frontiers | Frontiers in Marine Science

TYPE Original Research
PUBLISHED 02 October 2023
DOI 10.3389/fmars.2023.1116459

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OPEN ACCESS

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RECEIVED 05 December 2022
ACCEPTED 11 September 2023
PUBLISHED 02 October 2023

CITATION
Silveira RB, Vidal MD and Silva JRS (2023) Magnitude of bycatch of *Hippocampus patagonicus*, an endangered species, in trawl fisheries in Southeast and South Brazil.
Front. Mar. Sci. 10:1116459.
doi: 10.3389/fmars.2023.1116459

Magnitude of bycatch of *Hippocampus patagonicus*, an endangered species, in trawl fisheries in Southeast and South Brazil

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One of the biggest threats to the world's fish stocks is trawling with indiscriminate capturing of non-target organisms, typically referred to as bycatch. Some species of seahorses are globally threatened and are often targets caught as bycatch. The aim of this work is to describe the magnitude of bycatch of the Patagonian seahorse *Hippocampus patagonicus* (Sygnathidae) in trawling fisheries in the Southeast and South Brazil. Between 2016 and 2018 we monitored the catch of five trawling vessels off the coast of Rio de Janeiro and Sao Paulo. A total of 2,041 individuals of *H. patagonicus* were captured, 1,183 males and 858 females. They were evaluated as for injuries suffered during dragging. The average rate of body damage was 33%. Based on the individuals captured and the analysis of on-board maps, an average CPUE of 3.36 with a standard deviation of 5.95/ind./day/vessel was estimated for the study area, extrapolating an incidental removal of 2,282,515 individuals per year, or 9,427 metric tons of seahorses, along the South and Southeast Brazil, where 3700 trawlers operate, an area recognized as the geographic distribution of *H. patagonicus* in Brazil

KEYWORDS

incidental capture, fish stock, bycatch, unsustainability, seahorse, impact, syngnathidae

1 Introduction

Negative impacts of trawling are known all over the world. These effects indiscriminately mow down the fauna and flora of the ocean floor, damaging habitat and leading to bycatch of vulnerable species. Bycatch fauna, captured in large numbers and usually discarded before the boats dock in ports, includes animals of varying sizes or species considered of no commercial interest (Haimovici and Mendonça, 1996; Soetaert et al., 2015). Discarding small fish affects the composition of natural stocks and has a direct effect on the decrease in the volume caught in the next harvest, making the activity less productive and more costly each year (Polet et al., 2005). It also changes the distribution of sizes of affected populations and species composition in fishing areas and causes loss of diversity (Viana, 2020).

One of the biggest threats to the world's fish stocks is commercial trawling, especially the indiscriminate capturing of non-target organisms, typically referred to as bycatch (Foster and Arreguin-Sánchez, 2014). Just as the bycatch can be sold, it can also be unused, being therefore called discard. According to this definition, global marine fishery data indicate that 9.1 million tons of discards are produced annually and that 45% of this volume is due to bottom trawling (Pérez Roda et al., 2019). In Brazil, the discard rate in fisheries of shrimp, fish, and other organisms varies from 24% to 65,2% (Davies et al., 2009; Perez et al., 2013; Cardoso et al., 2021).

Global fish production (marine + inland waters) was estimated at 96.4 million tons in 2018, a 5.4% increase over the past three years (FAO, 2020). However, after the global problems of coping with COVID-19, with direct effects on marine extractive production, which showed a temporary decrease (FAO, 2021), it has again regained strength.

In Brazil, marine extractive production was estimated at 489,000 tons during 2017-2018 (FAO, 2020). However, the lack of Brazilian management of these resources, whose monitoring ceased in 2009, opened gaps in the data of more than one decade (Dias et al., 2020).

Although monitoring at a national level has ceased, in the State of Rio de Janeiro the Instituto de Pesca Foundation carried out a fishing monitoring program between the regions of Paraty and Cabo Frio. The results for 2018 show a discharge of 27,187.3 tons of fish, with industrial fishing accounting for 70.8% and artisanal fishing for 29.2% of this amount (PMAP-RJ, 2019). The four main ports in the State of Rio de Janeiro are Niterói, São Gonçalo, Angra dos Reis, and Cabo Frio. Niterói and São Gonçalo together account for 58.2% of all fishing production, 69.4% of industrial fishing, and 30.9% of artisanal fishing. Angra dos Reis ranks third in production port, accounting for 21.3% of the State production, and Cabo Frio accounts for 10.6%.

Among fishing gears, the Siege trawler accounted for 80.5% of industrial catches and 50.9% of artisanal catches. In second place, the double trawl accounted for 10.6% of industrial catches, and in fourth position was artisanal fishing catches (6.6%). The industrial double trawl fleet was the second most important in number of vessels (71) and unloaded production: 10.6%, i.e., 2,045.3 tons (Dias et al., 2020).

