involved in this relationship for the Paraná inner shelf. This model can assist in structuring and understanding of the socioecological components of the evaluated system, helping to identify opportunities and challenges for the effectiveness of management and conservation actions for marine biodiversity in the studied region, as well as strengthen recommendations and global diagnoses that involve directions for the effectiveness of these actions (FAO, 2021; De Castro *et al.*, 2021). It is important to highlight that, despite being carried out only in Paraná, the scenario of interaction between small-scale fisheries and threatened marine megafauna species is global, and the framework applied here can be reproduced for other regions as a way of comparison and search for solutions that consider a broader evaluation (for example, Southeast and South of Brazil).

Despite the evident economic, social, and cultural importance of small-scale fisheries for coastal communities, this activity exerts pressure on marine ecosystems and affects the maintenance of associated fauna. Through the literature review, a higher predominance of marine megafauna bycatch in bottom set gillnets was observed, mainly in the coastal areas of the Paraná, following international reports for fisheries (De Castro *et al.*, 2021). A factor that may intensify this interaction is the potential spatial overlap between the main fishing grounds used by fishing communities and the areas of occurrence and use by marine megafauna. Thus, the patterns of use of fishing areas and the seasonality of small-scale fisheries can reflect the levels of bycatches. Therefore, it is important to identify the areas of greatest concentration of megafauna occurrence and critical

habitats for these species, as well as the main areas of use by fishing communities, in order to establish inclusive and efficient strategies to mitigate impacts to threatened species. These results highlight the relevance of regional territorial assessments and the importance of developing conservation plans based on participatory and integrated assessments to enable assertive and more effective actions.

Small-scale fisheries are a complex and highly dynamic socioecological system, and, therefore, management strategies to mitigate bycatch must incorporate a broader interdisciplinary approach to governance, integrating environmental, social, economic, and cultural components. These components must be mapped, diagnosed, and understood by the multiple stakeholders involved in building efficient long-term alternatives and solutions through participatory approaches and engagement with coastal communities.

Furthermore, approaches such as adaptive management assist decision making as part of a constant learning process, through the implementation of conservation actions, systematic monitoring, and evaluation of adopted strategies, while learning which actions are most effective ("learning by doing") (Berkes *et al.*, 2001; Armitage *et al.*, 2009). Thus, the opportunities and challenges identified through the compilation and review of current literature should be incorporated into research strategies and management measures for biodiversity conservation in the region. Special attention should be given to strengthening mechanisms for systematic monitoring of fisheries interactions with threatened species (e.g., as per guidelines in FAO, 2021), in addition to evaluating the effectiveness of management measures currently adopted.

Although the present study focuses on small-scale fisheries, several other human activities, each with its drivers, pressures, and impacts act on the same system, amplifying the dynamics of interaction and impacts on the marine megafauna (Pirotta *et al.*, 2022). Elliott *et al.* (2017) emphasizes the need to understand the relationships between different uses of the marine environment, represented by the activities and their associated pressures within each *DAPSI(W)R(M)* cycle, integrating social, economic, and ecological components. Thus, a future evaluation of the networked and spatially interconnected *DAPSI(W)R(M)* approach may provide a better understanding of the complexity of the marine system, including all these components, and providing input for the ecosystem approach and integrated coastal zone management.

Acknowledgements

The authors would like to thank the Coordination for the Improvement of Higher Education Personnel (CAPES) and Araucária Foundation for the financial support (Process 88882.168574/2018-01), and to the Academic Publishing Advisory Center (Centro de Assessoria de Publicação Acadêmica, CAPA – www.capa.ufpr.br) of the Federal University of Paraná (UFPR) for assistance with English language translation and developmental editing.

References

Afonso, M. G. *Dinâmicas da pesca de emalhe em Matinhos/PR*: implicações para a conservação dos recursos pesqueiros. Curitiba, Dissertação (Mestrado em Zoologia) – UFPR, 2016.

Afonso, M. G.; Chaves, P. T.C. A pesca de emalhe costeiro de pequena escala no litoral do Paraná: um estudo de caso para a conservação. *Biodiversidade e Conservação Marinha*, 10(1), 2021. doi: 10.37002/revistacepsul.vol10.1754e2021001

Alfaro-Shigueto, J.; Mangel, J. C.; Bernedo, F.; Dutton, P. H.; Seminoff, J. A.; Godley, B. J. Small-scale fisheries of Peru: a major sink for marine turtles in the Pacific. *Journal of Applied Ecology*, 48(6), 1432-1440, 2011. doi: 10.1111/j.1365-2664.2011.02040.x.

Andriguetto-Filho, J. M. Sistemas técnicos de pesca no litoral do Paraná: caracterização e tipificação. In: Raynaut, C.; Zanoni, M.; Lana, P.C. (Orgs.). *Desenvolvimento e Meio Ambiente – em busca da interdisciplinaridade.* Curitiba: Editora UFPR, p. 213-233, 2002.

