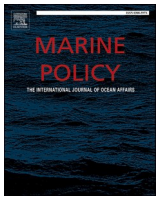
Marine Policy 140 (2022) 105068

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol



Impacts of COVID-19 on the value chain of a small-scale fishery system in a tropical metropolitan city

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ARTICLE INFO

Keywords:
Artisanal fisheries
Public policy
Coronavirus
Territorial Use Rights for Fisheries (TURFs)
Food security

ABSTRACT

The impacts of the COVID-19 pandemic on the value chain structure and dynamics of a small-scale fishery system within a TURF type marine reserve in the southwestern Atlantic were evaluated between July 2019 and December 2020. A systematic on site monitoring program of fisheries production and sales, and semi-structured questionnaires applied to representatives of the different links in the value chain were used to assess changes comparing pre-pandemic (Normality) and pandemic (Quarantine and Flexibility) periods. Our results revealed that most of the fishermen continued fishing throughout the pandemic period, without compromising local production. General restrictions were imposed by the pandemic to the population and commercial establishments, especially restaurants and snack bars, which remained closed during quarantine period. This scenario increased the demand for fresh seafood by endpoint consumers, and consequently raised the average prices of fish/shellfish commodities. In addition, the adoption of new commercial strategies including direct sales and seafood delivery to endpoint consumers helped to maintain commercial fluxes and cope with the limitations imposed by the pandemic. The auction system arena in which fisheries catches are sold, was an important internal process for maintaining the value chain operating. All of these characteristics reinforce the resilience of the system in the face of extreme conditions such as the COVID-19 pandemic.

1. Introduction

Fish and shellfish are one of the most traded food commodities around the world [1–3]. It is estimated that half of the world's seafood landings from developing countries are produced by small-scale artisanal fisheries (SSF) sector, 90% of which are destined for human consumption [3,4]. Fishing in SSF communities usually occurs in dynamic environments, with multiple supply and trade networks, creating jobs and adding value to fish commodities along the way [5,6]. However, SSF is often unable to maximize the value of seafood products due to the challenges of production, distribution and marketing, including inadequate handling and infrastructure (e.g., storage, transport, market) leading to economic losses throughout the value chain [7,8].

Since a new type of coronavirus was identified, the world has been facing one of the largest and most complex health crises of our times, creating a pandemic scenario with extensive social and economic effects [9–11]. The impacts of COVID-19 upon the SSF sector are becoming increasingly evident [10]. Although the disease does not directly affect fish and shellfish, social distance policies recommended by the World Health Organization [12] are altering the practices and relationships established between the different links in fisheries value chains. Changes in consumer demands, price collapse, market access or logistical problems caused by transport closures, and limited accessibility to direct marketing locations (beaches, fishing communities) have already been identified [13–16]. Such indiscriminate disruptions in fishing activities undoubtedly reveal a pre-existing tendency to underestimate the role of seafood in food systems [10]. Under such circumstances, the COVID-19 pandemic may be seen as a natural experiment to perceive how such impacts affect the seafood supply chain, including the relationships between fisheries, consumers and ecosystems [17]. A rare

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https://doi.org/10.1016/j.marpol.2022.105068
Received 15 January 2021; Received in revised form 8 November 2021; Accepted 8 April 2022
Available online 13 April 2022
0308-597X/

socio-economic shock of this magnitude may be compared even to an extreme scenario caused by wars and the dissolution of the state [17].

A global crisis like this exposes the fragility of SSFs and the failures of public policies in reaching such communities, especially if we consider the fact that the pandemic cumulative effects may be present for a longer period of time. Examining the effects of interruptions generated by COVID-19 in the SSF value chain can reveal hidden vulnerabilities and potentialities in face of extreme environmental, social or economic scenarios [18]. In this sense, it is essential to understand how the different links in the supply chains respond to disturbances such as the current pandemic, revealing emerging adaptive strategies in the SSF sector [10,18]. The experiences lived by the different links in the chain in facing situations of instability and deep changes in their dynamics may reveal the level of resilience of the production system as a whole. In addition, the learning acquired in this process can be incorporated into the system [19] adding a new knowledge framework that can be useful in making future decisions.

With that in mind, there is an urge to better understand how fishery systems, and most important the fishermen, are being affected in the short term by this unfortunate global phenomenon, with the aim of providing data to guide management and mitigation policies [20]. This article presents the different aspects of the organization of the value chain and the dynamics of a small-scale fishing system - Itaipu fishing community. This system is located in a protected area, Itaipu Marine Extractive Reserve, where fisheries are managed, but suffer strong urban pressure from the metropolitan region of Rio de Janeiro, Brazil, the third largest metropolitan region in South America.

2. Materials and methods

2.1. The fishing system

The SSF system selected for this study is representative of similar coastal fishing systems found in other parts of the southeastern-southern coast of Brazil, most of them suffering from urban development and gentrification [21,22]. The Itaipu fishing community is located in the municipality of Niterói, which is part of the metropolitan region of Rio de Janeiro, with more than 13 million inhabitants [23]. This proximity of large urban centers facilitates access to bathers, tourists and local residents into local beaches and restaurants. While population influxes in the area may expand markets for the fisheries value chain, the urban expansion and local gentrification may exert pressure upon fishermen, leading to SSF adaptations [24,25]. Its geographical location, within a large and expanding metropolitan area, is constantly pressured by real estate development, tourism enterprises. Also, the local government in search of development and economic expansion [26–28], often causes economic and social imbalances in the SSF. Until now, fishermen have resisted to such pressures including gentrification and changes in the abundance and composition of target resources [24]. The combination of these forcing vectors causes a permanent stress in the production system, forcing it to constantly learn and adapt to novel situations as a dynamic and experienced system.

