

## Artisanal fisher traditional knowledge and perceptions about small cetaceans' bycatch in North Brazil

*Conhecimentos tradicionais e percepções de pescadores artesanais sobre a captura incidental de pequenos cetáceos no norte do Brasil*

*Conocimientos tradicionales y percepciones de pescadores artesanales sobre la captura incidental de pequeños cetáceos en el norte de Brasil*

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**Resumo:** Interações entre pequenos cetáceos e pescarias artesanais têm sido registradas em todo o mundo. Entre as interações negativas está a captura acidental. Os pescadores, como partes interessadas em contato direto com os processos de captura, podem desempenhar um papel no compartilhamento/aplicação de seus conhecimentos. O estudo teve como objetivo realizar uma busca sobre a captura acidental de pequenos cetáceos no litoral do Pará, Norte do Brasil, utilizando o Conhecimento Ecológico Local (CEL) de pescadores artesanais como fonte de dados, associando-o a fotos georreferenciadas de captura acidental e análise descritiva local. Entre os principais achados, foi possível detectar que a captura acidental de golfinhos foi mencionada por todos os pescadores, e a rede de emalhar foi a principal ferramenta. De acordo com as fotos, todos os animais pertencem à espécie *Sotalia guianensis*. Os pescadores relataram descartar carcaças de golfinhos capturadas acidentalmente diretamente no mar, no entanto, alguns alegaram vendê-las no mercado local para fins religiosos, místico-medicinais. Os pescadores consideram a proteção dos cetáceos muito importante, mas não consideram a captura acidental como prejudicial ao meio ambiente, eles veem os golfinhos como animais carismáticos, às vezes humanizando seus atos e interações.

**Palavras-chave:** Captura acidental; cetáceos; *Sotalia guianensis*; pesca artesanal; proteção ambiental.

**Abstract:** Interactions between small cetaceans and artisanal fisheries have been recorded worldwide; Among the negative interactions is the bycatch. Fishers, as stakeholders in direct contact with the capture processes, can play a role in sharing/applying their knowledge. The study aimed to carry out a search on the bycatch of small cetaceans on the coast of Pará, North Brazil, using the Local Ecological Knowledge (LEK) from artisanal fishers as a data source, associating it with georeferenced bycatch photos and local descriptive analysis. Among the main findings, it was possible to detect that dolphin's bycatch was mentioned by all fishers, and gillnet was the main tool. According to the photos, all the animals belong to the species *Sotalia guianensis*. Fishers reported disposing of bycaught dolphin carcasses directly on the sea, however, some claimed to sell them in the local market for religious, mystic-medicinal purposes. Fishers consider the protection of cetaceans

to be very important but do not consider bycatch to be harmful to the environment, they see the dolphins as charismatic animals, sometimes humanizing their acts and interactions.

**Keywords:** Bycatch; cetacea; *Sotalia guianensis*; artisanal fishing; environmental protection.

**Resumen:** Se han registrado interacciones entre pequeños cetáceos y pesquerías artesanales en todo el mundo; Entre las interacciones negativas se encuentra la captura accidental. Los pescadores, como partes interesadas en contacto directo con los procesos de captura, pueden desempeñar un papel en el intercambio/aplicación de sus conocimientos. El estudio tuvo como objetivo realizar una búsqueda sobre la captura accidental de pequeños cetáceos en la costa de Pará, Norte de Brasil, utilizando como fuente de datos el Conocimiento Ecológico Local (CEL) de pescadores artesanales, asociándolo a fotografías georreferenciadas de captura accidental y datos locales. análisis descriptivo. Entre los principales hallazgos se pudo detectar que la captura accidental de delfines fue mencionada por todos los pescadores, siendo la red de enmalle la principal herramienta. Según las fotografías, todos los animales pertenecen a la especie *Sotalia guianensis*. Los pescadores han informado que arrojan directamente al mar cadáveres de delfines capturados accidentalmente; sin embargo, algunos afirman venderlos en el mercado local con fines religiosos, místico-medicinales. Los pescadores consideran muy importante la protección de los cetáceos, pero no consideran que las capturas incidentales sean perjudiciales para el medio ambiente, ven a los delfines como animales carismáticos, que en ocasiones humanizan sus acciones e interacciones. Una oportunidad para respuestas futuras reside en la voluntad de los pescadores de cooperar para reducir la captura incidental.

**Palabras clave:** Captura accidental; cetáceos; *Sotalia guianensis*; pesca artesanal; protección ambiental.

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## 1. Introduction

Studies with large-scale and industrial fisheries are reported worldwide, mostly due to their clear economic, social, and environmental importance or impacts (Rousseau et al. 2019). However, artisanal fishing has its own importance, sometimes neglected. The artisanal fishing activity is representative of fishing efforts, the volume of fish, and employment all over the world. Despite its important role, studies regarding artisanal fisheries are still limited and concentrated in developed countries (Rousseau et al. 2019). The artisanal fishery is a particular type of fishing activity and has its own particularities, being more than an activity but a lifestyle filled with traditions and knowledge that are passed through generations. However, as with all interactions between the environment and humans, it can have its impacts, tools, and management strategies.

Artisanal fishing is an activity practiced along the Brazilian coast, it is responsible for generating income opportunities, and helping the local economy dynamic. It generates direct and indirect jobs for many families (Santos 2015). For the state of Pará, North Brazil, artisanal fishing activity contributes to the economic development of the sector, but it also strengthens an entire culture and traditional knowledge about the marine ecosystem in the fishing community (Mesquita and Isaac Nahum 2015a).

Local Ecological Knowledge (LEK) is increasingly taking place associated with scientific research. LEK can be understood as the knowledge, practices, and beliefs that are acquired by the observations and/or interaction between people and the local ecosystems (Martha Johnson 1992). This knowledge is extremely valuable for these communities and is shared among them. Fishing communities are examples of the wealth of knowledge that LEK possesses (Bulengela et al. 2020). And as a bonus, as fishers are intrinsically related to the local environment they can act as monitors for future environmental alterations and management practices aiming to achieve sustainable development.

