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ECOSYSTEMS

Scomberomorus brasiliensis (Scombridae) fishery on southern and southeastern coast of Brazil

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Abstract: Fishing for serra Spanish mackerel takes place along the Brazilian coast. Studies in northern and northeastern regions show that has socioeconomic importance although risk of overexploitation. This article provides an assessment of fisheries in the southeastern and southern regions, where there is a gap in knowledge. To build a regional perspective, fishing monitoring data from Santa Catarina, Rio de Janeiro, São Paulo and Paraná were used. For more detailed analyses, data from São Paulo and Paraná were chosen. In these two states, census data were collected on the species and quantities caught, fishing gear used and sales value. This fishery, mostly artisanal, has socioeconomic importance. Santa Catarina has the largest production. However, Rio de Janeiro has the most significant industrial fishery. São Paulo and Paraná produces approximately 110 t/year, mainly using drift gillnets and encircling gillnets with a mesh size of 10 to 12 cm between knots. The harvest period is during the cooler months, between May and August for São Paulo and between June and September for Paraná. The ANOVA test did not show any significant variations in CPUE, thus indicating stability. The results reinforce the need for adequate management.

Key words: capture by unit effort, fisheries monitoring, fishery resources, gillnets, small-scale fishery.

INTRODUCTION

The marine area plays a crucial economic role, as well as being fundamental for food security worldwide (Pomeroy et al. 2014). In this context, artisanal fishery stands out as being responsible for the largest number of fishermen and fisherwomen involved in the activity in developing countries (FAO 2020). It has been estimated that 90% of the jobs generated in marine fisheries come from artisanal fisheries (Jentoft 2014), which account for half of the world's fishing effort (Rousseau et al. 2019). In addition, artisanal fisheries are characterized by different cultural aspects, such that this activity plays a central role in maintaining the social structure and traditionality in the coastal zone (FAO 2020). In Brazil, its production accounted for more than 50% of the catch (Vasconcellos et al. 2007, Mattos et al. 2022). This activity is responsible for the food security and for maintaining the way of life of these riverside *caiçaras* [traditional inhabitants of the coastal regions of the southeastern and southern regions of Brazil] (Begossi 2014). Among the common characteristics of artisanal fishery is the presence of multiple types of fishing gear, seasonality of the species caught and multi-species catches (Salas et al. 2007, Medeiros et al. 2014).

Fishing for *Scomberomorus brasiliensis* is present along the entire Brazilian coast. The range of distribution is also reflected in the various popular names for this species (Freire et al. 2015), which may be called "serra" in the northern and northeastern regions (Isaac-Nahum 2006, Lima et al. 2007, 2009, de Nóbrega & Lessa 2009, de Brito & Furtado-Junior 2010, Maia et al. 2015, Leão et al. 2019), "sororoca" in the southeastern region (Mendonça & Katsuragawa 2001, Blank et al. 2009, Namora et al. 2009, Begossi 2011), and "cavala" (Silva et al. 2017, Chaves & Ventura 2019) in the southern region.

The reproductive period for this species differs between the northern/northeastern regions and the southern region. In the northern/northeastern regions, this period is between the months of September and March, which is between the dry and rainy seasons (Lima et al. 2007); while in the southern region it is during the cold period between May and October (Chaves et al. 2021).

An assessment on historical data, from 1950 to 2010, relating to fish catches unloaded in Brazil showed that a mixture of fish species names had been logged (Freire et al. 2015). "Serra", listed as *S. maculatus*, should be corrected to *S. brasiliensis, S. regalis* and *Sarda sarda*. Serra Spanish mackerel, on the other hand, presents differences between the databases, such that although it is recognized as *S. brasiliensis*, assessment for the presence of *S. regalis* is required. This result indicate that some difficulty exists about identify the species caught along the Brazilian coast.

Catch per unit effort (CPUE) assessments on serra Spanish mackerel have been made in the states of Pará (de Brito & Furtado-Junior 2010, Leão et al. 2019) and Maranhão (Batista & Fabré 2001). These three studies showed that there were significant differences in CPUE according to the seasonality of the catch. Though, only one of the studies in Pará compared CPUE over the years, and that assessment indicated a slight tendency for the population to decrease (Leão et al. 2019).

However, little is known about the catches in the southern and southeastern regions. Recently, research on the coast of Paraná showed that serra Spanish mackerel production was growing relatively to other resources (Chaves & Birnfeld 2021) and indicated that, currently, small-scale fishery is not negatively affecting stock levels (Chaves et al. 2021).

This study aimed to fill gaps in knowledge about catches of this species in the southeastern and southern regions of Brazil, through analysis on abundance indexes and fishery resource management.

MATERIALS AND METHODS

The information analyzed related to fishing along the coasts of the states of São Paulo and Paraná. The data were obtained through the São Paulo Fishing Activity Monitoring Program (PMAP-SP), developed by the Fishing Institute; and through the Paraná Fishing Monitoring Project (PMAP-PR), developed by the Agribusiness Development Foundation and the Fishing Institute. In São Paulo, the information used was from 2009 to 2019, while in Paraná the period was from 2017 to 2019. Information was collected on a census form, seeking to obtain data from fishing catch unloadings (Cordeiro & Mendonça 2010, Jankowsky et al. 2019).

To begin the analysis, a panorama of fishing in the southeastern and southern regions was established, based on the total quantities caught, according to the type of fishery (artisanal or industrial) and state. Thus, fishery monitoring information from Rio de Janeiro covering the years 2018 and 2019, and from Santa Catarina covering the years 2017, 2018 and 2019, were used (FIPERJ 2020, UNIVALI/EMCT/LEMA 2020).

The data from the states of São Paulo and Paraná were used as a sample for the region. In these states, the economic importance of serra

Spanish mackerel was established, along with the municipalities with the largest catches.

The average monthly unloading was obtained through the unloadings per month over the period from 2009 to 2019 in São Paulo and from 2017 to 2019 in Paraná. The number of fishermen was estimated from the number of productive units, i.e. fishermen or vessels (Jankowsky et al. 2019) involved in the fishery of *S. brasiliensis*, and the fishing gear used. It was considered that use of each type of fishing gear would involve a certain average number of fishermen on the fishing trip. This average number of fishermen involved with each type of fishing gear was multiplied by the number of productive units.

After obtaining this fishery overview, the species abundance index was estimated by calculating the catch per unit effort (CPUE). Although CPUE is widely used as an index of relative abundance for many fish resources around the world (Large 1992, Fréon & Misund 1999, Gatica & Hernández 2003), some studies have shown that there are some restrictions, cautions and risks of misunderstanding when this approach is adopted (Harley et al. 2001, Maunder et al. 2006, Rincón-Sandoval et al. 2018).

