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Jatuarana fishing dynamics *Brycon amazonicus* (Spix & Agassiz, 1829) of the upper and middle Madeira River Basin

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ABSTRACT. The jatuarana (*Brycon amazonicus*), is an important species for the Madeira River commercial fisheries. The paper aims to characterize the jatuarana fishing dynamics in the middle Madeira River and test whether there are differences downstream and upstream the Teotônio waterfall. Commercial fisheries landings were monitored daily at 15 ports or riverine communities along that stretch, using semi-structured interviews with fishermen. With data from the fishing monitoring program of UHEs Santo Antônio and Jirau we analysed: the yield, catch per unit effort (CPUE), length structure, locations and fishing gear used, between 2009 to 2011. The fishing yield of this species was temporally analyzed with data from the Fishermen Colony of Porto Velho city (Rondônia state, Brazil), between 1990 to 2012. The yield and the CPUE showed significant differences by area and locations and the capture of the species was carried out primarily in the channel river and banks river through gillnets. In addition, the samples collected in the upstream area have higher distribution and modal lengths than from those collected downstream. These results suggest that the areas require distinct management measures.

Keywords: fishery production; fishing gear; fishing effort; Amazon.

Dinâmica da pesca da Jatuarana *Brycon amazonicus* (Spix & Agassiz, 1829) do alto e médio rio Madeira

RESUMO. A jatuarana (*Brycon amazonicus*) é uma espécie importante para a pesca comercial do médio rio Madeira. O objetivo deste trabalho foi caracterizar a dinâmica da pesca da jatuarana na região e testar diferenças entre os trechos a jusante e montante da Cachoeira do Teotônio. Os desembarques pesqueiros foram monitorados diariamente em 15 portos e/ou comunidades ribeirinhas, usando entrevistas semiestruturadas com os pescadores. Com dados do Programa de Monitoramento Pesqueiro das UHEs Santo Antônio e Jirau foram analisados: a produção, a captura por unidade de esforço (CPUE), a estrutura em comprimento, os locais e os apetrechos de pesca utilizados entre 2009 e 2011. A produção da espécie foi analisada temporalmente com dados da Colônia de Pescadores de Porto Velho (Rondônia, Brasil) de 1990 a 2012. A produção e a CPUE apresentaram diferenças significativas por área e localidades e a captura da espécie foi realizada, principalmente, na calha e nas margens do rio por meio de malhadeira. Verificou-se também que os exemplares amostrados na área montante exibiram distribuição e comprimentos modais maiores que na área jusante. Estes resultados sugerem a necessidade de estratégias de manejo distintas entre as áreas.

Palavras-chave: produção pesqueira; apetrechos de pesca; esforço pesqueiro; Amazônia.

Introduction

The Amazon region is noteworthy for having extensive hydrographic basins, hosting a diverse fish fauna, with an estimated fish species richness between 1800 and 3000 species (Latrubesse, Stevaux, & Sinha, 2005; Santos, Ferreira, & Zuanon, 2006; Petreire Jr., Batista, Freitas, Almeida, & Surgik, 2007). Among its tributaries, the Madeira River is considered the tributary with a greater number of

fish species known in the world (Queiroz et al., 2013), with ~ 1373 described species (www.amazon-fish.com).

Another intriguing feature of Madeira River basin is its complex geomorphology. The Madeira's watershed covering all three main types of drainage areas in the Amazon Basin: the Andean region, the Brazilian massif and the Amazon lowlands (Latrubesse et al., 2005). Along its wide area, with approximately 3,352 km length and width ranging

between 440 to 9900 m length, there are 19 rapids in its upper and middle stretch, within the Brazilian territory, that contribute to the high diversity of species (Goulding, 1979; Torrente-Vilara, Zuanon, Leprieur, Oberdoff, & Tedesco, 2011). This stretch of waterfalls in the Madeira River also is known to be a geographical barrier, structuring genetically populations of alligators, turtles, dolphins and even other fish (Pearse et al., 2006; Torrente-Vilara et al., 2011; Gravena, Farias, Silva, Silva, & Hrbek, 2014). However, nowadays this scenario has changed by the construction of two hydroelectric plants, *Santo Antônio Energia* (SAE) and *Energia Sustentável do Brasil* (ESBR), which submerged the three largest rapids of this system: Jirau, Teotônio and Santo Antônio.