Andriguetto-Filho, J. M. A mudança técnica e o processo de diferenciação dos sistemas de produção pesqueira do Litoral do Paraná, Brasil. *Desenvolvimento e Meio Ambiente*, 8(1), 43-58, 2003. doi: 10.5380/dma.v8i0.22050

Andriguetto-Filho, J. M.; Chaves, P. T.; Santos, C.; Liberati, S. A. Diagnóstico da pesca no litoral do estado do Paraná. In: Isaac, V. J.; Martins, A. S.; Haimovici, M.; Andriguetto-Filho, J. M. (Orgs.). *A pesca marinha e estuarina do Brasil no início do século XXI*: recursos, tecnologias, aspectos socioeconômicos e institucionais. Belém: Editora Universitária UFPA, p. 117-140, 2006.

Andriguetto-Filho, J. M.; Krul, R.; Feitosa, S. Contradições históricas entre gestão e fomento e a evolução da pesca de arrasto de camarão na plataforma interna do paraná. In: Haimovini, M.; Andriguetto-Filho, J. M.; Sunye, P. S. (Orgs.). *A pesca marinha e estuarina no Brasil: estudos de caso multidisciplinares*. Rio Grande: Editora FURG, p. 87-99, 2014.

Angulo, R. J.; Soares, C. R.; Marone, E.; Souza, M. C.; Odreski, L. L. R.; Noernberg, M. A. Paraná. In: Muehe, D.C.E.H. (Org.). *Erosão e progradação do litoral brasileiro*. Brasília: MMA, p. 347-400, 2006.

Armitage, D. R.; Plummer, R.; Berkes, F.; Arthur, R. I.; Charles, A. T.; Davidson-Hunt, I. J.; Diduck, A. P.; Doubleday, N. C.; Johnson, D. S.; Marschke, M.; McConney, P.; Pinkerton, E. W.; Wollenberg, E. K. Adaptive co-management for social-ecological complexity. *Frontiers in Ecology and the Environment*, 6(2), 95-102, 2008. doi: 10.1890/070089

Berkes, F.; Mahon, R.; McConney, P.; Pollnac, R.; Pomeroy, R. *Managing small-scale fisheries: alternative directions and methods*. Canadá: International Development Research Centre, 2001.

Bernardo, C.; Adachi, A. M. C.; Cruz, P.; Foresti, F.; Loose, R. H.; Bornatowski, H. The label “cação" is a shark or a ray and can be a threatened species! Elasmobranch trade in Southern Brazil unveiled by DNA barcoding. *Marine Policy*, 116(1), 2020. doi: 10.1016/j.marpol.2020.103920

Bertoncini, A. A.; Aguilar-Perera, A.; Barreiros, J.; Craig, M. T.; Ferreira, B. P.; Koenig, C. *Epinephelus itajara* (errata version published in 2019). The IUCN red list of threatened species, 2018. doi: 10.2305/IUCN.UK.2018-2.RLTS.T195409A145206345.en

Borges, L. M. M.; Maulin, G. C.; Andriguetto, J. M. Analysis of income sources of fishers' families on the coast of the state of Parana, Brazil. *Journal of Coastal Research*, 39(1), 1267–1271, 2006.

Bornatowski, H. A parturition and nursery area for *Carcharhinus limbatus* (Elasmobranchii, Carcharhinidae) off the coast of Paraná, Brazil. Brazilian *Journal of Oceanography*, 56(4), 317-319, 2008. doi: 10.1590/S1679-87592008000400008

Bornatowski, H.; Abilhoa, V.; Charvet-Almeida, P. Elasmobranchs of the Paraná Coast, southern Brazil, south-western Atlantic. *Marine Biodiversity Records*, 2(1), 1-6, 2009 doi:

10.1017/S1755267209990868

Bornatowski, H.; Vitule, J. R. S.; Abilhoa, V.; Corrêa, M. F. M. Unconventional fishing for large sharks in the State of Paraná, southern Brazil: a note of concern. *Journal of Applied Ichthyology*, 27(4), p. 1108-1111, 2011. doi: 10.1111/j.1439-0426.2010.01600.x

Bornatowski, H.; Abilhoa, V. *Tubarões e raias capturados pela pesca artesanal no Paraná*: guia de identificação. Curitiba: Hori Consultoria Ambiental, 2012.

Bornatowski, H.; Navia, A. F.; Braga, R. R.; Abilhoa, V.; Corrêa, M. F. M. Ecological importance of sharks and rays in a structural food web analysis in southern Brazil. *ICES Journal of Marine Science*, 71(7), 1586-1592, 2014a. doi: 10.1093/icesjms/fsu025

Bornatowski, H.; Braga, R. R.; Vitule, J. R. S. Threats to sharks in a developing country: the need for effective and simple conservation measures. *Natureza & Conservação*, 12(1), 11-18, 2014b. doi: 10.4322/natcon.2014.003

Bornatowski, H.; Angelini, R.; Coll, M.; Barreto, R. R. P.; Amorim, A. F. Ecological role and historical trends of large pelagic predators in a subtropical marine ecosystem of the South Atlantic. *Reviews in Fish Biology and Fisheries*, 28(1), 241-259, 2017. doi: 10.1007/s11160-017-9492-z

Bueno, L. S.; Bertoncini, A. A.; Koenig, C. C.; Coleman, F. C.; Freitas, M. O.; Leite, J. R.; Souza, T. F.; Hostim-Silva, M. Evidence for spawning aggregations of the endangered Atlantic goliath grouper *Epinephelus itajara* in southern Brazil. *Journal of fish biology*, 89(1), 876-889, 2016. doi: 10.1111/jfb.13028

Caldeira, G. A. *Diagnóstico socioecológico da pesca no município de Pontal do Paraná (PR)*: subsídios para a gestão compartilhada. Pontal do Paraná, Dissertação (Mestrado em Sistemas Costeiros e Oceânicos) – UFPR, 2009.