The impacts of fishing on target populations result in overfishing of many species (Dias et al., 2020). Fishing removed from the sea, as bycatch fauna, non-target populations of endangered species, such as seahorses (Foster and Vincent, 2004; Choo and Liew, 2005; Foster and Vincent, 2010; Silveira, 2011; Filiz and Taşkavak, 2012; Foster and Arreguin-Sánchez, 2014; Foster et al., 2017; Silveira et al., 2018). The three species of seahorses in Brazil (*Hippocampus reidi, H. erectus, and H. patagonicus*) are listed on the official Brazilian list of endangered species as Vulnerable (MMA, 2022b). They are protected by the National Action Plan for the Conservation of Coral Environments – PAN Corais (ICMBio, 2022). Internationally, *H. reidi* is considered "Near Threatened" (NT, A2d+4d)), while *H. erectus* and *H. patagonicus* are listed as "Vulnerable" (VU, A2cd) (IUCN, 2017). The three species are also included in the Appendix II of the International Convention on Trade in Endangered Fauna and Flora (CITES, 2022).

Considering the need for long-term monitoring of bycatch to obtain information that supports conservation actions, since more than 95% of seahorses traded worldwide are bycatches mainly from trawling (Foster and Vincent, 2004), the objective of this work is to describe the incidental capture of the seahorse *Hippocampus patagonicus* in trawl fisheries in Southeastern and South Brazil and estimate the number of metric tons and individuals captured per year throughout its geographic distribution area in Brazil.

2 Material and methods

2.1 Study area

The State of Rio de Janeiro is one of the main fishing landing ports in Brazil (Figure 1A). It has a Coastal Zone with 640 km in length and 156 docking sites distributed over 25 coastal municipalities (Begot and Vianna, 2014). The climate is tropical and the summers have more rainfalls than the winters. The annual average is 1,252 mm. The climate classification is Aw, according to Köppen and Geiger, and the average temperature is 23.6°C (Climate Data, 2022). The continental shelf in this region is classified as a "platform of tropical and equatorial climates under the action of river inputs," whose morphological type occurs in the regions located between the parallels 30° South and North (Corrêa, 2021).

2.2 Data collection and analyses

Data collection took place from December 2016 to August 2018. The data collected consisted of completing an on-board spreadsheet containing general information about fishing and the number of seahorses captured. It was adapted from Silveira et al. (2018). Fishing was carried out with four double trawl boats and one single trawler (all of them in industrial fishing) that landed products in five different ports: Angra dos Reis, Niterói, São Gonçalo, Cabo Frio, and Macaé, the latter using simple trawl. The fishing sites of the monitored vessels ranged from Maranduba, in the State of São Paulo, to Campos dos Goytacazes, in the State of Rio de Janeiro (Figure 1B). Fishing focused on marine shrimp (*Farfantepenaeus* spp.) and demersal fish, such as *Micropogonias furnieri*, *Umbrina canosai*, *Cynoscion striatus*, *Merluccius hubbsi*, *Lophius gastrophysus*, *Percophis brasiliensis*, *Scomberomorus* spp, *Paralichthys brasiliensis*, in addition to the mollusks *Sepioteuthis sepioidea* and *Octopus vulgaris*. The mesh used varied between 12 and 30 mm between opposite nodes. The anglers used a Global Positioning System (GPS) device attached to the boat to record the initial and final coordinates of the net in each haul, as well as capture depths, and recorded the number of seahorses caught. The trawls worked at a depth of up to 100 m.

