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Understanding changes to fish stock abundance and associated conflicts: Perceptions of small-scale fishers from the Amazon coast of Brazil

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ABSTRACT

The perceptions and knowledge of fishers are very important for fisheries management, especially in data-poor regions such as the Amazon coast of Brazil. Here, the perceptions of fishers were used to analyze the main conflicts faced by small-scale fisheries and to identify the status of fishery resources in the state of Amapá (Brazil). Data from interviews with 359 fishers were analyzed. Conflicts involve diverse actors with different and potentially competing interests and accountabilities, including small-scale and large-scale fishers, intermediaries, and government agents. The main conflict was related to access to fishery resources, including issues with the prohibition of fishing in No-Take Zones and competition with fishing fleets from other regions (outsiders). The lack of control over the access of users has culminated in increasing fishing effort. The invasion of traditional fishing territories was a central argument against the outsiders; however, these conflicts are also strongly related to the exhaustion of fishery resources, with about 75% of respondents perceiving a decrease in fish abundance. This scenario reveals a governance crisis and the weak performance and inability of the government to carry out effective enforcement, monitoring, and surveillance. The presence of people heavily reliant on natural resources in a region with very few alternative sources for livelihoods indicates that sustainable fisheries management requires wider cooperation between the government and all stakeholders, with co-management being required.

1. Introduction

Global marine fisheries present a worrying scenario, with 33% of assessed fish stocks being overfished (FAO, 2018), and an average catch decline rate of 1.2 mt per year since 1996 (Pauly and Zeller, 2016). The concern is even greater in developing countries, where fishing plays a crucial role to the livelihoods of millions of people that suffer from high levels of poverty, with few alternative sources of income, employment, and animal protein (Béné, 2006; Béné et al., 2007; Salas et al., 2011). This phenomenon occurs in most countries in Latin America and the Caribbean, where fisheries exhibit high heterogeneity in the gear, boats, and species. These regions also have a great diversity in geophysical, bioecological, and socioeconomic characteristics, as well as multiple political interactions. These various parameters combined, result in diffuse fisheries activity, with temporal and spatial dynamics that are challenging to understand and manage (Fischer et al., 2015; Salas et al., 2011).

In particular, fishing activity in Brazil is extremely heterogeneous, complex, and dynamic, due to the large size of the territory and major regional differences. As a result, the fishing communities in this country have developed adaptations to environmental, socioeconomic, political, and cultural characteristics intrinsic to each place (Silva, 2014). In the Amazon, small-scale fisheries (SSFs) are predominant, and are carried out by fishers operating small and medium-sized wooden boats using a large diversity of gears and catch techniques. Fish are sold through an informal network of intermediaries that supply regional and national markets, and the fishing sector is characterized by very low labor mobility (Almeida et al., 2003, 2011; Isaac-Nahum, 2006; Isaac et al., 2015a, 2009).

In the Amazon, fishers are heavily reliant on SSFs for their livelihoods, with this activity representing the major source of income, animal protein, and culture for coastal and riparian communities

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(Almeida et al., 2003; Castello et al., 2011; Ruffino, 2014). In some Amazon communities, fish comprise 64–76% of the animal food items intake and 79–87% of the weight ingested, with an average rate of 169 kg.person-1.year-1 or 462 g.person-1.day-1, representing one of the highest rates of fish consumption globally (Isaac et al., 2015b).

The Amazon coast encompasses the states of Amapá, Pará and Maranhão, where both small-scale and large-scale fishing is carried out from nearshore regions to the continental shelf (Isaac-Nahum, 2006). SSFs capture multiple species, with the Sciaenidae and Ariidae families providing the main fisheries resources; however, crabs and shellfish are also manually collected (Almeida et al., 2011; Isaac-Nahum, 2006; Isaac et al., 2009). In comparison, the industrial fisheries capture single species, including southern brown shrimp (*Penaeus subtilis*), Laulao catfish (*Brachyplatystoma vaillantii*), and southern red snapper (*Lutjanus purpureus*) (Isaac et al., 2009).

In the state of Amapá, fishing has high socioeconomic and food security importance, with 16,700 professional small-scale fishers operating (SISRGP, 2016). The capture and landing of estuarine and marine fish occurs predominantly in the municipalities of Oiapoque, Calçoene, and Amapá (PROZEE, 2006). In this region, the fishing grounds are shared with fishers from other Brazilian states and French Guiana, with catches occurring in and around No-Take Zones (NTZs), culminating in many conflicts (Crespi et al., 2015; Pinha et al., 2015). These conflicts are aggravated by the government having difficulty in controlling the access of users. There is also a lack of time series on biological and socioeconomic data needed for traditional quantitative fishery assessment models.

Consequently, in such 'data-poor' regions, the knowledge of fishers is a valuable information source (Saavedra-Díaz et al., 2015; Tesfamichael et al., 2014) and an important instrument for the Ecosystem Approach to Fisheries (EAF). The EAF aims to balance human and ecological well-being under the concept of sustainable development and is based on a holistic view of fisheries (Fischer et al., 2015). Fishers have a great amount of contextual and experiential-based knowledge about the socioecological system of fisheries, including target species and the ecosystem, as well as perspectives on social, economic, technological, behavioral, governance, and market aspects of fisheries (Stead et al., 2006; Stephenson et al., 2016). This knowledge is clearly important for fisheries management and has been highlighted in studies globally (Fischer et al., 2015; Saavedra-Díaz et al., 2015; Stead et al., 2006; Stephenson et al., 2016).

In data-poor situations, the knowledge of fishers is also potentially useful for recording the occurrence of temporal environmental changes, such as increases or decreases in fish abundance (Hallwass et al., 2013). Such information might complement data gaps for assessments (Tesfamichael et al., 2014) or could be used as indicators to prioritize the focus of management systems. The knowledge of fishers is also important to identify possible conflicts regarding the state of natural resources, environmental conservation, fishing regulations, and problems between sectors (Baigún, 2015). It is useful to understand what drives conflicts to identify problems that might lead to the unsustainable extraction of fishery resources (DuBois and Zografos, 2012), in addition to its being essential for cooperation in marine conservation (Majanen, 2007).

Within this context, this study aims to elucidate the main conflicts faced by SSFs and to identify possible changes in the abundance of fishery resources in the state of Amapá (Brazil), as well as to discuss potential causes and solutions to these problems based on the perceptions of fishers. The combined analysis of these two issues is expected to contribute towards identify potential risks for SSFs and assist in establishing key management priorities. This study was motivated by the first author participating as a representative of the Fisheries Agency of Amapá State (a fisheries management agency) on the advisory council of the NTZs in the study area. The councils provide spaces for dialogue, with participants including representatives from government agencies, civil society organizations, scientists, and other stakeholders. The main objective of the councils is to orient the decisions of managers (Almudi and Kalikoski, 2010). Discussions about the conflicts faced by small-scale fishers frequently occur in council meetings and include complaints by fishers about the decline in fish abundance. Fishers repeatedly state that the Brazilian government does not 'listen to them' or consider their interests and needs when regulating the use of natural resources, often disregarding their traditional knowledge built over many generations. Therefore, the authors decided to investigate the issues that have emerged at the meetings of these councils and identify how the perceptions of fishers could be used to help fisheries management on the Amazon coast of Brazil.