Artisanal fisheries developed in Itaipu have ancestral origins, existing for over 200 years, and were extensively studied since the 1970 s [24,26,27,29,30]. Natural, social, historical and archaeological assets attract attention from many society sectors [31]. The local fishing system is diversified in terms of fishing gear and specific composition of catches. The fishery includes 14 modalities, with emphasis on the most traditional beach seine, gill nets, hand line, manual mussel collection, spearfishing and traps. A description of the fisheries methods is presented by Tubino et al. [26]. Vessels are open-deck with limited navigational autonomy, small load and storage capacity [24,27]. The beach seine fishery is the most traditional and oldest one, operating from shore, at several stations distributed over Itaipu and Camboinhas beaches. It aggregates a broader number of fishermen, involving around 15 regular people. The core fishing group ("*companha*") has up to six components, but additional collaborators help to haul the net and receive fish in exchange of their work. Other local fisheries (e.g., gillnet and hook-and-line fisheries) involve around two people on each vessel. The diversity of fishing gear in the Itaipu fishing system, with different catch selectivity, allows the capture of specific categories of fish according to the seasonal variations of target species.

Since the 1920 s, local professional fishermen have been institutionally linked to the Z-7 Fisheries Colony (Federal Bill Nº 11.699/2008), which additionally includes fishermen from neighboring areas or local fishermen's associations [24]. In 2013, the Itaipu Marine Extractive Reserve was established through State Decree nº 44.417, of September 30, 2013 [32]. The Extractive Reserve (RESEX) represents a protected area of sustainable use of natural resources – Category VI [33]. In Brazil, it is classified as a Conservation Unit for sustainable use [34]. This fisheries management approach grants property rights to individuals or groups of fishermen, providing access privileges and fishing rights to fishery resources within a designated area [35]. Even though it is a sustainable use protected area, small-scale fishing systems represent historically vulnerable social groups that are subject to constant pressure, triggering the devaluation and marginalization of their economic activity [4]. Fisheries occur primarily concentrated within the Itaipu Marine Extractive Reserve (Itaipu RESEX-Mar) (Fig. 1). About 150 professional fishermen maintain their fishing grounds in the coastal area adjacent to Guanabara Bay at depths down to 50 m in some areas. The Itaipu RESEX-Mar encompasses an area of 3943.28 ha, which was previously approved by the fishermen and other representative groups, following national legislation guidelines [34].

2.2. Survey instrument and data collection

To describe the value chain associated with SSF of the Itaipu RESEX-Mar, a systematic fisheries production and marketing monitoring program was carried out between July 2019 and December 2020, except for the months of February and March 2020 when there was no collection. The first step included on site observations for identifying the different links and estimating the number of individuals within each link of the value chain. Subsequently, periodic visits were conducted to the landing site and marketing points on separate days of the week. On each occasion, information on fish flow, or the quantity of fish/shellfish (kg) circulating between links was recorded. Itaipu RESEX-Mar fisheries production data for 2019 was obtained from the Fundaç ão Instituto de Pesca do Estado do Rio de Janeiro (FIPERJ), through the Projeto de Monitoramento da Atividade Pesqueira (PMAP).

A total of 58 interviews was conducted with representatives of the different links of the value chain: 31 fishermen, 7 middlemen and 20 restaurant and snack bar owners. Among those, fishermen and buyers provided some extra information. Interviews with fishermen and potential buyers of seafood provided further information on the catch of the production unit and the marketing values of the production. Fishermen informed the total weight of the catch by species, the fishing modality (beach seine, gillnet, handline, manual mussel harvest and spearfishing), the value of first sale and type of buyer (defined as the subsequent links of the value chain). The total catch of each production unit (collective or individual), locally called as '*maré* ' (catches), was classified based on the species composition: a) target – more than 80% of the catch in weight composed by a single species; b) non-target – several species are represented in the catch at proportions less than or equal to 80% in weight. The catch is not exported, and the commercialization of the fish is carried out locally.

Buyers provided information on the sales volume and destination of the product. Finally, restaurants and snack bars informed about the species that were present in the menu and offered to the public, which ones were mostly acquired locally, and the three species that customers preferred and looked after in the restaurant menu. All monetary values were obtained in Brazilian currency (Real, R$) and latter converted into American dollars (US$) considering the average price of the American