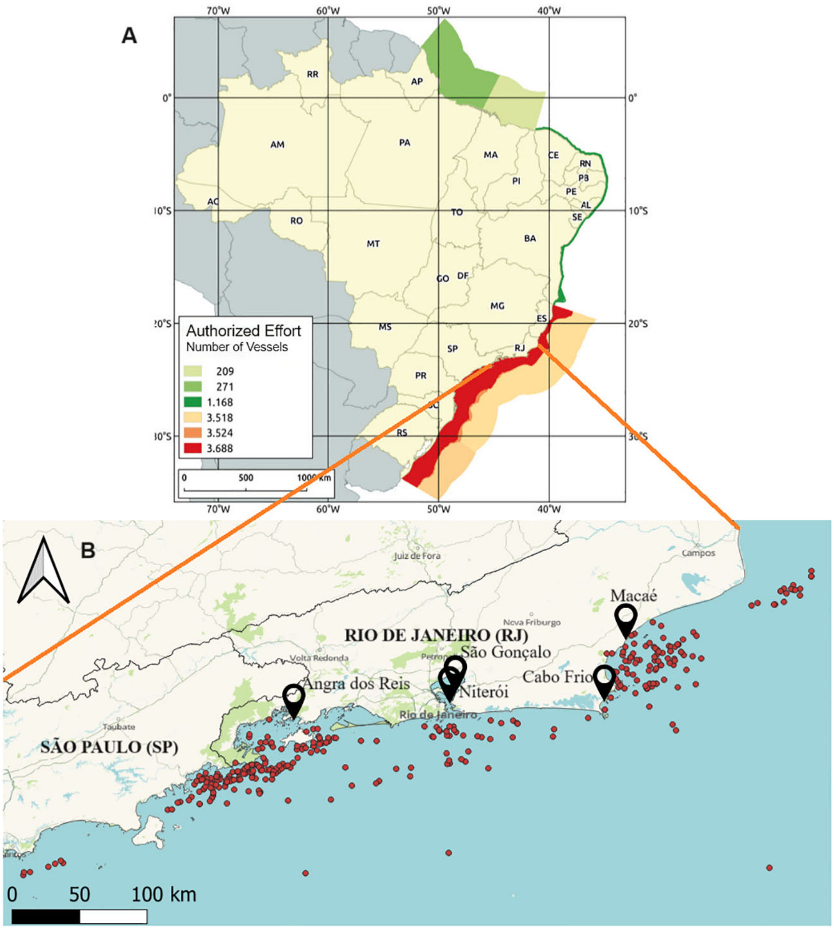

FIGURE 1
(A) Brazilian coastline showing the marine zones with their respective number of vessels authorized for trawling (Dias et al., 2020). **(B)** Study area covered by this work (red dots), represented by the numerous fishing trips and the fishing landing ports of this study (black markers).

The captured seahorses were deposited in containers with 90% alcohol provided by the research team. Once a month, researchers collected the containers with seahorses and on-board spreadsheets filled out by the fishermen themselves. All fishermen who participated in the activities received in return monthly food for the family until the end of the study.

The captured animals were transported to the Hippocampus Project laboratory in the State of Pernambuco. They were identified according to Silveira et al. (2014) and Piacentino and Luzzatto (2004). Height (linear measurement from the top of the head to the tip of the stretched out tail) was measured with a digital caliper (0.1 mm). The analysis of injuries resulting from trawl nets was performed in pregnant males (PM), non-pregnant males (NPM), and females (F) (data in percentage). The most common injuries found in fish expected to occur are crushing, abrasion (Davis, 2002), and organ eversion (Silveira et al., 2018).

Catch per effort unit (CPUE) was estimated by dividing the number of seahorses captured by the number of days, hauls, and total hours worked. The calculation of the total number of hours was performed by multiplying the number of hours of each throw by the total number of throws. Fishing effort focused on seahorses is presented in individuals per day (ind./day), per throw (ind./throw), and per hour (ind./hour) for all ports. Based on the CPUE of each port, the annual average CPUE was also estimated for the Southeast and South Brazil, where strong fishing pressure has already been recorded for seahorses that are removed as bycatch (Silveira et al., 2018; Silveira et al., 2020). The annual CPUE estimate for the South/Southeast Brazil is presented in individuals per year (ind./year) and metric tons per year (metric tons/year). Information on the size of the trawl fishing fleet (3,700 vessels), to calculate the annual CPUE, was obtained from Dias et al. (2020). To estimate metric tons/year, 557 individuals from the samples were weighed, and the average weight was multiplied by the estimated amount of ind./year. All seahorses were preserved in 70°gl alcohol after fishing and none of the individuals that were weighed were dry or missing any part of the body.

The reproductive period of seahorses was determined by the relative frequency of pregnant males over months.

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2.3 Statistical analysis

Spearman's correlation was used to assess the relationship between the number of seahorses captured, the number of hours trawled, and the size of the net mesh. To test the relationship between sex (males, pregnant males, and females) and bodily injuries, an Analysis of Variance (ANOVA) was conducted. Seahorse catches per unit effort were compared between ports using ANOVA and Tukey's *post-hoc* test. The Shapiro-Wilk test and the Levene test were used to verify the assumptions of normality and constant variance.

A scatterplot shows the relationship between the number of seahorses captured and the depth of capture. The estimates that represent capture depth were made using Kriging with a linear variogram, in which the blue scale represents the capture depth estimate and the red scale represents the number of captured animals. The contours of the territorial limits of the States were obtained through shapefiles made available by the Brazilian Institute of Geography and Statistics (IBGE, 2022). All analyses were performed using the R software (R Core Team, 2022), version 4.2.0, at a significance level of 5%.

3 Results

During the study period, 2,041 individuals of *H. patagonicus* were captured as bycatch, 1,183 males and 858 females, with no difference in sex ratio (p=0.298). The height of individuals ranged from 6.5 to 15.9 cm (10.47 ± 1.38 cm) and the weight varied between 1.0 and 12.1 g (4.13 ± 1.54 g). Six individuals of *H. reidi* were collected. They were not representative in the sample. No individual of *H. erectus* was identified. The ports that received the highest number of seahorses (relative frequency) were Niterói, São Gonçalo, Angra dos Reis, Macaé, and Cabo Frio (Figure 2). All seahorses captured in the State of São Paulo (n = 25) were landed to the port of Angra do Reis, in Rio de Janeiro.

There was no correlation between the hours of trawling and the number of seahorses caught overall (p=0.565). When we separated the data by depth range (18 to 48 m and 50 to 100 m), the number of hours of trawling did not interfere with the capture at the lowest depths (p=0.414), but interfered with capture at greater depths (p=0.007). There was also a weak and positive correlation between the number of seahorses captured and the net mesh size (p=0.043).