As fishing activities happen in the natural environment, interactions between the vessel and/or fishers with marine fauna may occur. These interactions can be positive (help with fishing, companionship) or negative (entanglement, bycatch, injuries, and economic loss) and have been reported for several species, being de most common marine mammals, birds, and turtles (Alexandre et al. 2022; Machado et al. 2019).

Interactions between cetaceans and artisanal fishing have been recorded throughout the Brazilian coast (Machado et al. 2019; Marega-Imamura et al. 2020; Secchi et al. 2021; Seminara et al. 2019) Some positive interactions were already recorded on the Brazilian coast such as cooperative fishing at Barra de Imbé/Tramandaí, Southern Brazil (Zappes et al. 2011), and at the municipality of Laguna, Santa Catarina (Peterson et al. 2008) or negative such as entanglement and bycatch (Zappes et al. 2016) collisions of cetaceans and boats have already been recorded on the Brazilian coast and in the Central Amazon (Zappes, Alves, et al. 2013; Zappes, da Silva, et al. 2013). Studies in South Brazil are more common. Since Brazil is a big country and has social, economic, and natural variations in its territory, there is still a need to understand the realities of fishing communities in the North region.

Bycatch or incidental capture can be defined as the unintentional capture of species that are not the objective of the fishery. This practice negatively affects the balance of marine ecosystems (Myers and Worm 2003). Usually, bycatch species have no commercial value, and can also be endangered species, juvenile individuals possibly under the minimum size allowed for fishing, meaning the material is often discarded. According to the Food and Agriculture Organization of the United Nations (FAO), between 2010 and 2014, approximately 9 million tons of bycatch animals were discarded (Pérez Roda et al. 2019).

According to (Read et al. 2006), bycatch is one of the main causes of cetacean mortality. In Brazil, the main species of small cetaceans bycaught are the Guiana dolphin (*Sotalia guianensis*), the bottlenose dolphin (*Tursiops truncatus*), and the La Plata dolphin, franciscana or toninha (*Pontoporia blainvillei*) considered the most endangered small cetacean in the southeastern Atlantic Ocean (Danilewicz et al. 2010). Among the impacts caused by bycatch is possible to find a decline in populations of small cetaceans, as seen for the freshwater dolphin found in the Indian subcontinent *Platanista gangetica* (Dewhurst-Richman et al. 2020) and can lead to population collapse as occurred with the Vaquita (*Phocoena sinus*) endemic to the Gulf of California (Jaramillo-Legorreta et al. 2019), and also the Baiji (*Lipotes vexillifer*), the Chinese lake dolphin found in the Yangtze River in China (Brownell et al. 2019) that is classified as critically endangered and may already be functionally extinct according to the Red List of Threatened Species of the International Union for the Conservation of Nature and Natural Resources (IUCN).

The fisherman, as a stakeholder who is in direct contact with the capture processes, is one of the key sectors in the development of public policies to reduce and mitigate bycatch (Murphy et al. 2020). Considering several benefits can be taken from this experience, from the union of theoretical and practical knowledge, from the vision of those who live from fishing, and from those who visit the aquatic environment daily. They can promote change in its initial stages and have a first-hand assessment of the current bycatch status in the region. Also, fishers can help in understanding what may or may not work to improve the techniques used in the management of fisheries resources (Suuronen and Gilman 2020).

Despite the importance of cetaceans in maintaining fish stocks, some fishers do not consider the bycatch of small cetaceans as something negative for the environment (Zappes et al. 2016) being sometimes related to negative for the fishers as economic loss, loss of fishing gear, and reduction of fishing volume (Alexandre et al. 2022). Fishing and molestation of cetaceans are prohibited in Brazil by Federal Law N° 7.643, December 18, 1987, with a penalty of 2 to 5 years of imprisonment and a fine. For that reason, some fishers might be afraid, when faced with a bycatch and do not report the incident nor give the carcasses to any research institute or protection governmental agency.

The development of strategies to reduce the bycatch and the willing of fishers to apply it to their fishing style are essential. Also, International initiatives such as that of the National Marine Food Service in the United States, which allocates some species from bycatch for donation to associations that fight hunger, can improve communication between the fishing sector and the authorities, opening the dialogue for future policies of environmental mitigation and socioeconomic status of incidental fishing (Watson et al. 2020).

Considering the importance of fishers as stakeholders in bycatch, the importance of the Local Ecological Knowledge (LEK), and the bycatch itself to the marine environment, we aimed to carry out a survey on the bycatch of small cetaceans on the coast of the state of Pará, North Brazil, using the LEK from artisanal fisherman as a data source, associating it with georeferenced bycatch photos and local descriptive analysis.

## 2. Materials and Methods

Data collection took place in three moments, the interview process, the bycatch photos, and the DPSIR local descriptive analysis (Elliott 2002). The interviews were conducted in three fishing harbors in the metropolitan region of the city of Belém, the capital of the state of Pará in North Brazil.

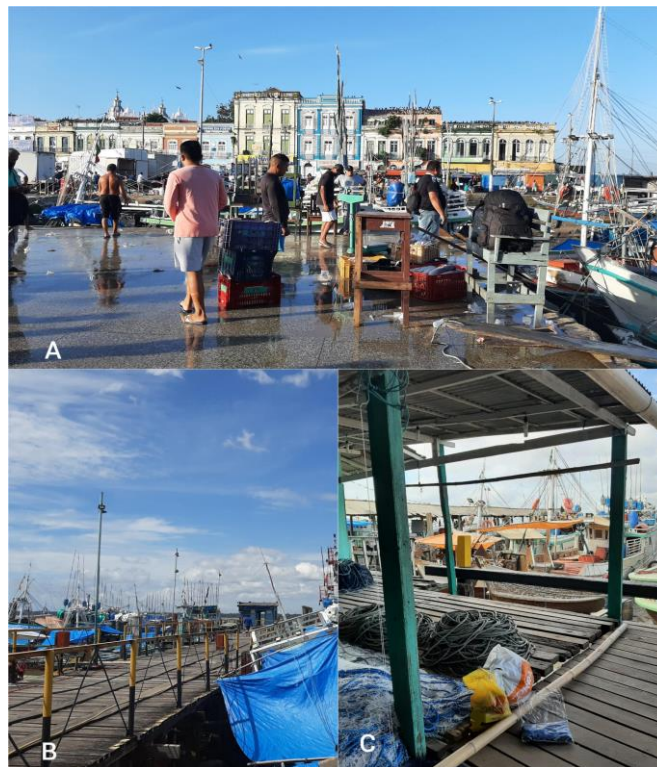
### 2.1 Interviews

The interviews were carried out in December 2021 and the photos were collected between July 2021 and January 2022. A semi-structured questionnaire (available in Portuguese -Supplementary Material I) developed based on Zappes and collaborators (2009) was applied. The questionnaire had open questions (N=35), closed (N=13), and questions with answers on the Likert scale (N=6). The questions were categorized into: (1) general information about the interviewee (name, age, gender, time of fishing activity, time of fishing activity in the region);