In Madeira as in the others Amazon regions, the species richness supports important fishing activities which, represents an essential source of jobs and income, as well as the main source of animal protein for the riverside dwellers (Smith, 1979; Lowe-McConnell, 1999; Ruffino, 2004; Doria, Ruffino, Hijazi, & Cruz, 2012; Doria & Lima, 2015). Despite the fish diversity, only a small group of species is the target for commercial fishing. The local exploitation focus mostly on Characiformes and Siluriformes large migratory species: tambaqui (*Colossoma macropomum*), jaraquis (*Semaprochilodus* spp.), curimatã (*Prochilodus nigricans*), jatuarana (*Brycon amazonicus*), piramutaba (*Brachyplatystoma vailantii*), dourada (*Brachyplatystoma rousseauxii*), surubim (*Pseudoplatystoma punctifer*) and piraíba (*Brachyplatystoma filamentosum*) (Barthem & Fabr , 2004; Santos et al., 2006; Doria, Lima, Souza, Carvalho, & Santos, 2014).

Among these, *B. amazonicus*, a medium size characiforme, distributed along the stretch Solim es-Amazonas and tributaries, in the Orinoco River basin (in Venezuela and Colombia) and Essequibo (Guyana). It shows a migratory behavior for reproductive and feeding goals, with omnivorous alimentary habits (Santos et al., 2006).

Until now, all studies about this specie were carried out along of the Central Amazon which had reported on age and growth (Barthem & Fabr , 2004), stocks state (Ruffino, 2004) and/or population dynamics (Filho & Batista, 2009). No studies on this species have been carried out in the Madeira River basin, where there is an important resource fishery with an annual production that represented around 8% of the total (Doria et al., 2012).

Owing to all the raised facts together with the recent construction of two hydroelectric dams in the Brazilian portion of the Madeira River, further emphasized the importance for a specific study about the fishery and biological aspects of *B. amazonicus* in this basin. This work therefore aimed to characterize the fishing dynamics, ecological and biological characteristics of *B. amazonicus* in the middle Madeira River and test whether there are differences in these characteristics downstreams and upstreams the Teot nio's waterfall.

Material and methods

Fish sampling and study area

Samples were collected in 15 points along the Madeira River, which were grouped above and below Teot nio Waterfalls: upstream areas - Surpresa, Guajar -Mirim, Iata, Abun , Fortaleza do Abun , Nova Mamor  and Jaci Paran ; and downstream areas - Teot nio waterfall, S o Carlos, S o Sebast o, Porto Velho, Cuni , Nazar , Calama and Humait . This data was obtained by the Fisheries Monitoring program of SAE and ESBR in partnership with the Laboratory of Ichthyology and Fisheries (LIP) at *Universidade Federal de Rond nia* (Unir) (Figure 1).

Analysis

The fishing dynamics was characterized through the analysis of: (1) the landing records carried out in Porto Velho fishing Market (Flutuante Cai n gua) by the Fishermen Colony Z-1, in the period between 1990 and 2012; and (2) the fisheries monitoring records, conducted in locations mentioned above, between 2009 and 2012. In the latter, the landings were monitored daily through interviews with fishermen, using structured questionnaires and conducted by LIP's technicians and/or local collectors. The questionnaires contained information about: fish yield by species, fishing gear, fishing effort (number of fishermen and fishing days) and locations of capture. In addition, biometric data were collected from a random sample of fish from these landings: standard length (in centimeters) and total weight (in grams).

For the analysis of the historical total yield species we used data from the Fishermen Colony Z-1 (1990 to 2012); and the spatial analysis of the fishing productivity (per sample area and locations) was performed with the data from fishery monitoring (2009 to 2011).