Cantor, M.; Barreto, A. S.; Taufer, R. M.; Giffoni, B.; Castilho, P. V.; Maranho, A.; Beatriz, C.; Kolesnikovas, C.; Godoy, D.; Rogério, D. W.; Dick, J. L.; Groch, K. R.; Rosa, L.; Cremer, M. J.; Cattani, P. E.; Valle, R. R.; Domit, C. High incidence of sea turtle stranding in the southwestern Atlantic Ocean. *ICES Journal of Marine Science*, 77(5), 1–15, 2020. doi: 10.1093/icesjms/fsaa073

Chaves, P. T. C.; Robert, M. C. Extravio de petrechos e condições para ocorrência de pesca-fantasma no litoral norte de Santa Catarina e sul do Paraná. *Boletim do Instituto de Pesca*, 35(3), 513-519, 2009. Disponível em: https://www.pesca.agricultura.sp.gov.br/35_3_513-519.pdf

Chaves, P. T. C.; Almeida, M. P.; Platner, M. Tubarões e raias como captura incidental na pesca artesanal do litoral do Paraná: condição reprodutiva e variações sazonais em composição e abundância. *Arquivos de Ciências do Mar*, 52(2), 7-23, 2019. doi: 10.32360/acmar.v52i2.39966

Costa, L.; Chaves, P. T. C. Elasmobrânquios capturados pela pesca artesanal na costa sul do Paraná e norte de Santa Catarina, Brasil. *Biota Neotropica*, 6(3), 1-10, 2006. doi: 10.1590/S1676-06032006000300007

Crespo, E. A.; Alacorn, D.; Alonso, M.; Bazzalo, M.; Borobia, M.; Cremer, M.; Filla, G.; Lodi, L.; Magalhaes, F.; Marigo, J.; Queiróz, H. L.; Reynolds, J. E.; Schaeffer, Y.; Dorneles, P. R.; Lailson-Brito, J.; Wetzel, D. L. Report of the working group on major threats and conservation. *Latin American Journal of Aquatic Mammals*, 8(1-2), 47-56, 2010. doi: 10.5597/lajam00153

Danilewicz, D.; Moreno, I.; Ott, P.; Tavares, M.; Azevedo, A. F.; Secchi, E. R.; Andriolo, A. Abundance estimates for a threatened population of franciscana dolphins in southern coastal Brazil: uncertainties and management implications. *Journal of the Marine Biological Association of the United Kingdom*, 90(8), 1649-1657, 2010. doi: 10.1017/S0025315409991482

Davidson, L. N. K.; Dulvy, N. K. Global marine protected areas to prevent extinctions. *Nature Ecology & Evolution*, 1(2), 2017. doi: 10.1038/s41559-016-0040

De Castro, R. M.; Broadhurst, M. K.; Domit, C. Towards mitigating marine-mammal and sea-turtle mortalities in small-scale fisheries. *Regional Studies in Marine Science*, 48, 2021. doi: 10.1016/j.rsma.2021.101999

Derrick, D. H.; Cheok, J.; Dulvy, N. K. Spatially congruent

sites of importance for global shark and ray biodiversity. PLoS ONE, 15(7), 1-19, 2020. doi: 10.1371/journal.pone.023555924(2), 111-127, 2014. doi: 10.1002/aqc.2512

Domiciano, I. G., Domit, C., Broadhurst, M. K.; Koch, M. S.; Bracarense, A. P. F. R. L. Assessing disease and mortality among small cetaceans stranded at a world heritage site in Southern Brazil. *PLoS ONE*, 11(2), 1-17, 2016. doi: 10.1371/journal.pone.0149295

Domit, C., Barreto, A.S., Bertozzi, C. P.; Vidal, L. G.; Cremer, M. J.; Zerbini, A. N. Threats to franciscana dolphins (*Pontoporia blainvillei*) in FMA II: a review and future recommendations. *Report to the Scientific Committee of the International Whaling Commission*, SC/68B/SM, 2020a. Disponível em: <https://archive.iwc.int/pages/search.php?search=!collection29958&bc_from=themes#>. Acesso em: dez. 2021

Domit, C.; Rosa, L.; Possatto, F.; Torre, F.; Altoe, M.; Cabral, A.; Barreto, A. S. Strandings of marine mammals, sea turtles and seabirds along the Paraná coast, Brazil, from 2015 to 2018. *Dryad Dataset*, 2020b. doi: 10.5061/dryad.k0p2ngf48

Domit, C., Caballero, S., Miranda, A. et al. Report of the *Sotalia guianensis* pre-assessment workshop: main results and status of the current knowledge. *Journal of Cetacean Research and Management*, 22(1), 333-378, 2021. Disponível em: <https://archive.iwc.int/pages/view.php?ref=17766&k=>. Acesso em: dez. 2021.