2. Material and methods

2.1. Study area

This study was carried out in the municipalities of Oiapoque, Calçoene, and Amapá, in the state of Amapá (Amazon coast of Brazil) (Fig. 1). The coastal zone of these municipalities is approximately 400 km long, with extensive muddy tidal plains and mangroves (Santos et al., 2016). This area is influenced by the discharge of the Amazon River and by the Brazil North Current (Curtin, 1986). There are three coastal NTZs in the region (Fig. 1): Cabo Orange National Park (CONP), Maracá-Jipióca Ecological Station (MJEE), and Lago Piratuba Biological Reserve (LPBR). These NTZs are managed by Chico Mendes Institute for Biodiversity Conservation (referred as ICMBio), and integrate a network of 17 protected areas, covering 72% (10 million ha) of the territory of the state of Amapá, including flooded and non-flooded forests, savannah, mangroves, and estuaries (CI-Brazil, 2007). This area also encompasses two Ramsar Sites: CONP and the Amazon Estuary and its Mangroves. Wetlands of international importance are designated as Ramsar sites under the Ramsar Convention, which is an intergovernmental treaty that aims to improve the conservation of wetlands and their wise use (Ramsar Convention Secretariat, 2016).

In the study area, there are approximately 1,330 professional fishers (SISRGP, 2016) that mostly live in urban areas, and are organized into four Fishers' Colonies (i.e., formal fisherfolk organizations). Small-scale nearshore and continental fisheries are carried out using passive fishing gears. Nearshore fisheries have an average landing of 5.400 tons.year[1], with gillnets accounting for more than 70% of fish catches. Weakfishes (*Cynoscion virescens* and *C. acoupa*) and marine catfishes (*Sciades couma*, *S. proops*, and *S. parkeri*) represent about 76% of the total catch (PROZEE, 2006).

Based on data collected in socioeconomic surveys, it is estimated that the fishing fleet is composed of 500 small and medium-sized wooden boats distributed into three categories: (i) Canoes: boats with outboard engines, no cabin, and 5–12 m in length, with fish being stored in ice in old refrigerators or in polystyrene boxes (90–1,500 kg); (ii) Small-sized boats: boats with outboard or inboard engines, with or without cabins, and 6–12 m in length, with fish being stored in ice tanks (1,000–7,000 kg); and (iii) Medium-sized boats: boats with inboard engines, decks with cabins, and 12.5–18 m in length, with fish being stored in ice tanks (7,000–14,000 kg).

2.2. Data collection and analysis

Data were collected through face-to-face interviews based on a standardized semi-structured questionnaire on the perceptions of fishers regarding conflicts and changes in fish abundance. The questionnaire consisted of five open-end questions: (1) Is there any conflict related to fishing in your community? (2) What do you think could be done to solve or reduce these conflicts? (3) Do you think that some fish

[1] Data available from the ICMBio (Chico Mendes Institute for Biodiversity Conservation) website: www.icmbio.gov.br/cepsul/acervo-digital.

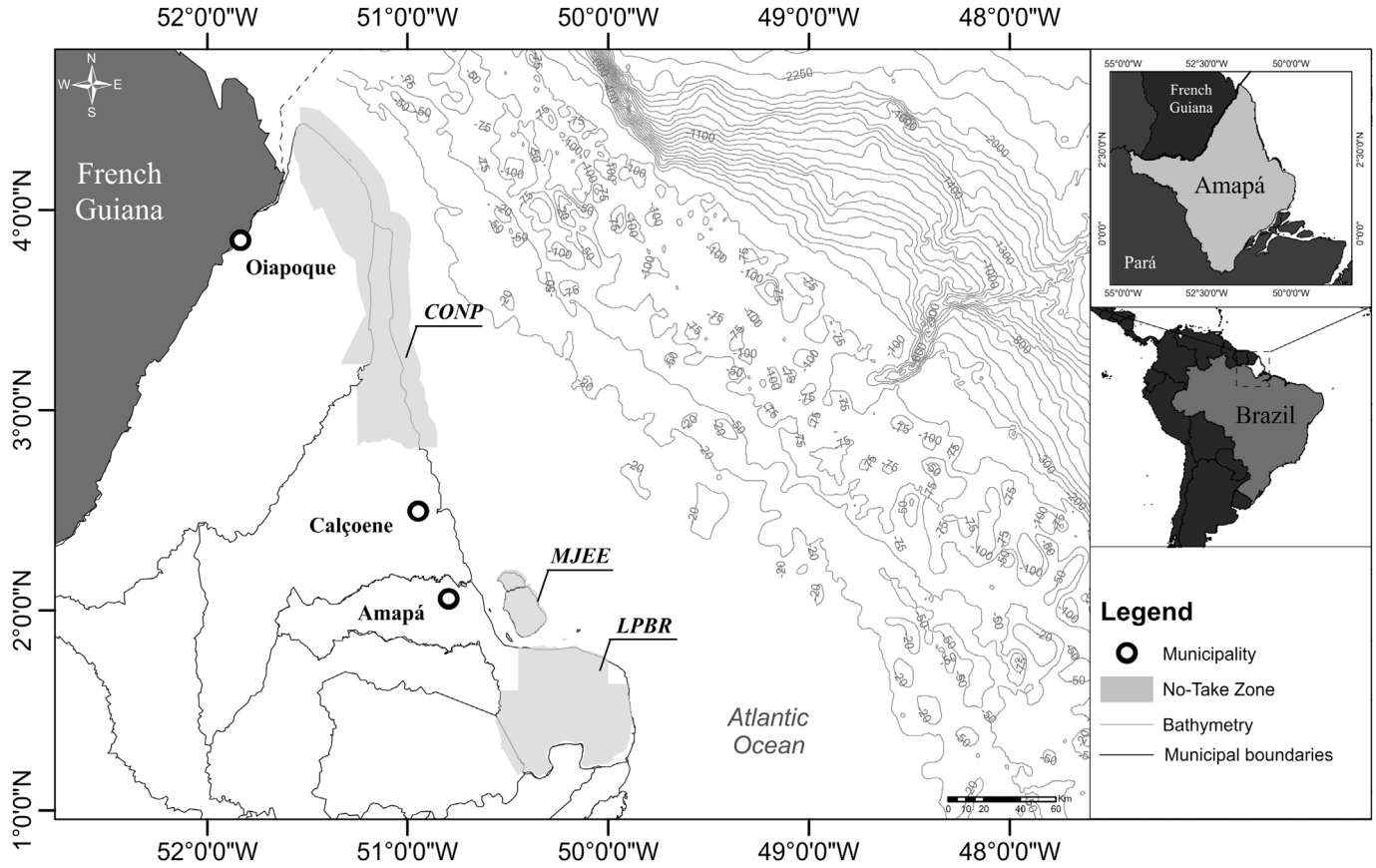

Fig. 1. Location of the studied municipalities (Oiapoque, Calçoene, and Amapá) and the No-Take Zones (Cabo Orange National Park - CONP, Maracá-Jipióca Ecological Station - MJEE, and Lago Piratuba Biological Reserve - LPBR), in the tate of Amapá (Amazon coast, Brazil).

stocks are declining? (4) In your opinion, what is the possible cause for this decline? (5) What do you think could be done to mitigate this decline?

The first and second questions aimed to identify the experiences of conflict by respondents and possible solutions they have considered. This approach allows interviewees to freely list all actions they perceive as conflicting and explain why, as well as the solutions that they believe are possible. The third question aimed to analyze the status of the fishery resources in the study area, and to identify the fish species impacted by anthropic pressure or natural changes. In the last two questions, the respondents were given the opportunity to suggest possible causes and solutions associated with these issues based on their views and experiences.

Fieldwork was carried out with the logistic support of ICMBio during several field trips conducted between January 2014 and September 2016. In total 359 fishers were interviewed, representing 27.6% of all fishers registered in the study area. Respondents were mainly men (92%), aged 18–82 years (39.76 ± 12.69), with low educational level (70% did not complete elementary school). Most had fishing experience of more than 10 years (75%), with fishing being their only source of income (70%).