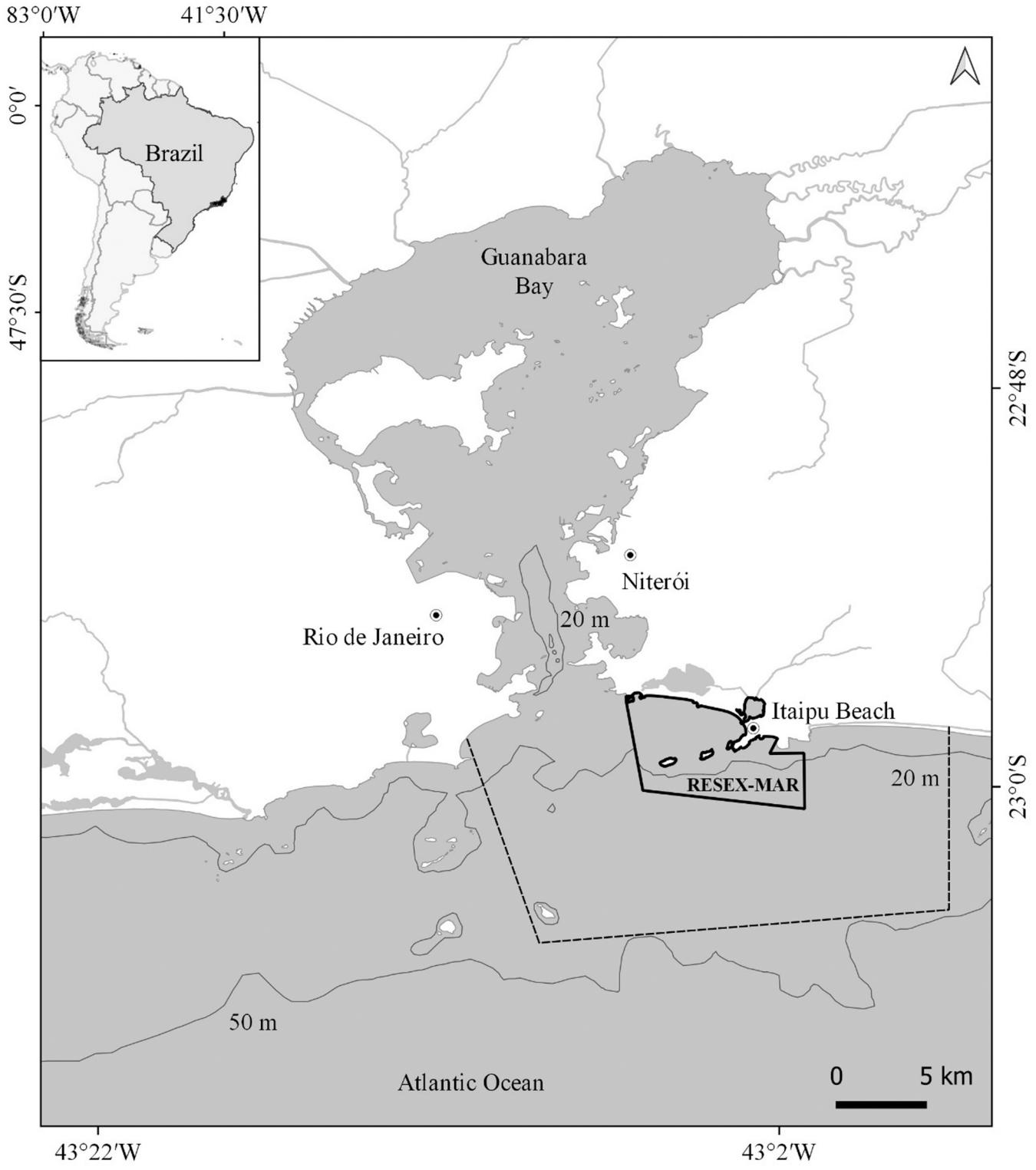

Fig. 1. Geographic location of the Itaipu coastal zone (Itaipu Beach), Brazil, in the southwestern Atlantic. The inner polygon indicates the limits of the Itaipu RESEX-Mar. The outer polygon represents the fishing area used by fishermen extrapolating the limits of the RESEX-Mar.

currency during the study period (US$ 1.00 = R$ 4.84). This procedure was adopted to minimize the influence of monetary fluctuations of the international market and detect local value changes caused by the COVID-19 pandemic upon the SSF.

To identify the impacts of the COVID-19 pandemic on the Itaipu RESEX-Mar SSF value chain, we divided the entire work period into three phases with varying levels of restriction: a) Normality – the pre-pandemic phase between July 2019 and January 2020; b) Quarantine – between April and August 2020, a period of official restrictions, when the State government imposed measures for the population to adhere to social isolation and municipal decrees blocked access to beaches and prohibited the operation of non-essential commercial establishments like bars and restaurants; c) Flexibility – between September and December 2020, when restrictive measures were relaxed with the

reopening of commercial activities release of access to the beaches at restricted times (see more in Appendix A.1).

During each of the pandemic phases, the Quarantine and Flexibility, a semi-structured questionnaire was applied to the individual's representative of the different links of the SSF value chain (fishermen, middlemen and local restaurant owners). Guided interviews contained questions about the interviewee's socioeconomic profile (e.g., age, gender, source of income), how the fish was marketed, the daily workload, perceptions of the level of impact of the pandemic on their lives and their adopted strategies for coping with the perceived impacts. The first round of interviews (Quarantine) took place between April and May 2020 and the second round (Flexibility) between October and November of the same year. Because of the need for social distancing in the first round, interviewees were reached through digital questionnaires (Appendix A.2), sent via WhatsApp application, or interviewed by phone call. In the second round, the interviews took place in person (Appendix A.3), respecting security measures and social distance.

2.3. Socioeconomic profile of the interviewed

Thirty-one fishermen ranging from 38 to 66 years of age (average = 54.0 years) answered the questionnaires. From these, 23 worked on the beach seine and gillnet fisheries, six were exclusively hand liners, one diver captured fish with speargun, and one collected mussel manually on the rocky shores. Most fishermen (90.3%) reported that they had been fishing in the region for more than 30 years, and fishing was their main source of income.

Middlemen interviewed (n = 7) aged between 30 and 62 years (average = 45.7 years). On average, they have been in activity for 19.5 years, buying fish and shellfish directly from the fishermen through the auction process on the beach. Six middlemen reported this was their only source of income. Restaurant and snack bar owners participating in the survey (n = 20) ranged between 32 and 66 years of age (average = 50.4 years), and 95% of them reported this economic activity was their exclusive source of income. At least 20% of them paid rent for the establishment, characterizing a permanent cost.

2.4. Data analysis

The average first sale value was log transformed (log10 x + 1) to calculate Euclidean Distances to be used in comparisons. A two-way Permutational Analysis of Variance (PERMANOVA) was used to evaluate the differences between periods, and the catches (Target and Non-Target). As the PERMANOVA revealed a significant difference between factors (fixed), the pair-wise test was applied for both. Deviations from the null hypothesis of the links of the value chain in the fishing system of the Itaipu Marine Extractive Reserve by period (Normality and Pandemic) were statistically tested performing the chi-squared test ($\chi 2$) with a 5% significance level. The chi-square test was applied adopting the formula proposed by Zar [36]. The PERMANOVA analysis was additionally employed to assess the differences between the average of daily working hours by fishermen, middlemen and restaurants between periods (Normality, Quarantine and Flexibility). Analyses were performed on PRIMER v6 +PERMANOVA add-on [37,38].

3. Results

3.1. The Itaipu RESEX-Mar SSF value chain

The fishery in the Itaipu RESEX-Mar captured 115 different categories of fish/shellfish with a total production in 2019 of 91 tons. More than half of this volume (55.1%) came from gillnet catches. The three most important species landed in the year were whitemouth croaker (*Micropogonias furnieri* - 28 tons), largehead hairtail (*Trichiurus lepturus* - 12 tons), and atlantic bigeye (*Priacanthus arenatus* - 10 tons).

The SSF value chain in the Itaipu RESEX-Mar consists of five links: a) fishermen representing individual or collective production units; b) middlemen which include both local (from the community) and external (from other localities, also called '*mulas*' - mules – [22]) dealers; c) local fish markets or retailers within the locality; d) restaurants and snack bars; and e) endpoint consumers (local residents or residents from other locations and neighborhoods coming to the beach to buy fresh seafood). Together, all links involve more than 350 people, not including endpoint consumers.