Dulvy, N. K.; Sadovy, Y.; Reynolds, J. D. Extinction vulnerability in marine populations. *Fish and Fisheries*, 4(1), 25-64, 2003. doi: 10.1046/j.1467-2979.2003.00105.x

Elliott, M.; Burdon, D.; Atkins, J. P.; Borja, A.; Cormier, R.; Jonge, V. N.; Turner, R. K. And DPSIR begat DAPSI(W)R(M)! – A unifying framework for marine environmental management. *Marine Pollution Bulletin*, 118(1-2), 27-40, 2017. doi: 10.1016/j.marpolbul.2017.03.049

Estes, J.; Terborgh, J.; Brashares, J. *et al.* Trophic downgrading of planet Earth. *Science*, 333, p. 301-306, 2011. doi: 10.1126/science.1205106

European Commission, Eurostat. *Towards environmental pressure indicators for the EU*. Luxembourg: Publications Office, 1999. Disponível em: <https://op.europa.eu/en/publication-detail/-/publication/80ce03d9-fc51-4bb6-a6fc-c3997efa3525>. Acesso em: dez. 2021.

FAO – Food and Agriculture Organization of the United States. *Increasing the contribution of small-scale fisheries to poverty alleviation and food security*. Roma: FAO, 2005.

FAO – Food and Agriculture Organization of the United States. *International guidelines on bycatch management and reduction of discards.* Roma: FAO, 2011.

FAO – Food and Agriculture Organization of the United States. *Fisheries operations: Guidelines to prevent and reduce bycatch of marine mammals in capture fisheries*. Roma: FAO, 2021.

Félix-Hackradt, F. C.; Hackradt, C. W. Populational study and monitoring of the goliath grouper, *Epinephelus itajara* (Lichtenstein, 1822), in the coast of Paraná, Brasil. *Natureza e Conservação*, 6(2), 141-156, 2008.

Fiedler, F. N.; Pazeto, D. M.; Valle de Lacerda, L. L. High mortality rates of *Chelonia mydas* in a small-scale bottom gillnet fishery in the south-west Atlantic Ocean. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 30(10), 1902-1909, 2020. doi: 10.1002/aqc.3370

Filla, G. D. F.; Monteiro-Filho, E. L. A. Group structure of *Sotalia guianensis* in the bays on the coast of Paraná State, south of Brazil. *Journal of the Marine Biological Association of the United Kingdom*, 89(5), 985-993, 2009. doi: 10.1017/S0025315409002926

Fuentes, M. M. P. B.; Wildermann, N.; Gandra, T. B.; Domit, C. Cumulative threats to juvenile green turtles in the coastal waters of southern and southeastern Brazil. *Biodiversity and Conservation*, 29, 1783-1803, 2020. doi: 10.1007/s10531-020-01964-0

Fuzetti, L. *A pesca na Ilha do Mel (Paraná-Brasil)*: pescadores, atividades e recursos pesqueiros. Curitiba, Dissertação (Mestrado em Zoologia) – UFPR, 2007.

Gallo, B. M. G.; Macedo, S.; Giffoni, B. B.; Becker, J.

H.; Barata, P. C. R. Sea turtle conservation in Ubatuba, southeastern Brazil, a feeding area with incidental capture in coastal fisheries. *Chelonian Conservation and Biology*, 5(1), 93-101, 2006. doi: 10.2744/1071-8443(2006)5[93:STCIUS]2.0.CO;2

Gama, L. R.; Domit, C.; Broadhurst, M. K.; Fuentes, M. M. P. B.; Millar, R. B. Green turtle *Chelonia mydas* foraging ecology at 25°S in the western Atlantic: evidence to support a feeding model driven by intrinsic and extrinsic variability. *Marine Ecology Progress Series*, 542, 209-219, 2016. doi: 10.3354/meps11576

Gama, L. R.; Fuentes, M. M. P. B.; Trevisani, T. H.; Pellizzari, F.; Lemons, G. E.; Seminoff, J. A.; Domit, C. Trophic ecology of juvenile green turtles in the Southwestern Atlantic Ocean: insights from stable isotope analysis and niche modelling. *Marine Ecology Progress Series*, 678, 139-152, 2021. doi: 10.3354/meps13868

Giglio, V. J.; Bertoncini, A. A; Ferreira, B. P.; Hostim-Silva, M.; Freitas, M. O. Landings of goliath grouper, *Epinephelus itajara*, in Brazil: despite prohibited over ten years, fishing continues. *Natureza e Conservação*, 12(2), 118-123, 2014. doi: 10.1016/j.ncon.2014.09.004

González-Carman, V. G.; Falabella, V.; Maxwell, S.; Albareda, D.; Campagna, C.; Mianzan, H. Revisiting the ontogenetic shift paradigm: the case of juvenile green turtles in the SW Atlantic. *Journal of Experimental Marine Biology and Ecology*, 429, 64-72, 2012. doi: 10.1016/j.jembe.2012.06.007

Guebert-Bartholo, F. M., Barletta, M., Costa, M. F., Monteiro-Filho, E. L. A. Using gut contents to assess foraging patterns of juvenile green turtles *Chelonia mydas* in the Paranaguá Estuary, Brazil. *Endangered Species Research*, 13(2), 131-143, 2011. doi: 10.3354/esr00320