Shrimp trawling was responsible for removing 38% of seahorses in the samples at capturing depths that varied between 18 and 48 m, while trawling for demersal fish captured 62% of seahorses at depths between 50 and 100 m. Of the five vessels monitored, three fished only shrimp, one fished shrimp and fish, and one vessel fished only fish.

The main injuries observed on the bodies of seahorses were everted digestive tract (65,6%), everted cloaca (32%), and broken tails (0,3%), broken heads (0,6%), and broken rings (0,87%). There was no significant difference in the percentage of injuries between males, pregnant males, or females (p=0.648). There were more animals without injuries than animals with apparent injuries (p=0.001). Table 1 shows the number of injuries/sex in the study period and the average percentage of injuries by port and total injuries.

The highest percentages of injuries to animals occurred with specimens landed in the ports of São Gonçalo and Niterói (Table 1). Of the 2,041 seahorses captured as bycatch, 1,183 were males and 44.5% were pregnant males. Among pregnant males, 39.73% suffered some type of injury. On the other hand, of the 858 females captured, 30.65% suffered injuries. Non-pregnant males (657 specimens) suffered injuries at a percentage of 30.90%. There was no significant difference between the percentage of injuries to males, pregnant males, or females (p=0.648). Regarding injuries and body size, there was no significant difference in height of males with or without injuries (p=0.1273), but for females there was a difference (p<0.001). The average height of females with injuries was 10.23 ± 1.10, while for females without injuries it was 9.63 ± 1.27. The reproductive period of *H. patagonicus* occurs throughout the year (Figure 3).

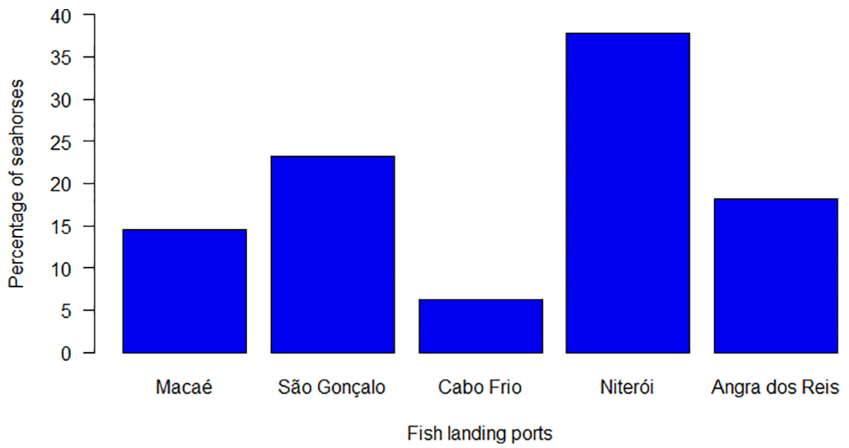

FIGURE 2
Percentage of seahorses captured as bycatch landed in monitored ports.

TABLE 1 Number of injuries by sex and percentage of injuries to animals by landing port.

Port	PM	NPM	Total M	F	Seahorse Total	INJ				
						PM	NPM	F	Total	%
CABO FRIO	21	55	76	52	128	1	1	12	14	10.9
SÃO GONÇALO	162	140	302	172	474	68	47	112	227	47.9
MACAÉ	59	88	147	149	296	8	4	7	19	6.4
NITEROI	170	264	434	337	771	90	126	103	319	41.4
ANGRA DOS REIS	114	110	224	148	372	42	25	29	96	25.8
TOTAL	526	657	1183	858	2041	209	203	263	675	33.1

PM, pregnant males; NPM, non-pregnant males; F, females; INJ, injury; MID%INJ, mean percentage of injury.

3.1 CPUE

Considering the five vessels monitored, 839 days of fishing were recorded, with 2,251 sets of nets thrown totaling 8,604 hours of fishing. Of the 2,251 sets of nets thrown, 1,783 were for shrimp fishing and 468 for demersal fish. These activities resulted in 2,041 seahorses caught as bycatch, of which 773 in shrimp fishing and 1268 in fish fishing. Also, 161 seahorses were captured (26 in Cabo Frio and 135 in Niterói), but they could not be considered in CPUE calculations because spreadsheets were lost.

Although the Port of Niterói recorded the highest absolute frequency of seahorses as bycatch (Table 1), the CPUE calculation shows that the rates of incidental capture and landing occurred (in order of importance) in the ports of São Gonçalo, Niterói, Cabo Frio, Angra dos Reis, and Macaé (Table 2). There was a significant difference between the number of seahorses landed in ports by trawl (p=0.0084), and São Gonçalo was the main landing port. When we compare the different fisheries, the CPUE calculation in ind/throw shows a significant difference with 0.75 ± 2 ind/throw for the marine shrimp fishery and 2.3 ± 3.4 ind/throw for the demersal fishery (p=0.001).