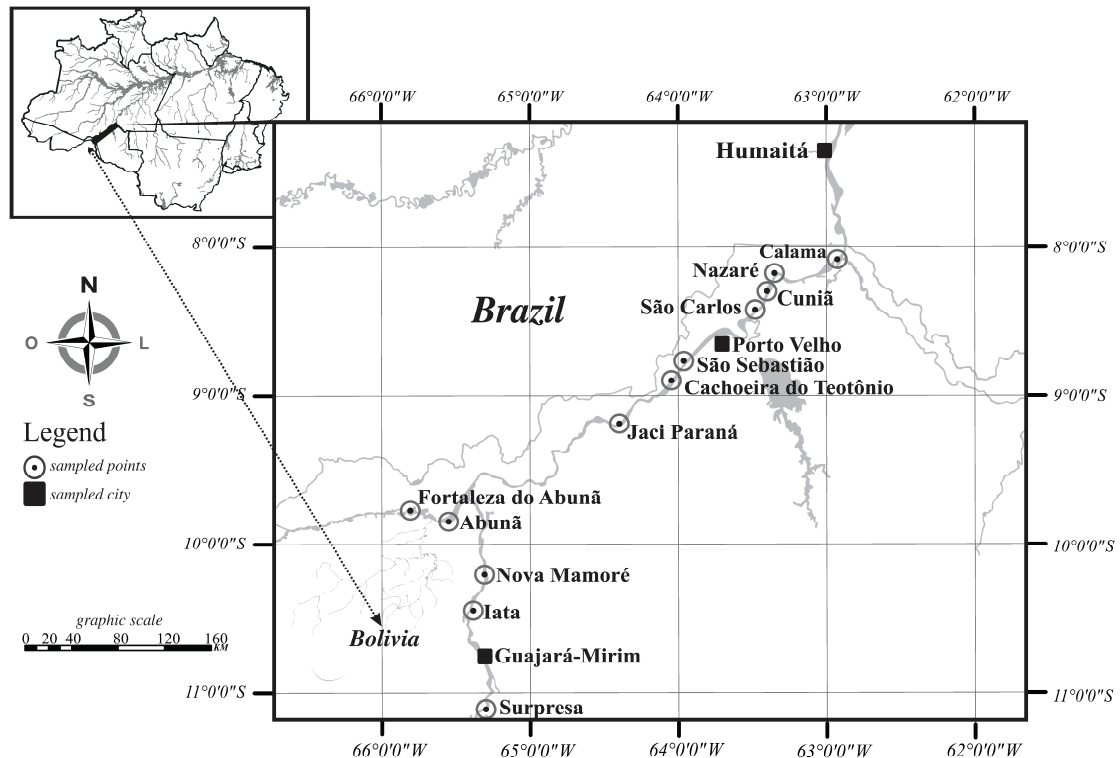


Figure 1. Study area with the location of sampling sites and cities in the Madeira River basin, Brazil.

The fisheries yield was analyzed spatially by means of catch per unit effort (CPUE), analyzed spatially (per area and locations) using the Equation 1:

$$CPUE = \frac{Catch(kg)}{N^{\circ} \text{ of fishermen} * N^{\circ} \text{ days}} \quad (1)$$

where:

Catch (kg) = the total yield captured (kg),

N^o fishermen = total number of fishermen who participated in the fishing activity,

N^o days = total number of days fished.

To test for significant differences by area and places, we applied the Mann-Whitney and the Kruskal-Wallis tests, respectively, considering the non-normality and homoscedasticity of the data (Software Statistica 7, StatSoft, 1996).

The size structure (length), the fishing places, and gear had been used to catch *B. amazonicus* were analyzed only by area per means relative frequency. For the first variable, the amplitude of the standard length classes was established by Sturges' rule (Vieira, 1991).

Results and discussion

The annual yield of *B. amazonicus* between 1990 and 2012 presented an average of 51,942 kg. The

largest yield recorded in this period was in 1997, which represented 35.44% (353,605 kg) of total yield landed in the Porto Velho fishing market. The lowest was in 2009, corresponding only 1.75% (9,689 kg) of the total landed. For others years evaluated the yield of the species remained without major variations (Table 1).

According to the spatial analysis of catches of *B. amazonicus* between 2009 and 2011, it was observed that both the yield as the CPUE were significantly higher in the downstream area, when compared to the upstream (Y_{yield} = 582311,01; U_{CPUE} = 721826,02; $p < 0.01$) (Figure 2A and 3A). Analyses of these parameters by locality presented also significant differences (H_{yield} = 703; H_{CPUE} = 491; $p < 0.01$), with Humaitá showing the greatest increase in yield, while Abunã and São Carlos presented the highest CPUE values (Figure 2B and 3B).

The capture of jatuarana in both studied areas was mainly realized in the channel rivers or on its banks, demonstrating the importance of this environment for the local fisheries (Figure 4).