Because of the reproductive characteristics of serra Spanish mackerel, this species shoals when young and in the reproductive period (Lima et al. 2009). Thus, there is a need to adjust the information for abundance estimates. In the states of São Paulo and Paraná, the species forms shoals in the autumn and winter period, from May to September (Afonso & Chaves 2021), which determines the harvest period for the species. Although the species is present in all months of the year, only the harvest period (May to September) was used in the CPUE analysis to minimize possible distortions in interpretation of the results from the abundance analysis.

Due to differences in catchability between different types of fishing gear, it was chosen to focus on the fishing gear that is used for harvesting the resource in the states of São Paulo and Paraná. Through this, it was sought to reduce noise in the analysis, since the normal pattern of presence of serra Spanish mackerel in unloadings has high monthly variation throughout the year. Thus, by analyzing only the unloadings during the harvest period, from catches in which the main fishing gear was used, we could obtain a more precise estimate of the catch. This would avoid an annual sample with large variations, which could affect comparisons between years and would bring a risk of results indicating stability in the CPUE, even if the reality showed some decline or increase, considering that the wide fluctuations in the amount caught would be “normal” for the purposes of statistical analysis.

After selecting the harvest period and the main fishing gear for the CPUE estimates (in kg/hour), the total production of the month was divided by the total effort, in fishing hours, in which the fishing time was recorded as the length of time for which the nets were in the water. From this, 4,554 and 1,232 catch unloadings in São Paulo and Paraná, respectively, were analyzed.

After estimating the CPUE, the Shapiro-Wilk and Levene tests were performed to evaluate the normality of the residuals and homogeneity of variances, respectively (Zar 2010). In both states, the CPUE in the harvest period showed normality of residuals and homogeneity of variances, thus meeting the assumptions for ANOVA. This calculation was made from the null hypothesis that there would be no significant difference in the CPUE between the years, considering a significance level (α) of 5% (Zar 2010).

To conclude the analysis on this fishery, information was sought on the legal framework for this practice. Complementarily, information on fisheries management initiatives were obtained through participation in Protected Area Councils and in working groups focusing on fisheries planning.

RESULTS

Catches of *Scomberomorus brasiliensis*

In the states of Rio de Janeiro, São Paulo, Paraná, and Santa Catarina, in the years from which data on serra Spanish mackerel unloadings were available for all these states (2018 and 2019), presence of industrial fishing was observed, especially in the state of Rio de Janeiro, but the largest quantities unloaded for from the artisanal fleet (Figure 1). The state of Santa Catarina accounted for the largest quantity landed, about 62.87%. The greater presence of industrial fishing in the fishery resource in Rio de Janeiro over the period 2018-2019 was seen through fewer unloadings of this species, but with large volumes, carried out by a trawler fleet in some ports in the state.

In São Paulo and Paraná, the average annual catches were remarkably similar: 107.70 tons/year and 113.15 tons/year, respectively. In the latter, the serra Spanish mackerel fishing is artisanal, while in São Paulo there is also a small contribution from industrial fishing.

During the analysis period, for the fishing unloadings in São Paulo and Paraná, an average of one thousand fishermen/year were registered in these two states involved in the *S. brasiliensis* fishery. In São Paulo, an average of 107.75 tons/year of *S. brasiliensis* were unloaded, generating about 215,354.11 dollars per year, for about 700 fishermen. The municipality of Cananeia accounted for 40.5% of the amount unloaded, while Ubatuba and São Sebastião contributed 13.1% and 12.0% respectively.

In Paraná, an average of 113.15 tons/year of *S. brasiliensis* were unloaded, generating about 224,980.49 dollars per year, for about 305 fishermen. Its catch was especially important in the cities of Matinhos and Pontal do Paraná,

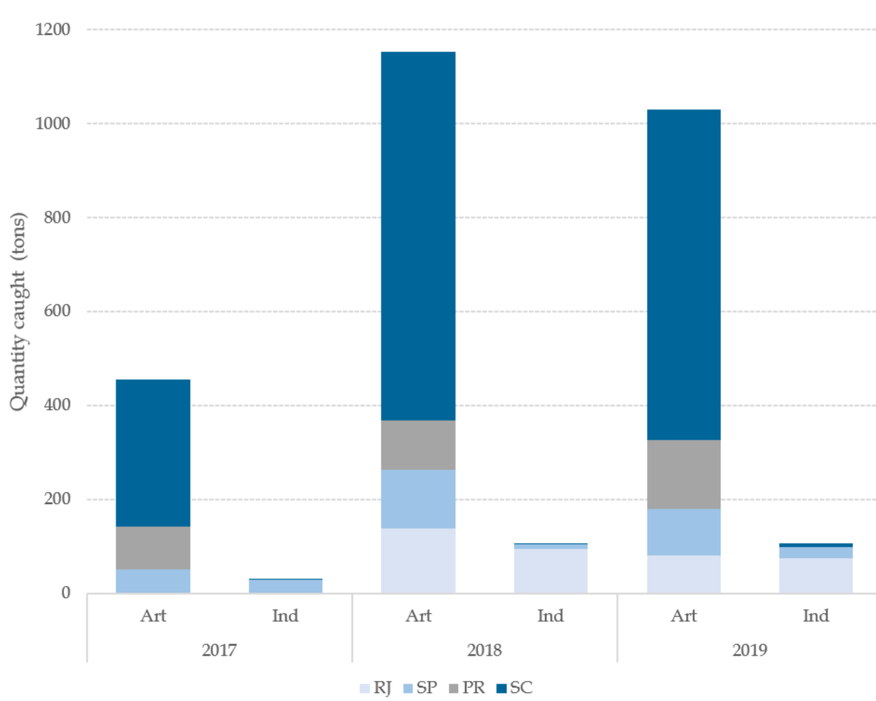

Figure 1. Quantity caught each year by artisanal (Art) and industrial (Ind) fishing in each state.

which accounted for 55.14% and 34.64% of the total amount in the state. In Matinhos, this species was the main resource caught. Fishing takes place especially in the cold period, between May and August in São Paulo, and between June and September in Paraná (Figure 2).

Gillnets, especially nets used on the surface, are the main catch strategies for serra Spanish mackerel (Figure 3). In Paraná, encircling gillnets (Reis-Filho 2019) used in siege mode form the main strategy, and this together with drift gillnets (He et al. 2021) accounts for more than 80% of the total catch. Encircling gillnets occupy the entire water column, with a height of almost 25 meters. These nets have a mesh size of 10 to 12 cm and are usually handled by three fishermen. Due to the characteristics of this type of net and the floats left on the surface, it can be understood to be a derivative of drift gillnets. In São Paulo, drift gillnets form the strategy most used for catching serra Spanish mackerel. This is a passive catch technique, in which the net is placed in the upper portion of the water column. The mesh size most used is between 11 and 12 cm, between opposite knots.