Guebert, F. M.; Barletta, M.; Costa, M. F. Threats to sea turtle populations in the Western Atlantic: poaching and mortality in small-scale fishery gears. *Journal of Coastal Research*, 65, 42-47, 2013. doi: 10.2112/SI65-008.1

Hackradt, C. W.; Félix-Hackradt, F. C. Assembleia de peixes associados a ambientes consolidados no litoral do Paraná, Brasil: uma análise qualitativa com notas sobre sua bioecologia. *Papéis Avulsos de Zoologia*, 49(31), 389–403, 2009. doi: 10.1590/s0031-10492009003100001

Hall, M. A.; Alverson, D. L.; Metuzals, K. I. By-catch: problems and solutions. *Marine Pollution Bulletin*, 41(1–6), 204-219, 2000. doi: 10.1016/S0025-326X(00)00111-9

Heithaus, M. R.; Frid, A.; Wirsing, A. J.; Worm, B. Predicting ecological consequences of marine top predator declines. *Trends in Ecology and Evolution*. 23(4), 202-210, 2008. doi: 10.1016/j.tree.2008.01.003

Hooker, S. K.; Gerber, L. R. Marine reserves as a tool for ecosystem-based management: the potential importance of megafauna. *BioScience*, 54(1), 27-39, 2004. doi: 10.1641/0006-3568(2004)054[0027:MRAATF]2.0.CO;2

Isaac, V. J.; Martins, A. S.; Haimovici, M.; Andriguetto-Filho, J. M. *A pesca marinha e estuarina do Brasil no início do século XXI*: recursos, tecnologias, aspectos socioeconômicos e institucionais. Belém: UFPA, 2006.

IAP – Instituto Ambiental do Paraná. *Plano de conservação para tetrápodes marinhos no Paraná*. Projeto Paraná Biodiversidade, 2009. Disponível em: http://www.conexaoambiental.pr.gov.br/Pagina/Conservacao-da-Natureza.

IBGE – Instituto Brasileiro de Geografia e Estatística. População estimada em 2021, segundo os municípios, Paraná, Brasil. Disponível em: <http:www.cidades.ibge.gov.br> Acesso em: jan. 2022.

ICMBio – Instituto Chico Mendes de Conservação da Biodiversidade. *Livro vermelho da fauna brasileira ameaçada de extinção, volume I*. Brasília, DF: ICMBio/MMA, 2018a.

ICMBio – Instituto Chico Mendes de Conservação da Biodiversidade. *Livro vermelho da fauna brasileira ameaçada de extinção, volume II*: mamíferos. Brasília, DF: ICMBio/MMA, 2018b.

ICMBio – Instituto Chico Mendes de Conservação da Biodiversidade. *Livro vermelho da fauna brasileira ameaçada de extinção, volume IV*: répteis. Brasília, DF: ICMBio/MMA, 2018c.

ICMBio – Instituto Chico Mendes de Conservação da Biodiversidade. *Livro vermelho da fauna brasileira ameaçada de extinção, volume VI*: peixes. Brasília, DF: ICMBio/MMA, 2018d.

ICMBio – Instituto Chico Mendes de Conservação da Biodiversidade. *Planos de ação nacional. 2022*. Disponível em: <https://www.gov.br/icmbio/pt-br/assuntos/biodiversidade/pan>. Acesso em: jan. 2022.

IUCN – International Union for Conservation of Nature. *The IUCN red list of threatened species*. Version 2021-1. Disponível em: <https://www.iucnredlist.org>. Acesso em: nov. 2020.

Komoroske, L. M.; Lewison, R. L. Addressing fisheries bycatch in a changing world. *Frontiers in Marine Science*, 2, 1–11, 2015. doi: 10.3389/fmars.2015.00083

Kotas, J. E., Petrere, M., Santos, R. A.; Bustamante, A.; Lin, C. F.; Menezes, A. A. S.; Micheleti, E. L. V. The horizontal migration of hammerhead sharks along the southern Brazilian coast, based on their explotation pattern and considerations about the impact of anchored gillnets activities on these species. *Revista CEPSUL Biodiversidade e Conservação Marinha*, 3(1), 45-68, 2012. doi: 10.37002/revistacepsul.v%25v.32245-68

Lana, P. C.; Marone, E.; Lopes, R.M.; Machado, E.C. The subtropical estuarine complex of Paranaguá Bay, Brazil. In: Seeliger, U.; Kferve, B. (Orgs.). *Coastal Marine Ecosystem of Latin America*, 144, 131-145, 2001. doi: 10.1007/978-3-662-04482-7_11

Lascelles, B.; Di-Sciara, G. N.; Agardy, T. Cuttelod, A.; Eckert, S.; Glowka, L.; Hoyt, E.; Llewellyn, F.; Louzao, M.; Ridoux, R.; Tetley, M. J. Migratory marine species: their status, threats, and conservation management needs. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 24(2), 111-127, 2014. doi: 10.1002/aqc.2512

Lewison, R. L., Crowder, L. B.; Read, A. J.; Freeman, S. A. Understanding impacts of fisheries bycatch on marine megafauna. *Trends in Ecology and Evolution*, 19(11), 598-604, 2004. doi: 10.1016/j.tree.2004.09.004