(2) vessel (type of vessel, engine power, length of vessel); (3) fishing (fishing time, fishing location); (4) fishing gear (nets: type, mesh size, height, net length, depth at which they are placed, time of year when the gear is used, time at which they are removed, target species, additional information about the fishing gear); (5) Interaction between fisherman and cetaceans initially containing questions about general characteristics (e.g.: non-target species, dolphins/cetaceans species in the region, the common name of the animal in the region, presence, behavior, presence of young, number of individuals seen), interactions considered negative (collision with the vessel, entanglement in the gillnet or other fishing gear) and positive (help during fishing), Bycatch during the fishing activity (place where it occurs, if the animals are found alive or dead and what is done with this animal), environmental factor that can lead to an increase in bycatch, (6) responses on a scale of 1 to 5 (Likert scale), with 1 corresponding to 'strongly disagree' and 5 to 'strongly agree' (affirmations such as: cetacean conservation is very important for the cetacean population, the impact of bycatch on cetaceans' population, fisheries and the environment, and whether they were willing to test methods that can help to reduce bycatch); (7) suggestions on what the fisherman thinks can be done to reduce bycatch; (8) fishers personal information (participation in environmental events, religion, if any myth related to the local dolphins is known).

The interviews took place in the morning and in the afternoon in three fishing harbors. The first is located at Mercado do Ver-o-Peso (Figure 1A), considered the largest fish market in the Amazon region (Souza and Pontes 2020), and a place with an intense flow of boats and goods. The second and third harbors are Porto Tamandaré (Figure 1B) and the harbor at AM company that works with fixing boats and fishing gear (Figure 1C).

**Figure 1.** Fishing harbors where the interviews were carried out (A) Mercado do Ver-o-peso, (B) Porto Tamandaré, (C) AM Company, in Belém-PA



**Source:** Authors.

The participant selection was made through the recruitment method or "Snowball", which consists of indicating other members for the research. Some of the interviews were recorded after the fishers's permission and all the participants sign the free and informed consent form. The interviews were transcribed, and the responses were classified according to the topics. Through the application of content analysis (Bardin, 2011) it was possible to identify recording units and separate them into categories (Vessel and fishing; interactions; scale questions; personal questions) to answer the study objectives.

## 2.2 Bycatch Photos

The photos were provided by a fisherman and correspond to 10 capture records that occurred during 5 trips carried out from July to December 2021 (Supplementary Material II). Through the photos, the cetacean species and sex were identified, when possible. Other relevant information taken from the record is the number of individuals captured and the georeferenced location where the capture took place.

## 2.3 DPSIR analysis

Gathering the interview results, bycatch photos records, and literature search it was developed a DPSIR (Drivers, Pressures, State, Impacts, Responses) analysis (Elliott 2002) focused on small cetacean bycatch. In this paper, we considered Drivers as an anthropogenic activity that can result in environmental impacts, Pressures as direct environmental effects of drivers (in our case focused on small cetaceans' bycatch), State as the condition of the ecosystem, Impact as effects on the ecosystem, covering economic, social, and environmental spheres, and Responses as policy and decision-making suggestion to deal with the Drives, Pressures, and Impacts.

## 3. Results and Discussion

### 3.1 Interviews

A total of 16 interviews were performed. During the interview, some fishers showed nervousness during the questions, so not all responses were recorded, allowing them to be more comfortable and more open to giving information. In this case, all the answers were written by the researcher, aiming to transcript the content as it was told, to preserve accuracy. Another interesting factor was that after the recording was finished, some sought to justify their answers and establish a conversation on the topic. The impressions after the recording stopped were also taken into consideration.

About the first category of analysis, personal information, the fishers were well distributed (4 in each class) between 23 and 61 years old. The shortest fishing time was one year (for fishers in the age class 21 to 30 years old), while the longest was about 49 years (for fishers the in age class 50+). The fishing time in the region was shorter than the fishing time period, indicating that some fishers started their activity elsewhere.

Fishing activity is potentially the main source of income for the fishers. In addition, most of the fishers interviewed started working when they were still underage, highlighting the necessity of starting contributing to familiar income, which possibly led to school dropouts and interfered with their formal education. This reinforces that the knowledge acquired by these fishers is a set of information mainly obtained through practice. Artisanal fishing is an art used by a community that reflects the natural characteristics of the environment, in particular the distribution and availability of resources as well as local traditions and customs (Mesquita and Isaac Nahum 2015b). An example is the use of the animals' color to differentiate the species, or the most favorable tide and moon for fishing.

All fishers interviewed were male. It is worth mentioning that generally, the role of women in artisanal fishing is more associated with the post-processing of the fish or the collection of organisms than with the capture. In addition, the role of women in the success of the fishing activity as the matriarch of the family has already been reported, subsidizing the male fishers' trips to the sea with domestic work, however, the role of women in fishing is still very undervalued and made invisible (Santos 2015). Related to the family, the number of members in the fisherman's family ranged from one to fifteen. Five fishers (31.25%) have between 1 to 3 family members, five respondents (31.25%) answered having four members in the family, four fishers (25%) have between 5 to 8 family members, and one fisher (6,25%) answered 15 family members.