Comparison of CPUE over the years showed that there was no significant change (Figure 4). The ANOVA test showed that there were no statistically significant differences in comparisons of CPUE between 2017 and 2019 in Paraná (d.f. = 11, F = 1.056, p = 0.387), or between 2009 and 2019 in São Paulo (d.f. = 43, F = 0.827, p = 0.606), although there was an apparent downward trend.

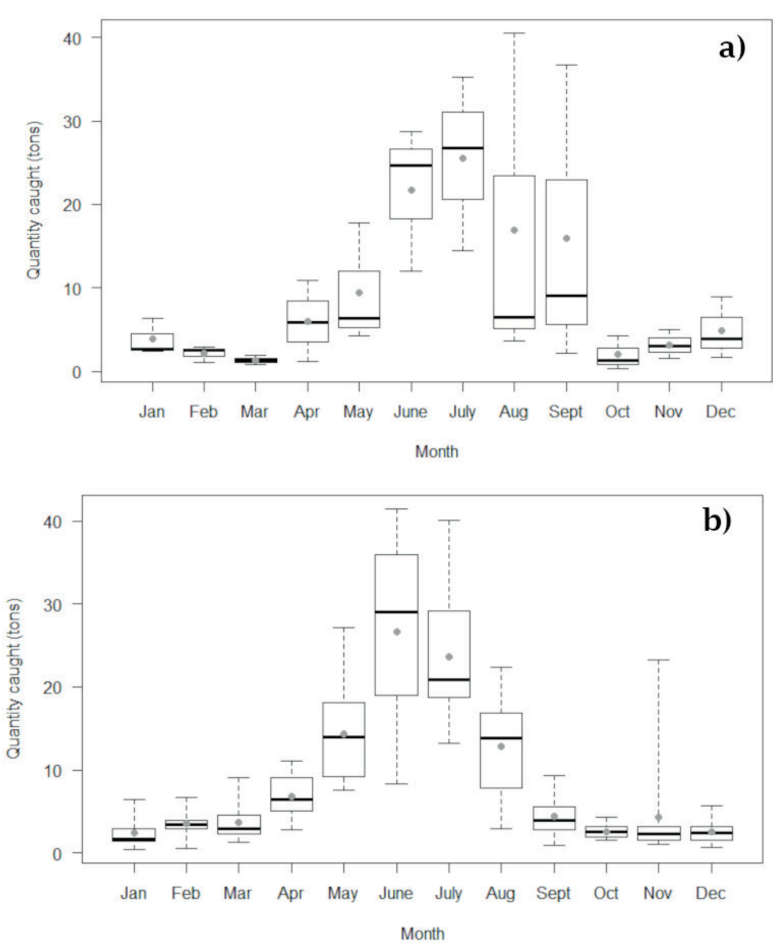

Figure 2. Boxplot with the production distributed throughout the year. a) refers to production in the State of Paraná (period from 2017 to 2019) and b) to production in the State of São Paulo (period from 2009 to 2019). The gray dot shows the average production for each month.

Legal and management considerations

Since 2007, there have been restrictions on the use of drift gillnets that have made their use unviable. The new legal limits have limited the height of the net and depth of operation in the water column (Brasil 2007). This measure was implemented with a view to reducing incidental catch, without fisherman participation. In the state of São Paulo, a thematic board for Marine Protected Areas for Sustainable Use was created to discuss the issues, involving fishermen, managers and researchers. This has led to proposals for viable adjustments to fishing activity in order to preserve resources (Quito et al. 2019). Meanwhile, in the state of Paraná, there is a fishing agreement in place that allows use of encircling gillnets in siege mode to catch target species such as mackerel and mullet, which has also shown promising progress (Madeira et al. 2018). However, even though this agreement has been successful, it is only in force over a small territorial area, within the Ilhas do Currais National Marine Park. Table I shows a summary of the attributes of the *S. brasiliensis* fishery.

DISCUSSION

Artisanal fishery has great importance because of its contribution to the maintenance of livelihoods, food security and production, and because of the number of fishermen involved (Pauly 2006, Salas et al. 2007, Begossi et al. 2011, Begossi 2014, Loto et al. 2019). The fishery for *S. brasiliensis* is mainly artisanal and is similar in the states studied here. This species is caught especially through using drift gillnets and an active derivation of this technique, called the encircling gillnet, in siege mode. Catches this species are especially important in the municipalities of Matinhos and Pontal do Paraná in Paraná and Cananeia, Ubatuba and São Sebastião in São Paulo. However, in municipalities where the amounts caught are not representative, the importance of this species also appears in local studies along the São Paulo coast (Clauzet et al. 2005, Blank et al. 2009, Namora et al. 2009, Begossi et al. 2011, Vaz-dos-Santos et al. 2013).

The mesh size (10 to 12 cm) targets adult individuals over 45 cm in length, which are

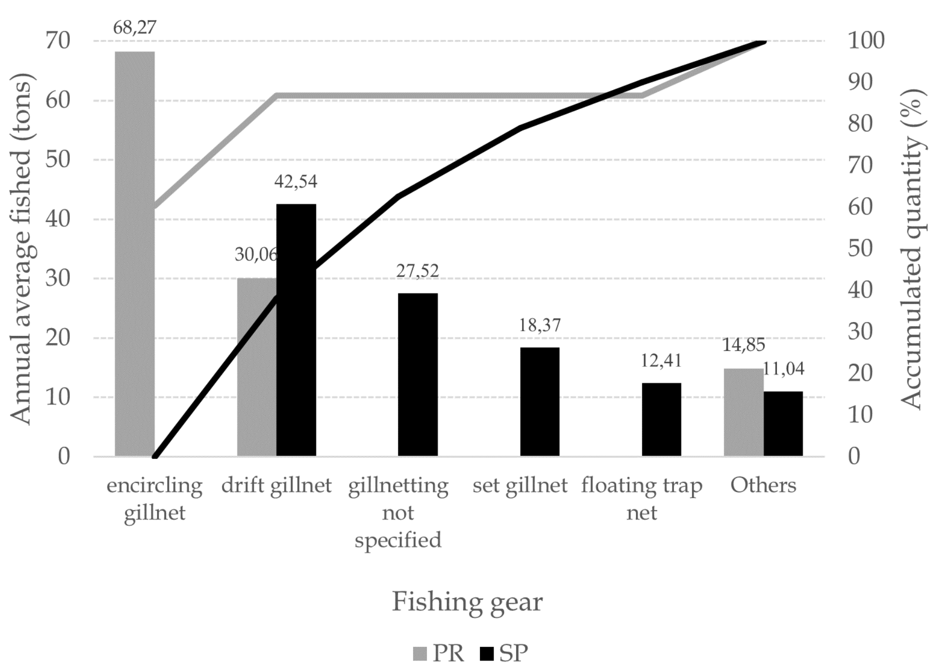

Figure 3. Main fishing gears and tons/years catches by state during the study period. To Paraná state, unloadings numbers were: encircling gillnet – 1,316; drift gillnet – 1,219; others – 1,251. To São Paulo state unloadings numbers were: drift gillnet – 7,435; gillnetting not specified – 8,114; set gillnet – 11,495; floating trap net – 4,480; others – 2,106.

therefore above the size for sexual maturity (Ximenes 1981, Lima et al. 2007, Chaves et al. 2021). In other states, there have been reports of use of nets with different mesh sizes. In Maranhão, the “serreira” [sawmill] net has been described, using mesh sizes of 9 and 10 cm. It was pointed out that in the fishermen’s perception, this was a non-predatory net, since it catches adult individuals (Almeida et al. 2007). However, in the states of Amapá and Pará, fishing takes place using with gillnets with mesh sizes of 4 and 6 cm, which catch juveniles (Isaac-Nahum 2006). Catching juveniles has also been pointed out to be a common practice in the northeastern region, and an analysis on unloadings in the state of Ceará showed that 44% of the individuals were still sexually immature (Lessa 2006).