Interviews were conducted at fish landing sites and at the houses and Colonies of fishers. A combination of random and snowball sampling methods was applied. The first respondents were fishers' leaders (i.e., presidents of the Fishers' Colonies), to obtain a general overview of the local context. Then, the fishers leaders indicated other fishers they believed to have a high fishing experience. The nominated fishers then suggested others. In this way, the snowball sampling procedure was followed, based on key informants (Bailey, 1982). When nominated fishers had already been interviewed, respondents were randomly selected according to the availability of fishers during the field period. This procedure aimed to minimize possible bias in the interviews (Musiello-Fernandes et al., 2018). Information acquired outside the context of interviews was used to support the collected data; such information included observations, experiences, and interactions with community members.

The interviews were carefully translated from Portuguese to English to maintain the original connotations of the narratives. Data from key informants and randomly selected respondents were analyzed together, because the same response patterns were observed. The qualitative responses about conflict experiences and their solutions were organized into categories according to the actors involved and the principal themes that emerged from the data. A response could contain more than one dominant theme. The percentage of respondents that mentioned each theme was calculated, and only themes cited by at least 10% of respondents were considered.

To analyze the status of fish stocks, the relative frequency that each species was mentioned was calculated. The discourses of respondents on the causes and solutions regarding changes to the abundance of fish stocks were analyzed through a quantitative method called 'similarity analysis.' This method extends information beyond the level of individual interviews, providing a deeper analysis of similarities in the structure of arguments used by the interviewees to justify their approach, based on the words used in the narratives, their frequency, and organization (Delattre et al., 2015). The similarity analysis allows the recognition of co-occurrences and connections between words, assisting the identification of the most common and important themes in discourses. This analysis is based on graph theory and is classically used for studying social representations (Flament, 1981).

To evaluate the possible influence of data translation on the results, the similarity analysis was performed in both languages (i.e., Portuguese and English). The two analyses generated very similar

results, indicating that the data translation did not bias the results. The similarity analysis were performed using IRAMUTEQ (*Interface de R pour les Analyses Multidimensionnelles de Textes et de Questionnaires*) software (Ratinaud, 2009). To run this analysis, the software replaces all terms in the narratives by their canonical form (e.g., plural forms with singular forms, verbal forms with infinitive forms, elided words with corresponding non-elided words), and only the 'active forms' (e.g., content words like nouns, verbs, and adjectives) are considered (Delattre et al., 2015). The correlation among all active forms taken in pairs was calculated to obtain a similarity matrix, using the similarity index available in the R proxy library. The summary of information contained in the similarity matrix is graphically represented in a maximum tree (i.e., the simplest and most informative tree, containing only the strongest links) (Delattre et al., 2015; Vergès and Bouriche, 2001), in which the words are the vertices and the edges/links represent co-occurrences. The most frequently used words in the narratives appeared proportionately with larger size, with the same occurring for the thickness of the edges/links connecting the words, which reflects the strength of the relations between them. The algorithm of Fruchterman Reingold was used to optimize the display of the graph and to visualize the most 'central' words (Baril and Garnier, 2015).

3. Results

3.1. Conflicts in small-scale fisheries on the Amazon coast of Brazil

The main conflicts experienced by the respondents were grouped into three categories (Table 1): a) Local fishers and outsiders (73.1%); b) Fishers and surveillance agents (20.4%); and c) Fishers and middlemen (11.3%). The conflicts, their causes, actors, and possible solutions were examined.

3.1.1. Conflicts between local fishers and outsiders

Competition with outsiders (i.e., fishers that does not live in the state of Amapá) is clearly the most significant conflict experienced by local fishers. This conflict involved mainly fishers from the state of Pará, with the overlap in fishing grounds and predatory fishing (44.4%) representing the main causes of tension. The fishing practices considered as predatory by the respondents included the use of very extensive gillnets, longlines with many hooks, and technological equipment to support fisheries (e.g., GPS, sonar, and power rollers to pull the nets), as well as the industrial trawl fisheries and their high fish catches and discards. Other conflicts involving outsiders were related to the increasing scarcity of fishery resources (37.5%) and the illegal catches of *S. parkeri* during the closed-season (10.2%), which was facilitated by the fact that surveillance is restricted to landings in the state of Amapá. Consequently, illegal catches landed in other states are not punished. The combination of these issues caused respondents to believe that their fishing activity and rights are negatively impacted by outsiders, whose fishing practices are considered an obstacle to the survival of local SSFs.

The solutions proposed by the respondents to the conflicts with outsiders mostly focused on the surveillance and prohibiting outsiders from fishing in the territories of local fishers (i.e., fishing grounds close to the coast) (Table 1). The fishers believed that these actions would reduce conflicts without any major social impacts, because the fishing fleet of Pará is formed of larger boats with more autonomy and technology to fish far from the coast. Within this context, the creation of a protected area for local small-scale fishers was also cited as solution (13.8%).

3.1.2. Conflicts between fishers and surveillance agents

In Brazil, environmental surveillance is carried out by two institutions: ICMBio (the national protected areas' manager) and IBAMA (the national environmental agency). The conflicts between fishers and surveillance agents (20.4%) was mainly related to the conservation of natural resources in NTZs, including the prohibition of fishing in these areas (13.1%), the approaches used by surveillance agents (10.5%), and the effectiveness of surveillance (10.2%).

NTZs in traditional fishing territories were created in the 1980s under different contexts in each municipality of the study area. However, in all cases, the government imposed restrictions on the livelihoods of local residents, who heavily depend on natural resources as sources of food and income. In Oiapoque, the president of the Fishers' Colony reported the history of expulsion of the residents of Taperebá Village, which is located inside the CONP. According to this actor, after the NTZ was created, the government deactivated the public services offered to the village and implemented restrictions on access to natural resources. These events forced many residents to migrate to the urban area of Oiapoque, without any compensation. At present, just five families live in the village.

There are two fishers' villages (Araquiçaua and Paratu) inside the LPBR, and one other (Sucuriju) in the nearby area. Their livelihoods are intrinsically linked to the catch of freshwater and estuarine fishes in the protected lakes. The residents were not removed from their homes when the NTZ was created, but many restrictions were imposed by the government on their livelihoods. According to respondents, surveillance agents were aggressive, burning the wooden shelters built by fishers around the lakes. Respondents stated that conflicts with both CONP and LPBR were reduced by establishing Commitment Terms (CT) that regulate SSFs within NTZs by complying with rules that were collectively constructed by fishers and managers.

Respondents stated that there were only a few residents in the MJEE when it was created, but that many fishers used to fish and anchor their boats on the coastal islands that formed the NTZ, leading to many conflicts. In recent years, managers informally authorized fisheries using longlines aimed at reducing conflicts, but many fishers that use gillnets complained that there was no physical demarcation of the NTZ limits. Respondents also cited conflicts regarding the catching of bait

Table 1
Actors, conflicts, and solutions identified from the discourses of respondents from the state of Amapá (Amazon coast, Brazil).