The gillnets was the main fishing gear used to capture *B. amazonicus*, in both upstream and downstream areas. However, in the downstream area, fishermen made also considerable use of set long lines (Figure 5).

Table 1. Values of total annual yield (kg) and *B. amazonicus* relative yield (%), landed in Porto Velho fishing market in the period between 1990 and 2012 (Standar deviation \pm 6,8).

Year	Yield (kg)		
	Total	<i>Brycon amazonicus</i>	%
1990	614.080	25.590	4.17
1991	742.260	83.300	11.22
1992	391.604	24.891	6.36
1993	1.060.939	148.670	14.01
1994	377.238	46.448	12.31
1995	490.588	34.365	7.00
1996	483.582	39.762	8.22
1997	997.636	353.605	35.44
1998	566.804	18.411	3.24
1999	528.970	23.265	4.39
2000	438.589	23.353	5.32
2001	782.534	46.467	5.93
2002	676.540	42.298	6.25
2003	575.420	39.285	6.82
2004	489.330	16.193	3.30
2005	717.812	47.525	6.62
2006	758.075	68.346	9.01
2007	401.442	28.730	5.92
2008	1.581.147	64.251	4.06
2009	550.983	9.689	1.75
2010	369.410	26.815	7.25
2011	669.755	35.267	5.26
2012	440.493	10.770	2.44
Average	668.419	51.942	7.8

In relation to the spatial analysis of the size structure (length), the upstream had a higher frequency of samples measuring between 40 and 44 cm standard length. In the downstream area, this mode moved a little to the left, where individuals measured between 36 and 40 cm standard length (Figure 6).

The jatuarana's importance in Madeira River commercial fisheries, as reported by other authors (Cardoso & Freitas, 2007; Doria et al., 2012), is confirmed in spite of changes recorded over the years studied. The higher yield years (1993 and 1997) may have been influenced by higher hydrological measurements in previous years (1992 and 1996), which reflects on the catches of subsequent years (Doria et al., 2012). Corroborating with Lima, Kaplan, and Doria (2017) evaluated models that correlated the fishery production of some species caught in the Madeira River and hydrological variables, verified that the number of flooded days showed a significant and positive correlation for a subset of species, including jatuarana.

Fisheries studies in the upper and middle Madeira River also reported differences to total catch and CPUE between the areas (Cardoso & Freitas, 2007; Doria et al., 2012). The variations in catch may be related to different factors such as: environmental characteristics, fishing effort, spatial distribution of the fishing fleet, urban demand, and

population density among others (Gonçalves & Batista, 2008; Doria, Machado, Souza, & Lima, 2016; Silva Júnior, Raseira, Ruffino, Batista, & Leite, 2017; Tregidgo, Barlow, Pompeu, Rocha, & Parryand, 2017). Often, these factors are correlated and difficult to size with fisheries data (Silva Júnior et al., 2017).

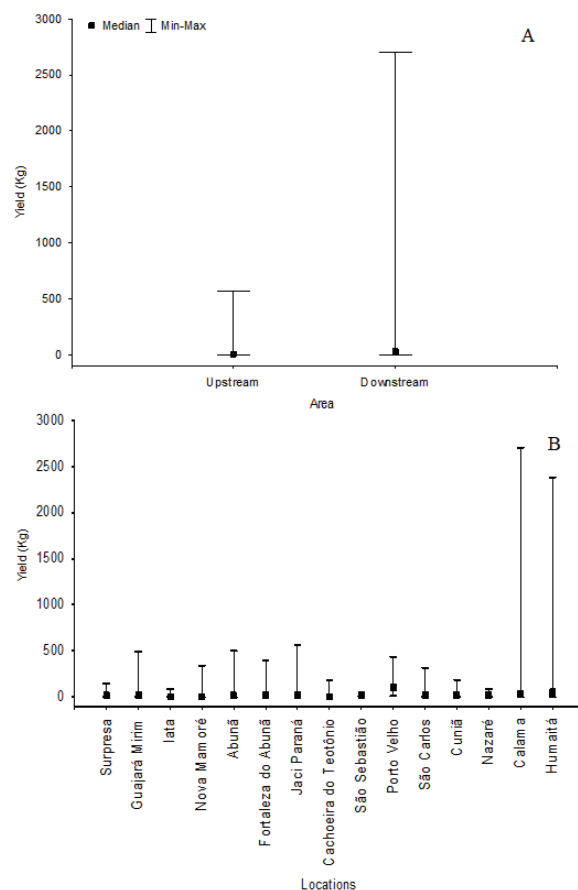


Figure 2. Median, minimum and maximum values of annual fish yield (kg) of *B. amazonicus* between 2009 and 2011, landed in the study area, analyzed by area: Teotônio Waterfalls upstream and downstream (A) and all sites (B).