The harvest period for serra Spanish mackerel in São Paulo and Paraná, is during the cooler months, between May and September. Differently, in the state of Pará, the harvest was recorded in the period from March to June (Lessa 2006), and in the state of Maranhão from June to August (Sousa et al. 2003).

It was observed that the state of Santa Catarina accounted for the largest volume caught and unloaded, which indicates that this state had the greatest fishing efforts in relation to this resource. In comparison with the production of the northern and northeastern regions, the southeastern and southern regions present lower production. However, the data from the statistical yearbooks present a mixture of species, which leaves doubts as to

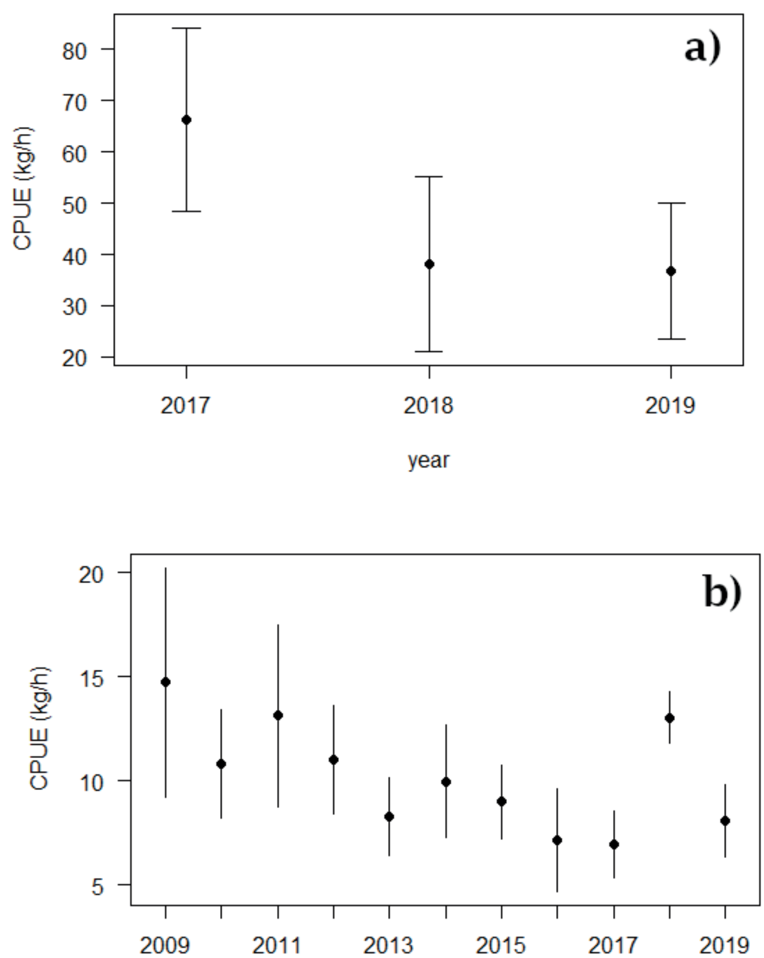

Figure 4. **Graphs with the annual means and standard error of CPUE in the harvest months. a) shows data from Paraná and b) data from São Paulo.**

which species are involved in the northern and northeastern regions (Freire et al. 2015). It is therefore difficult to compare the results. In addition, since 2014, Brazil no longer presents national data on fishing unloading, which makes the national statistics only an extrapolation (FAO 2020) and does not allow more reliable updating of the fishery.

It is important to point out that fish that form shoals and are exploited through delimited fisheries, such as *S. brasiliensis*, tend to be overly sensitive to climatic and oceanographic changes. Interconnections and teleconnections between climatic events at different time scales have been observed, and these may interfere with environments and natural variability (Wang et al. 2014). In the state of Rio Grande do Norte, a strong negative correlation between fishery production of serra Spanish mackerel and precipitation and minimum temperature was also found, especially during La Niña, and this was attributed to changes in behavioral patterns and different habitats (Barbalho et al. 2013). The Pacific Decadal Oscillation and the Antarctic Anomaly have already been shown to have great influence on CPUE variations of *Sardinella brasiliensis* in southern Brazil, especially in areas near the present study region (Faccin 2019), which may also have an influence on shoals such as those of serra Spanish mackerel along the coasts of São Paulo and Paraná. A similar pattern was observed for *Xiphias gladius* in the subtropical North Pacific region, which also presented a relationship between warm events and decreasing abundance (Hazin 2006). Besides shoaling behavior, weather and oceanographic conditions also influence catches. This situation leads to limitations on the ability of artisanal vessels to carry out fishing, given that they need good sea conditions for navigation and operation of fishing equipment (Rousseau et al. 2019).

Added to the influence of climatic factors and oceanographic conditions, it was noted that a tendency towards decreased stock was also observed in Pará, from comparison of CPUE over the years, although without any statistically significant reduction (Leão et al. 2019). In the northern and northeastern regions, several studies have been suggesting that there is a risk of overexploitation of *S. brasiliensis* (Lessa et al. 2004, Isaac-Nahum 2006, Lessa 2006, Almeida et al. 2007, Espírito-Santo & Isaac 2012, Palheta et al. 2016, Leão et al. 2019). In the southern region,

Table I. Overview of the main fishing attributes of *S. brasiliensis* in São Paulo and Paraná.

	São Paulo	**Paraná**
Device	Drift gillnet	Encircling gillnet
Mesh (cm)	11 and 12	10 to 12
CPUE ton/h in water	Stable	Stable
Type	Mainly artisanal	Exclusively artisanal
Economic importance	Medium	High
Rules	Prohibited fishing device	Prohibited fishing device
Management forums	Debating the issue	Local regulation, in small proportion to the fishing area

catches of smaller individuals as bycatches are also a matter of concern, especially their presence in trawl catches (Nobrega 2018, Afonso & Chaves 2021). In the most recent national list of endangered species, using a IUNC method, the Brazilian assessment considered that *S. brasiliensis* presented low concern (Brasil 2018).