Actors	Conflicts	Solutions
A) Local fishers and outsiders (73.1%)	(AI) Overlapping of fishing grounds and predatory fishing (44.4%)	(AI) Surveillance (36.4%) (AI) To prohibit outsiders from fishing near the coast (26%) (AI) To create a protected area for local fishers (13.8%)
	(AII) Reduction of fish stocks (37.5%)	(AII) Surveillance (31.6%) (AII) To prohibit outsiders from fishing near the coast (10.5%)
	(AIII) Catches during the closed-season (10.2%)	(AIII) Surveillance (10.2%)
B) Fishers and surveillance agents (20.4%)	(BI) Prohibition of fishing in No-Take Zones (13.1%)	(BI) To create a protected area for local fishers or an agreement to allow fishing in No-Take Zones (13.1%)
	(BII) Aggressive, disrespectful and abusive approach (10.5%)	(BII) To improve approaches and enforcement (10.5%)
	(BIII) Ineffective and unequal surveillance (10.2%)	(BIII) Effective and egalitarian surveillance (10.2%)
C) Fishers and middlemen (11.3%)	(CI) Low price of fish (11.3%)	(CI) Investment in infrastructure and public policies (11.3%)

for longlines inside the protected islands and the catching of crab by outsiders.

The interviewees also stated that surveillance was unequal and ineffective (10.2%), because it was only applied to local fishers, with outsiders fishing inside NTZs remaining unpunished. According to respondents, outsiders escape satellite surveillance by using small and untracked boats that operate in forbidden areas, supplying larger boats. Interviewees also complained about the approach used by the surveillance agents, which was considered aggressive, disrespectful, and abusive (10.5%).

Respondents cited three solutions to conflicts with surveillance agents: 1) the creation of a protected area for local fishers or an agreement to allow fishing in NTZs (13.1%), 2) improved performance of these agents, with a less aggressive approach (10.5%), and 3) transforming surveillance to be an effective and egalitarian activity, placing outsiders under intensive surveillance (10.2%).

A particular transnational conflict was cited by 22% of the interviewees of Oiapoque, regarding the performance of the surveillance agents. These respondents feel wronged because the fishers from French Guiana frequently fish in the state of Amapá but are not controlled, whereas Brazilian fishers entering French Guiana are aggressively combated by French surveillance agencies. Respondents reported that French fishers fish in the CONP and buy ice and sell fish to companies in Oiapoque. To resolve this conflict, respondents proposed an agreement between Brazilian and French governments to release SSFs in the transboundary region.

3.1.3. Conflicts between fishers and middlemen

The dependence of fishers on middlemen for production flow also constitutes an important source of conflict, cited by 11.3% of the respondents. The absence of structures for preserving fish meat and the lack of financial resources for production flow force fishers to sell their catches to middlemen, usually at low prices. The respondents believe that this conflict could be resolved by the intervention of government agencies, whose presence is perceived to be lacking in this region. The fishers highlighted the need for governmental investments in infrastructure to improve conditions associated with anchoring, landing, lighting, and availability of inputs (e.g., ice and fuel). In addition, fishers identified the need to implement policies and measures that promote fair marketing, as well as strategies that allow a greater diversification and valuation of the fishery products, with the aim of reducing the dependence of fishers on middlemen, which, in turn, would increase their income.

3.2. Status of fish stocks from the Amazon coast of Brazil

In the study area, approximately 75% of the respondents recognized a decrease in the abundance of fishery resources (71.5% in Oiapoque, 87.1% in Calçoene, and 72.8% in Amapá) (Table 2). *S. parkeri* was the main species cited in Amapá (64%) and Calçoene (55.7%), while in Oiapoque, *C. virescens* (32.3%) and *C. acoupa* (24.8%) were the most mentioned. Many respondents (26.8%) also stated that the abundance of all fishery resources have reduced.

The similarity analysis of the discourses of respondents about the causes for declining fish abundance in the study area is shown in Fig. 2. Considering the number of occurrences, 'lot' was the most frequent active form and played a central role in the discourses, followed by 'boat,' 'fishery,' and 'fisherman', which were strongly linked to 'lot.' These words reflected the perception of respondents about intensive fishing activity, high fishing effort, and catching power. Fig. 2 also shows the connection between the words 'lot-gillnets,' 'lot-catch,' 'lot-boat-large,' and 'lot-fish-technology' (which was related to the use of technological equipment to support fish catches).

The presence of outsiders was cited as prejudicial, due to the increased fishing effort and catching power, as well as the predatory fishing, carried by these fishers. The activity of fishers from Pará State in the study area is shown in Fig. 2 through the connection between the words 'lot-Pará' and 'lot-boat-Belém.' Discourses about predatory fishing practices were observed through the words 'small-mesh,' 'industrial,' trawl,' 'closed-season,' and 'predatory,' which were linked to 'fishery' (Fig. 2). Industrial trawl fisheries were considered harmful, due to high fish catches and discards, and the use of small-mesh gillnets was considered predatory, due to the low selectivity of this gear. Outsiders were also accused of disrespecting closed-season of *S. parkeri*, which was demonstrated by the connection between the words 'lot-fishery-closed-season' and 'lot-spawn' (referring to catches during the spawning season).

Table 2
Fishery resources with reduced abundance according to the number (N) and percentage (%N) of citation by respondents from the studied municipalities in the state of Amapá (Amazon coast, Brazil).

Fishery resource	Oiapoque		Calçoene		Amapá		Total	
	N	%N	N	%N	N	%N	N	%N
Acoupa weakfish (*Cynoscion acoupa*)	33	24.8	19	31.1	7	9.3	59	21.9
Crucifix sea catfish (*Sciades proops*)	15	11.3	5	8.2	11	14.7	31	11.5
Gillbacker sea catfish (*Sciades parkeri*)	23	17.3	34	55.7	48	64.0	105	39.0
Green weakfish (*Cynoscion virescens*)	43	32.3	13	21.3	–	–	56	20.8
Others	48	36.1	12	19.7	8	10.7	68	25.3
All	42	31.6	16	26.2	14	18.7	72	26.8
Number of respondents	133	71.5	61	87.1	75	72.8	269	74.9

Another cause cited by respondents was the trade of swim bladders (referred to as 'grude'), which is stimulated by their high value (USD 9–276 kg^{-1}) compared to fish meat (USD 0.15–3.69 kg^{-1}). Interviewees associated the high value of swim bladders with increasing pressure on fishery resources in the study area, because it is necessary to catch many fishes to obtain one kilogram of 'grude.' This discourse is shown in Fig. 2, through the connection between the words 'lot-fishery-grude.' According to respondents, the swim bladder trade includes all the four fishery resources listed in Table 2, and also *Sciades couma.*

The similarity tree (Fig. 3) shows that, according to the perception of respondents, 'surveillance' represents the main solution for recovering fish abundance, because this word was the main active form in discourses, followed by 'boat,' 'fisherman,' and 'fishery.' Interviewees also suggested the need to reduce fishing effort and catching power, as observed by the connection between the words 'stop-freezer-boats' (i.e., boats with freezing systems on board), 'boat-move,' and 'boat-reduce-quantity.'

The similarity analysis (Fig. 3) also showed the perceptions of interviewees about the need to intensify the surveillance of outsiders, as verified by the connection between the words 'surveillance-Pará,' 'surveillance-boat-Belém,' 'surveillance-boat-state-increase,' and 'surveillance-fisherman-industrial.' The same was observed for predatory fishing, because 'surveillance' was also linked to 'trawl,' 'boat-large-discard,' 'fish-death,' and 'fish-mesh-size.'

The need for surveillance during the closed-season of *S. parkeri* also appears in the similarity tree (Fig. 3), through the link between the words 'surveillance-closed-season-respect,' 'surveillance-reproduction,' and 'surveillance-fish-period.' Many interviewees considered that the closed-season (November to March) does not cover the entire breeding season of *S. parkeri*, and that other species should be included in the closed-season, such as those listed in Table 2.