The CPUE calculation for the study region estimated 3.36 animals captured per day/boat considering an average of 15.3 (± 5.95) fishing days/boat/month, resulting in a bycatch of 2,282,515 individuals per year (3.36 seahorses/day x 3,700 boats x 183.6 days), or 9427 Kg year^{-1} of seahorses, along the South and Southeast Brazil, an area recognized as the main geographic distribution of *H. patagonicus*. Although fishing effort was standardized for the analyses here, Table 2 shows that the two ports with the highest rates of seahorse bycatch contributed the least in the sampled months, which suggests that our results may be underestimated.

Analyzing capture depth data allows establishing that *H. patagonicus* occurs along the coast of Rio de Janeiro at depths ranging from 25 m to 90 m, with a preference for the depth range between 40 and 80 m (Figures 4, 5).

4 Discussion

Considering that the data for the present study were collected entirely by the trawler fishermen and that, although they received a counterpart for collaborating, there is no way to be sure that all the material collected was delivered for research, since we detected a local trade in seahorses for curiosities and folk medicine. In addition, there may simply not have been enough effort to collect seahorses from the large amount of demersal fish or shrimp. Whatever the case, the data

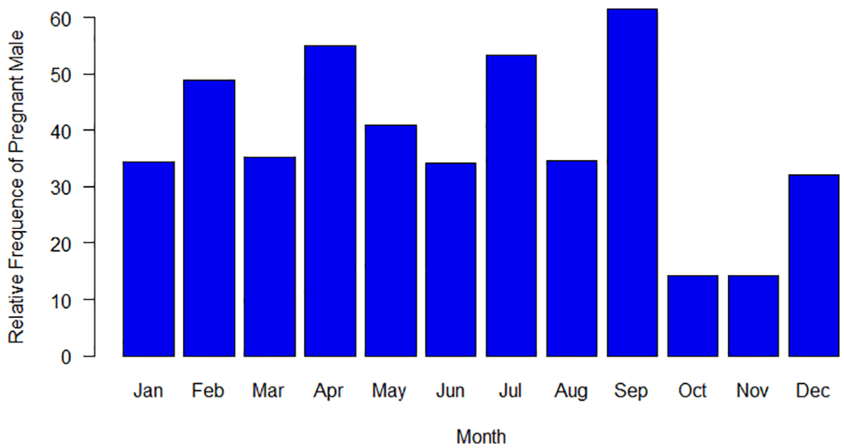

FIGURE 3
Reproductive period of *Hippocampus patagonicus* in the State of Rio de Janeiro (n = 1183).

TABLE 2 Capture per effort unit of seahorses as bycatch in trawl fisheries in the State of Rio de Janeiro between December 2016 and August 2018 (Same letters represent statistically similar averages).

Months	Port	CPUE/day	CPUE/throw	CPUE/hour
5	NITERÓI	2.59 ± 3.24^{B}	1.37 ± 1.71^{AB}	0.31 ± 0.37^{AB}
2	SÃO GONÇALO	8.62 ± 15.21^{A}	2.91 ± 5.05^{A}	0.72 ± 1.27^{A}
11	ANGRA DOS REIS	1.44 ± 5.23^{B}	0.60 ± 2.21^{B}	0.13 ± 0.45^{B}
6	CABO FRIO	2.52 ± 4.41^{B}	1.53 ± 2.19^{AB}	0.71 ± 1.01^{A}
9	MACAÉ	1.31 ± 1.66^{B}	0.31 ± 0.40^{B}	0.08 ± 0.10^{B}
33	Average	3.36 ± 5.95	1.34 ± 2.31	0.39 ± 0.64
	p-value (ANOVA)	0.0034	0.0084	<0.0001

would be underestimated and, unfortunately, the situation would be even more critical. However, the fact that we collected seahorses and fishing information (on-board spreadsheets) on a monthly basis allowed for verification and control between what was declared on the on-board map and the quantity delivered for the survey. The applied methodology was an excellent alternative for this type of work, since scientific observers on board are extremely expensive, especially in these cases where the permanence at sea is, on average, 20 days. However, very important information from these data is discussed here.

The reproductive period of *H. patagonicus* in Rio de Janeiro occurs in all seasons of the year and without interruptions, similar as *H. reidi* in tropical and temperate regions of Brazil (Silveira, 2005; Mai and Velasco, 2011; Silveira et al., 2022a) and other species around the world (Lourie et al., 2004). Although the samples of males had a good size (n=1183), they were collected according to the calendar of target fishing (shrimp and demersal fish), and showed a greater reproductive activity of *H. patagonicus* between February and September. However, it was not possible to establish a reproductive peak and perhaps it does not exist. Taking into account the fertility of *H. patagonicus* of 156.38 ± 66 embryos per pregnancy (Silveira et al., 2020) and that in the current survey 44.5% of males were pregnant, 81,588 animals still in formation were lost only in this sample.