The catches from the production units are landed within a limited area on the beach where fishing boats come ashore. The catches are traded according to a traditional auction system in which individuals of every link (middlemen, restaurant and snack bar owners, local fish markets and endpoint consumers) may participate. The fisherman who brought the catch conducts the auction by stating the desired highest value of the catches as a starting bid. Interested buyers evaluate the catch and offer lower bids, which may rise until both parties, the fisherman and the potential buyer, reach the price of consensus and the catch is sold. Target catches often reach higher prices than non-target ones. According to responses from interviews, middlemen purchase more than half of the volume caught (59.7%) during the normality period. The remaining may be acquired by endpoint consumers (22.9%), restaurants/snack bars (11.3%), and local fish markets (6.0%).

Local middlemen sell the fish/shellfish acquired in the auction, right at the beach, using a small support structure in which the product is stored on iceboxes. The predominant sales flux from local middlemen is to endpoint consumers looking for fresh seafood of known origin (66.4%). They also supply fish/shellfish to local fish markets and restaurants, however at a smaller scale. On the other hand, external middlemen buy their seafood and take it to other distant neighborhoods and markets, acting as export agents of the Itaipu RESEX-Mar SSF production. Since this group does not spend much time at the beach, we were unable to obtain additional information about the fluxes from these buyers. Local fish markets represent an additional link from which consumers may buy seafood. Similar to restaurants, 100% of the flux goes to clients or endpoint consumers. There are approximately five establishments with four workers each on average.

The restaurants and snack bars are present along the beachfront, offering the necessary infrastructure for seafood consumption by clients enjoying a day at the beach. There are 40 establishments in the locality, with the most recent opened in September 2020, and the oldest dating more than 50 years old. Each establishment has an average of six workers involved in different tasks such as cooking, kitchen helpers and waiters.

Information obtained through questionnaire responses from restaurant and snack bar owners resulted in a pooled list of 26 species of fish and shellfish offered in the different menu charts of the establishments

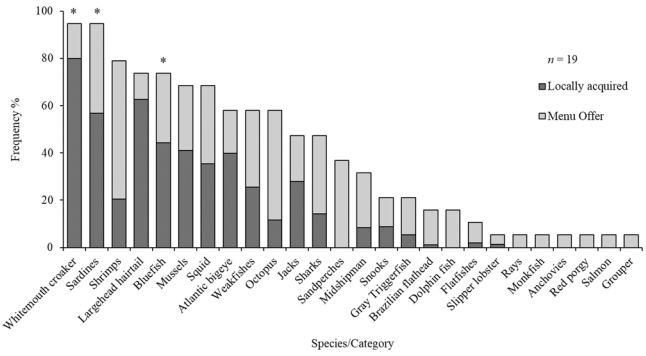

Fig. 2. Percent frequency of occurrence of fish and shellfish species or categories reported by restaurant and snack bar owners to be part of the menu (menu offer) available for clients. Dark grey bar represents the proportion of the reported list that is locally acquired (local production). Asterisks indicate the three species most sought after by customers, according with establishment owners. n = number of interviews.

(Fig. 2). Approximately 48% of the restaurant and snack bar owners informed that they buy the fish/shellfish from fishermen in Itaipu, 22% at local fish markets, 18% at the regional market (Mercado São Pedro) and 12% with the middlemen. The whitemouth croaker, sardines (mostly *Sardinella brasiliensis*), shrimps, largehead hairtail and bluefish were reported to be present in the menu charts of more than 70% of the establishments represented in the survey. At least 18 out of 26 species from the list were supplied by the local SSF, with six species (whitemouth croaker, largehead hairtail, bluefish, mussels, Atlantic bigeye and squid) participating in more than 50% of these proportions individually. Regarding customer preferences, owners reported the whitemouth croaker (84.2%), bluefish (52.6%) and sardines (36.8%) and as the most requested fish species to be served on meals and plates (Fig. 2). Eventually, restaurants have to buy seafood in other markets beyond the Itaipu fishery to meet their demands. These often include exotic species (e.g.: salmon) or less abundant ones that are uncommon in the local fisheries.

3.2. The Pandemic in the Itaipu RESEX-Mar SSF

Out of 31 fishermen interviewed, 83.9% reported they continued fishing during the Quarantine period. Those that ceased their fishing activities blamed fear of virus contamination and difficulties for accessing the beach since public transport was reduced in the period. During flexibilization, with the reopening of economic activities, 96.8% of fishermen stated they returned to their normal fishing activities. When argued about their income situation from fishing in 2019, 48.4% stated they were experiencing an increase, whereas 38.7% reported stability on their income. In contrast, when asked about the current effects of the pandemic on their gains, 77.4% of the 31 fishermen declared a reduction, with 61.3% reporting losses of more than half of their income from previous years.

3.3. The pandemic and commercial relations in the value chain

Both types of catches – target and non-target – increased their market price during the COVID-19 pandemic in the Itaipu RESEX-Mar SSF. PERMANOVA indicated significant differences for the type of catch (Pseudo-F = 36.18; p = 0.0001; Pair-wise test: target > non-target) and period (Pseudo-F = 7.56; p = 0.0004; Pair-wise test: Normality < Quarantine, Flexibility), and non-significant interactions between factor levels (Pseudo-F = 1.96; p = 0.1381) (Fig. 3). The non-target production

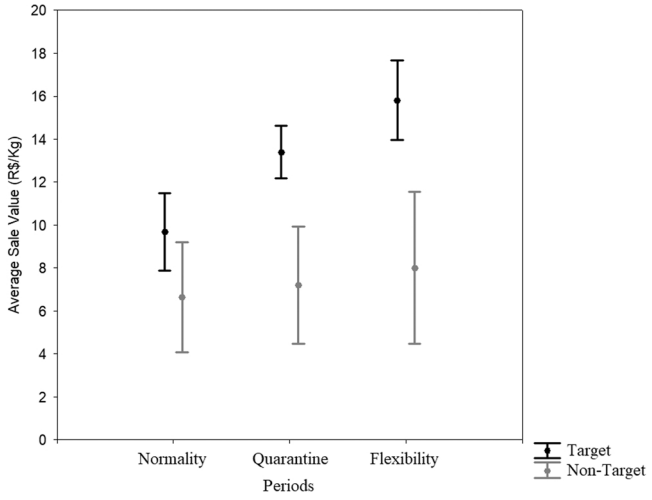

Fig. 3. Average values of first sale (R$/kg) of target and non-target catches during the Normality, Quarantine and Flexibility periods. Bars and whiskers indicate confidence intervals. The values are in Brazilian currency (Real, R$; conversion rate of US$ 1.00 = R$ 4.84).

characterized by a mix of species without predominance of any of the most valued ones, showed greater variability in sales and an increasing trend in both, the average and maximum values. Notable changes were observed in the target production, where one species comprises most of the catches. During the period of Normality, the lowest market values were observed. These values increased significantly during both, the Quarantine and the Flexibility (Fig. 3).