The highest yield values were observed downstream, which could be justified by the greater number of fishermen, canoes and boats that influence fisheries effort in these area (Doria et al., 2012; Doria & Lima, 2015). As well, the largest yield in Humaitá possibly reflects the differences in characterization of fishing fleet of this city when compared to others: the greater number of fishing boats, which have the largest sizes (average length of 10 meters in length) (Doria & Lima, 2015). Such characteristics allow increased storage on trips of long duration, which favors the yield. Moreover, the higher number of fishermen downstream, allowing a greater fishing effort.

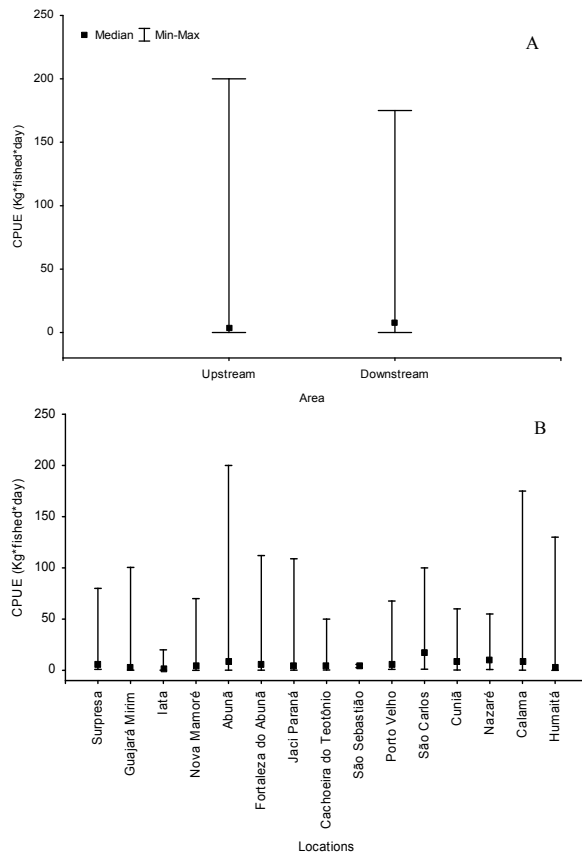


Figure 3. Median, minimum and maximum values of annual CPUE of *B. amazonicus* landed in the study area, between 2009 and 2011. Analyzes by area: Teotônio Waterfalls upstream and downstream (A) and all sites (B).

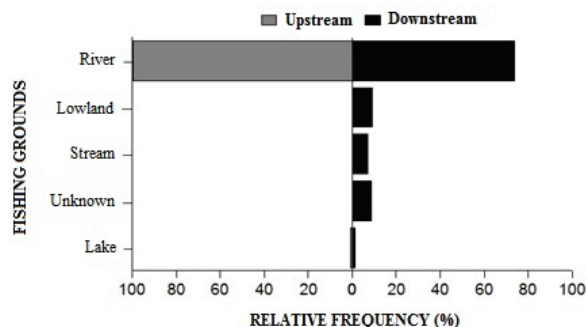


Figure 4. Relative frequency by fishing grounds of the *B. amazonicus* landed upstream and downstream Teotônio Waterfalls, between 2009 and 2011.

On the other hand these values may also be a reflection of urban demand (Tregidgo et al., 2017). The fishery in the downstream area supplies the city of Porto Velho (Rondônia state), the largest city in the region (~ 494,000 inhabitants, 90% in the urban area of the city, *Instituto Brasileiro de Geografia e Estatística* [IBGE], 2014), while the upstream fishery supplies the small villages and towns of Guajará Mirim (~ 46,000 inhabitants, 80% in the urban area of the city, IBGE, 2014) and Nova Mamoré

(~ 22,500 inhabitants, 50% in the urban area of the city IBGE, 2014). Notwithstanding, the influence of the urban demand on the fishery are difficult to assess without modeling long-term fishing data (Tregidgo et al., 2017), the fishing pressure driven by Porto Velho demand, evidenced by the high relative yield (~ 8%) during the years studied, seems to influence the higher CPUE value and lower length observed in the downstream areas.