A third aspect of interference with fishing is the anthropogenic impact on the marine environment. Factors such as pollution, climate change (Cheung et al. 2013, Steneck & Pauly 2019) and exotic species also play an important role affecting marine environments (Halpern et al. 2008, Magris et al. 2020) and consequently their fisheries. In Brazil, the Coastal Vulnerability Index, which considers socioecological factors relating to fishing activity, suggests that most states are in a vulnerable situation, especially in the northern and northeastern regions (Silva et al. 2019). In the northeastern region, low quality-of-life indicators among *S. brasiliensis* fishermen have been registered (Mourão et al. 2014). Thus, factors other than fishing activities that place fish resources at risk, linked to socioeconomic factors and environmental pressure factors, may be preponderant, compared with the fishing effort that is applied.

The CPUE analysis did not show any significant variation over the years. This indicated that the fish stock had not become compromised, although this analysis indicated fluctuations and a tendency towards a decline. The trend observed can be explained by the shoaling characteristics of the species and may also have been associated with climatic and/or oceanographic influences. Comparison of fishing in the northern/northeastern and southeastern/southern regions is hampered by the lag in recent information for the northern/northeastern regions. However, given the distinct harvest behaviors and reproductive periods, it is possible that there are distinct populations between the northern/northeastern and southeastern/southern regions. A population dynamics study showed that the population in Paraná could be considered to be not directly related to the northeastern Brazilian group (Chaves et al. 2021).

Even though the need for management of artisanal fisheries, especially with regard to the main resources, as is the case here, was first pointed out more than fifteen years ago (Isaac-Nahum 2006), no initiatives for fishery management on a national scale have so far been implemented. On the contrary, with successive changes in administrative portfolios and institutional de-structuring, there have been insufficient actions to revert the vulnerability of the fishing communities or promote sustainable management (de Azevedo & Pierri 2014, Mendonça et al. 2018, Gonçalves-Neto et al. 2021).

Brazilian restrictions to drift gillnets were implemented with a view to reducing incidental catches, especially of large mammals, while disregarding the situation of fish stocks. This is an example of top-down management measures, without participation by the people involved, and this model has been highly criticized for its inefficiency and criminalization of artisanal fishing (Pauly 2006, Salas et al. 2007, Begossi 2010). Incidental capture of other species is a global reality, but greater success in reducing this is being achieved through technological measures of adaptation of nets, management strategies and fishing agreements, in a participative and adaptive way (Folke et al. 2005, Tixier et al. 2015, 2020, Cummings et al. 2019, Guerra 2019, Hamilton & Baker 2019). Furthermore, a study on monitoring of encircling gillnets did not register any incidental capture (Madeira et al. 2018).

Through the example of what occurs in Ilhas do Currais National Marine Park, it is possible see a potential for adaptive and participative management. However, this still needs to be consolidated and assessed against national demands. It is important to highlight that this management approach, even if it is not a panacea, has brought positive results to management of artisanal fisheries (Jentoft 2005, Olsson et al. 2007, Begossi 2010, 2014, Biggs et al. 2010, Medeiros et al. 2014, Mozumder et al. 2020). Moreover, these management approaches can include measures to enhance the value of artisanal fisheries, such as payment for environmental services (Begossi et al. 2011, Begossi 2014, Bladon et al. 2016).

Furthermore, it needs to be considered that fish stocks also suffer other interferences relating to the contexts of climate change, increased pollution and intensification of use of the coastal zone. Regarding fishing activity, the context of socioeconomic vulnerability observed in other studies also suggests that there is a need for a management system capable of dealing with the complexity of the current situation.

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REFERENCES

AFONSO MG & CHAVES PT. 2021. A pesca de emalhe costeiro de pequena escala no litoral do Paraná: um estudo de caso para a conservação. Rev CEPSUL Biodiversidade e Conserv Mar 10: 1-18. https://doi.org/10.37002/revista cepsul.v10.1754e2021001.

ALMEIDA ZS, DA SILVA CML, CAVALCANTE AN, PAZ AC, SANTOS NB & GONÇALVES FS. 2007. Contribuição à conservação e manejo do peixe serra *Scomberomorus brasiliensis* (Collette Russo & Zavalla-Camin, 1978) (Osteichtyes, Scombridae) no Estado do Maranhão, Brasil. Bol Técnico Científico do CEPENE 15: 87-97.

BARBALHO ES, BARROS JD & DA SILVA FM. 2013. Comportamento Da Produção Pesqueira Norte-Rio-Grandense Em Anos De El Niño E La Niña. Soc e Territ 25: 55-66.

BATISTA VS & FABRÉ NN. 2001. Temporal and spatial patterns on serra, *Scomberomorus brasiliensis* (teleostei, scombridae), catches from the fisheries on the maranhão coast, Brazil. Brazilian J Biol 61: 541-546. https://doi.org/10.1590/s1519-69842001000400003.

BEGOSSI A. 2010. Small-scale fisheries in Latin America: management models and challenges. Mast 9: 7-31.

BEGOSSI A. 2011. O cerco flutuante e os caiçaras do litoral norte de São Paulo, com ênfase à pesca de trindade, RJ. Interciencia 36: 803-807.

BEGOSSI A. 2014. Ecological, cultural, and economic approaches to managing artisanal fisheries. Environ Dev Sustain 16: 5-34. https://doi.org/10.1007/s10668-013-9471-z.

BEGOSSI A, MAY PH, LOPES PF, OLIVEIRA LEC, DA VINHA V & SILVANO RAM. 2011. Compensation for environmental services from artisanal fisheries in SE Brazil: Policy and technical strategies. Ecol Econ 71: 25-32. https://doi.org/10.1016/j.ecolecon.2011.09.008.

BIGGS R, WESTLEY FR & CARPENTER SR. 2010. Navigating the Back Loop: Fostering Social Innovation and Transformation in Ecosystem Management. Ecol Soc 15(2): 9. http://www.ecologyandsociety.org/vol15/iss2/art9/ES-2010-3411.pdf.

BLADON AJ, SHORT KM, MOHAMMED EY & MILNER-GULLAND EJ. 2016. Payments for ecosystem services in developing world fisheries. Fish Fish 17: 839-859. https://doi.org/10.1111/faf.12095.

BLANK AG, CARNEIRO MH, SECKENDORFF RWV & OSTINI S. 2009. A pesca de cerco-flutuante na Ilha Anchieta, Ubatuba, São Paulo, Brasil. Série Relatórios Técnicos 34: 1-18.

BRASIL. 2007. Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. Instrução Normativa IBAMA 166, Brasil, Seção I, 59 p.

BRASIL. 2018. Instituto Chico Mendes de Conservação da Biodiversidade. Livro Vermelho da Fauna Brasileira Ameaçada de Extinção: Volume I, Brasília, 492 p.