Comparing the estimates of the number of participating individuals within links of the Itaipu RESEX-Mar value chain among periods, only the restaurants and snack bars showed significant differences between normality vs pandemic (χ2calc = 206.2; $p < 0.05$) and Quarantine vs Flexibility (χ2calc = 147.02; $p < 0.05$). Remaining links did not indicate significant differences between observed vs expected proportions. With the exception of the external middlemen, a general trend of reduced number of people within links during the Quarantine period may be observed (Table 1).

These changes are partially reflected in the fluxes of the value chain during the COVID-19 pandemic. Comparing with the pre-pandemic normality period, interviewees reported sale increases to middlemen (4.0%) and endpoint consumers (6.1%), and considerable reductions to local fish markets (−2.0%) and restaurants (−8.3%) which remained closed during the Quarantine period. This situation is most evident considering the sale fluxes from the middlemen to the restaurants that reduced in 25.8% and increased in 25.0% to endpoint consumers (Fig. 4). In fact, all middlemen surveyed manifested that closed restaurants in the Quarantine period hindered their sales.

3.4. Adaptation

Practically all fishermen interviewed (90.3%) said that the COVID-19 exerted no direct influence on catching fish itself. Regardless of the pandemic, those that went fishing continued to catch fish/shellfish on their traditional fishing grounds. Nevertheless, three members of collective production units (beach seine) reported the number of partners had reduced in the pandemic period. In this case, the "*companha*" may stop fishing if important members are unable to work. When fishermen were inquired about the sales of their catches, 35.3% said that the number of endpoint consumers dropped, mainly during Quarantine period, forcing them to adapt to the current situation in which the usual customers were not present in the similar numbers. These adaptations included freeze storage of the catch, processing and selling their product at home, and adhering to a delivery call system. More than half of the fishermen interviewed (61.3%) also considered necessary to improve fish/shellfish processing installations, cold/freeze storage capacity and transport conditions for the delivery system during the COVID-19 pandemic.

Of the seven middlemen interviewed, 57.1% said they were also adapting to the pandemic conditions by taking more of the fish/shellfish home for processing, storage, and delivering to consumer homes, almost in the same way as the fishermen. Regarding the restaurants and snack bars that participated in the survey, most of them closed during Quarantine, but in the Flexibility, 19 out of 20 reopened with services adapted to safety standards and regulations.

When each of the interviewees within links was questioned about their daily working hours, fishermen reported working approximately an average of 4.6 h per day without significant differences on the workload between periods (PERMANOVA: Pseudo-F = 1.077; p = 0.3454). Middlemen reported working an average of 8.4 h per day, also with no significant differences between periods (Pseudo-F = 2.718; p = 0.0924). Restaurants and snack bars were the only links that present significant differences in the working hours between periods (Pseudo-F = 78.868; p = 0.0001; Pair-wise test: Normality > Flexibility, Quarantine). A sharp drop in the Quarantine and a latter recovery in the Flexibility periods were observed (Fig. 5). Nevertheless, the workload was never completely recovered to pre-pandemic working hours.

Table 1
Estimates of the number of individuals associated with each link of the value chain in the Itaipu RESEX-Mar SSF and the respective trends during the periods of Normality, Quarantine and Flexibility.

Value chain link	Period			Trend
	Normality	Quarantine	Flexibility	
Fishermen	80	67	80	
Middlemen				
Fixed	8	5	8	
External	9	4	4	
Local fishmarkets	20	20	20	
Restaurants	240	12	180	
Total people associated	357	108	292	