Regarding the fishing activity, for the type of vessel, all the interviewees reported working on large vessels, however, six did not know how large the vessel was. Eight fishers (50%) reported working in wooden vessels, with lengths ranging from 14 to 18 meters. Only one reported working on a smaller vessel (9 meters), and one reported working on a larger vessel (25 meters). In addition, nine glacier-type vessels were also reported among the types of vessels. Glacier vessels are vessels adapted for storing up to 14 tons of ice, used to maintain the quality of the fish. The autonomy of the glacier-type boat is also determined by the duration of the ice, but the general average

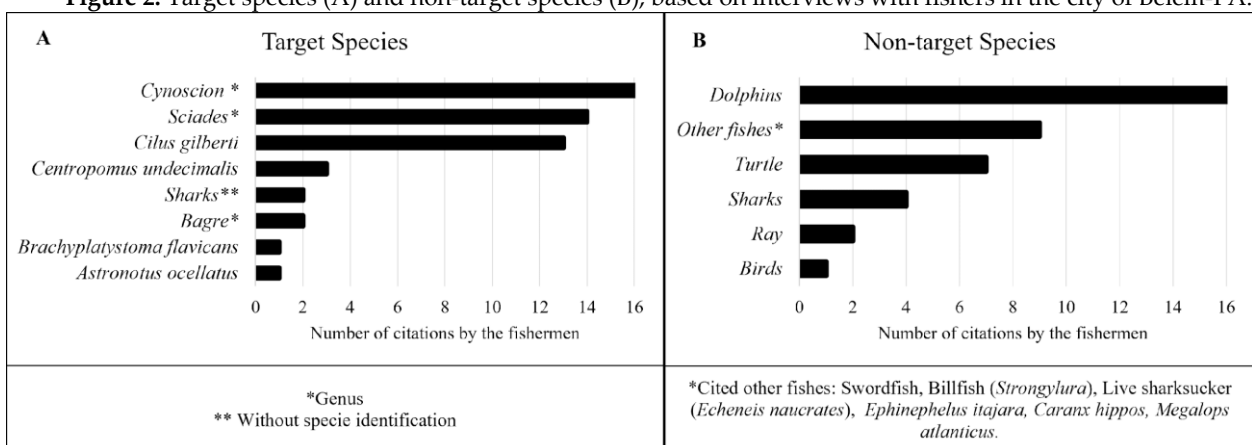
is 20 to 30 days of travel. This technology allows the vessel to spend more time at sea, possibly saving fuel, instead short trips going in and back to the fishing places. Also, the glacier-type vessel allows fish in areas far from the shore, possibly accessing other fish stocks.

The types of fishing gear used were waiting (56.3%) and trawling (43.8%), two fishers reported that they also use longlines and hooks as alternative fishing gear. Most of the types of fishing gear have already been reported to be related to the bycatch of some marine species (FAO 2021; William F. Perrin et al. 1994). For example, Hall and colleagues (Hall et al. 2000) reported that for most of the bycatch of cetaceans in Europe the fishers use purse seiners, bottom set-nets, and pelagic trawls. Another study in Europe, also found the purse seine and bottom set-nets to be more related to the bycatch of cetaceans in Algarve, Portugal, being able to associate the type of gear with the specie caught. While the most common dolphin related to purse seine bycatch is the common dolphin *Delphinus delphis*, the bottom set-net most common catch is a bottlenose dolphin *Tursiops truncatus* (Alexandre et al. 2022). However, there are also other aspects associated with cetaceans' bycatch than fishing gear.

The average size of the net was 7315.2 meters. It was reported that there is no fixed time for fishing, and it can occur at any period of the day (morning, afternoon, or night). The depth of placement of the net ranged from 3 to 36 meters, with the average being 12 to 27 meters. The net is kept underwater for an approximated period of 6 to 8 hours. The time and depth of placement of the net can be factors directly related to bycatch since the bycaught species can be trapped in the net for 6 hours or more, if it is a mammal, reptile, or bird aerial respiration deprivation can be a problem and a dead cause. If the net is placed at night is possible to hypothesize that some animals cannot see the gear, as well as if the animal is a predator following their prey it can be trapped in the process or pursue the prey already caught. Also, the entanglement and energy spent on the escape attempt can lead animals to be exhausted and dead on the net. According to fishers, fishing is closely related to the influence of the tide, and the net should preferably be launched during high tide. Local knowledge about tides and when place the nets can guarantees the fishing success (Alves et al. 2019)

Furthermore, the target fish species can also play a part in the occurrence of cetaceans' bycatch. Some fish species can be the favorite prey for cetaceans and lead the animals to the fishing gear, increasing the chance of bycatch (Kaschner and Pauly 2005; Plagányi and Butterworth 2009). Among the target species mentioned by all the 16 fishers are species from the genus *Cynoscion* including *Acoupa* weakfish (*Cynoscion acoupa*). Species from the genus *Sciades* were mentioned by 14 fishers. The specie *Cilus gilberti* were mentioned 13 times. Being the three most representative target target species. The common snook (*Centropomus undecimalis*) was mentioned 3 times. The genus *Bagre* and sharks were mentioned twice and *Brachyplatystoma flavicans* and *Astronotus ocellatus* was mentioned once (Figure 2).

**Figure 2.** Target species (A) and non-target species (B), based on interviews with fishers in the city of Belém-PA.



Source: Authors.

Among the non-target species captured, dolphins were cited by all the fishers (16), other fish species were mentioned nine times, turtles were mentioned seven times, sharks four times, ray was mentioned twice, and birds once. Among the non-target fishes, the species mentioned were Swordfish, Billfish (*Strongylura*), Live sharksucker (*Echeneis naucrates*), *Ephinephelus itajara*, *Caranx hippos*, *Megalops atlanticus*. The fishers reinforce that the

capture of these animals is not intentional, and they are returned to the water if they are captured alive, however, the small cetaceans, which are the most captured species, are usually found dead.

Sharks appear in both, target specie and non-target species. Although the capture of sharks is prohibited, some Brazilian fish markets sell some shark species for human consumption, and some restaurants serve them as meals, hence the fishers mentioning it as a target specie. The common name in Brazil, *cação*, leads people to not associate it with shark meat, believing they are eating other fish species (Bornatowski et al. 2015).