CHAVES PT & BIRNFELD PO. 2021. The Serra Spanish mackerel fishery (*Scomberomorus brasiliensis* - Teleostei) in Southern Brazil: the growing landings of a high trophic level resource. Braz J Biol 83: e246180. https://doi.org/10.1590/1519-6984.246180.

CHAVES PT, BIRNFELD PO & VAZ-DOS-SANTOS AM. 2021. Population dynamics of *Scomberomorus brasiliensis* from a small-scale fishery off Southern Brazil. Ocean Coast Res 69: 1-17. https://doi.org/10.1590/2675-2824069.20-016pdtdcc.

CHAVES PT & VENTURA A. 2019. Recursos - alvo que são também bycatch, e recomendação para a gestão da pesca de emalhe no litoral do Paraná , Brasil. Rev CEPSUL Biodiversidade e Conserv Mar 8: 1-11. https://doi.org/https://doi.org/10.37002/revistacepsul%25v%25y732e2019001.

CHEUNG WWL, WATSON R & PAULY D. 2013. Signature of ocean warming in global fisheries catch. Nature 497: 365-368. https://doi.org/10.1038/nature12156.

CLAUZET M, RAMIRES M & BARELLA W. 2005. Pesca Artesanal e Conhecimento Local de Duas Populações Caiçaras (Enseada do Mar Virado e Barra do Una) no Litoral de São Paulo, Brasil. Multiciência, p. 1-22.

CORDEIRO AG & MENDONÇA JT. 2010. Estatística Pesqueira do Litoral Sul de São Paulo - Metodologia e Resultados. In: Silva RB & Ming LC (Eds), Relatos de Pesquisas e Outras Experiências Vividas No Vale Do Ribeira, p. 171-190.

CUMMINGS CR, LEA MA & LYLE JM. 2019. Fur seals and fisheries in Tasmania: an integrated case study of human-wildlife conflict and coexistence. Biol Conserv 236: 532-542. https://doi.org/https://doi.org/10.1016/j.biocon.2019.01.029.

DE AZEVEDO NT & PIERRI N. 2014. A política pesqueira no Brasil (2003-2011): a escolha pelo crescimento produtivo e o lugar da pesca artesanal. Desenvolv e Meio Ambient 32: 61-80. https://doi.org/10.5380/dma.v32i0.35547.

DE BRITO CSF & FURTADO-JUNIOR I. 2010. Dinâmica Sazonal da CPUE da Serra, *Scomberomorus brasiliensis*, Capturada com rede de Emalhar do tipo Serreira no Estado do Pará. Arq Ciência do Mar 43: 88-95. https://doi.org/10.32360/acmar.v43i1.6015.

DE NÓBREGA MF & LESSA RP. 2009. Age and growth of the king Mackerel (*Scomberomorus cavalla*) off the northeastern coast of Brazil. Brazilian J Oceanogr 57: 273-285. https://doi.org/10.1590/s1679-87592009000400003.

ESPÍRITO-SANTO RV & ISAAC VJ. 2012. Desembarques da Pesca de Pequena Escala no Município de Bragança - PA, Brasil: Esforço e Produção. Bol do Laboratório Hidrobiol 25: 31-48.

FACCIN JRM. 2019. Efeito das mudanças climáticas de curto prazo sobre a operação da frota de cerco direcionada à captura da sardinha-verdadeira no sudeste-sul do Brasil. Tese de doutorado, Universidade do Vale do Itajaí, 138 p. http://siaibib01.univali.br/pdf/Jos%C3%A9%20Ricardo%20Munari%20Faccin2019.pdf.

FAO. 2020. The State of World Fisheries and Aquaculture 2020. Sustainability in action, 244 p. https://doi.org/10.4060/ca9229en.

FIPERJ. 2020. Estatística Pesqueira do Rio de Janeiro. Consulta On-Line, Projeto De Monitoramento Da Atividade Pesqueira Do Estado do Rio de Janeiro, Accessed on 18 January 2021. http://pescarj.fundepag.br.

FOLKE C, HAHN T, OLSSON P & NORBERG J. 2005. Adaptive Governance of Social-Ecological Systems. Annu Rev Environ Resour 30: 441-473. https://doi.org/10.1146/annurev.energy.30.050504.144511.

FREIRE KMF ET AL. 2015. Reconstruction of catch statistics for Brazilian marine waters (1950-2010). Fish Cent Res Reports 23: 48.

FRÉON P & MISUND OA. 1999. Dynamics of Pelagic Fish Distribution and Behaviour: Effects on Fisheries and Stock Assessment. Fishing News Books, 348 p. https://doi.org/10.1023/A:1008928315202.

GATICA C & HERNÁNDEZ A. 2003. Tasas de captura estandarizadas como índice de abundancia relativa en pesquerías: Enfoque por Modelos Lineales Generalizados. Investig Mar 31: 107-115. https://doi.org/10.4067/s0717-71782003000200011.

GONÇALVES-NETO JB, GOYANNA FAA, FEITOSA CV & SOARES MO. 2021. A sleeping giant: the historically neglected Brazilian fishing sector. Ocean Coast Manag 209: 105699. https://doi.org/10.1016/j.ocecoaman.2021.105699.

GUERRA AS. 2019. Wolves of the Sea: Managing human-wildlife conflict in an increasingly tense ocean. Mar Policy 99: 369-373. https://doi.org/https://doi.org/10.1016/j.marpol.2018.11.002.

HALPERN BS ET AL. 2008. A Global Map of Human Impact on Marine Ecosystems. Science 319(5865): 948-952. https://doi.org/10.1126/science.1149345.

HAMILTON S & BAKER GB. 2019. Technical mitigation to reduce marine mammal bycatch and entanglement in commercial fishing gear: lessons learnt and future directions. Rev Fish Biol Fish 29: 223-247. https://doi.org/10.1007/s11160-019-09550-6.

HARLEY SJ, MYERS RA & DUNN A. 2001. Is catch-per-unit-effort proportional to abundance? Can J Fish Aquat Sci 58: 1760-1772. https://doi.org/10.1139/cjfas-58-9-1760.

HAZIN HG. 2006. Influência das variáveis oceanográficas na dinâmica populacional e pesca do espadarte, *Xiphias gladius* Linnaeus 1758, capturados pela frota brasileira. Influência das variáveis oceanográficas na dinâmica populacional e pesca do espadarte, *Xiphias glad*. Tese de Doutorado, Universidade do Algarve, 202 p. http://hdl.handle.net/10400.1/576.

HE P, CHOPIN F, SUURONEN P, FERRO RS & LANSLEY J. 2021. Classification and illustrated definition of fishing gears, FAO Fisheries and Aquaculture Technical Paper No. 672. FAO, Rome. https://doi.org/10.4060/cb4966en.