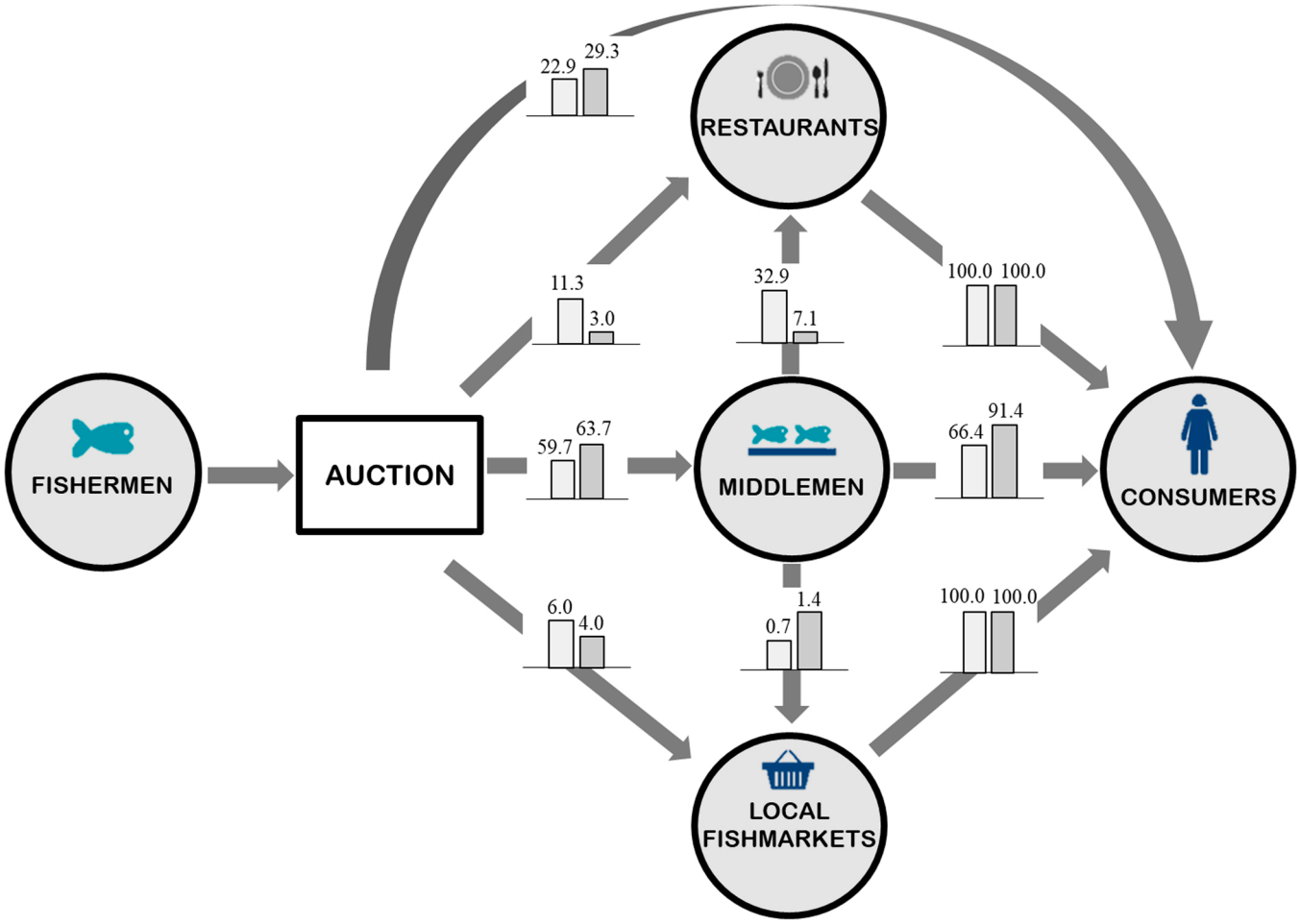

Fig. 4. Diagram representing the Itaipu RESEX-Mar SSF value chain, indicating sale fluxes (bars) and their relative proportion before (light gray) during the COVID-19 pandemic (dark gray). Quarantine and Flexibility periods were pooled to reflect changes in the value chain. Outflows from each link add up to 100%.

3.5. Policy implications and institutional responses dealing COVID-19 pandemic impacts

The town of Niterói started in June 2020 a free testing program for the population. Citizens would fill a questionnaire in the 'Dados do Bem' system platform, reporting personal data and possible symptoms. After that, the system would schedule a date and place for the test to be conducted. Until the end of this survey, from all of the 58 respondents, only 12 people (20.7%) had taken the COVID-19 test. Six people (3 fishermen, 1 middleman and 2 restaurant owners) claimed they had been infected because they felt the common symptoms of the disease. Nevertheless, only three of them were tested. When asked about the incidence of COVID-19 cases in their families, 32.8% answered positive. Most cases occurred in the families of fishermen participating in the survey (38.7%), followed by middlemen (28.6%) and owners of restaurants and snack bars (25.0%).

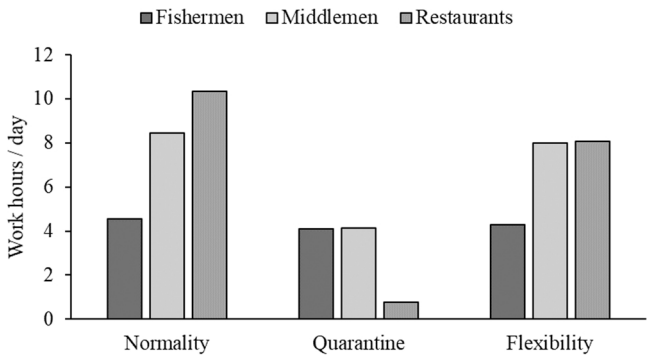

Fig. 5. Average working hours per day of fishermen, middlemen and restaurants and snack bars during Normality, Quarantine and Flexibility periods in the Itaipu RESEX-Mar SSF.

A large proportion of respondents reported the need of some financial support to deal with income losses due to the COVID-19 pandemic, both in the short and long terms. Out of the 150 fishermen affiliated to the Fishermen's Colony (Z7), 95 established in Itaipu were granted emergency aids from both, the Municipality of Niterói (Municipal Bill No. 3.485/2020) and the Federal Government (Federal Bill 13.982/2020). The financial relief from the City Hall started in April 2020 and is expected to end in December 2021. This financial assistance is a credit card with a balance of US$ 103.3 (R$ 500.00) to be used in supermarkets, pharmacies and gas stations for fuel. Fishermen unable to register for the benefit, are receiving a monthly package of general foodstuffs ('Cesta Básica'). Retired fishermen and those that have other sources of income other than fishing, were not included in the financial aid programs. Most of the middlemen interviewed (85.7%) were receiving the emergency financial aid from the Federal government. Only eight restaurant and snack bar owners were receiving the benefit. The Federal Government aid was established at US$ 123.9 (R$ 600.00), began in April 2020 and ended in December 2020. For the year 2021, the value has changed, varying from US$ 30.99 to US$ 77.48 (R$ 150.00 to R$ 375.00) depending on the number of people in the family household. The proposal consisted of seven installments that started in April 2021 and lasted until October 2021. Nevertheless, the payment schedule for these three extra installments, however, has not been released yet. Despite this, no fisherman has received the new 2021 Federal aid because they are receiving unemployment insurance ("Seguro Defeso").

4. Discussion

The value chain developed in Itaipu Marine Extractive Reserve represents further evidence of traditional fishing communities' subsistence and points out to alternative strategies to the maintenance of these systems. Through the pre-pandemic and pandemic questionnaires used in the survey, our results allowed us to identify changes in the sales flow and some commercial strategies adopted during the COVID-19 pandemic. During the Quarantine and Flexibility periods, we identified an increase in fish consumption, a sales reduction to local restaurants and fish markets, followed by a trading increase to middlemen. The latter represents a key player in this buying and selling relationship, guaranteeing the outflow of fisheries products, supplying local fish markets and consumers. Therefore, fishermen and middlemen represent adjustable links to the changes imposed by the pandemic, since they adopt alternative strategies, including direct deliveries, to target the endpoint consumers. In addition, we bring to light that the fish auction represents the primary vector for the distribution of resources (fish and income) targeting the consumers.