Fishers use coloration as the most striking characteristic to describe and differentiate the dolphin species (Supplementary Material III). According to the fisherman, there are two most common coloration types, the black dolphin, and the gray dolphin possibly referring to *Sotalia fluviatilis*, and *Sotalia guianensis*, respectively, two species that occur in the region.

Dolphin sightings vary in number during one trip, and also in the number of individuals seen each time. It has been said that dolphins might appear several times during a trip, and there are trips where they are not seen at all. Therefore, they can appear at any time of the year, which corroborates the results of Zappes et al., (2010). Also, according to the fishers, dolphins are rarely seen alone, but the size of the groups varies. They are usually seen in pairs, and the pairs are usually associated by fishers with a couple (male and female) when they are the same size, and with a mom and their child with one of the dolphins is smaller. However, there is no proof that this association is correct. Manzan & Lopes (2016) using LEK strategies found that *Sotalia guianensis* has predominant diurnal feeding habits and live in small groups, with 2 to 5 individuals. But it is common to find several groups occupying the same area while feeding. In the present study it was reported by the fishers that the dolphins are seen in groups with more than ten individuals, the same behavior that has been already observed in other studies carried out in the states of Bahia, Espírito Santo, Rio de Janeiro, and São Paulo on the Southeast Brazilian coast (Zappes et al. 2010). Another piece of information is that they are always seen during the day and afternoon, but they are not seen at night.

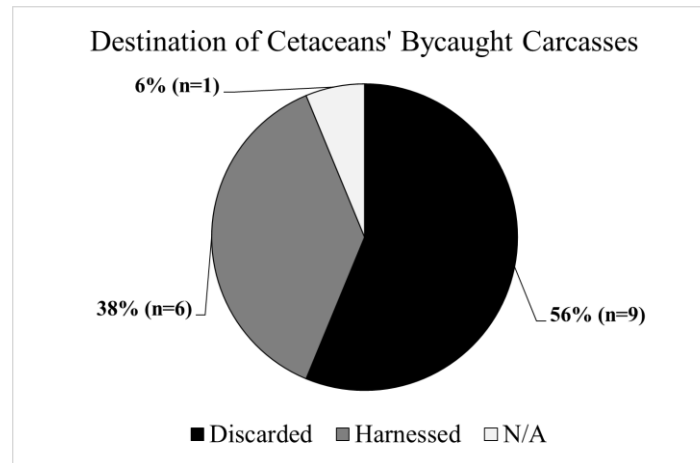
According to the fishers, the surface behavioral reactions performed by the dolphins in the presence of the fishing boats are: approaching the boat followed by a type of "interest demonstration" such as jumps, reactions described as 'playing', following the boat, and negative reactions such as diving, escape, and retreating. Among the behaviors, escape was the most representative being mentioned 6 times. All of these behaviors have been observed in *Sotalia guianensis* in the presence of boats in studies conducted in different Brazilian's States such as Pernambuco (Araújo et al. 2008), and in the states of Bahia, Espírito Santo, Rio de Janeiro, and São Paulo (Zappes et al. 2010)

It is possible to start noticing that the fishers's comments about the dolphins tend to 'humanize' the animals through sayings related to interest demonstration by the dolphins, and playing behavior. It is also interesting to notice that escape and retreat behavior is seen as negative, demonstrating the interest of the fishers in presence of the cetaceans. These perceptions point out the cetaceans' importance as flagship species and can be an opportunity to develop environmental education projects or management actions. An example is the porpoise project (Projeto Toninhas in Portuguese) in South Brazil that develops research and environmental education action mainly in South Brazil focused on *Pontoporia blainville* conservation (<https://projetotoninhas.org.br/>).

A total of fourteen fishers (87.5%) answered that there is no interference from the dolphins in the fishing activity. Two fishers (12.5%) believe that dolphins can help attract fish to the net and all responded that they had never witnessed incidents involving the small cetaceans and boats such as collisions. The entanglement, leading to bycatch, was the most cited type of negative interaction, only one fisherman (6.25%) said he had not witnessed it. When questioned about the distance at which entanglements occur, seven fishers said far from shore, 4 said close to shore, 3 answered it may vary and 2 did not know. Despite the distance from the shore, all the entanglements lead to the bycatch of dead dolphins.

Regarding the disposal of carcasses from bycatch, 56.25% (N=9) of fishers discard it directly at sea and 37.5% (N=6) of respondents claimed that they use animal remains (Figure 3). In the states of Bahia, Espírito Santo, Rio de Janeiro, and São Paulo, carcasses from bycatch are consumed as food, as well as used as bait and/or discarded on site (Zappes et al. 2009). In the present study, the fishers did not report carcass consumption, but some fishers who use the longline as an alternative method reported that they use the meat as bait or sell it to other fishers for the same purpose.

**Figure 3.** Destination gave to carcasses of small cetaceans bycaught, based on interviews with fishers in the city of Belém-Pará.



Source: Authors.

The removal of the eyes and sexual organs were also mentioned by 25% (N=4) of fishers, these parts are removed for sale in the Ver-o-Peso local market. The sale of these items is related to popular beliefs that these pieces have mystical properties (Sholl et al. 2008; Siciliano et al. 2018). Locals believe that the eyes can be used as a talisman to attract luck and money, and the genitals to attract romantic partners, which corroborates the study carried out by Bitencourt, Lima, and Barros (2014) on a local market Guamá, in Belém, North Brazil. Another use reported by 18.75% (N=3) of the fishers is that the oil from the fat of the dolphins is used for medicinal purposes. Furthermore, the use of dolphin oil for medicinal purposes has already been reported in other studies in the state of Pará, North Brazil, and in southern Brazil (Pinheiro and Cremer n.d.; Sá Leitão Barboza et al. 2014). It is important to emphasize that the use and molestation of the carcasses of these animals are forbidden in Brazil (Federal Law no. 7.643/87).