ISAAC-NAHUM VJ. 2006. Explotação e manejo dos recursos pesqueiros do litoral amazônico: um desafio para o futuro. Ciênc Cult São Paulo 58: 33-36.

JANKOWSKY M, MENDONÇA JT & MORRONI DA. 2019. Monitoramento Pequeiro no Litoral do Paraná. In: Tullio L (Ed), Fronteiras Da Sustentabilidade 2, Atena, p. 41-55. https://doi.org/10.22533/at.ed.731192312.

JENTOFT S. 2005. Fisheries co-management as empowerment. Mar Policy 29: 1-7. https://doi.org/10.1016/j.marpol.2004.01.003.

JENTOFT S. 2014. Walking the talk: implementing the international voluntary guidelines for securing sustainable small-scale fisheries. Marit Stud 13: 1-15. https://doi.org/10.1186/s40152-014-0016-3.

LARGE PA. 1992. Use of a multiplicative model to estimate relative abundance from commercial cpue data. ICES J Mar Sci 49: 253-262. https://doi.org/10.1093/icesjms/49.3.253.

LEÃO SAS, FURTADO-JUNIOR I, ABRUNHOSA FA & SILVA JA. 2019. Análise Histórico De CPUES Padronizadas da Serra *Scomberomorus brasiliensis* (Pisces: Scombridae) Desembarcada no Estado do Pará - Costa Amazônica. Bol Técnico Científico do CEPNOR 18: 23. https://doi.org/10.32519/tjfas.v18i1.2146.

LESSA RP. 2006. Recursos Vivos na Zona Econômica Exclusiva. In: Programa Revizee (Ed), Avaliação Do Potencial Sustentável de Recursos Vivos Na Zona Econômica Exclusiva, 304 p.

LESSA RP, NÓBREGA M & BEZERRA JLJ. 2004. Dinâmica de populações e avaliação de estoques de recursos pesqueiros da região nordeste. REVIZEE Relatório, Avaliação do Potencial Sustentável de Recursos Vivos na zona econômica exclusiva, Volume II, 246 p. https://doi.org/10.1139/f05-015.

LIMA JTAX, FONTELES-FILHO AA & CHELLAPPA S. 2007. Biologia Reprodutiva da Serra, *Scomberomorus brasiliensis* (Osteichthyes:Scombridae), em Água Costeiras do Rio Grande do Norte. Arq Ciências do Mar 40: 24-30. https://doi.org/10.32360/acmar.v40i1.6139.

LIMA PRS, LESSA RPT, DE CASTRO ACL & AZEVEDO JWJ. 2009. Growth and First Sexual Maturation Size of *Scomberomorus brasiliensis* (Osteichthyes; Scombridae - Collette Russo & Zavalla-Camin,1978) on the Maranhão Coast West - Brazil. Bol do Lab Hidrobiol 22: 39-44.

LOTO L, LOBÃO R, SILVA EP & MONTEIRO-NETO C. 2019. Fishermen ecological knowledge and complex adaptive systems: An interpretative model for small-scale fisheries. Ambient e Soc 22: 1-18. https://doi.org/10.1590/1809-4422ASOC0140R1VU19L4TD.

MADEIRA JA, MULLER BR, MEDEIROS R, GIRALDI AC, MENDONÇA JT, ALVITE C, STEENBOCK W & CORRE FM. 2018. Termo de Compromisso: Conciliação permite a pesca em unidade de proteção integral recém-criada pelo poder legislativo. In: ICMBio (Ed), Boas Práticas Na Gestão de Unidades de Conservação, Brasília, p. 149-152.

MAGRIS RA ET AL. 2020. A blueprint for securing Brazil's marine biodiversity and supporting the achievement of global conservation goals. Divers Distrib 27: 198-215. https://doi.org/10.1111/ddi.13183.

MAIA RCN, SILVA BB, PEREIRA LJG & HOLANDA FCAF. 2015. Pesca Comercial e Estrutura Populacional da Serra, *Scomberomorus brasiliensis* (Collette, Russo & Zavala, 1978), Desembarcada em Um Pólo Pesqueiro na Costa Norte do Brasil. Biota Amaz 5: 99-106. https://doi.org/10.18561/2179-5746/biotaamazonia.v5n2p99-106.

MATTOS SMG, MENDONÇA JT, PEDROSA BMF, MATTOS MPS, WOJCIECHOWSKI MJ & GERHARDINGER LC. 2022. Coastal Small-Scale Fisheries in Brazil: Resentment Against Policy Disarray. In: Jentoft S, Chuenpagdee R, Said A & Isaacs M (Eds), Blue Justice: Small-scale Fisheries in a Sustainable Ocean Economy, MARE Publications Series, Vol 26, Springer International Publishing, p. 35-54. https://doi.org/10.1007/978-3-030-89624-9_3.

MAUNDER MN, SIBERT JR, FONTENEAU A, HAMPTON J, KLEIBER P & HARLEY SJ. 2006. Interpreting catch per unit effort data to assess the status of individual stocks and communities. ICES J Mar Sci 63: 1373-1385. https://doi.org/10.1016/j.icesjms.2006.05.008.

MEDEIROS RP, SERAFINI TZ & MCCONNEY P. 2014. Fortalecendo o ecosystem stewardship na pesca artesanal: perspectivas para a América Latina e Caribe. Desenvolv e Meio Ambient 32: 181-191. https://doi.org/10.5380/dma.v32i0.38819.

MENDONÇA JT, CAMPANHA PMGC, MACHADO IC & SILVA MHC. 2018. Emprego de métodos participativos, qualitativos e mistos na pesquisa voltada para a gestão pesqueira no Brasil. In: Anais Congresso Ibero-Americano Em Investigação Qualitativa, p. 54-88.

MENDONÇA JT & KATSURAGAWA M. 2001. Caracterização da pesca artesanal no complexo estuarino-lagunar de Cananéia-Iguape, Estado de São Paulo, Brasil (1995-1996). Acta Sci Biol Sci 23: 535-547.

MOURÃO KRM, ESPÍRITO-SANTO RV, SILVA BB, ALMEIDA MC, ISAAC VJ, FREDOU T & FRÉDOU FL. 2014. A Pesca da Serra *Scomberomorus brasiliensis* e Alternativas para o seu Manejo no Litoral Nordeste do Pará – Brasil. In: Haimovici M, Andriguetto Filho JM & Sunye PS (Eds), A Pesca Marinha e Estuarina No Brasil A Pesca Marinha e Estuarina No Brasil Estudos de Caso Multidisciplinares, Editora da FURG, Rio Grande, p. 171-179.

MOZUMDER MMH, PYHÄLÄ A, WAHAB MA, SARKKI S, SCHNEIDER P & ISLAM MM. 2020. Governance and power dynamics in a small-scale hilsa shad (Tenualosa ilisha) fishery: A case study from Bangladesh. Applied Sciences Switzerland 12(14): 1-24. https://doi.org/10.3390/su12145738.