Lewison, R. L., Soykan, C. U.; Cox, T.; Peckham, H.; Pilcher, N.; LeBoeuf, N.; McDonald, S.; Moore, J.; Safina, C.; Crowder, L. B. Ingredients for addressing the challenges of fisheries bycatch, *Bulletin of Marine Science*, 87(2), 235–250, 2011. doi: 10.5343/bms.2010.1062

Lewison, R. L.; Crowder, L. B.; Wallace, B. P. et al. Global patterns of marine mammal, seabird, and sea turtle bycatch reveal taxa-specific and cumulative megafauna hotspots. *Proceedings of the National Academy of Sciences*, 111(14), 5271-5276, 2014. doi: 10.1073/pnas.1318960111

Lewison, R. L.; Rudd, M. A.; Al-Hayek, W.; Baldwin, C.; Beger, M.; Lieske, S. N.; Jones, C.; Satumanatpan, S.; Junchompoo, C.; Hines, E. How the DPSIR framework can be used for structuring problems and facilitating empirical research in coastal systems, *Environmental Science and Policy*, 56, 110-119, 2016. doi: 10.1016/j.envsci.2015.11.001

López-Barrera, E. A.; Longo, G. O.; Monteiro-Filho, E. L. A. Incidental capture of green turtle (*Chelonia mydas*) in gillnets of small-scale fisheries in the Paranaguá Bay, Southern Brazil. *Ocean and Coastal Management*, 60, 11-18, 2012. doi: 10.1016/j.ocecoaman.2011.12.023

Loyola e Silva, J.; Nakamura, I. T. Produção do pescado no litoral do Paraná. *Acta Biológica Paranaense*, 4(3-4), 75-119, 1975.

Lucifora, L. O.; Menni, R. C.; Escalante, A. H. Reproductive ecology, and abundance of the sand tiger shark, *Carcharias taurus*, from the southwestern Atlantic. *ICES Journal of Marine Science*, 59(3), 553-561, 2002. doi: 10.1006/jmsc.2002.1183

Marcovaldi, M. A.; Sales, G.; Thomé, J. C. A.; Dias da Silva, A. C. C.; Gallo, B. M. G.; Lima, E. H. S. M.; Lima, E. P.; Bellini, C. Sea turtles and fishery interactions in Brazil: identifying and mitigating potential conflicts. *Marine Turtle Newsletter*, 112, 4-8, 2006.

Maxwell, S.; Cazalis, V.; Dudley, N. *et al* Area-based conservation in the twenty-first century. *Nature*, 586, 217-227, 2020. doi: 10.1038/s41586-020-2773-z

Mendonça, J. T.; Lucena, A. C. M.; Muehlmann, L. D.; Medeiros, R. P. Socioeconomia da pesca no litoral do estado do Paraná (Brasil) no período de 2005 a 2015. *Desenvolvimento e Meio Ambiente*, 41(1), 140-157, 2017. doi: 10.5380/dma.v41i0.49194

Mikich, S. B.; Bérnils, R. S. *Livro vermelho da fauna ameaçada no estado do Paraná*. Curitiba: Instituto Ambiental do Paraná, 2004. CD-ROM. Disponível em: <http://www.conexaoambiental.pr.gov.br/Pagina/Livro-Vermelho-da-Fauna-Ameacada-no-Estado-do-Parana-0> Acesso em: jan. 2022.

Miranda, A. V. *Estimativa de densidade e tamanho populacional de botos-cinza, Sotaliaguianesis, no Complexo Estuarino de Paranaguá, Paraná*. Pontal do Paraná, Dissertação (Mestrado em Sistemas Costeiros e Oceânicos) – UFPR, 2017.

MMA – Ministério do Meio Ambiente. *Portaria n.º 444, de 17 de dezembro de 2014*. Lista nacional oficial de espécies da fauna ameaçadas de extinção. Brasília: DOU de 18/12/2014a.

MMA – Ministério do Meio Ambiente. *Portaria n.º 445, de 17 de dezembro de 2014*. Lista nacional oficial de espécies da fauna ameaçadas de extinção – peixes e invertebrados aquáticos. Brasília: DOU de 18/12/2014b.

MMA – Ministério do Meio Ambiente. *Áreas prioritárias para a conservação da biodiversidade brasileira*. 2020. Disponível em: < http://areasprioritarias.mma.gov.br/ > Acesso em: nov. 2020.

MMA – Ministério do Meio Ambiente. *Sítios Ramsar*. 2021. Disponível em: <http://antigo.mma.gov.br/processo-eletronico/item/8564>. Acesso em: dez. 2021.

Moura, S. P. G.; Cantor, M.; Broadhurst, M. K.; Domit, C. Environmental and behavioral factors influencing individual variation in spatial use by Guiana dolphins (*Sotalia guianensis*). *Journal of Mammalogy*, 102(4), 1009-1019, 2021. doi: 10.1093/jmammal/gyab056

MPA – Ministério da Pesca e Aquicultura; MMA – Ministério do Meio Ambiente. *Instrução Normativa n.° 10, de 10 de junho de 2011*. Brasília: DOU de 13/06/2011.