In relation to seahorses that have suffered bodily injuries, 33% of captured seahorses had their body damaged to the point of death, but the remaining 77% (1,339 individuals) appeared to be in good condition. Perhaps, were they returned to the sea, they could have a chance of surviving and, eventually, find a reproductive partner. However, we have to consider the difference in atmospheric pressure to which *H. patagonicus* lives in Brazilian waters. These animals live in a preferred range around 40 and 80 m deep; having been captured at 90 m deep, this means that a pressure of five to ten atmospheres routinely act on their physiology. Suddenly, after hundreds of meters of trawling, the animals are brought to sea level after being carried by a net. In this case, not only pressure, but also temperature, which can quickly vary, cause thermal shock in fish and may lead to death before reaching the boat deck (Davis and Olla, 2001). For fish, mortality during trawling is related, among others, to trawling time, total catch weight, trawling depth, water temperature, time the fish stays on deck exposed to air, and atmospheric temperature (Morfin et al., 2017).

In this study, we could not assess the survival rate of seahorses that did not show apparent injuries, not even quantify death from

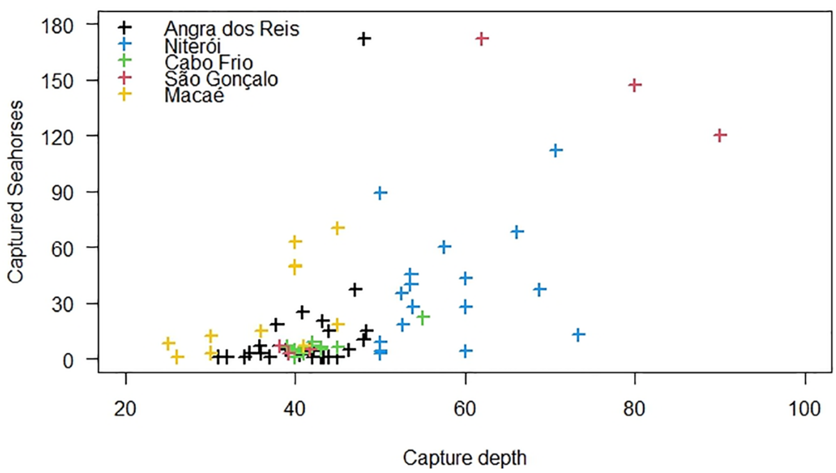

FIGURE 4
Frequency of occurrence of *Hippocampus patagonicus* captured as bycatch in relation to depth (m) and landing ports in Southeast Brazil.

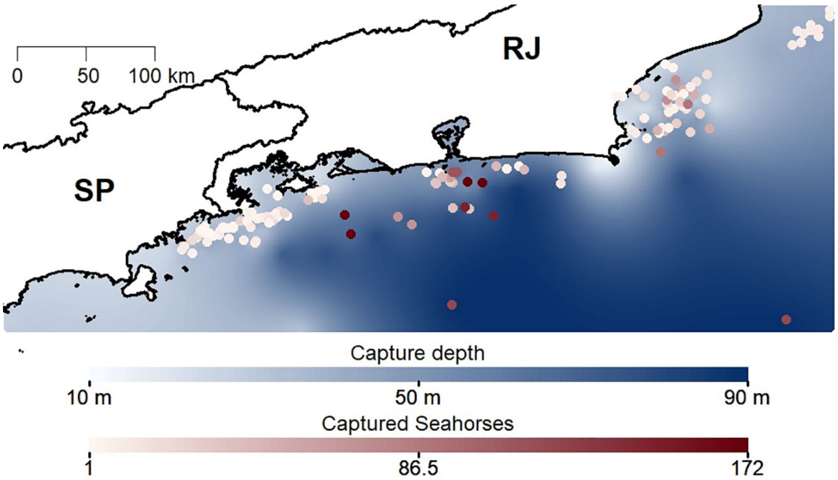

FIGURE 5
Spatial distribution map of *Hippocampus patagonicus* in relation to depth.

fatigue. A project for such a study would be very important in order to know whether there is a possibility of recovery and return of specimens, including pregnant males. According to Morfin et al. (2017), survival rates for plaice in trawl fisheries range between 45.2% and 66.6%. Among the fish that survive trawls and are exposed on deck for handling, most suffocate within the first 20 minutes out of the water and die. Animals that are still alive and thrown back into the sea are weakened individuals that are vulnerable to predation by birds or other fish (Davis and Olla, 2002; Macbeth et al., 2006).

The most frequent injuries found in this study were the eversion of the digestive tube and the cloaca (65.6 and 32%, respectively) where the meshes of the capture nets varied between 12-20 mm (shrimp) and 30 mm (fish). In general, the most common injuries in fish are crushing, abrasion, loss of scales, and fatigue from excessive swimming, which is aggravated by net overcrowding (Davis, 2002; Uhlmann et al., 2016; Morfin et al., 2017). Baum et al. (2003) observed that less than 1% of seahorses were killed in trawls where the mesh size of the net was 2.54 to 3.18 cm, and it was recorded as the main injury that 4.7% of the animals lost their tail rings (about 61% of tail size). The low trawl depth (1.8-6.4 m) and time per drag (40-50 min) contributed to results of less damage when compared to the results of the present study (33.1% of injuries), in depths between 20 and 100m and dragging time between one and six hours. The correlation between injuries and depth of capture was not verified, but it is likely that it exists, not only because of the greater stress to which the animal is exposed when removed from deeper places, but also because the number of seahorses increases with depth, between 20 and 60 m (increasing the sample number), and after that it starts to decrease (Figure 4).