NAMORA RC, MOTTA FS & GADIG OBF. 2009. Caracterização Da Pesca Artesanal Na Praia Dos Pescadores, Município De Itanhaém, Costa Centro-Sul Do Estado De São Paulo. Arq Ciências do Mar 42: 60-67. https://doi.org/10.32360/acmar.v42i2.6026.

NOBREGA RA. 2018. Condição reprodutiva da cavala, *Scomberomorus brasiliensis*, capturada no litoral do Paraná. Monografia, Universidade Federal do Paraná, 37 p. https://hdl.handle.net/1884/68606. (Unpublished).

OLSSON P, FOLKE C, GALAZ V, HAHN T & SCHULTZ L. 2007. Enhancing the fit through adaptive co-management: creating and maintaining bridging functions for matching scales in the Kristianstads Vattenrike Biosphere Reserve Sweden. Ecol Soc 12(1): 28. http://www.ecologyandsociety.org/vol12/iss1/art28/.

PALHETA MKS, CAÑETE VR & CARDOSO DM. 2016. Mulher e mercado: Participação e conhecimentos femininos na inserção de novas espécies de pescado no mercado e na dieta alimentar dos pescadores da RESEX Mãe Grande em Curuçá (PA). Bol Mus Para Emílio Goeldi Cienc Hum 11(3): 601-619. https://doi.org/10.1590/1981.81222016000300004.

PAULY D. 2006. Major Trends in Small-Scale Marine Fisheries, with Emphasis on Developing Countries, and Some Implication fro Social Sciences. Marit Stud 4: 7-22.

POMEROY RS, BALDWIN K & MCCONNEY P. 2014. Marine Spatial Planning in Asia and the Caribbean: Application and Implications for Fisheries and Marine Resource Management. Desenvolv e Meio Ambient 32: 151-164. https://doi.org/10.5380/dma.v32i0.35627.

QUITO L, MENDONÇA JT & JANKOWSKY M. 2019. Desafios à Gestão Pesqueira Compartilhada: Conflitos com a Pesca de Emalhe nas APAs Marinhas de São Paulo. in: Silva RP, Muhle RP, Paixão WB, Santos JE, Selva VSF, Cavalcanti ER & Pedrosa BMJ (Eds), Anais Do IX Seminário Brasileiro Sobre Áreas Protegidas e Inclusão Social e IV Encontro Latino-Americano Sobre Áreas Protegidas e Inclusão Social. Fundação Joaquim Nabuco, Editora Massangana, Recife-PE, p. 734-739.

REIS-FILHO JA. 2019. Historical perspective of artisanal encircling gillnet use at the Brazilian coast: Changes in fishing behaviour is mirrored by dwindling stocks. Fish Manag Ecol 27: 155-166. https://doi.org/10.1111/fme.12393.

RINCÓN-SANDOVAL LA, VELAZQUÉS-ABUNADER I & BRULÉ T. 2018. Factors Influencing Catchability on Longline Fisheries: The Case of Red Grouper (*Epinephelus morio*), Yucatan Mexico El Caso del Mero Americano (*Epinephelus morio*), Yucatán México Factors Influencing Catchability on Longline Fisheries: The Case of Re. In: Proceedings of the 71st Gulf and Caribbean Fisheries Institute, p. 5-9.

ROUSSEAU Y, WATSON R, BLANCHARD J & FULTON EA. 2019. Defining global artisanal fisheries. Mar Policy 108: 103634. https://doi.org/10.1016/j.marpol.2019.103634.

SALAS S, CHUENPAGDEE R, SEIJO JC & CHARLES A. 2007. Challenges in the assessment and management of small-scale fisheries in Latin America and the Caribbean. Fish Res 87: 5-16. https://doi.org/10.1016/j.fishres.2007.06.015.

SILVA JO, LIN CF, CERÂNTOLA B, MENEZES A & FIEDLER FN. 2017. A pesca artesanal no litoral norte de Santa Catarina e as espécies ameaçadas. In: 17 Congresso Latino-Americano de Ciências Do Mar, p. 1638-1640.

SILVA MRO, PENNINO MG & LOPES PFM. 2019. Social-ecological trends: managing the vulnerability of coastal fishing communities. Ecol Soc 24: art4. https://doi.org/10.5751/ES-11185-240404.

SOUSA RFC, IKEDA R, FONSECA A, SOUZA L, BRITO C, FREDOU FL, LIMA PR, CASTRO ACL & DOURADO E. 2003. Dinâmica populacional da *Scomberomorus brasiliensis* da costa Norte do Brasil. In: Relatório de Atividades Do Programa REVIZEE, p. 48.

STENECK RS & PAULY D. 2019. Fishing through the Anthropocene. Curr Biol 29: R987-R992. https://doi.org/10.1016/j.cub.2019.07.081.

TIXIER P, LEA MA, HINDELL MA, WELSFORD D, MAZÉ C, GOURGUET S & ARNOULD JPY. 2020. When large marine predators feed on fisheries catches: Global patterns of the depredation conflict and directions for coexistence. Fish Fish 22(1): 31-53. https://doi.org/10.1111/faf.12504.

TIXIER P, VACQUIE GARCIA J, GASCO N, DUHAMEL G & GUINET C. 2015. Mitigating killer whale depredation on demersal longline fisheries by changing fishing practices. ICES J Mar Sci 72: 1610-1620. https://doi.org/10.1093/icesjms/fsu137.

UNIVALI/EMCT/LEMA. 2020. Estatística Pesqueira de Santa Catarina. Consulta On-line. Projeto de Monitoramento da Atividade Pesqueira do Estado de Santa Catarina. Accessed on 18 January 2021. URL http://pmap-sc.acad.univali.br.

VASCONCELLOS M, DIEGUES AC & SALES RR. 2007. Limites e Possibilidades na Gestão da Pesca Artesanal Costeira. In: Costa AL (Ed), Nas Redes Da Pesca Artesanal, IBAMA, Brasília, p. 15-83.

VAZ-DOS-SANTOS AM, COSTA MR & CRUVINEL CM. 2013. Análise da ictiofauna capturada em cerco fixo flutuante na Praia de Toque- Toque Pequeno, Litoral Norte do Estado de São Paulo, Brasil. UNISANTA Biosci 2(2): 7-16.

XIMENES MOC. 1981. Age and growth of the Brazilian mackerel, *Scomberomorus brasiliensis* Collete & Russo, 1978 off northeastern Brazil. Arq Ciências do Mar 21: 47-54.

WANG S, HUANG J, HE Y & GUAN Y. 2014. Combined effects of the Pacific Decadal Oscillation and El Niño-Southern Oscillation on Global Land Dry–Wet Changes. Sci Rep 4: 6651. https://doi.org/10.1038/srep06651.

ZAR JH. 2010. Biostatistical Analysis, 5th ed, Pearson Prentice Hall, 944 p.

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