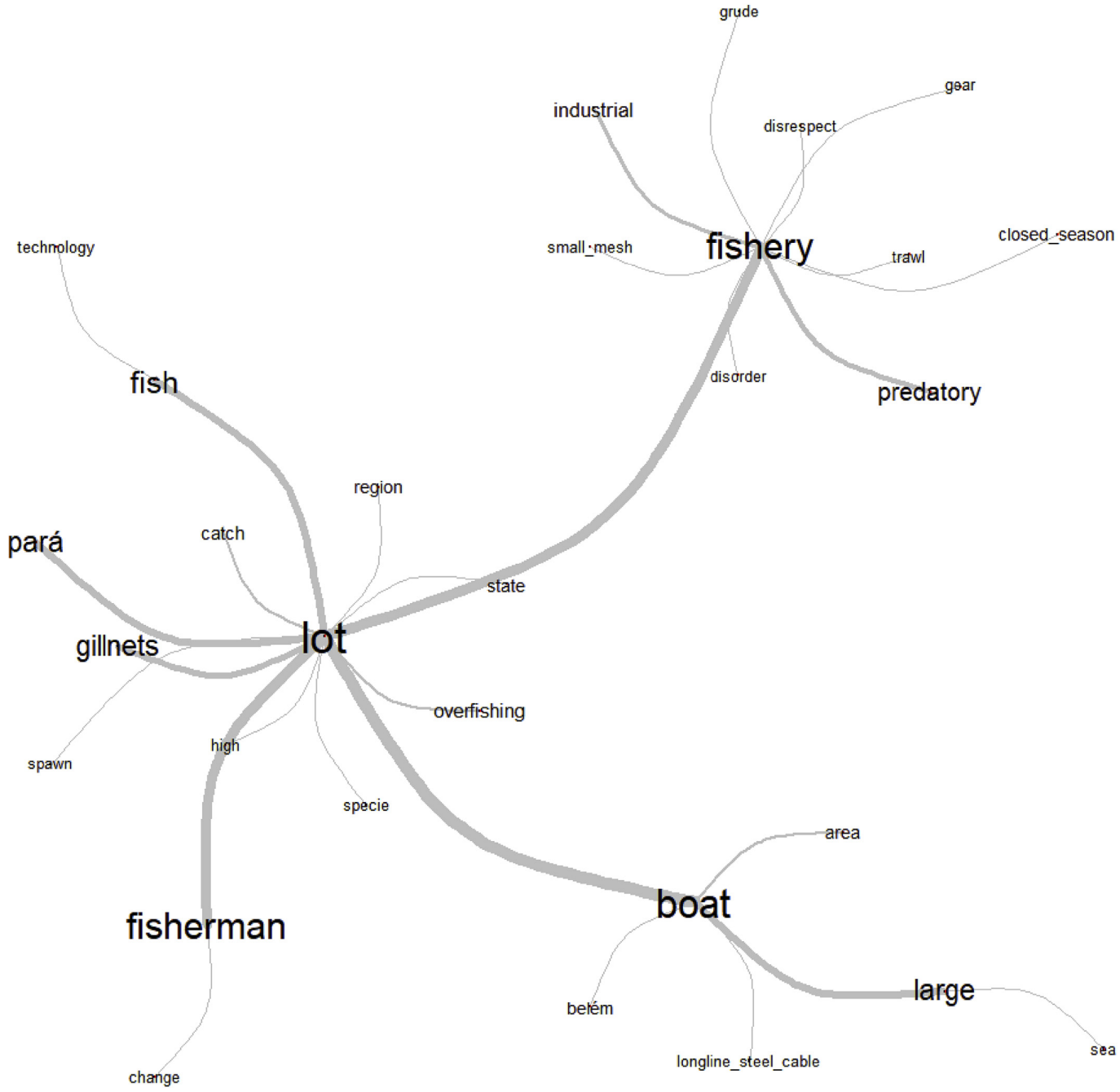

Fig. 2. Similarity analysis of respondents' discourses about the causes for the declining fish abundance in the state of Amapá (Amazon coast, Brazil).

4. Discussion and conclusions

4.1. Conflicts in small-scale fisheries on the Amazon coast of Brazil

On the Amazon coast of Brazil, conflicts exist over access to fishing territories and fisheries resources, which are also conflicts over livelihoods. These conflicts involve small-scale fishers, large-scale fishers, intermediaries, and government agents (e.g., surveillance agents and managers). Among these actors, power relationships are asymmetrical, with small-scale fishers holding the weakest position.

The most evident conflict experienced by local fishers is competition for fishing grounds with outsiders. Anyone involved in fisheries, whether a seaman, fish trader, manager, or scientist, is familiar with this problem. The main conflicts involve large-scale artisanal fisheries and industrial bottom trawlers from the state of Pará, who have the largest fishing fleet on Amazon coast (Bentes et al., 2012). Large-scale artisanal fisheries occupy an intermediate position between industrial and small-scale artisanal systems, as they have larger and more advanced boats than most of the small-scale fleets on the Amazon coast (Isaac et al., 2009).

Growing competition for fishery resources and territories between commercial fisheries is a global trend, especially in developing countries (Camargo et al., 2009; DuBois and Zografos, 2012; Murshed-e-Jahan et al., 2014; Pomeroy et al., 2007), with the small-scale fishery (SSF) tending to be the loser. For example, in southeast Asia, industrial fleets monopolize coastal fishery resources through high catching power and technology, undermining the productivity of SSFs (Pomeroy et al., 2007). In Sri Lanka, SSFs are threatened by the invasion of fishing grounds by Indian trawl fishers (Scholtens and Bavinck, 2018).