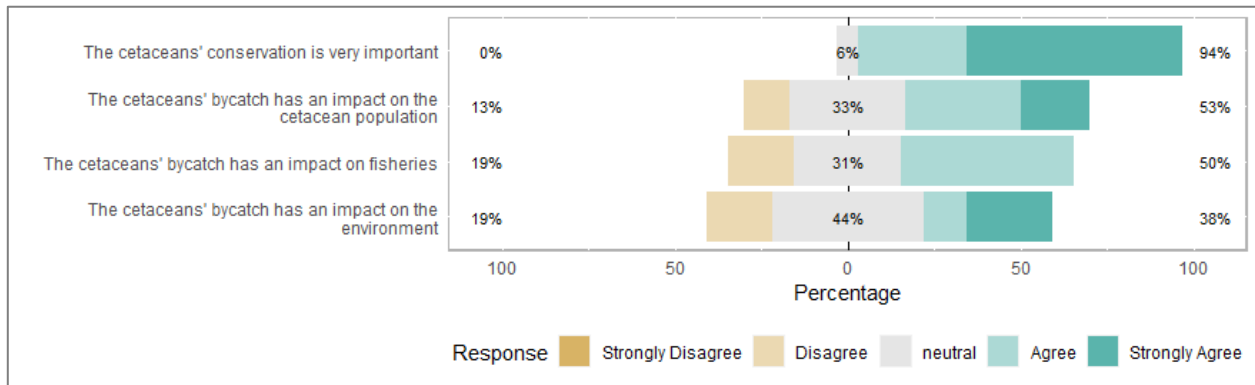
Moving on to the Likert scale's questions, when faced with the affirmative "The cetaceans' conservations is very important", 62.5% (N=10) chose 'strongly agree' and 31.25% (N=5) chose 'agree' justifying their choice mostly motivated by the charismatic factor of animals (Figure 4). It is noteworthy that the charismatic factor can be an important tool if we take into account that cetaceans are considered flagship species and the protection of their habitat generates the so-called umbrella effect, which is the act of protecting other species that occupy the same space inhabited by flagship species (Bowen-Jones and Entwistle 2002).

When the affirmative was "The cetaceans' bycatch has an impact on the cetacean population", 31.25% (N=5) of the fishers 'agree' and 18.75% (N=3) 'strongly agree' (Figure 4). However, it is difficult to know if the fishers fully understand why and how the bycatch affects the cetacean population. According to one of the fishers, the animals lose a 'friend' or part of the group because of the bycatch. Again, it is possible to notice the humanization of the animal, attributing feelings of loss and grief to the dolphins. Also, 25% of the fishers chose the 'neutral' alternative with the justification that they did not understand this problem or did not have an opinion about it.

About the affirmative, "The cetaceans' bycatch has an impact on fisheries", 50% of the fishers 'agree' (Figure 4), justifying that it did not interfere with fishing activity, but they were susceptible to paying fines if they were caught transporting dolphins. Demonstrating that the financial factor, in this case, was the stimulus for non-capture. In another study, it was found that fishers from Rio de Janeiro hand over the carcasses to environmental agencies (Brazilian Institute of the Environment - IBAMA), and in São Paulo they hand them over to research (Zappes et al. 2009). However, in North Brazil, this does not occur, mostly because the fishers probably are afraid of some punishment or fee. This is unfortunate because the carcasses could be used for scientific and/or didactic purposes if delivered to a governmental or research agency. Furthermore, the report of the bycatch could help in monitoring activities and management actions. Nowadays there is no trustworthy information about cetaceans' bycatch in the North region of Brazil.



**Figure 4.** Questions answered by fishers (N=16) from Belém-PA using the scale methodology (Likert). The answers were considered on a scale of 1 (Strongly disagree) to 5 (Strongly Agree).



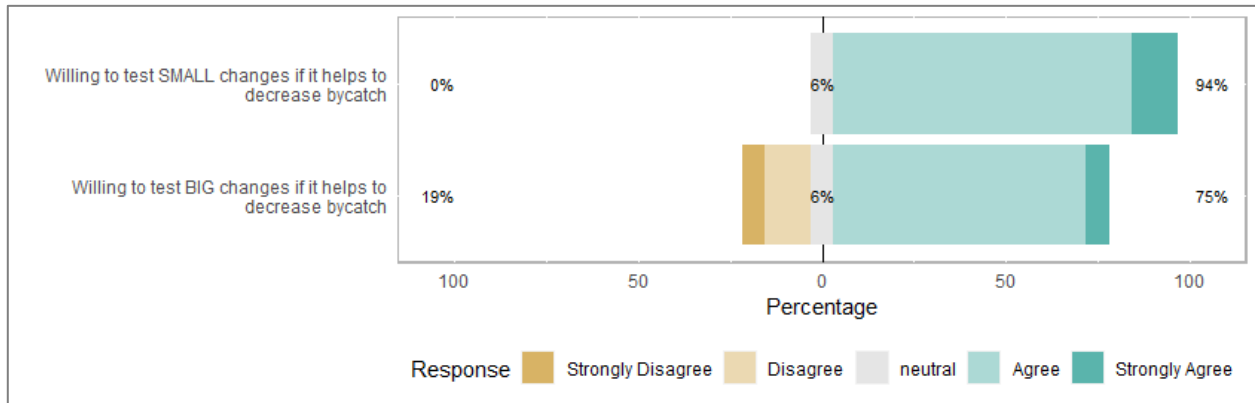
Source: Authors.

The last affirmative of this group was “The cetaceans’ bycatch has an impact on the environment”, and 43.8% (N=7) of the fishers were "neutral" and 18.75% (N=3) 'disagree'. Some said they did not know how to respond because they never thought about it or because they believed that the presence or absence of these animals did not make a difference to the environment. This demonstrates that they do not know the ecological role of dolphins, being able to connect the animals with the marine ecosystem as a whole, or did not think about it.

At certain times some fishers referred to the animal as a fish, some studies already pointed out that this association on the part of fishers occurs because both are aquatic species. The same association happens with sharks as already mentioned (Bornatowski et al. 2015). The gathering of all marine organisms in the same category, fish, makes it difficult to understand the role of each group and/or species in the environment.