Myers, R. A.; Baum, J. K.; Shepherd, T. D.; Powers, S. P.; Peterson, C. H. Cascading effects of the loss of apex predatory sharks from a coastal ocean. *Science*, 315(5820), 1846-1850, 2007. doi: 10.1126/science.1138657

Occhialini, D. S.; Rodrigues, A. M.; Kotas, J. E. Caracterização e análise comparativa da pesca industrial de emalhe-de-fundo costeiro, considerando a evolução física da frota a partir de 1995 e a produção pesqueira entre 2001 e 2010. *Revista Cepsul: Biodiversidade e Conservação Marinha*, 3(1), 133-138, 2012. doi: 10.37002/revistacepsul.v%25v.3171-21

Ott, P. H.; Secchi, E. R.; Moreno, I. B.; Danilewicz, D.; Crespo, E. A.; Bordino, P.; Ramos, R.; Di Beneditto, A. P.; Bertozzi, C.; Bastida, R.; Zanelatto, R.; Perez, J.; Kinas, P. G. Report of the working group on fishery interactions. *Latin American Journal of Aquatic Mammals*, 1(1), 55-64, 2002. doi: 10.5597/lajam00008

Patrício, J.; Elliot, M.; Mazik, K.; Papadopoulou, K. N.; Smith, C. J. DPSIR-Two decades of trying to develop a unifying framework for marine environmental management? *Frontiers in Marine Science*, 3, 1-14, 2016. doi: 10.3389/fmars.2016.00177

Paraná. *PDS litoral 2035*: plano para o desenvolvimento sustentável do litoral do Paraná, 2019. Disponível em: <www.planejamento.pr.gov.br/Pagina/Plano-de-Desenvolvimento-Sustentavel-do-Litoral-do-Parana-PDSLitoral>. Acesso em: jan. 2022.

Peckham, S. H.; Maldonado-Dias, D.; Walli, A.; Ruiz, G.; Crowder, L. B.; Nichols, W. J. Small-scale fisheries bycatch jeopardizes endangered pacific loggerhead turtles. *PLoS ONE*, 2(10), 1-6, 2007. doi: 10.1371/journal.pone.0001041

Peckham, S. H.; Maldonado-Dias, D.; Koch, V.; Mancini, A.; Gaos, A.; Tinker, M. T.; Nichols, W. J. High mortality of loggerhead turtles due to bycatch, human consumption and strandings at Baja California Sur, Mexico, 2003 to 2007. *Endangered Species Research*, 5, 171-183, 2008. doi: 10.1007/978-1-4020-6078-6_8

Peres, M. B., Vercillo, U. E.; Dias, B. F. de S. Avaliação do estado de conservação da fauna brasileira e a lista de espécies ameaçadas: o que significa, qual sua importância, como fazer? *Biodiversidade Brasileira*, 1, 45-48, 2011.

PETROBRAS – Petróleo Brasileiro S.A. *Projeto de caracterização socioeconômica da atividade de pesca e aquicultura na Bacia de Santos PCSPA-BS,* 2015. Disponível em: <https://comunicabaciadesantos.petrobras.com.br/programa-ambiental/projeto-de-caracterizacao-socioeconomica-da-pesca-e-aquicultura-pcspa-bs.html>. Acesso em: out. 2021.

PETROBRAS – Petróleo Brasileiro S.A. *Projeto de monitoramento da atividade pesqueira da Bacia de Santos PMAP-BS (jul-dez 2019)*, 2020. Disponível em: <https://comunicabaciadesantos.petrobras.com.br/programa-ambiental/projeto-de-monitoramento-da-atividade-pesqueira-pmap.html>. Acesso em: out. 2021.

Petrucci, I. N. *A pesca artesanal e as tartarugas marinhas na Ilha do Mel, Paraná*: aspectos etnobiológicos visando à conservação. Pontal do Paraná, Dissertação (Mestrado em Sistemas Costeiros e Oceânicos) – UFPR, 2019.

Petticrew, M.; Roberts, H. *Systematic reviews in the social sciences*: a practical guide. Blackwell Publishing, 2008.

Pierri, N.; Angulo, R. J.; Souza, M. C.; Kim, M. K. A ocupação e o uso do solo no litoral paranaense: condicionantes, conflitos e tendências. *Desenvolvimento e Meio Ambiente*, 13, 137-167, 2006. doi: 10.5380/dma.v13i0

Pina, J. V.; Chaves, P. T. A pesca de tainha e parati na Baía de Guaratuba, Paraná, Brasil. *Acta Biológica Paranaense*, 34(1), 103-113, 2005.

Pirotta, E.; Thomas, L.; Costa, D. P.; Hall, A. J.; Harris, C. M.; Harwood, J.; Kraus, S. D.; Miller, P. J. O.; Moore, M. J.; Photopoulou, T.; Rolland, R. M.; Schwacke, L.; Simmons, S. E.; Southall, B. L.; Tyack, P. T. Understanding the combined effects of multiple stressors: a new perspective on a longstanding challenge. *Science of The Total Environment*, 821, 2022.

Przbylski, C. B.; Monteiro-Filho, E. L. A. Interação entre pescadores e mamíferos marinhos no litoral do Estado do Paraná – Brasil. *Biotemas*, 14(2), 141-156, 2001.