On the north coast of Brazil, the state of Amapá represents the last

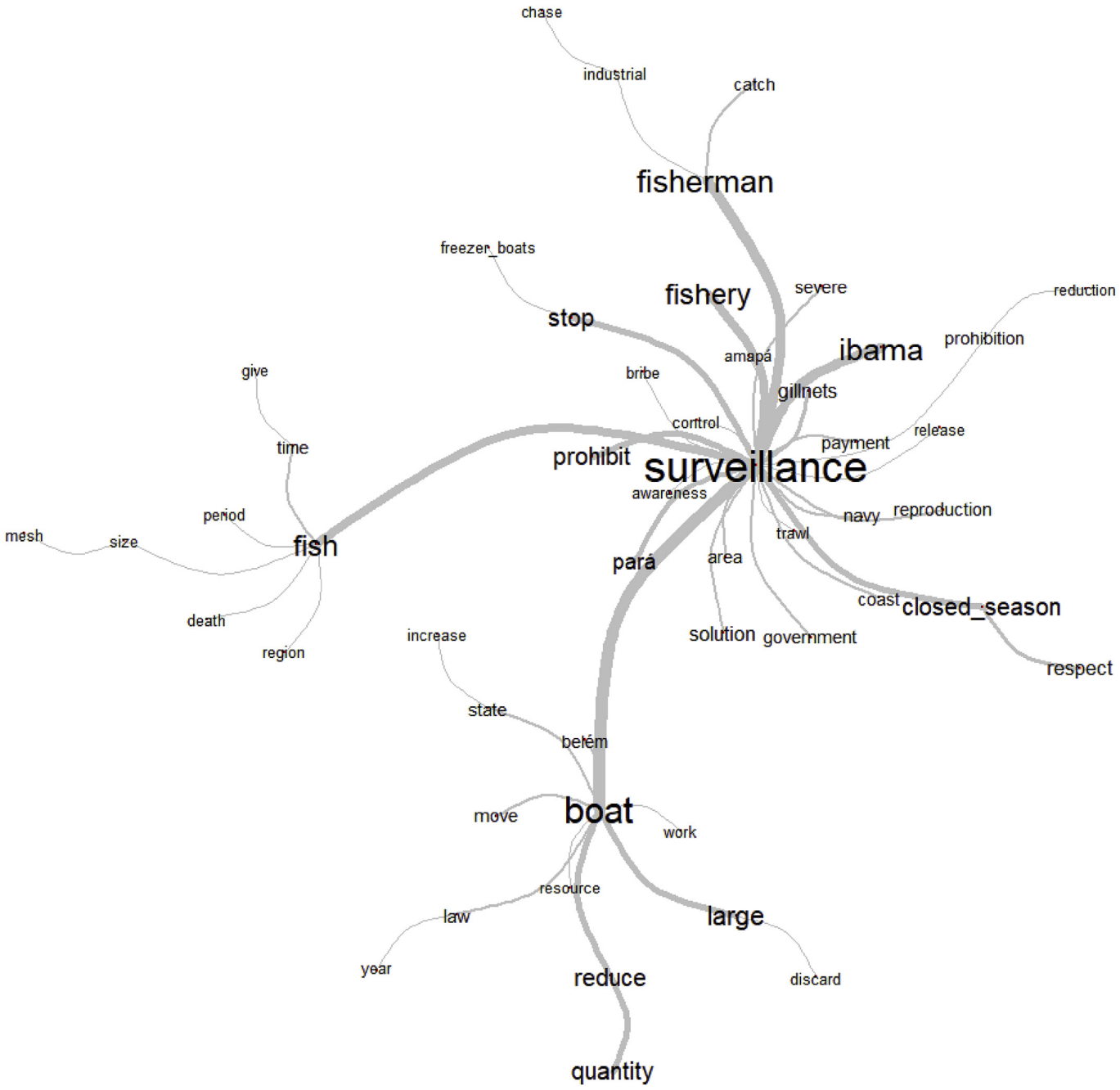

Fig. 3. Similarity analysis of respondents' discourses about the solutions for declining fish abundance in the state of Amapá (Amazon coast, Brazil).

frontier for fishing, with increasing number of fishers from Pará migrating to this region in the past 10–15 years. The open access conditions and the decrease in fishing productivity in Pará (Betancur et al., 2015; Isaac et al., 2009; Lucena Frédou and Asano-Filho, 2006) have culminated in an increasing migration flow and a disorganized growth of the fishing sector. A similar scenario occurred when fishers from northeastern Brazil migrated to Pará, due to the exhaustion of snapper and lobsters stocks (Isaac et al., 2009).

The migration of fishers to the state of Amapá has intensified the pressure on fishery resources, imposing major challenges on fisheries management and the conservation of natural resources in NTZs, because outsiders illegally fish in these areas using small boats that are not tracked by satellite surveillance. This illegal activity is facilitated by the deficiency in the surveillance system, due to lack of human and financial resources, infrastructure, and equipment. The same strategy is used in Senegal, where industrial vessels transport small boats that fish in forbidden areas (DuBois and Zografos, 2012). Invasion of traditional fishing territories used by local communities and illegal fishing in protected areas also occur in other countries of West Africa, where migrant fishers benefit from the poor enforcement of management measures (Binet et al., 2012).

In this context, the fishery resources are not effectively protected within NTZs in the study area. In practice, restrictions are only imposed on local fishers, which is why they consider surveillance to be unequal and ineffective. This imbalance also results in the unequal distribution of conservation costs and benefits. Another conflict that reinforces this negative perception about surveillance is that the illegal catches of outsiders during the closed-season are not punished, since surveillance is restricted to landings in the state of Amapá. Conflicts involving the unequal application of restrictions between different actors or activities

in protected areas are also observed in other regions (Bavinck and Vivekanandan, 2011; Begossi et al., 2011; Camargo et al., 2009; Majanen, 2007).

In different places in Brazil, fishers faces the significant loss of fishing territories due to the creation of NTZs, competition with industrial fishing, and other uses of the marine and coastal space (Begossi et al., 2011; Prestrelo and Vianna, 2016). This phenomenon was also observed in the study area, where local fishers are cornered between NTZs and outsiders working in larger and better equipped boats. In the 1980s, most NTZs were established in Brazil without consulting the local populations. In general, the NTZs were based on the North American preservationist model of that time, which aimed to protect wildlife independent of the human environment (Diegues, 2008). Due to this centralized and top-down approach, the creation of NTZs has culminated in conflicts related to the prohibition of access to natural resources and the expropriation of resident populations. This scenario has been observed in different regions of Brazil (Almudi and Kalikoski, 2010; Begossi et al., 2011; Leal, 2013), as well as other developing countries (Bennett and Dearden, 2014; Camargo et al., 2009; De Pourcq et al., 2015; Majanen, 2007).

In the study area, the creation of NTZs was also marked by a top-down process that did not consider the existence of communities reliant on natural resources, which directly affected local fishers, reducing the territories historically exploited by SSFs (Crespi et al., 2015; Pinha et al., 2015). In the first years after the creation of the NTZs, the relationship between local residents and managers was marked by tensions and highly repressive actions by surveillance agents. In the CONP, the prohibition of commercial fishing, the violent repression actions with military support, and the closure of public services (e.g., education and health services) by the government forced the residents of Taperebá to migrate to the uran area of Oiapoque. These actions led to profound changes to their livelihoods, because traditional activities developed in villages (e.g., agriculture, vegetal extraction, and hunting) could not be carried out in the urban area. As a result, the former residents of Taperebá became full-time fishers, leading to the expansion of fishing activity due to disputes with other fishers and the need to integrate local socioeconomic dynamics. This culminated in increased fishing effort and catching power, along with the replacement of more selective gears (i.e., longlines) in favor of gillnets (Crespi et al., 2015).

Many traditional communities live in and use the natural resources of LPBR, and their livelihoods were impacted by the creation of the NTZ. The repressive actions of surveillance agents included the destruction and burning of fishing gears and wooden shelters used to support fisheries (Pinha et al., 2015). In the MJEE, there were only a few residents on the islands that became protected; however, many fishers used to fish there. Until 2000, conflicts were mitigated by informal agreements. However, the prohibition of boat anchoring in some areas and increased surveillance between 2000 and 2010, culminated in the intensification of conflicts and the disruption of relationships between fishers and managers. These disruptions included retaliatory actions by fishers, such as threats to management teams and the deliberate setting of forest fires on the protected islands (Coutinho and Oliveira, 2016).

In the early 2000s, recognition of the rights of traditional populations, driven by international debates, led to the paradigm changing, including the focus of management agencies. This change facilitated the beginning of a dialogue that culminated years later in the establishment of the Commitment Terms (CT) in CONP and LPBR. CT is a legal instrument that allows the temporary regularization in the use of natural resources by traditional populations whose livelihoods are associated with protected areas where their presence is not permitted (e.g., NTZs) or who disagree with management mechanisms (ICMBio, 2012). In the MJEE, managers adopted an educational and informative approach since 2013, initiating a process of dialogue and conflict resolution, with the planned implementation of a CT (Coutinho and Oliveira, 2016).

The reduction in conflict between fishers and NTZs through CTs is one of the main reasons why this problem appeared as secondary in the narratives of respondents. At present, disputes with outsiders are considered to represent the main threat to SSFs by the interviewees. However, latent conflicts with NTZs are very worrying, because CTs are a transitory instrument that should only be used until a definitive solution is established. Such solutions might include changing or adapting the limits of NTZs or recategorization to a sustainable use area (Pinha et al., 2015). Both solutions should take account of the tradition, knowledge, and skills of local fishers to fish in coastal areas. In particular, the fishing technology (e.g., vessels and gears) used by local fishers does not allow them to fish in deeper water environments.