Regarding making small changes in fishing gear, 93% (N=15) of fishers were willing to carry out tests performing small changes in fishing gear, if this helps to decrease bycatch. This is already a great achievement and shows that despite not fully understanding the role of small cetaceans in the environment they feel the desire/need to protect those animals either by the charismatic factor or any other reason. On the other hand, 75% (N=12) were willing to test big changes in fishing gear, which is still a high percentage, and the remaining 25% (N=4) say they are not willing if it results in more work for them. Artisanal fishing is already an activity that demands a lot of time and energy from fishers, so it is understandable that actions that demand a lot of work may not be so easy to implement, especially if the actors do not understand the importance of incidental capture, not only for fisheries but also to the environment. Mitigation measures can also be expensive, for small fishing communities, tougher approaches such as fishing bans or expensive technologies are impractical and usually only work in the short term (McClanahan et al. 2006).

**Figure 5.** Questions answered by fishers (N=16) from Belém-PA using the scale methodology (Likert) about the willingness to test small and big changes in their fishing gear to reduce the bycatch. The answers were considered on a scale of 1 (Strongly disagree) to 5 (Strongly Agree).



Source: Authors.

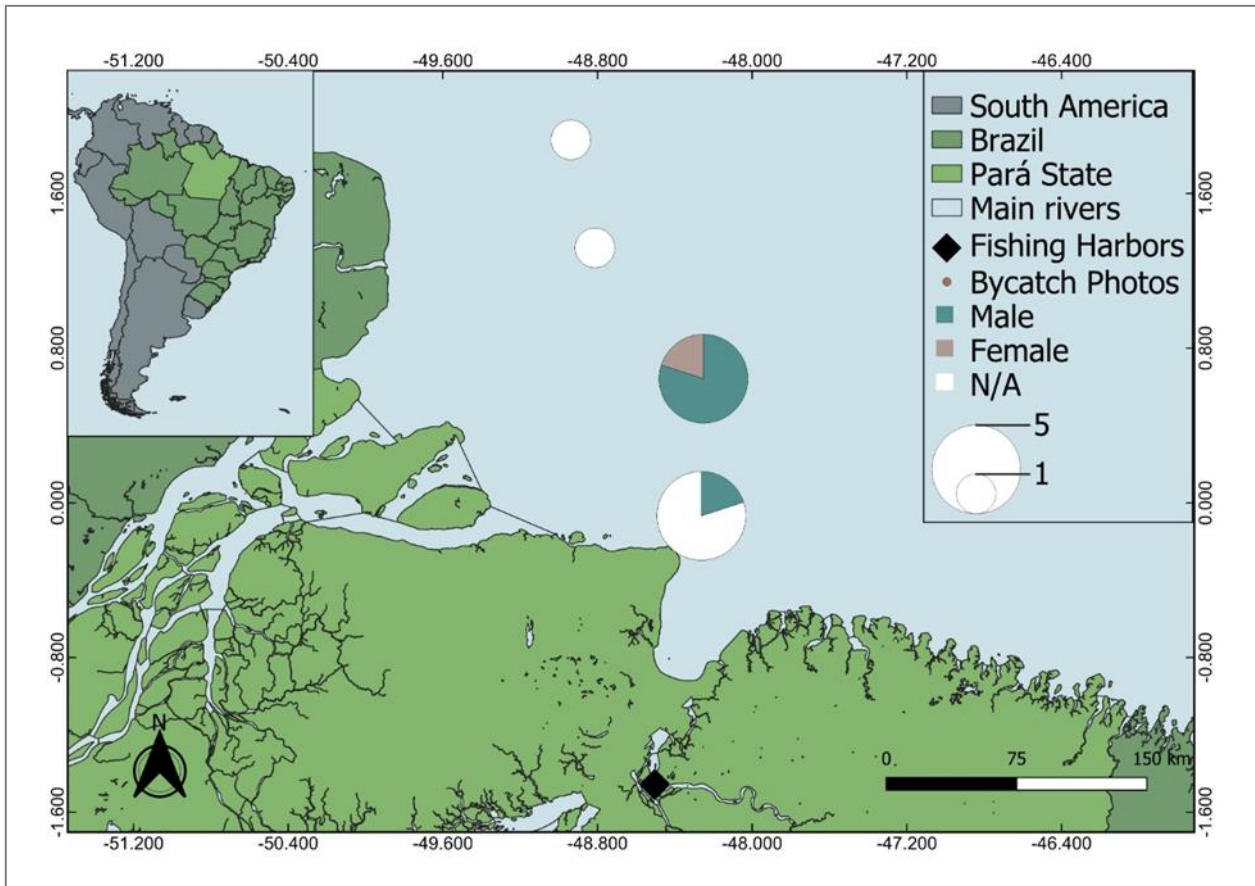
Regarding suggestions that could reduce incidental capture, 62.5% (N=10) said they had no suggestions and 37.5% (N =6) of the fishers made more general suggestions especially related to a possible protection area or some mechanism that could signal when the dolphins are present in the area, so the net would not be thrown in the place.

### 3.2 Bycatch photos

Photographic records of bycatch were provided by a collaborating fisherman and correspond to the bycatch that occurred in five trips carried out between July and December 2021. Photographic records performed by fishers are an innovation in the scientific literature and can be an important step in monitoring and understanding the current status of the bycatch in the region. Also, it can contribute to the trust building between science and the local community.

Fifteen animals were captured, all belonging to the *Sotalia guianensis* species. The number of individuals captured varied among the trips. On two trips the capture was of one animal each trip, on one trip the capture was of three animals and on two trips the capture was of five animals in each trip. On the trips that captured five animals, the bycatch occurred on different days and varied between 1 and 2 animals each day (Supplementary material II). Of the captured animals, 40% (N=6) were male, 13% (N=2) were female, and 46.7% (N=7) (Figure 6) were not possible to identify through the photos. Also, three animal records were not georeferenced and were not possible to know where the capture occurred. Most of the captures occurred in two regions, 5 animals were captured in each region. The other captures occurred further from the departure harbor (Figure 6). It can be related to the coastal habits of *Sotalia guianensis* (Manzan and Lopes 2016).

**Figure 6.** Map indicating the location of the state of Pará - Brazil in South America. circles indicate the area where the incidental captures occurred, based on photographic records from the vessel's GPS. The size of the circle represents the number of animals captured and the color indicates the sex.



Source: Authors.