Despite the restrictions of social distancing, limited public transport, and blocking access to the beach where landings and seafood trade occur, most fishermen from the Itaipu RESEX-Mar continued fishing as usual during the pandemic period, not compromising the local fisheries production. This decision indicates that fishermen are dependent on fisheries itself since this is their primary source of income. This dependence is predominant in SSF, where many small-scale fishers and fish workers are self-employed and are involved in the direct supply of food to their families and communities [39,40]. Furthermore, the non-interruption of these activities even in the most critical periods of the pandemic demonstrates the adaptive capacity of this protected fisheries management area. The set of experiences previously lived by this system throughout its history (e.g., gentrification, changes in target resources and internal rules for the use of space) constitutes an important referential base [24,25], in which the current pandemic experience may be incorporated and further used to build resilience in face of future macroeconomic shocks. In addition, another reliable indicator of the maintenance of this value chain was observed in the integration of internal agents (fishermen and the local market - bars and restaurants) that use about 48% of the fish caught locally. The whitemouth croaker, besides being one of the most abundant species in the fishing area of this community, is equally the most sought after/offered on the local menus.

According to Belton et al. [41] all stages of a supply chain can be interrupted because of the restrictions of COVID-19. Among the main justifications for the interruptions observed in the production flow in the SSF are the isolation of certain communities in relation to urban centers and the dependence on direct export of fish, often linked to the HORECA network (Hotels, Restaurants and Catering) [13–17,20,42]. Behind this scenario, the Itaipu supply chain has not stopped its activities, because of two fundamental aspects: 1) it is the unique source of income for many of these fishermen and 2) it is located close to the metropolitan region, which facilitates the flow of production. In this way, SSF Itaipu RESEX-Mar represents a fishing system inserted in the second largest metropolitan region of Brazil [23], which uses the fish auction as a way to survive guaranteeing its historical and traditional characteristics [29,30].

Even with the increased interest in value chains of seafood products and the connections established between their different actors and economic agents in recent years [43], studies of the influence of urbanization on urban fishing communities is still neglected in policy and academia scenarios [44–46]. The fishing activity practiced at the Itaipu RESEX-Mar has proved to be resilient in relation to the various technological [24] and anthropic transformations [47], imposed by the proximity to a vast metropolis, the city of Rio de Janeiro. In fact, local fishermen may be benefiting from the proximity of large urban centers, contrasting with rural and isolated SSF communities. In general, urban life provides easy access to markets and consumers and expands fisheries-related facilities [46]. Thus, even in the COVID-19 pandemic scenario, the productive system developed at the Itaipu RESEX-Mar, located within a large urban center, was essential to keep the system working.

Observed changes in the Itaipu RESEX-Mar value chain corroborate the analogy of the SSF as a Complex Adaptive System (CAS), a mathematical model postulated by Holland [48]. For instance, Loto et al. [25] proposed that the Itaipu RESEX-Mar SSF could be interpreted metaphorically as a CAS with internal mechanisms maintaining its functional structure. Following this approach, the value chain under study may be adjusted into the four properties of CAS: *i*) diversity (the numerous links of the value chain), *ii*) aggregation (the local fishing community), *iii*) flow (the sales), and *iv*) non-linearity (yields from specific target resources). Our CAS interpretation of the value chain is supported not only by its unique components, but also through a point of convergence: the auction. This market system, with catches being auctioned shortly after landing, provides a window of opportunity for marketing the fishery production with multiple links in the value chain (e.g., middlemen, restaurants and endpoint consumers). Each one of these stakeholders has specific interests and distinct negotiation and auction skills for purchasing the catch. Lima and Pereira [29] suggested that prices negotiated in the auction did not follow the rules of supply and demand,

but included other factors such as species composition, quantity, size of fish and type of buyer. While exceptionally skilled middlemen tend to buy fish/shellfish at lower prices, endpoint consumers may pay more with less negotiation skills at the auction, but looking for a specific product in the catch.

The auctions taking place at the RESEX-Mar Itaipu are part of a local traditional knowledge incorporated into the fisheries value chain flow for more than half a century [29]. The auction, occurring moments after landing, provides the fisherman with the advantage of a quick sale of recently caught fresh fish [49]. Therefore, independent form other links in the chain, fishermen may return back to the fishery at sea or to dedicate himself to any other chore [29,30]. Moreover, the informal scenario in which auction negotiations occur, allows considerable flexibility in the end value of fish sales. This is an advantage for all participants of the value chain. Fishermen consistently have their catch placed in the market, sometimes at a higher price, especially when sold directly to endpoint consumers. Nevertheless, many of the fishermen have enduring relationships with particular middlemen or local food business. As regular customers, these particular stakeholders provide security that the catch will be sold. However, most of the time, payment to fishermen is not made at the time of sale and occurs later. These bonds of trust between stakeholders have guaranteed not only the fishery production flow but also fishermen's livelihoods.

The COVID-19 pandemic forced the Itaipu RESEX-Mar value chain to experiment alternative arrangements to prevent chain disruptions. One of the characteristics of CAS is the fact that the system learns through experience [48]. Therefore, any tested experience may or may not be incorporated into the system. In times of crisis, new sales practices and opportunities emerge, contributing to a more prosperous future for the sector. In light of this, the sale losses experienced by the fishermen in the early days of the COVID-19 pandemic needed to be recovered, and selling their production to endpoint consumers appeared as a window of opportunity to zero out their losses. Local residents looked after their contacts at the beach, either a fisherman or a local middleman, demanding fish/shellfish products. This increased demand from a link that was not as demanding in normal times, raised first sale prices. In this context, among the adaptations and commercial practices experienced during the most restrictive periods of the pandemic, some fishermen joined the delivery call system. Local fishermen used social media channels to sell and provide delivery service of fish products to endpoint consumers. In many places, the online app WhatsApp has been widely used by small-scale fishers to reach the costumers effectively [50]. Therefore, as seen by Besset et al. [51], our observations from the present study are yet another indication that the strengthening of pre-existing ties is important to prevent future adverse situations.