The respondents perceived that the solution to conflicts with outsiders is centered around surveillance. Despite existing tensions and conflicts, they believe that the presence of surveillance agents should help in reducing the different pressures on NTZs that also threaten their well-being (Melo and Irving, 2012), including fishing by outsiders and illegal mining. Another solution cited by respondents was the creation of a sustainable use protected area, with the aim of ensuring access to fishery resources by local fishers and to compensate them for the loss of fishing territories due to the creation of NTZs. This solution is also an attempt to prohibit outsiders from fishing near the coast. Since 2005, fishers have been attempting to create a Marine Extractive Reserve (MER), which is a protected area with the sustainable use of natural resources (IUCN category VI), where co-management is a prerogative (Gerhardinger et al., 2009). In recent years, the movement to create the MER is gaining strength, mainly due to the efforts of fishers from Oiapoque and the support of Non-Governmental Organizations (NGOs).

The third, most important, conflict experienced by respondents was their dependence on middlemen, which is commonly observed in SSFs worldwide. Globally, SSFs are subject to a lack of basic infrastructure for the fishing sector, and landing points are widely dispersed across the territory, distant from markets (Partelow et al., 2018; Salas et al., 2011; World Bank, 2012). The absence of a local market to absorb the catches and the lack of structures to preserve fish meat might compromise the entire catch, because fish are a highly perishable product. Therefore, the fish supply chain is dominated by a network of intermediaries that link SSF trading networks and the local, national and globalized export markets (Crona et al., 2010; Pedroza, 2013).

Intermediaries finance fisheries, providing credits to fishers in exchange for supplying fish at low prices, which is an obstacle in improving fishers' income (Capellesso and Cazella, 2013; Crona et al., 2010; Pedroza, 2013; Salas et al., 2011), with implications on fisheries management and conservation efforts. Partelow et al. (2018) argued that many fishers are beholden to patron-client systems, which are often exploitative, but are their only market access option. The low prices paid by intermediaries can lead to overharvesting, because increased extraction is the only way for fishers to earn enough income to meet their basic needs and live with dignity. In addition, middlemen often do not comply with the rules of the states (e.g., taxation, labor, and fisheries legislation). This issue is an incentive for fishers to fish illegally, as their products are bought, even if they do not meet formal regulations, creating a state of ungovernability (Pedroza, 2013). The patron-client relationship also reinforces rent maximization tendencies and hampers the ability of fishers to self-organize. This issue, in turn, hinders their capacity to engage in collective actions for resource stewardship (Johnson, 2010). For instance, Seixas (2004) affirmed that the patron-client relationship is one of the barriers to the participation of resource users in fisheries management in Brazil.

The solutions proposed by the respondents regarding the conflicts with middlemen were focused on governmental investment in infrastructure and policies to facilitate fair marketing and to increase the value of fishery products. Policy makers and managers should also encourage fishers to form cooperatives for pre-sale processing aimed at improving the value added to fishery products, because, at present, only gutted fish are sold. Furthermore, cooperatives might represent an alternative tool to store fish catches, allowing fishers to negotiate better

selling prices. This would overcome the issue of the high perishability of the fish and absence of freezing structures, which currently limits the bargaining power of fishers.

4.2. Status of fish stocks exploited by small-scale fisheries on the Amazon coast of Brazil

On the Amazon coast of Brazil, there is no continuous and effective monitoring of fisheries, leading to a deficiency in quantitative data for evaluating the status of fish stocks. However, in the present study, most respondents cited a decline in fish abundance, with the species mentioned by fishers forming the main fishery resources on the Amazon coast (Almeida et al., 2011; Bentes et al., 2012; Isaac-Nahum, 2006). The perception of interviewees was corroborated by landing data from the state of Pará, indicating a 47–54% decrease in the landings of *S. parkeri* between 1997 and 2007, even with increasing fishing effort. It is estimated that the decline of *S. parkeri* populations in Brazil is higher than 30% (ICMBio, 2018). In addition, estimated *C. acoupa* landings have declined by 27% over the last 10 years (Chao et al., 2015). Currently, *S. parkeri* is classified as 'Vulnerable,' while *C. acoupa* is classified as 'Near Threatened' (Chao et al., 2015; ICMBio, 2018). Both species were considered to be fully exploited in northern Brazil (Lucena Frédou and Asano-Filho, 2006).

The respondents perceived that the main causes for the decline in fish abundance are high fishing effort and catching power. In fact, fishing effort by the large-scale artisanal fleet of Pará has been systematically increasing as a consequence of good economic yields and government subsidies for purchasing fuel and financing fishing vessels (Isaac et al., 2009). The number of boats has increased significantly due to funds from the Constitutional Fund for the Financing of North, which has been operated by the Amazon Bank since 1997 (Lucena Frédou and Asano-Filho, 2006).

There are clear differences in the fishing effort and catching power between the fleets of Amapá and Pará. More than 60% of the fishing fleet from Amapá is composed of small-sized wooden boats of up to 12 m in length, with engine power of up to 160 HP, and storage capacity of one to seven tons, operating gillnets (average of 2,100 m in length) and longlines (average of 1,600 m in length and 1,400 hooks). The large-scale artisanal fishery of Pará is carried out by wooden boats of up to 20 m in length, using gillnets (> 3,000 m in length) and longlines (2,000 m in length and 3,000 hooks). In comparison, the industrial fleet of Pará employs large-sized steel boats (> 18 m in length), with powerful motors (average of 425 HP) and a storage capacity of up to 40 tons (Bentes et al., 2012). The industrial vessels are equipped with communication and navigation devices, and sophisticated catch processing onboard. Furthermore, shrimp trawlers have refrigerated chambers on board to freeze the catches (Bentes et al., 2012; Isaac et al., 2009).

Respondents considered industrial trawl fisheries to be harmful, due to the high fish catches and discards. Studies in the 1990s estimated that about 30 thousand tons of fish were discarded per year by trawl fisheries on the Amazon coast of Brazil (Isaac and Braga, 1999). However, recent studies have suggested that the waste has declined. Klautau et al. (2016) estimated that the trawler fleet catching *B. vaillantii* discarded 30% (311.276 tons) of its total production between 2002 and 2008, with about 44.468 tons being rejected per year during this period. Paiva et al. (2009) estimated that *Penaeus subtilis* represents only 20% of the total catch, with a ratio of 4.1 kg of bycatch for each 1 kg shrimp, leading to 17 thousand tons of bycatch in 2003.

Another predatory fishing practice cited by respondents was the illegal catches of *S. parkeri* during the closed-season. Moreover, fishers believe that the closed-season (November to March) does not cover the entire breeding season of *S. parkeri*. This demonstrates possible controversies in legislation, and the need for new studies on the life cycle of this species. Fishers also believe that other species should be protected during the closed-season, including *C. virescens*, *C. acoupa,* and *S. proops*.

The trade of swim bladder ('grude') was also cited by the interviewees as contributing to increasing fishing pressure because many fish are required to obtain 1 kg 'grude.' In the case of *C. acoupa* (the most valued species), 1 kg 'grude' is obtained from 10 large individuals weighing at least 7 kg each (Mourão et al., 2009). 'Grude' is used in the beverage, food, and cosmetics industries (Isaac et al., 1998). It is also marketed in Pará and Maranhão, from where it is primarily exported to Asian countries, such as Japan and China (Almeida et al., 2014; Mourão et al., 2009).