In the records, it was also possible to identify some injuries in the captured animals (Supplementary Material II). As reported by the fishers, these injuries occur when removing animals from the net, since it was necessary to cut the material, often hitting the animal. However, at that moment the animal is already dead. This highlights the economic loss related to bycatch. To free the animal from the nets and gears, the fishers need to cut it off, most of the time losing the gear. For that reason, the reducing bycatch could be beneficial not only for the environment but also for the fishers.

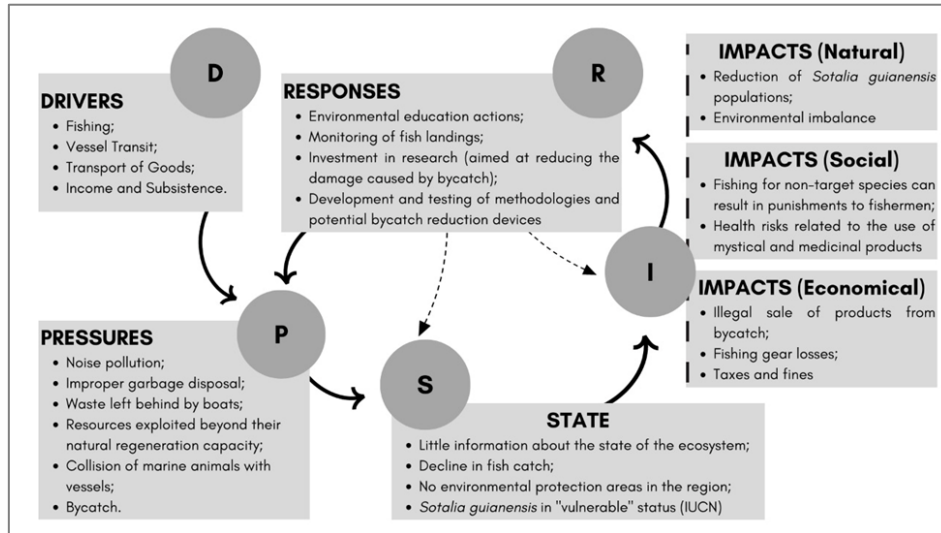
### 3.3 DPSIR

Successful actions aiming bycatch reduction, mitigation, or sensibilization must involve different sectors, integrating different stakeholders, considering biological, and socioeconomic information, and the political context of each region (Lewison et al. 2011). In addition, some studies have already shown that the inclusion of fishers in studies and initiatives related to bycatch increases the commitment of these stakeholders to adopt measures that work in the long term (Campbell and Cornwell 2008; Hall et al. 2000). DPSIR is a method developed by Elliot (2002) that aims to separate and organize information about a given topic to provide a clearer picture and present potential solutions. Each letter corresponds to the initial of a certain category (Drivers, Pressures, State, Impacts, and Responses).

Drivers correspond to the anthropogenic forces that generate impacts on the environment. For this study, the drivers included fishing activity, vessel traffic, transport of goods, and subsistence (Figure 7). Pressures correspond to the pressures of the activity on the environment. Fishing can be responsible for generating noise pollution, and this is very harmful to cetaceans because they are animals that communicate through echolocation.

In addition, there might also be the improper disposal of garbage and waste left by boats that can cause accidents such as ingestion of plastics, which can result in comorbidities and even death (Simmonds 2017). Pressures also included bycatch and the possibility of decreasing population and even extinction.

**Figure 7.** DPSIR analysis focused on cetaceans' bycatch in North Brazil. Full arrows represent direct influence and dotted arrows represent indirect influences.



Source: Authors.

Regarding the State of the ecosystem. Data about the fishing area is scarce, and according to the fishers' perception, fish availability has dropped over the years. Besides, there is no environmental protection area in the region, which could maintain the fish stock. Fish stock can vary strongly over the years due to natural or anthropogenic factors. Natural factors such as rain, temperature, el Nino, la Nina, and coastal currents can vary each year, and anthropogenic factors such as climate change, and ocean acidification, can aggravate the situation in long term. Also, other anthropogenic problems can also affect fish stock, such as pollution, contamination, invasive species, and overexploitation, among others.

The Impacts correspond to all the effects of the activity that cover the natural, social, and economic environment. Regarding the natural impact, *Sotalia guianensis*, the species identified by the bycatch photographs, is in a vulnerable state on the IUCN red list, and as described by the fishers all the animals from bycatch are found dead. On a large scale, the bycatch can contribute to the reduction of the species, causing an environmental imbalance, since dolphins are top predators.

The social impact caused by bycatch is related to the punishments caused by transporting and fishing non-target species, such as the confiscation of fishing gear and vessels. These measures make it impossible for fishers to carry out their work and livelihood, being also related to economic losses, since artisanal fishing is the main income for most of the fishers besides being a key factor in the community subsistence. There are also risks related to the use of products from the cetacean's carcasses since there is no scientific evidence that proves the effectiveness of products like dolphin oil in the treatment of diseases. The economic damage besides the fees and reduced fishing catches (sales) there is also economic loss related to the damaged gears from the bycatch, and impacts related to the illegal sale of products from bycatch and the consequences of overfishing, which in long term can reduce the availability of fish.

For the responses, possible solutions that help reduces the damage caused before and after the bycatch were listed. Some of them are environmental education actions involving not only fishing communities but also other stakeholders involved in artisanal fishing activities. Investment and studies of methodologies that potentially reduces bycatch, for example devices on fishing gear. Most the fishers interviewed, were willing to make changes and test devices and/or strategies to reduce bycatch. The monitoring of fish landings, especially at the Ver-o-Peso market, where sales of products from the carcasses take place. More studies that involve a partnership between

fishers and researchers, such as monitoring using the fishers's photographic records, proved to be essential for the study.

## 5. Conclusion

The study was a pioneer in the use of photographic records of bycatch provided by a fisherman, indicating a possible partnership with the local community to monitor the bycatch status in the region. Through the photos was possible to identify that all bycatches recorded were from the species *Sotalia guianensis*. Also, the georeferenced coordinates showed exactly where the bycatch occurred, being mainly close to the shore. Currently, there is no method of monitoring bycatch on the Brazilian north coast. This study opens a possible chance of interaction between the fishers and other stakeholders.

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