The geographic area covered by the study was largely sampled by trawl nets that traversed the seabed, and the boats often overlapped fishing areas. In this study, we found a curious relationship between larger net mesh sizes and a larger number of seahorses captured. This possibly reflects the environment of the target fishery. Were sampled 2,251 net trawl and the most seahorses (62%) were captured by trawling aiming demersal fish; this type of fishing requires the largest meshes and the greatest depths (from 50 to 100 m). Although seahorses could escape due to the mesh size of this net, they are trapped by the accumulation of fish in the net and by anchoring their prehensile tail to the net itself or objects that have been dragged along. We would expect that smaller net meshes would capture more seahorses, as well as a longer trawl time, but these correlations were not seen, probably because the depth of occurrence of the species was the preponderant factor in this case. That is, regardless of the mesh size and dragging time, the capture takes place along the vertical distribution of *H. patagonicus*, although important, the other factors become secondary. The highest number of seahorses captured beyond 50 m of depth, even with the lowest number of bids for trawling for fish (compared to shrimp fishing), emphasizes the vertical distribution of the species. As for the horizontal distribution of *H. patagonicus*, there seem to be no gaps along the coast of Rio de Janeiro, but we must consider, in general, the skills/dedication of each fisherman in collecting seahorses from nets and the number of months sampled for each boat, influencing the different capture rates in the ports.

Our annual catch estimates for the Southeast and South Brazil (more than two million seahorses) place Brazil in a catch level similar to the Philippines (1.7 million seahorses/year), which are a known center of capture and trade of seahorses. However, what is the fate of seahorses captured as bycatch in Brazil? We do not know yet. Unfortunately, in Brazil there is no effective control over the seahorse trade. Only a few records in CITES exist, where an export of 16,669 individuals of *H. reidi* between 2010 and 2020 was reported (www.cites.org). There are no export records for *H. patagonicus*. There are records of Brazilian exports of 350 specimens of *H. erectus* in this period. Between 2000 and 2009, CITES recorded an export declaration of 5,588 specimens of *H. erectus* (tradeview.cites.org), which possibly means a misidentification of species or a strategy to disguise an over-quota in the export of *H. reidi* (Rosa et al., 2011). The Brazilian legislation that protects seahorses is satisfactory; however, once again, we fail to comply with and enforce laws. In the absence of government records and oversight of exports of live and dried seahorses (including correct species identification), alternative work by researchers may help to explain the problem (Rosa et al., 2011; Silveira et al., 2018), but how to solve it will require great government efforts.

In Brazil, seahorse bycatch data are scarce (Rosa et al., 2005; Vianna and Almeida, 2005; Rosa et al., 2011; Silveira, 2011; Silveira et al., 2018). Silveira et al. (2018) estimated 8,342 animals removed annually only by dragging pairs in southern Brazil (28 boats). However, according to Dias et al. (2020), the trawl fleet in the South and Southeast Brazil consists of boats proper for pair trawling, double trawling, and single trawling. The total is 3,700 vessels that operate in these areas. Many have additional authorizations that allow them to operate with other types of trawl or gillnet in the Territorial Sea and Exclusive Economic Zone - EEZ areas. All types of trawling and even gill fishing, at some point, captured seahorses in the South and Southeast Brazil (Pereira, 2016; Abilhoa et al., 2018; Silveira et al., 2018).

The trawling that occurs in South and Southeast Brazil is certainly the main source of dried seahorses that supplies the clandestine internal and external trade of seahorses (Rosa et al., 2011; Silveira et al., 2018) and removes a large number of *H. patagonicus* (Silveira et al., 2018; Silveira et al., 2022b). The clandestine trade of seahorses in Brazil also occurs through undeclared import. In response to a demand from the Chico Mendes Institute for Biodiversity Conservation - ICMBio (Taiamã Ecological Station, Cáceres), in 2016 the Hippocampus Project identified the species *H. ingens*. It was seized by the Federal Police while being smuggled from Peru, passing through Bolivia, and entering the State of Mato Grosso to be sold in the State of São Paulo, Brazil. Along with 30 kg of dried seahorses, sea cucumbers and shark claspers (copulatory organ) were also seized; they are used as an aphrodisiac delicacy in restaurants in São Paulo. The dried animals were being moved in cardboard boxes and plastic bags transported by line buses. Dried *H. patagonicus* were sold in the public market in Recife, PE, Northeast Brazil (Silveira, 2005). However, as we have seen, their distribution is restricted to the South and Southeast Brazil, which indicates a smuggling route of these animals.