Robert, M. D. C.; Chaves, P. D. C. Dinâmica da atividade pesqueira artesanal em duas comunidades da região litorânea limítrofe Santa Catarina-Paraná, Brasil. *Boletim do Instituto de Pesca*, 32(1), 15-23, 2006.

Robert, M. C.; Domit, C.; Rosa, L. *Relatório Técnico do Projeto INTERMAR*. Associação MarBrasil e Centro de Estudos do Mar/UFPR, 2012.

Rosas, F. C. W.; Monteiro-Filho, E. L.; Oliveira, M. R. Incidental catches of franciscana (Pontoporia blainvillei) on the southern coast of São Paulo state and the coast of Paraná state, Brazil. *Latin American Journal of Aquatic Mammals*, 1(1), 161-167, 2002. doi: 10.5597/lajam00020

Rosso-Londoño, M. C. *Caracterização da mortalidade de cetáceos no litoral do estado do Paraná e sua relação com a pesca*. Pontal do Paraná, Dissertação (Mestrado em Sistemas Costeiros e Oceânicos) – UFPR, 2010.

Sadowsky, V. Selachier aus dem Litoral von Sao Paulo, Brasilien. *Beitrage zur Neotropischen Fauna*, 5(2), 71-88, 1967. doi: 10.1080/01650526709360398

Santos, M. C. O.; Oshima, J. E. F.; Silva, E. Sightings of franciscana dolphins (*Pontoporia blainvillei*): the discovery of a population in the Paranaguá estuarine complex, southern Brazil. *Brazilian Journal of Oceanography*, 57(1), 57-63, 2009. doi: 10.1590/S1679-87592009000100006

Schipper, J.; Chanson, J. S.; Chiozza, F. et al. The status of the world's land and marine mammals: diversity, threat, and knowledge. *Science*, 322, 225-230, 2008. doi: 10.1126/science.1165115

Secchi, E. R.; Cremer, M. J.; Danilewicz, D.; Lailson-Brito, J. A synthesis of ecology, human-related threats, and conservation perspectives for the endangered franciscana dolphin. *Frontiers in Marine Science*, 8, 2021. doi: 10.3389/fmars.2021.617956

Soykan, C. U.; Moore, J. E.; Zydelis, R.; Crowder, L. B.; Safina, C.; Lewison, R. L. Why study bycatch? An introduction to the Theme Section on fisheries bycatch. *Endangered*

Species Research, 5, 91-102, 2008. doi: 10.3354/esr00175

Sucunza, F.; Danilewicz, D.; Andriolo, A.; Azevedo, A. F.; Secchi, E. R.; Zerbini, A. N. Distribution, habitat use, and abundance of the endangered franciscana in southeastern and southern Brazil. *Marine Mammal Science*, 36(2), 421-435, 2020. doi: 10.1111/mms.12650

Tavares, D. C.; Moura, J. F.; Acevedo-Trejos, E.; Merico, A. Traits shared by marine megafauna and their relationships with ecosystem functions and services. *Frontiers in Marine Science*, 6, 1-12, 2019. doi: 10.3389/fmars.2019.00262

Uhlmann, S. S.; Broadhurst, M. K. Mitigating unaccounted fishing mortality from gillnets and traps. *Fish and Fisheries*, 16(2), 183-229, 2013. doi: 10.1111/faf.12049

UNESCO – United Nations Educational, Scientific and Cultural Organization. *Convention concerning the protection of the world cultural and natural heritage: Atlantic Forest South/East Brazil*. World Heritage Centre, 1999.

Vasconcellos, M.; Diegues, A. C.; Salles, R. Limites e possibilidades na gestão da pesca artesanal costeira. In: Lobo, A. (Org.). *Nas redes da pesca artesanal costeira*. Brasília: Edições IBAMA, Brasília, 2007.

Vooren, C. M.; Klippel, S. *Ações para a conservação de tubarões e raias no sul do Brasil*. Porto Alegre: Igaré, 2005.

Wallace, B. P.; Kot, C. Y.; DiMatteo, A. D.; Lee, T.; Crowder, L. B.; Lewison, R. L. Impacts of fisheries bycatch on marine turtle populations worldwide: toward conservation and research priorities. *Ecosphere*, 4(3), 1-49, 2013. doi: 10.1890/ES12-00388.1

Worm, B.; Davis, B.; Kettemer, L.; Ward-Paige, C. A.; Chapman, D.; Heithaus, M. R.; Kessel, S. T.; Gruber, S. H. Global catches, exploitation rates, and rebuilding options for sharks. *Marine Policy*, 40(1), 194-204, 2013. doi: 10.1016/j.marpol.2012.12.034

Zamboni, A.; Martin-Dias, L. I. *Auditoria da pesca - Brasil 2020*: uma avaliação integrada da governança, da situação dos estoques e das pescarias. Brasília: Oceana Brasil, 2020.

Zappes, C. A.; Gama, R.M.; Domit, C.; Gatts, C. E. N.; Di Beneditto, P. M. Artisanal fishing and the franciscana (*Pontoporia blainvillei*) in Southern Brazil: ethnoecology from the fishing practice. *Journal of the Marine Biological Association of the United Kingdom*, 98(4), 867-877, 2016. doi: 10.1017/S0025315416001788