The peculiarities of the Itaipu RESEX-Mar SSF value chain may be the key to understand how individuals conducted their commercial relations maintaining gains and minimizing conflicts under the influence of the COVID-19 pandemic. Our results suggest that, although fishermen may be at the mercy of the middlemen (they buy most of the local production and usually set a lower end price), they were the necessary actors to secure the fisheries production flow. In a situation of reduced number of buyers and closed restaurants in the auction arena, middlemen were better prepared for storing the fisheries production, either on site (ice boxes, sun shade, processing table) as they routinely do, but most important at home. Official data from the Brazilian Institute of Statistics [52] indicated that since March 2020, more than 2.7 million citizens were removed from their work due to social distancing, and at least 7.9 million are spending much of their time in home office and preparing their own food. With closed restaurants, street produce fairs ('feiras livres') and larger retail fish markets, consumers searched to buy fresh seafood in the Itaipu RESEX-Mar SSF.

With less middlemen to buy their catches, beaches closed to the public, fishermen were forced to adapt to this new condition, especially during the Quarantine period, behaving in such a manner as a complex adaptive system. Loto et al. [25] stated that a complex adaptive system creates choices among a set of possibilities. At one extreme, the system is organized, working under a set of established operating rules, used in all possible manners. In the opposite side, behavior of the system is chaotic and exploratory, continuously searching for new possible rules. A successful Complex Adaptive System may be established between these two extremes, alternating at times between order and chaos. The short-term adaptations mentioned in the survey (e.g., selling their catch at home through a delivery call system) were exploratory and intended to keep the system going. If the value chain flows were maintained or redirected, their income from fisheries would be secured. Bennett et al. [10] identified that food networks and community-supported fisheries emerged in different parts of the world at the beginning of the COVID-19 pandemic. As the demand for fresh seafood delivery increased, the SSF were able to adapt their distribution models, creating and strengthening direct connections with local household consumers [20]. Thus, by filling the market gaps in the value chain caused by the pandemic impacts, fishermen shortened the fluxes of money and goods, realizing financial gains [20] to compensate for reduced sales in volume. Undoubtedly, these were fundamental alternatives to overcome the initial stages of the COVID-19 pandemic. Nevertheless, the capacity of fishermen to be involved in long-term adaptations will depend on the acceptance by fishermen, either individually or collective, of the success (or not) of the new rules explored in the chaotic phase.

Fishermen may be used to short- and long-term uncertainties, including those related to biological conditions such as changes in the ecosystem, habitat loss, pollution, climate change, and socioeconomic conditions [53,54]. The unpredictability of fishing also raises challenges for local food security and national food supply [55]. The responses of the fishermen within the SSF to the pandemic have predominantly constituted actions that can be translated in the long term as adaptive strategies that create resilience [56]. The COVID-19 pandemic may provide a window of opportunity for fisheries managers and stakeholders to assess the likelihood of future shocks in the fisheries systems. Furthermore, it provides the chance for learning from the current situation, and building resilience for SSF [20]. In addition, the pandemic is lasting longer than anticipated. In current times, the unpredictable has become the rule. Government assistance made available through monthly emergency funds to fishermen and middlemen, were extremely important complementing their source of income and covering their basic household needs [10]. We believe that these measures should be extended to the end of the pandemic.

5. Conclusion

The results of this research indicate that, although Itaipu RESEX-Mar SSF fishing production was not directly affected by the COVID-19 pandemic, there were changes in the commercial relations between the value chain links, especially for restaurants, which were strongly affected by the restrictive measures adopted. In addition, an increase in local demand for seafood at times of great restrictions, stimulated fishermen to test new sales strategies, which in turn increased the value of their fish/shellfish production.

The auction arena in which catches are traded, and the presence of middlemen as the main conveyor of seafood to other links in the value chain, were fundamental elements for the operation of the system during pandemic times. These characteristics reinforce the system's resilience capacity when exposed to extreme conditions such as the COVID-19 pandemic. The situation of social isolation led endpoint consumer to further appreciate the local seafood products. Consumers had the opportunity to choose the type of fish, with the assurance of its quality and origin. In addition, with restaurants and snack bars closed, consumers exercised their negotiation power with greater participation in the auction bidding process, opening a window of opportunity for new relations in the value chain of the Itaipu RESEX-Mar small-scale fishery system.

The critical context provided by the COVID-19 pandemic is far from

over, especially in Brazil. The observed effects on the SSF value chain highlighted here are likely to be present for a longer period. Among the predicted difficulties, we can highlight economic crises and impacts on different links in the value chain. Due to the vital role in food security and subsistence that the SSF sector plays, we emphasize the need for rapid mobilization by all managers and decision makers in support of the sector. Considering this context, these responses must be efficient and targeted at the most vulnerable links. In the long term, however, a coordinated response to a support network is necessary. From it, it will be possible to increasingly strengthen supply chains with the aim of improving the conditions and resilience of the SSF sector.

CRediT authorship contribution statement

Júlia Benevenuti Soares: Conceptualization, Methodology, Investigation, Data curation, Visualization, Writing – original draft, Writing – review & editing. **Marcus Rodrigues da Costa:** Conceptualization, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Supervision. **Cassiano Monteiro-Neto:** Conceptualization, Visualization, Writing – original draft, Writing – review & editing, Supervision. **Luciana Loto:** Investigation, Writing – review & editing. **Maurício Düppré de Abreu:** Conceptualization, Writing – review & editing. **Rafael de Almeida Tubino:** Conceptualization, Methodology, Data curation, Writing – original draft, Writing – review & editing, Supervision.

Acknowledgments

We are extremely grateful to fishermen, middlemen, employees and owners of Itaipu beach restaurants and snack bars. We thank Lidiane Vieira, president of the Fishermen's Colony Z7, for providing information about the fishermen in Itaipu. Everyone was very attentive and kind in cooperation with this research. We thank Instituto de Pesca do Estado do Rio de Janeiro (FIPERJ) for providing data on fishery production, and Priscila Oliveira for making the map. Special thanks to Ronaldo Angelini for providing helpful insights in structuring the value chain. We also thank the anonymous reviewer who clearly contributed to improving this manuscript. The work complied with ethical precepts being approved by the ethics council. J. B. Soares holds a PhD's degree scholarship from CAPES. C. Monteiro-Neto is a Research Productivity Fellow from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) (Grant # 305934/2019–8).

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2022.105068.

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