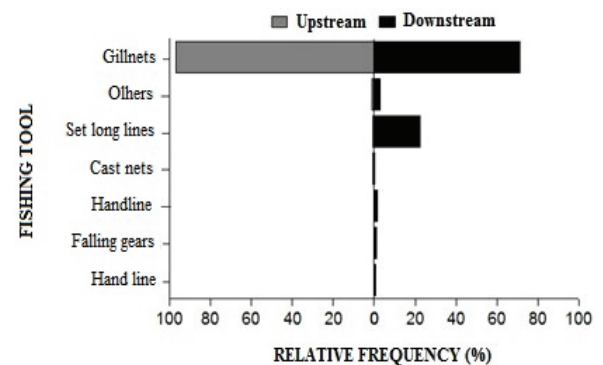


Figure 5. Relative frequency by fishing gear of the *B. amazonicus* landed upstream and downstream Teotônio Waterfalls, between 2009 and 2011.

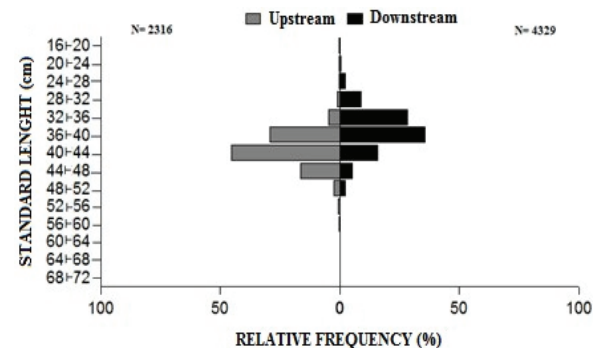


Figure 6. S Relative frequency of the *B. amazonicus* size structure in length landed upstream and downstream Teotônio Waterfalls, between 2009 and 2011.

The loss of larger size classes can also be driven by a higher fishing pressure on larger fish, because of the preference of the consumer and harvest, that get a high value per kilograma on these specimens (Tregidgo et al., 2017). The loss of size classes can trigger stock depletion and should be one alert for the manager. Despite of, for both areas, the catches were concentrated on the classes of adults fish (from 38 to 40 cm standard length - individuals able to reproduce, considering the minimum size at first maturity of 32 cm standard length; Filho & Batista, 2009).

Factors such as environment and fishing gears were the same in both areas and did not influence the difference in catch and follow the pattern of the

fisheries in other regions of the Amazon, as reported by Barthem (1999), Batista and Petrere Jr. (2003) and Ruffino (2004) the capture of jatuarana in both studied areas was mainly realized in the channel rivers or on its banks, demonstrating the importance of this environment for the local fisheries. Goulding (1979) observed that the capture of many Characiformes in the Madeira River (including jatuarana) was performed mainly in mouths of tributaries, rivers and the lowland, with catches in rivers occurring mainly during reproductive migration when *B. amazonicus* was more vulnerable to fishing gear. The same pattern was observed in subsystems of the Purus and Solimões Rivers for this specie where the river is the habitat most used by fishermen (Fernandes, Vicentini, & Batista, 2009). The preferred fishing gear was the gillnet as it is in many Amazon's regions (Ruffino, 2004; Cardoso & Freitas, 2007; Doria et al., 2012). This preference occurs due to its lower cost and uncomplicated way to handle, which allows to be used in diverse environments, large quantities, and throughout the year, increasing the catches (Petrere Jr., 1978).

Conclusion

Brycon amazonicus is an import fishery resource in the Madeira River basin where its relative yield remained stable over the years. Significant differences were observed in the yield, catches efforts and size structure length between upstream and downstream Teotônio waterfalls areas, influenced by diferents fators, which require distinct management measures. The results generate references of Jatuarana fishery in the Madeira basin and Amazon region, as well as showed the importance of knowledge the characteristics of the fishery and of the resource exploited in a wide spatial scale, considering the different localities and not only the largest markets, to avoid generalization.

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