The trade of dried seahorses (*H. patagonicus*) from the South and Southeast Brazil may occur illegally thanks to trawl fisheries. Therefore, what can we do? The zoning of fishing by fleet, further rules for trawling, further inspection, reduction of target stocks and bycatch species threatened with extinction or not, banning of trawling, and creation of marine protected areas are measures that scholars have claimed over the years (Haimovici and Mendonça, 1996; Perez et al., 2001; Haimovici et al., 2006; Hilborn et al., 2006; Lessa and Vooren, 2007; Rosso, 2015; Ricardo-Pezzuto and Mastella-Benincà, 2017; Dias et al., 2020). However, governments have done little. This absence places Brazil in the 26th position in world fishery management ranking; there are no positive outcomes for this performance (Melnychuk et al., 2017). Furthermore, the vertical distribution of *H. patagonicus* does not allow the protection of this species by PAN Corais (Silveira et al., 2020), the current protection instrument for seahorses in Brazil. In the absence of fishery management, the banning of trawl fishing within 12 miles of the Brazilian territorial sea promoted by the State of Rio Grande do Sul (RS) on its coast is certainly an effective action for the conservation of many species, including seahorses, and which could be replicated in other Brazilian States. However, the document banning trawling in RS was replaced for the Ordinance MAPA/SAP no. 634 (MAPA/SAP, 2022), which authorizes additional practices for sustainable fishing of motorized shrimp trawling in the maritime strip of the coastal zone adjacent to the RS, extending it from three nautical miles to 12 nautical miles. A few months after publication, the Ordinance no. 634 was suspended by the Federal Regional Court of the 4th Region (TRF4), as well as traction fishing. This measure benefits not only the thousands of species that are dragged for kilometers during motorized fishing, but also artisanal anglers, who feel impaired by the visibly unfair competition. In view of areas recognized as priority for conservation on the Brazilian coast (MMA, 2022a), the creation of new marine protected areas and their effective implementation in the Southeast and South Brazil may promote protection for *H. patagonicus* in its area of occurrence in Brazil. Strategies for the conservation of this and many other species caught in incidental trawl fisheries must be developed in partnership with environmental authorities, researchers, and the fishing industry.

Trawling is the world's "villain of the seas," claiming life in the oceans and providing 95% of seahorses for the global dry trade (Foster and Vincent, 2004). The global catch data for seahorses is alarming. According to data of 22 countries where capture and trade are known, it is estimated that around 76 million animals are removed from the sea annually (Lawson et al., 2017). Countries such as India, with estimates between 4.98 and 13.64 million seahorses/year, the Philippines, with 1.7 million, Thailand, with 29 million, and Vietnam, with 16.7 million seahorses, are known centers of capture and trade of these animals (Foster et al., 2017; Foster et al., 2019; Vaidyanathan et al., 2021). Unfortunately, Brazil appears in this scenario with alarming estimates and a complete lack of knowledge and control of the situation (Silveira et al., 2018; Silveira et al., 2020; this work). Based on these data, we need to build plans for monitoring and researching the possible and probable routes for the clandestine seahorse trade, providing people with knowledge and environmental education and ensuring the viability of seahorse populations in Brazilian waters.

5 Conclusion

Hippocampus patagonicus is a threatened species listed as "Vulnerable" in the international and Brazilian lists. However, this threat assumes even greater proportions when its only area of occupation in Brazil (Southeast and South) shows no subsidies for protection and conservation. Although there are many marine protected areas in the Southeast region, in the South region, such as in the State of Rio Grande do Sul, they are nonexistent. As we could see in this work, even in the Southeast region, with the presence of several marine protected areas, trawl fishing showed can further "vulnerability" and extrapolate it to a more serious condition if a government intervention is not carried out that can ensure sustainability to the natural stocks of this population or of populations of *H. patagonicus*. Unfortunately, the current seahorse protection laws in Brazil do not address this issue because seahorses are in the list of species protected by the PAN Corais. Furthermore, these reef environments are not preferred habitats of *H. patagonicus*, which continues to occupy preferential niches between 40 and 80 meters deep, thus risking being caught by the next trawl.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors upon request, without undue reservation.

Ethics statement

Ethical approval was not required for the study involving animals in accordance with the local legislation and institutional requirements because the seahorses used were caught incidentally, independently of our will.

Author contributions

RS contributed to the conceptualization, methodology, data analysis, writing – original draft, writing –, and review/editing. MV contributed to the data analysis, writing – review/editing. JS contributed to methodology, statistical analysis, preparation of figures, and review/editing. All authors contributed to the article and approved the submitted version.

Acknowledgments

The authors would like to thank the anglers who collaborated in monitoring fishing, completing the logbook, and collecting the seahorses captured as bycatch for the accomplishment of this work. We thank the Chico Mendes Institute for Biodiversity Conservation - ICMBio for the authorization SISBIO no. 53582-5, which allowed carrying out the research.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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