According to respondents, the main solution to recover fish stocks is surveillance. However, they also recognize the need to reduce fishing effort and catching power to protect fish stocks and SSFs. At present, there is no monitoring or control measures to regulate artisanal fisheries on the Amazon coast. However, the fishery resources cannot be sustained under uncontrolled exploitation for long periods. The imminent risk of overfishing threatens the integrity of ecosystems and the livelihoods of fishing communities in this region.

4.3. Fisheries management on the Amazon coast of Brazil

The two topics addressed in the present study are intrinsically related. The depletion of fish stocks has led to conflicts, which potentially lead to the unsustainable exploitation of fishery resources, with both issues threatening the NTZs. This scenario reveals the weak performance of management agencies and the government's incapacity to carry out effective enforcement, monitoring, and surveillance. It also reveals the lack of cooperation between stakeholders, culminating in a fisheries governance crisis. The major challenge seems to be to align the interests of different stakeholders and the conservation goals.

In this complex context, which includes the existence of diverse actors with different and, potentially, competing interests and accountabilities, new patterns of governance are necessary. Sustainable fisheries management could only be achieved through a wider cooperation between the government and all stakeholders. Co-management systems are characterized by the involvement and participation of resource users, the government, and external agents in decision-making (Jentoft et al., 1998; Pomeroy and Rivera-Guieb, 2005; Sen and Raakjaer Nielsen, 1996). Within these systems, the involvement of local populations and the incorporation of their needs and knowledge into decision-making process is essential (Andrade and Rhodes, 2012; Castello et al., 2009; Castilla et al., 2007; Oldekop et al., 2016). In turn, regulatory regimes are legitimized, with populations contributing to compliance, resulting in more effective conservation strategies (Jentoft et al., 1998).

Co-management arrangements are recognized as satisfactory approaches to achieve sustainable environmental governance. These arrangements are guided by the search for negotiated solutions that allow different interests to be balanced. In South America, Chile's experience in granting Territorial User Rights for Fisheries (TURFs) to small-scale fishers' organizations stands out as a successful co-management strategy (Castilla et al., 2007). One of the positive impacts of this initiative was the prevention of stocks that were being overexploited (Gelcich et al., 2010). Many studies have also demonstrated the role of co-management in reducing fisheries conflicts. For example, in Colombia and southeast Asia, places where co-management arrangements were established had lower levels of conflict, resulting in better fisheries management aimed at long-term sustainability (De Pourcq et al., 2015; Pomeroy et al., 2007). Furthermore, a study in developing countries demonstrated a direct relation between the participation of communities in decision-making process and compliance with conservation strategies within protected areas (Andrade and Rhodes, 2012).

In Brazil, most co-management systems are concentrated in the Amazon, where they contribute towards maintaining fish abundance, sustainable fisheries, and food security (Castello et al., 2009; Silvano et al., 2014). Nevertheless, most of these systems belong to continental

areas, and involves territories characterized by well-delimited spatial boundaries, including many lakes (Pezzuti et al., 2018). On the Amazon coast, there are about 15 MERs that are still experimenting with this type of management. Consequently, it is too early to determine whether they are successful. However, they contribute towards protecting mangroves against shrimp farming and towards ensuring the access of traditional people to territories, allowing the maintenance of their culture. A recent study on land use in mangroves has demonstrated the important role MER play in protecting this ecosystem on the Amazon coast of Brazil (Hayashi, 2018). In addition, in the state of Bahia (northeastern Brazil), the implementation of the Cassurubá MER has enhanced social organization, with a gradual increase in social participation in decision making. In particular, this approach has reduced competition for resources with outsiders (Nobre et al., 2017).

The implementation of a MER provides an opportunity to establish a collaborative governance regime because, within this category of protected area, management responsibilities must be shared between managers and the community through deliberative councils, which are important spaces for dialogue, conflict mediation, and a platform for the inclusion of local knowledge in decision-making (Gerhardinger et al., 2009). At the study site, the good performance of the 'Commitment Terms' indicates that there is some willingness by local fishers to adopt co-management.

However, the success of co-management is strongly related to the presence of legitimate community leaders and robust social capital. Gutiérrez et al. (2011) analyzed 130 co-managed fisheries in several countries and identified that the presence of at least one highly motivated individual who was respected as a local leader and guided by collective interests could facilitate resilience to changes in governance, influence users compliance to regulations, and enhance conflict resolution. At present, fishing communities in the state of Amapá are experiencing an emerging leadership crisis, with the president of the Fishers' Colony of Oiapoque being the only leader that is widely respected and who has legitimacy. Therefore, the initial process of implementing a MER should include efforts to identify potential fishers that could be trained for the development of leadership skills and self-organization for collective actions. This process should be supported by scientists, universities, and NGOs.

The issues with local government agencies and the high cost of surveillance and enforcement emphasize the importance of co-management in the study area. In this sense, experiences related to community surveillance have been reported in the Brazilian Amazon as part of fisheries co-management in lake systems (McGrath et al., 2008). In addition, experiences in Mexico show that well-organized local groups can secure viable fisheries and coastal livelihoods (Méndez-medina et al., 2015). Furthermore, examples from Japan and the Philippines show that fishers' organizations contribute towards cost-effective ecosystem monitoring, which is indispensable for adaptive capacities (Makino et al., 2014). Sustainable use protected areas may also contribute to preserve endangered livelihoods, which seems to be the case for fishers from the present study. In Spain, La Restinga and Lira reserves have reinforced local fishing identities, preserving the traditional way of living, and a sense of ownership and responsibility over marine territories. These approaches have increased the control of local fishers in territories that they traditionally use (Pascual-Fernández and Cruz-Modino, 2011).

In the Brazilian Amazon, coastal fisheries management is essential to safeguard the food security of local populations. It is also important for the marine conservation of a region considered to be Ecologically or Biologically Significant Marine Area – EBSA (CBD, 2012), as well as a priority for biodiversity conservation (MMA, 2007). This region also encompasses two Ramsar sites. In this context, the creation of a MER favors the establishment of a network of no-take and sustainable use protected areas, as well as the connectivity between terrestrial and marine environments. This approach would contribute to the progress of Brazil in implementing elements of Aichi Target 11 within the Convention on Biological Diversity, such as connectivity between protected areas, as well as effectiveness and equity in the management of these spaces (CBD, 2010).

Achieving a balance between protecting ecosystems and their sustainable use is a major challenge, especially in the current scenario of the increasing human population, habitat loss, and the depletion of fish stocks. Therefore, NTZs are required, but are not sufficient to guarantee conservation. Effective environmental protection is only possible if local communities support and benefit from the implementation of conservation projects. A study by Oldekop et al. (2016) demonstrated that protected areas with positive conservation outcomes are associated with positive socioeconomic outcomes, which are more likely to occur when protected areas adopted co-management regimes that empower local populations, reduce economic inequalities, and maintain cultural and livelihoods benefits.

Without engagement from all resource users, it is very difficult to achieve fair and effective governance facilitating conflict resolution. Therefore, investment in capacity-building is needed to enable resource users and other stakeholders (e.g., managers, scientists, NGOs) to actively engage in participatory forms of coastal management (Seixas, 2004; Wever et al., 2012). Furthermore, efforts to facilitate interactions between stakeholders are needed, including the creation of a regional fisheries committee. This committee could then objectively discuss fishing rules and responsibilities and incorporate fishers' knowledge in the management process. Another important measure is the establishment of a research agenda that will subsidize a marine spatial planning in the future. The challenges are great, and require mobilization of people, conflict resolution, training, and a regional and multidisciplinary approach. Finally, the methodology used here could be improved by including the perspectives of other stakeholders (e.g., managers, policy makers, surveillance agents, outside fishers) to obtain an in-depth understanding of the identified issues.

Declarations of interest

None.

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